

Physics 30
Curriculum Package
February 2012



2012

Unit A: Momentum and Impulse

Specific Outcomes	Achievement Indicators – Measurable outcomes
<i>It is expected that students will:</i>	<i>The following set of indicators may be used to assess student achievement for each related specific learning outcome. Students who have fully met the specific learning outcomes are able to:</i>
<p>Focusing Questions: What characteristics of an object affect its momentum? How are momentum and impulse related? How does our understanding of concepts relating momentum and impulse influence the design of safety and sporting equipment?</p>	
<p>GENERAL OUTCOMES: STUDENTS WILL EXPLAIN HOW MOMENTUM IS CONSERVED WHEN OBJECTS INTERACT IN AN ISOLATED SYSTEM.</p>	
<p>Knowledge: explain how momentum is conserved when objects interact in an isolated system.</p>	<ul style="list-style-type: none"> • Define momentum as a vector quantity equal to the product of the mass and the velocity of an object • Explain, quantitatively, the concepts of impulse and change in momentum, using Newton’s laws of motion • Explain, qualitatively, that momentum is conserved in an isolated system • Explain, quantitatively, that momentum is conserved in one- and two-dimensional interactions in an isolated system • Define, compare and contrast elastic and inelastic collisions, using quantitative examples, in terms of conservation of kinetic energy.
<p>Explain that technological problems often require multiple solutions that involve different designs, materials and processes and that have both intended and unintended consequences</p> <p>Specific Outcomes for Science, Technology and Society (STS) (Science & Technology Emphasis)</p>	<ul style="list-style-type: none"> • Investigate the role of impulse and momentum in the design and function of rockets and thrust systems • Assess the roles that conservation laws, the concepts of impulse and inertia and Newton’s laws play in the design and use of injury-prevention devices in vehicles and sports • Describe the limitations of applying the results from studies of isolated systems in solving a practical problem, as occurred with the early design and deployment of airbags.
<p>SKILLS OUTCOMES: (embed throughout the unit)</p>	
<p>Initiating and Planning: Formulate questions about observed relationships; plan investigations of questions, ideas, problems and issues</p>	<ul style="list-style-type: none"> • Design an experiment and identify and control major variables; e.g., demonstrate the conservation of linear momentum or illustrate the relationship between impulse and change in momentum
<p>Performing and Recording: Conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information</p>	<ul style="list-style-type: none"> • Perform an experiment to demonstrate the conservation of linear momentum, using available technologies; e.g., air track, air table, motion sensors, strobe lights and photography • Collect information from various print and electronic sources to explain the use of momentum and impulse concepts; e.g., rocketry and thrust systems or the interaction between a golf club head and the ball
<p>Analyzing and Interpreting: Analyze data and apply mathematical and conceptual models to develop and assess possible solutions</p>	<ul style="list-style-type: none"> • Analyze graphs that illustrate the relationship between force and time during a collision • Analyze, quantitatively, one- and two-dimensional interactions, using given data or by manipulating objects or computer simulations
<p>Communication and Teamwork: Work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results</p>	<ul style="list-style-type: none"> • Use appropriate International System of Units (SI) notation, fundamental and derived units and significant digits • Use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate ideas, plans and results • Use the delta notation correctly when describing changes in quantities

Unit B: Forces and Fields

Specific Outcomes	Achievement Indicators – Measurable outcomes
<i>It is expected that students will:</i>	<i>The following set of indicators may be used to assess student achievement for each related specific learning outcome. Students who have fully met the specific learning outcomes are able to:</i>
<p>Focusing Questions: How was the value of the elementary charge determined? What is the relationship between electricity and magnetism? How does magnetism assist in the understanding of fundamental particles? How has this understanding revolutionized the modern way of life?</p>	
<p>1 GENERAL OUTCOMES: STUDENTS WILL EXPLAIN THE BEHAVIOUR OF ELECTRIC CHARGES, USING THE LAWS THAT GOVERN ELECTRICAL INTERACTIONS.</p>	
Knowledge: explain the behaviour of electric charges, using the laws that govern electrical interactions.	<ul style="list-style-type: none"> • Explain electrical interactions in terms of the law of conservation of charge • Explain electrical interactions in terms of the repulsion and attraction of charges • Compare the methods of transferring charge (conduction and induction) • Explain, qualitatively, the distribution of charge on the surfaces of conductors and insulators • Explain, qualitatively, the principles pertinent to Coulomb’s torsion balance experiment • Apply Coulomb’s law, quantitatively, to analyze the interaction of two point charges • Determine, quantitatively, the magnitude and direction of the electric force on a point charge due to two or more other point charges in a plane • Compare, qualitatively and quantitatively, the inverse square relationship as it is expressed by Coulomb’s law and by Newton’s universal law of gravitation
Explain that concepts, models and theories are often used in interpreting and explaining observations and in predicting future observations Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)	<ul style="list-style-type: none"> • Explain that the electric model of matter is fundamental to the interpretation of electrical phenomena • Explain that charge separation and transfer from one object to another are fundamental electrical processes
Explain that scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery	<ul style="list-style-type: none"> • Compare and contrast the experimental designs used by Coulomb and Cavendish, in terms of the role that technology plays in advancing science.
<p>SKILLS OUTCOMES: (embed throughout the unit)</p>	
Initiating and Planning: Formulate questions about observed relationships; plan investigations of questions, ideas, problems and issues	<ul style="list-style-type: none"> • Design an experiment to examine the relationships among magnitude of charge, electric force and distance between point charges • Predict the results of an activity that demonstrates charge separation and transfer
Performing and Recording: Conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information	<ul style="list-style-type: none"> • Perform an activity to demonstrate methods of charge separation and transfer • Perform an experiment to demonstrate the relationships among magnitude of charge, electric force and distance between point charges
Analyzing and Interpreting: Analyze data and apply mathematical and conceptual models to develop and assess possible solutions	<ul style="list-style-type: none"> • Infer, from empirical evidence, the mathematical relationship among charge, force and distance between point charges • Use free-body diagrams to describe the electrostatic forces acting on a charge • Use graphical techniques to analyze data; e.g., curve straightening (manipulating variables to obtain a straight-line graph)

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<i>It is expected that students will:</i>	<i>The following set of indicators may be used to assess student achievement for each related specific learning outcome. Students who have fully met the specific learning outcomes are able to:</i>
Communication and Teamwork: Work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results	<ul style="list-style-type: none"> • Select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions
2 GENERAL OUTCOMES: STUDENTS WILL DESCRIBE ELECTRICAL PHENOMENA, USING THE ELECTRIC FIELD THEORY	
Knowledge: describe electrical phenomena, using the electric field theory	<ul style="list-style-type: none"> • Define vector fields • Compare forces and fields • Compare, qualitatively, gravitational potential energy and electric potential energy • Define electric potential difference as a change in electric potential energy per unit of charge • Calculate the electric potential difference between two points in a uniform electric field • Explain, quantitatively, electric fields in terms of intensity (strength) and direction, relative to the source of the field and to the effect on an electric charge • Define electric current as the amount of charge passing a reference point per unit of time • Describe, quantitatively, the motion of an electric charge in a uniform electric field • Explain, quantitatively, electrical interactions using the law of conservation of energy • Explain Millikan’s oil-drop experiment and its significance relative to charge quantization.
Explain that the goal of technology is to provide solutions to practical problems Specific Outcomes for Science, Technology and Society (STS) (Science and Technology Emphasis)	<ul style="list-style-type: none"> • Assess how the principles of electrostatics are used to solve problems in industry and technology and to improve upon quality of life; e.g., photocopiers, electrostatic air cleaners, precipitators, antistatic clothing products, lightning rods
Explain that scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery	<ul style="list-style-type: none"> • Explain, qualitatively, how the problem of protecting sensitive components in a computer from electric fields is solved.
SKILLS OUTCOMES: (embed throughout the unit)	
Initiating and Planning: Formulate questions about observed relationships; plan investigations of questions, ideas, problems and issues	<ul style="list-style-type: none"> • Evaluate and select appropriate procedures and instruments for collecting data and information and for determining and plotting electric fields
Performing and Recording: Conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information	<ul style="list-style-type: none"> • Plot electric fields, using field lines, for fields induced by discrete point charges, combinations of discrete point charges (similarly and oppositely charged) and charged parallel plates
Analyzing and Interpreting: Analyze data and apply mathematical and conceptual models to develop and assess possible solutions	<ul style="list-style-type: none"> • Analyze, quantitatively, the motion of an electric charge following a straight or curved path in a uniform electric field, using Newton’s second law, vector addition and conservation of energy • Use accepted scientific convention and express energy in terms of electron volts, when appropriate

Unit B: Forces and Fields

Specific Outcomes	Achievement Indicators – Measurable outcomes
<i>It is expected that students will:</i>	<i>The following set of indicators may be used to assess student achievement for each related specific learning outcome. Students who have fully met the specific learning outcomes are able to:</i>
(Continued)	<ul style="list-style-type: none"> • Use free-body diagrams to describe the forces acting on a charge in an electric field
Communication and Teamwork: Work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results	<ul style="list-style-type: none"> • Select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions
3 General Outcome: STUDENTS WILL EXPLAIN HOW THE PROPERTIES OF ELECTRIC AND MAGNETIC FIELDS ARE APPLIED IN NUMEROUS DEVICES.	
Knowledge: explain how the properties of electric and magnetic fields are applied in numerous devices	<ul style="list-style-type: none"> • Describe magnetic interactions in terms of forces and fields • Compare gravitational, electric and magnetic fields (caused by permanent magnets and moving charges) in terms of their sources and directions • Describe how the discoveries of Oersted and Faraday form the foundation of the theory relating electricity to magnetism • Describe, qualitatively, a moving charge as the source of a magnetic field and predict the orientation of the magnetic field from the direction of motion • Explain, qualitatively and quantitatively, how a uniform magnetic field affects a moving electric charge, using the relationships among charge, motion, field direction and strength, when motion and field directions are mutually perpendicular • Explain, quantitatively, how uniform magnetic and electric fields affect a moving electric charge, using the relationships among charge, motion, field direction and strength, when motion and field directions are mutually perpendicular • Describe and explain, qualitatively, the interaction between a magnetic field and a moving charge and between a magnetic field and a current-carrying conductor • Explain, quantitatively, the effect of an external magnetic field on a current-carrying conductor • Describe, qualitatively, the effects of moving a conductor in an external magnetic field, in terms of moving charges in a magnetic field.
Explain that concepts, models and theories are often used in interpreting and explaining observations and in predicting future observations Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)	<ul style="list-style-type: none"> • Discuss, qualitatively, Lenz’s law in terms of conservation of energy, giving examples of situations in which Lenz’s law applies investigate the mechanism that causes atmospheric auroras
Explain that the goal of technology is to provide solutions to practical problems and that the appropriateness, risks and benefits of technologies need to be assessed for each potential application from a variety of perspectives, including sustainability	<ul style="list-style-type: none"> • Evaluate an electromagnetic technology, such as magnetic resonance imaging (MRI), positron emission tomography (PET), transformers, alternating current (AC) and direct current (DC) motors, AC and DC generators, speakers, telephones • Investigate the effects of electricity and magnetism on living organisms, in terms of the limitations of scientific knowledge and technology and in terms of quality of life
Explain that scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery	<ul style="list-style-type: none"> • Describe how technological developments were influenced by the discovery of superconductivity • Investigate how nanotubes can be used to construct low-resistance conductors.

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<i>It is expected that students will:</i>	<i>The following set of indicators may be used to assess student achievement for each related specific learning outcome. Students who have fully met the specific learning outcomes are able to:</i>
SKILLS OUTCOMES: (embed throughout the unit)	
Initiating and Planning: Formulate questions about observed relationships; plan investigations of questions, ideas, problems and issues	<ul style="list-style-type: none"> • Design an experiment to demonstrate the effect of a uniform magnetic field on a current-carrying conductor • Design an experiment to demonstrate the effect of a uniform magnetic field on a moving conductor • Design an experiment to demonstrate the effect of a uniform magnetic field on a moving electric charge
Performing and Recording: Conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information	<ul style="list-style-type: none"> • Perform an experiment to demonstrate the effect of a uniform magnetic field on a current-carrying conductor, using the appropriate apparatus effectively and safely • Perform an experiment to demonstrate the effect of a uniform magnetic field on a moving conductor, using the appropriate apparatus effectively and safely • Predict, using appropriate hand rules, the relative directions of motion, force and field in electromagnetic interactions
Analyzing and Interpreting: Analyze data and apply mathematical and conceptual models to develop and assess possible solutions	<ul style="list-style-type: none"> • State a conclusion, based on experimental evidence that describes the interactions of a uniform magnetic field and a moving or current-carrying conductor • Analyze, quantitatively, the motion of an electric charge following a straight or curved path in a uniform magnetic field, using Newton’s second law and vector addition • Analyze, quantitatively, the motion of an electric charge following a straight path in uniform and mutually perpendicular electric and magnetic fields, using Newton’s second law and vector addition • Use free-body diagrams to describe forces acting on an electric charge in electric and magnetic fields
Communication and Teamwork: Work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results	<ul style="list-style-type: none"> • Select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions

Unit C: Electromagnetic Radiation

Specific Outcomes	Achievement Indicators – Measurable outcomes
<i>It is expected that students will:</i>	<i>The following set of indicators may be used to assess student achievement for each related specific learning outcome. Students who have fully met the specific learning outcomes are able to:</i>
<p>Focusing Questions: What roles do electricity and magnetism play in EMR? Does EMR have a wave or a particle nature? What experimental evidence is required to decide whether EMR has a wave or a particle nature? What technological devices are used today as a result of investigating and applying electromagnetic phenomena?</p>	
<p>1 GENERAL OUTCOMES: STUDENTS WILL EXPLAIN THE NATURE AND BEHAVIOUR OF EMR, USING THE WAVE MODEL.</p>	
<p>Knowledge: explain the nature and behaviour of EMR, using the wave model.</p>	<ul style="list-style-type: none"> • Describe, qualitatively, how all accelerating charges produce EMR • Compare and contrast the constituents of the electromagnetic spectrum on the basis of frequency and wavelength • Explain the propagation of EMR in terms of perpendicular electric and magnetic fields that are varying with time and travelling away from their source at the speed of light • Explain, qualitatively, various methods of measuring the speed of EMR • Calculate the speed of EMR, given data from a Michelson-type experiment • Describe, quantitatively, the phenomena of reflection and refraction, including total internal reflection • Describe, quantitatively, simple optical systems, consisting of only one component, for both lenses and curved mirrors • Describe, qualitatively, diffraction, interference and polarization • Describe, qualitatively, how the results of Young’s double-slit experiment support the wave model of light • Solve double-slit and diffraction grating problems using, $\lambda = \frac{xd}{xt}$, $\lambda = \frac{d\sin\theta}{n}$ • Describe, qualitatively and quantitatively, how refraction supports the wave model of EMR, using $\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$ • Compare and contrast the visible spectra produced by diffraction gratings and triangular prisms
<p>Explain that scientific knowledge is subject to change as new evidence becomes apparent and as laws and theories are tested and subsequently revised, reinforced or rejected</p> <p>Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)</p>	<ul style="list-style-type: none"> • Use examples, such as Poisson’s spot, speed of light in water, sunglasses, photography and liquid crystal diodes, to illustrate how theories evolve
<p>Explain that scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery</p>	<ul style="list-style-type: none"> • Describe procedures for measuring the speed of EMR • Investigate the design of greenhouses, cameras, telescopes, solar collectors and fibre optics • Investigate the effects of frequency and wavelength on the growth of plants • Investigate the use of interferometry techniques in the search for extrasolar planets.
<p>SKILLS OUTCOMES: (embed throughout the unit)</p>	
<p>Initiating and Planning: Formulate questions about observed relationships; plan investigations of questions, ideas, problems and issues</p>	<ul style="list-style-type: none"> • Predict the conditions required for diffraction to be observed • Predict the conditions required for total internal reflection to occur • Design an experiment to measure the speed of light

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Specific Outcomes	Achievement Indicators – Measurable outcomes
<i>It is expected that students will:</i>	<i>The following set of indicators may be used to assess student achievement for each related specific learning outcome. Students who have fully met the specific learning outcomes are able to:</i>
<p>Performing and Recording: Conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information</p>	<ul style="list-style-type: none"> • Perform experiments to demonstrate refraction at plane and uniformly curved surfaces • Perform an experiment to determine the index of refraction of several different substances • Conduct an investigation to determine the focal length of a thin lens and of a curved mirror • Observe the visible spectra formed by diffraction gratings and triangular prisms • Perform an experiment to determine the wavelength of a light source in air or in a liquid, using a double-slit or a diffraction grating • Perform an experiment to verify the effects on an interference pattern due to changes in wavelength, slit separation and/or screen distance
<p>Analyzing and Interpreting: Analyze data and apply mathematical and conceptual models to develop and assess possible solutions</p>	<ul style="list-style-type: none"> • Derive the mathematical representation of the law of refraction from experimental data • Use ray diagrams to describe an image formed by thin lenses and curved mirrors • Demonstrate the relationship among wavelength, slit separation and screen distance, using empirical data and algorithms; determine the wavelength of EMR, using data provided from demonstrations and other sources • Determine the wavelength of EMR, using data provided from demonstrations and other sources; e.g., wavelengths of microwaves from the interference patterns of television signals or microwave ovens
<p>Communication and Teamwork: Work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results</p>	<ul style="list-style-type: none"> • Select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions; e.g., draw ray diagrams
<p>2 GENERAL OUTCOMES: STUDENTS WILL EXPLAIN THE PHOTOELECTRIC EFFECT, USING THE QUANTUM MODEL</p>	
<p>Knowledge: explain the photoelectric effect, using the quantum model</p>	<ul style="list-style-type: none"> • Define the photon as a quantum of EMR and calculate its energy • Classify the regions of the electromagnetic spectrum by photon energy • Describe the photoelectric effect in terms of the intensity and wavelength or frequency of the incident light and surface material • Describe, quantitatively, photoelectric emission, using concepts related to the conservation of energy • Describe the photoelectric effect as a phenomenon that supports the notion of the wave-particle duality of EMR • Explain, qualitatively and quantitatively, the Compton effect as another example of wave-particle duality, applying the laws of mechanics and of conservation of momentum and energy to photons
<p>Explain that scientific knowledge and theories develop through hypotheses, the collection of evidence, investigation and the ability to provide explanations Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)</p>	<ul style="list-style-type: none"> • Describe how Hertz discovered the photoelectric effect while investigating electromagnetic waves • Describe how Planck used energy quantization to explain blackbody radiation

Unit C: Electromagnetic Radiation

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<i>It is expected that students will:</i>	<i>The following set of indicators may be used to assess student achievement for each related specific learning outcome. Students who have fully met the specific learning outcomes are able to:</i>
Explain that concepts, models and theories are often used in interpreting and explaining observations and in predicting future observations	<ul style="list-style-type: none"> Investigate and report on the development of early quantum theory Identify similarities between physicists' efforts at unifying theories and holistic Aboriginal worldviews
Explain that the goal of technology is to provide solutions to practical problems	<ul style="list-style-type: none"> Analyze, in general terms, the functioning of various technological applications of photons to solve practical problems; e.g., automatic door openers, burglar alarms, light meters, smoke detectors, X-ray examination of welds, crystal structure analysis.
SKILLS OUTCOMES: (embed throughout the unit)	
Initiating and Planning: Formulate questions about observed relationships; plan investigations of questions, ideas, problems and issues	<ul style="list-style-type: none"> Predict the effect, on photoelectric emissions, of changing the intensity and/or frequency of the incident radiation or material of the photocathode Design an experiment to measure Planck's constant, using either a photovoltaic cell or a light-emitting diode (LED)
Performing and Recording: Conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information	<ul style="list-style-type: none"> Perform an experiment to demonstrate the photoelectric effect Measure Planck's constant, using either a photovoltaic cell or an LED
Analyzing and Interpreting: Analyze data and apply mathematical and conceptual models to develop and assess possible solutions	<ul style="list-style-type: none"> Analyze and interpret empirical data from an experiment on the photoelectric effect, using a graph that is either drawn by hand or is computer generated
Communication and Teamwork: Work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results	<ul style="list-style-type: none"> Select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions

Unit D: Atomic Physics

Focusing Questions:
 How is the atom organized?
 How can a model of the atom and the nucleus be subjected to experimental tests?
 How does knowledge of the internal structure of the atom lead to the development of applications of energy supply and to the technology of diagnostic imaging?

1 GENERAL OUTCOMES:

Knowledge: describe the electrical nature of the atom	<ul style="list-style-type: none"> Describe matter as containing discrete positive and negative charges Explain how the discovery of cathode rays contributed to the development of atomic models Explain J. J. Thomson's experiment and the significance of the results for both science and technology Explain, qualitatively, the significance of the results of Rutherford's scattering experiment, in terms of scientists' understanding of the relative size and mass of the nucleus and the atom
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Unit D: Atomic Physics

Specific Outcomes	Achievement Indicators – Measurable outcomes
<i>It is expected that students will:</i>	<i>The following set of indicators may be used to assess student achievement for each related specific learning outcome. Students who have fully met the specific learning outcomes are able to:</i>
Explain that scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)	<ul style="list-style-type: none"> Analyze how the identification of the electron and its characteristics is an example of the interaction of science and technology Analyze the operation of cathode-ray tubes and mass spectrometers.
SKILLS OUTCOMES: (embed throughout the unit)	
Initiating and Planning: Formulate questions about observed relationships; plan investigations of questions, ideas, problems and issues	<ul style="list-style-type: none"> Identify, define and delimit questions to investigate; Evaluate and select appropriate procedures and instruments for collecting evidence and information, including appropriate sampling procedures
Performing and Recording: Conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information	<ul style="list-style-type: none"> Perform an experiment, or use simulations, to determine the charge-to-mass ratio of the electron
Analyzing and Interpreting: Analyze data and apply mathematical and conceptual models to develop and assess possible solutions	<ul style="list-style-type: none"> Determine the mass of an electron and/or ion, given appropriate empirical data Derive a formula for the charge-to-mass ratio that has input variables that can be measured in an experiment using electric and magnetic field
Communication and Teamwork: Work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results	<ul style="list-style-type: none"> Select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions
2 GENERAL OUTCOMES: STUDENTS WILL DESCRIBE THE QUANTIZATION OF ENERGY IN ATOMS AND NUCLEI	
Knowledge: describe the quantization of energy in atoms and nuclei	<ul style="list-style-type: none"> Explain, qualitatively, how emission of EMR by an accelerating charged particle invalidates the classical model of the atom Describe that each element has a unique line spectrum Explain, qualitatively, the characteristics of, and the conditions necessary to produce, continuous line-emission and line-absorption spectra Explain, qualitatively, the concept of stationary states and how they explain the observed spectra of atoms and molecules Calculate the energy difference between states, using the law of conservation of energy and the observed characteristics of an emitted photon Explain, qualitatively, how electron diffraction provides experimental support for the de Broglie hypothesis Describe, qualitatively, how the two-slit electron interference experiment shows that quantum systems, like photons and electrons, may be modelled as particles or waves, contrary to intuition

Unit D: Atomic Physics

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<i>It is expected that students will:</i>	<i>The following set of indicators may be used to assess student achievement for each related specific learning outcome. Students who have fully met the specific learning outcomes are able to:</i>
Explain that scientific knowledge and theories develop through hypotheses, the collection of evidence, investigation and the ability to provide explanations. Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)	<ul style="list-style-type: none"> Investigate and report on the use of line spectra in the study of the universe and the identification of substances Investigate how empirical evidence guided the evolution of the atomic model
Explain that scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery	<ul style="list-style-type: none"> Investigate and report on the application of spectral or quantum concepts in the design and function of practical devices, such as street lights, advertising signs, electron microscopes and lasers
SKILLS OUTCOMES: (embed throughout the unit)	
Initiating and Planning: Formulate questions about observed relationships; plan investigations of questions, ideas, problems and issues	<ul style="list-style-type: none"> Predict the conditions necessary to produce line-emission and line-absorption spectra Predict the possible energy transitions in the hydrogen atom, using a labelled diagram showing energy levels
Performing and Recording: Conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information	<ul style="list-style-type: none"> Observe line-emission and line-absorption spectra Observe the representative line spectra of selected elements Use library and electronic research tools to compare and contrast, qualitatively, the classical and quantum models of the atom
Analyzing and Interpreting: Analyze data and apply mathematical and conceptual models to develop and assess possible solutions	<ul style="list-style-type: none"> Identify elements represented in sample line spectra by comparing them to representative line spectra of elements
Communication and Teamwork: Work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results	<ul style="list-style-type: none"> Select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions
3 GENERAL OUTCOMES: STUDENTS WILL DESCRIBE NUCLEAR FISSION AND FUSION AS POWERFUL ENERGY SOURCES IN NATURE	
Knowledge: describe nuclear fission and fusion as powerful energy sources in nature	<ul style="list-style-type: none"> Describe the nature and properties, including the biological effects, of alpha, beta and gamma radiation Write nuclear equations, using isotope notation, for alpha, beta-negative and beta-positive decays, including the appropriate neutrino and antineutrino Perform simple, non-logarithmic half-life calculations Use the law of conservation of charge and mass number to predict the particles emitted by a nucleus Compare and contrast the characteristics of fission and fusion reactions Relate, qualitatively and quantitatively, the mass defect of the nucleus to the energy released in nuclear reactions, using Einstein's concept of mass-energy equivalence

Unit D: Atomic Physics

Specific Outcomes	Achievement Indicators – Measurable outcomes
<i>It is expected that students will:</i>	<i>The following set of indicators may be used to assess student achievement for each related specific learning outcome. Students who have fully met the specific learning outcomes are able to:</i>
Explain that the goal of science is knowledge about the natural world Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)	<ul style="list-style-type: none"> • Investigate the role of nuclear reactions in the evolution of the universe (nucleosynthesis, stellar expansion and contraction) • Investigate annihilation of particles and pair production
Explain that the products of technology are devices, systems and processes that meet given needs and that the appropriateness, risks and benefits of technologies need to be assessed for each potential application from a variety of perspectives, including sustainability	<ul style="list-style-type: none"> • Assess the risks and benefits of air travel (exposure to cosmic radiation), dental X-rays, radioisotopes used as tracers, food irradiation, use of fission or fusion as a commercial power source and nuclear and particle research • Assess the potential of fission or fusion as a commercial power source to meet the rising demand for energy, with consideration for present and future generations
SKILLS OUTCOMES: (embed throughout the unit)	
Initiating and Planning: Formulate questions about observed relationships; plan investigations of questions, ideas, problems and issues	<ul style="list-style-type: none"> • Predict the penetrating characteristics of decay products
Performing and Recording: Conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information	<ul style="list-style-type: none"> • Research and report on scientists who contributed to the understanding of the structure of the nucleus
Analyzing and Interpreting: Analyze data and apply mathematical and conceptual models to develop and assess possible solutions	<ul style="list-style-type: none"> • Graph data from radioactive decay and estimate half-life values • Interpret common nuclear decay chains • Graph data from radioactive decay and infer an exponential relationship between measured radioactivity and elapsed time • Compare the energy released in a nuclear reaction to the energy released in a chemical reaction, on the basis of energy per unit mass of reactants
Communication and Teamwork: Work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results	<ul style="list-style-type: none"> • Select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions
4 GENERAL OUTCOMES: STUDENTS WILL DESCRIBE THE ONGOING DEVELOPMENT OF MODELS OF THE STRUCTURE OF MATTER	
Knowledge: describe the ongoing development of models of the structure of matter	<ul style="list-style-type: none"> • Explain how the analysis of particle tracks contributed to the discovery and identification of the characteristics of subatomic particles • Explain, qualitatively, in terms of the strong nuclear force, why high-energy particle accelerators are required to study subatomic particles • Describe the modern model of the proton and neutron as being composed of quarks • Compare and contrast the up quark, the down quark, the electron and the electron neutrino, and their antiparticles, in terms of charge and energy (mass-energy) • Describe beta-positive (β^+) and beta-negative (β^-) decay, using first-generation elementary fermions and the principle of charge conservation (Feynman diagrams are not required)

Unit D: Atomic Physics

Specific Outcomes	Achievement Indicators – Measurable outcomes
<i>It is expected that students will:</i>	<i>The following set of indicators may be used to assess student achievement for each related specific learning outcome. Students who have fully met the specific learning outcomes are able to:</i>
Explain that concepts, models and theories are often used in interpreting and explaining observations and in predicting future observations Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)	<ul style="list-style-type: none"> • Research and report on the development of models of matter
Explain that scientific knowledge is subject to change as new evidence becomes apparent and as laws and theories are tested and subsequently revised, reinforced or rejected	<ul style="list-style-type: none"> • Observe how apparent conservation law violations led to revisions of the model of the atom; i.e., an apparent failure of conservation laws required the existence of the neutrino
Explain that scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery	<ul style="list-style-type: none"> • Investigate how high-energy particle accelerators contributed to the development of the Standard Model of matter.
SKILLS OUTCOMES: (embed throughout the unit)	
Initiating and Planning: Formulate questions about observed relationships; plan investigations of questions, ideas, problems and issues	<ul style="list-style-type: none"> • Predict the characteristics of elementary particles, from images of their tracks in a bubble chamber, within an external magnetic field
Performing and Recording: Conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information	<ul style="list-style-type: none"> • Research, using library and electronic resources, the relationships between the fundamental particles and the interactions they undergo
Analyzing and Interpreting: Analyze data and apply mathematical and conceptual models to develop and assess possible solutions	<ul style="list-style-type: none"> • Analyze, qualitatively, particle tracks for subatomic particles other than protons, electrons and neutrons • Write β^+ and β^- decay equations, identifying the elementary fermions involved • Use hand rules to determine the nature of the charge on a particle (AI–NS6) • Use accepted scientific convention and express mass in terms of mega electron volts per c^2 (MeV/c^2), when appropriate
Communication and Teamwork: Work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results	<ul style="list-style-type: none"> • Select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions