FARLabs Radioactivity Experiments Curriculum Relevance

Contents

Radioactivity Experiment Details:

Experiments	Year Level Relevance	Subjects	Class Sizes
Turntable	9, 10, 11, 12	Physics, Chemistry, Earth Sciences	16 students (8 groups of 2)
Inverse Square Law	9, 10, 11, 12	Physics, Chemistry, Earth Sciences	16 students (8 groups of 2)

Radioactivity Australian Curriculum Relevance

Australian Curriculum Education Level	Curriculum Learning Outcomes and Examples

Year 9 Science Australian Curriculum	**Science Understanding: Chemical Sciences**
	• All matter is made of atoms that are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms (ACSSU177)
	    • investigating how radiocarbon and other dating methods have been used to establish that Aboriginal Peoples have been present on the Australian continent for more than 60,000 years (OI.6)
	    • describing and modelling the structure of atoms in terms of the nucleus, protons, neutrons and electrons
	    • comparing the mass and charge of protons, neutrons and electrons
	    • describing in simple terms how alpha and beta particles and gamma radiation are released from unstable atoms
	
	Science as a Human Endeavour
	• Nature and development of science
	    • Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community (ACSHE157)
	    • Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries (ACSHE158)
	• Use and influence of science
	    • People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities (ACSHE160)
	    • Values and needs of contemporary society can influence the focus of scientific research (ACSHE228)
	
	Science Inquiry Skills
	• Questioning and predicting
	    • Formulate questions or hypotheses that can be investigated scientifically (ACSIS164)
	• Planning and conducting
	    • Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS165)
	    • Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately (ACSIS166)
	• Processing and analysing data and information

	• Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies (ACSIS169)
	• Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS170)
	• Evaluating
	  • Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data (ACSIS171)
	  • Critically analyse the validity of information in primary and secondary sources and evaluate the approaches used to solve problems (ACSIS172)
	• Communicating
	  • Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS174)

Year 10 Science Australian Curriculum	**Science as a Human Endeavour**
	• Nature and development of science
	  • Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community (ACSHE191)
	  • Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries (ACSHE192)
	• Use and influence of science
	  • People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities (ACSHE194)
	  • Values and needs of contemporary society can influence the focus of scientific research (ACSHE230)
	
	Science Inquiry Skills
	• Questioning and predicting
	  • Formulate questions or hypotheses that can be investigated scientifically (ACSIS198)
	• Planning and conducting
	  • Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS199)
	  • Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately (ACSIS200)
	• Processing and analysing data and information

	(continued) - Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies (ACSIS203) - Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS204) - Evaluating - Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data (ACSIS205) - Critically analyse the validity of information in primary and secondary sources and evaluate the approaches used to solve problems (ACSIS206) - Communicating - Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS208)
Senior School Science Australian Curriculum – Physics Unit 1: Thermal, nuclear and electrical physics	**Learning Outcomes:** - understand how the nuclear model of the atom explains radioactivity, fission, fusion and the properties of radioactive nuclides - understand how scientific models and theories have developed and are applied to improve existing, and develop new, technologies - use science inquiry skills to design, conduct and analyse safe and effective investigations into heating processes, nuclear physics and electrical circuits, and to communicate methods and findings - use algebraic and graphical representations to calculate, analyse and predict measurable quantities associated with heating processes, nuclear reactions and electrical circuits - evaluate, with reference to empirical evidence, claims about heating processes, nuclear reactions and electrical technologies - communicate physics understanding using qualitative and quantitative representations in appropriate modes and genres. **Examples in context:** - Radioisotopes and radiometric dating - Radiometric dating of materials utilises a variety of methods depending on the age of the substances to be dated. The presence of natural radioisotopes in materials such as carbon, uranium, potassium and argon and knowledge about their half life and decay processes enables scientists to develop accurate geologic timescales and geologic history for particular regions (ACSPH011). This information is used to inform study of events such as earthquakes and volcanic eruptions, and helps scientists to predict their behaviour based on past events (ACSPH014). Dating of wood and carbon-based materials has also led to improvements in our understanding of more recent history through dating of preserved objects (ACSPH014).

	• Harnessing nuclear power ◦ Knowledge of the process of nuclear fission has led to the ability to use nuclear power as a possible long-term alternative to fossil fuel electricity generation (ACSPH013). Nuclear power has been used very successfully to produce energy in many countries but has also caused significant harmful consequences in a number of specific instances (ACSPH013). Analysis of health and environmental risks and weighing these against environmental and cost benefits is a scientific and political issue in Australia which has economic, cultural and ethical aspects (ACSPH012). The management of nuclear waste is based on knowledge of the behaviour of radiation. Current proposals for waste storage in Australia attempt to address the unintended harmful consequences of the use of radioactive substances (ACSPH013). • Nuclear fusion in stars ◦ Energy production in stars was attributed to gravity until knowledge of nuclear reactions enabled understanding of nuclear fusion. Almost all the energy used on Earth has its origin in the conversion of mass to energy that occurs when hydrogen nuclei fuse together to form helium in the core of the sun (ACSPH010). According to the Big Bang Theory, all the elements heavier than helium have been created by fusion in stars. The study of nuclear fusion in the sun has produced insights into the formation and life cycle of stars (ACSPH010). An unexpected consequence of early understanding of fusion in stars was its use to inform the development of thermonuclear weapons (ACSPH010). Research is ongoing into the use of fusion as an alternative power source (ACSPH013). • Mathematical representations and relationships ◦ The nuclear model of the atom describes the atom as consisting of an extremely small nucleus, which contains most of the atom's mass and is made up of positively charged protons and uncharged neutrons surrounded by negatively charged electrons (ACSPH026) ◦ Nuclear stability is the result of the strong nuclear force, which operates between nucleons over a very short distance and opposes the electrostatic repulsion between protons in the nucleus (ACSPH027) ◦ Some nuclides are unstable and spontaneously decay, emitting alpha, beta and/or gamma radiation over time until they become stable nuclides (ACSPH028) ◦ Each species of radionuclide has a specific half-life (ACSPH029) ◦ Alpha, beta and gamma radiation have sufficient energy to ionise atoms (ACSPH030) ◦ Einstein's mass/energy relationship, which applies to all energy changes, enables the energy released in nuclear reactions to be determined from the mass change in the reaction (ACSPH031) ◦ Alpha and beta decay are examples of spontaneous transmutation reactions, while artificial transmutation is a managed process that changes one nuclide into another (ACSPH032)

- Neutron-induced nuclear fission is a reaction in which a heavy nuclide captures a neutron and then splits into two smaller radioactive nuclides, with the release of neutrons and energy (ACSPH033)
- A fission chain reaction is a self-sustaining process that may be controlled to produce thermal energy, or uncontrolled to release energy explosively (ACSPH034)
- Nuclear fusion is a reaction in which light nuclides combine to form a heavier nuclide, with the release of energy (ACSPH035)
- More energy is released per nucleon in nuclear fusion than in nuclear fission because a greater percentage of the mass is transformed into energy (ACSPH036)

Mathematical representations and relationships

$N = N_o\left(\frac{1}{2}\right)^n$ (for whole numbers of half-lives only)

$N =$ number of nuclides remaining in a sample, n = number of whole half-lives,

$\Delta E = \Delta mc^2$

$N_o =$ original number of nuclides in the sample

$\triangle E =$ energy change, $\Delta m =$ mass change, $c =$ speed of light

$(3 \times 10^8 \text{ m s}^{-1})$

Codes:

- Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSPH010)
- Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSPH011)
- The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSPH012)
- The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSPH013)
- Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions (ACSPH014)

Senior School Science Australian Curriculum – Physics Unit 4: Revolutions in modern physics	**Learning Outcomes:**
	• understand how the Standard Model explains the nature of and interaction between the fundamental particles that form the building blocks of matter
	• understand how models and theories have developed over time, and the ways in which physical science knowledge and associated technologies interact with social, economic, cultural and ethical considerations
	• use algebraic and graphical models to solve problems and make predictions related to the theory and applications of special relativity, quantum theory and the Standard Model
	• communicate physics understanding using qualitative and quantitative representations in appropriate modes and genres.
	
	Science Understanding: Special Relativity
	Examples in context:
	• Nuclear Reactors
	    • Special relativity leads to the idea of mass-energy equivalence, which has been applied in nuclear fission reactors. Nuclear reactors are most commonly used for power generation, propulsion and scientific research. Research reactors have resulted in advances in areas such as medicine and materials testing and fabrication through provision of nuclear isotopes for industrial and medical applications. Although nuclear reactors provide a range of benefits, there is considerable public concern over safety and security issues (ACSPH124). Data from the nuclear industry indicates that nuclear power reactors pose an acceptable risk to public safety and that much has been done to limit that risk. However, other groups argue that such a risk is not acceptable, and, even if no accidents occur, storage of the radioactive waste produced from nuclear facilities remains a safety concern (ACSPH126).
	
	Science Understanding: The Standard Model
	Examples in context:
	• Particle Accelerators
	    • Particle accelerators propel charged particles to high speeds using a combination of electric and magnetic fields. High-energy particle accelerators are used in particle physics research to create and observe particles. These machines have gradually increased in size, complexity and in their ability to accelerate particles to higher speeds, thus increasing scientists' ability to observe new particles (ACSPH122). More practical uses of particle accelerators include their use in production of radioisotopes for medical treatments and as synchrotron light sources. The construction of the Australian Synchrotron involved collaboration between Australian and New Zealand science organisations, state and federal governments and international organisations and committees including the International Science Advisory Committee and the International Machine Advisory Committee (ACSPH127).

	Codes: • ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of datasets with which scientists work (ACSPH122) • The acceptance of science understanding can be influenced by the social, economic and cultural context in which it is considered (ACSPH124) • Science can be limited in its ability to provide definitive answers to public debate; there may be insufficient reliable data available, or interpretation of the data may be open to question (ACSPH126) • International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSPH127)
Senior School Science Australian Curriculum – Chemistry Unit 1: Chemical fundamentals: Structure, properties and reactions	**Learning Outcomes** • understand how the atomic model and models of bonding explain the structure and properties of elements and compounds • use science inquiry skills to design, conduct, evaluate and communicate investigations into the properties of elements, compounds and mixtures and the energy changes involved in chemical reactions • evaluate, with reference to empirical evidence, claims about chemical properties, structures and reactions • communicate, predict and explain chemical phenomena using qualitative and quantitative representations in appropriate modes and genres. **Examples in context:** • Models of the atom ◦ In the early nineteenth century, Dalton proposed some fundamental properties of atoms that would explain existing laws of chemistry. One century later, a range of experiments provided evidence that enabled scientists to develop models of the structure of the atom. These included using radiation in the form of X-rays and alpha particles, and the passing of particles through a magnetic field to determine their mass (ACSCH010). Evidence from French physicist Becquerel's discovery of radioactivity suggested the presence of subatomic particles, and this was also a conclusion from gas discharge experiments. British physicist J.J. Thomson was able to detect electrons, and his results, combined with the later work of Millikan, an American experimental physicist, resulted in both the charge and mass of electrons being calculated (ACSCH009). The British chemist Rutherford proposed a model of the atom comprising a heavy nucleus surrounded by space in which electrons were found, and Danish physicist Bohr's model further described how these electrons existed in distinct energy levels. The last of the main subatomic particles, the neutron, was discovered by the English physicist Chadwick in 1932, by bombarding samples of boron with alpha particles from radioactive polonium (ACSCH010). • Radioisotopes

	- Radioisotopes have a wide variety of uses, including Carbon-14 for carbon dating in geology and palaeobiology; radioactive tracers such as Iodine-131 in nuclear medicine; radioimmuno-assays for testing constituents of blood, serum, urine, hormones and antigens; and radiotherapy that destroys damaged cells (ACSCH011). Use of radioisotopes requires careful evaluation and monitoring because of the potential harmful effects to humans and/or the environment if their production, use and disposal are not managed effectively (ACSCH013). Risks include unwanted damage to cells in the body, especially during pregnancy, and ongoing radiation produced from radioactive sources with long half-lives. **Codes:** - Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility (ACSCH009) - Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSCH010) - Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSCH011) - The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSCH013)
Senior School Science ACARA Curriculum – Earth and Environmental Science Unit 1	**Learning Outcomes** - understand how theories and models have developed based on evidence from multiple disciplines; and the uses and limitations of Earth and environmental science knowledge in a range of contexts - use science inquiry skills to collect, analyse and communicate primary and secondary data on Earth and environmental phenomena; and use these as analogues to deduce and analyse events that occurred in the past - evaluate, with reference to empirical evidence, claims about the structure, interactions and evolution of Earth systems - communicate Earth and environmental understanding using qualitative and quantitative representations in appropriate modes and genres. **Examples in context:** - Understand the interior of Earth - Precise dates can be assigned to points on the relative geological time scale using data derived from the decay of radioisotopes in rocks and minerals; this establishes an absolute time scale and places the age of the Earth at 4.5 billion years (ACSES017)

Radioactivity Victorian Certificate of Education (VCE) Curriculum Relevance

VCE Education Level	Curriculum Learning Outcomes and Examples

VCE - Physics Unit 1: What ideas explain the physical world?	**Area of Study 3 (Outcome 3): What is matter and how is it formed?**
	
	Key Knowledge:
	• Particles in the nucleus:
	  ◦ explain nuclear stability with reference to the forces that operate over very small distances
	  ◦ describe the radioactive decay of unstable nuclei with reference to half-life
	  ◦ model radioactive decay as random decay with a particular half-life, including mathematical modelling with reference to whole half-lives
	  ◦ apply a simple particle model of the atomic nucleus to explain the origin of α, β- , β+ and γ radiation, including changes to the number of nucleons
	  ◦ explain nuclear transformations using decay equations involving α, β- , β+ and γ radiation
	  ◦ analyse decay series diagrams with reference to type of decay and stability of isotopes
	  ◦ relate
	• Energy from the atom:
	  ◦ compare the processes of nuclear fusion and nuclear fission
	  ◦ explain, using a binding energy curve, why both fusion and fission are reactions that produce energy
	
	Assessment:
	• a modelling activity
	• a summary report of selected practical investigations
	• a test comprising multiple choice and/or short answer and/or extended response.
	• Practical work is a central component of learning and assessment. As a guide, between 3½ and 5 hours of class time should be devoted to student practical work and investigations in each of Areas of Study 1 and 2 and to investigations in Area of Study 3 involving the use of secondary data and/or modelling.
	
	Key Skills:
	• Develop aims and questions, formulate hypotheses and make predictions
	  ◦ determine aims, hypotheses, questions and predictions that can be tested
	  ◦ identify independent, dependent and controlled variables
	• Plan and undertake investigations

	• determine appropriate type of investigation: conduct experiments; design-build-testevaluate a device; explore operation of a device; solve a scientific or technological problem; perform simulations; access secondary data, including data sourced through the internet that would otherwise be difficult to source as raw or primary data through a laboratory or a classroom
	• select and use equipment, materials and procedures appropriate to the investigation, taking into account potential sources of error and uncertainty
	• Comply with safety and ethical guidelines
	  • apply ethical principles when undertaking and reporting investigations
	  • apply relevant occupational health and safety guidelines while undertaking practical investigations
	• Conduct investigations to collect and record data
	  • work independently and collaboratively as appropriate and within identified research constraints
	  • systematically generate, collect, record and summarise both qualitative and quantitative data
	• Analyse and evaluate data, methods and scientific models
	  • process quantitative data using appropriate mathematical relationships, units and number of significant figures
	  • organise, present and interpret data using tables, line graphs, correlation, line of best fit, calculations of mean and fitting an appropriate curve to graphical data, including the use of error bars on graphs
	  • take a qualitative approach when identifying and analysing experimental data with reference to accuracy, precision, reliability, validity, uncertainty and errors (random and systematic)
	  • explain the merit of replicating procedures and the effects of sample sizes to obtain reliable data
	  • evaluate investigative procedures and possible sources of bias, and suggest improvements
	  • explain how models are used to organise and understand observed phenomena and concepts related to physics, identifying limitations of the models
	• Draw evidence-based conclusions
	  • determine to what extent evidence from an investigation supports the purpose of the investigation, and make recommendations, as appropriate, for modifying or extending the investigation
	  • draw conclusions consistent with evidence and relevant to the question under investigation
	  • identify, describe and explain the limitations of conclusions, including identification of further evidence required
	  • critically evaluate various types of information related to physics from journal articles, mass media and opinions presented in the public domain
	  • discuss the implications of research findings and proposals
	• Communicate and explain scientific ideas

	- use appropriate physics terminology, representations and conventions, including standard abbreviations, graphing conventions and units of measurement - discuss relevant physics information, ideas, concepts, theories and models and the connections between them - identify and explain formal physics terminology about investigations and concepts - use clear, coherent and concise expression - acknowledge sources of information and use standard scientific referencing conventions
VCE - Physics Unit 2: What do experiments reveal about the physical world?	**Area of Study 2 (Options 2.6, Option 2.7): What is matter and how is it formed?** **Option 2.6 (Outcome 2.6): How do fusion and fission compare as viable nuclear energy power sources?** Fission and fusion are nuclear reactions that produce relatively large quantities of energy from comparatively small quantities of fuel. This option enables students to compare the production of energy from fission and fusion reactions. They study a model of the atom that explains the source of the large amounts of energy produced. Students explore the viability of using nuclear power as an energy source and evaluate its benefits and risks. **Key Knowledge:** - Energy from the nucleus - explain nuclear fusion reactions of proton-proton and deuterium-tritium with reference to: - reactants, products and energy production - availability of reactants - energy production compared with mass of fuel - explain nuclear fission reactions of 235U and 239Pu with reference to: - fission initiation by slow and fast neutrons respectively - products of fission including typical unstable fission fragments and energy - radiation produced by unstable fission fragments - describe neutron absorption in 238U, including formation of 239Pu - explain fission chain reactions including: - the effect of mass and shape on criticality - neutron absorption and moderation - Nuclear energy as a power source - compare nuclear fission and fusion with reference to: - energy released per nucleon and percentage of the mass that is transformed into energy

	▪ availability of reactants ▪ limitations as a source of energy for electricity production ▪ environmental impact • analyse fission and fusion with reference to their viabilities as energy sources • describe the energy transfers and transformations in the systems that convert nuclear energy into thermal energy for subsequent power generation • explain the risks and benefits for society of using nuclear energy as a power source. **Option 2.7 (Outcome 2.7): How is radiation used to maintain human health?** In this option students use concepts of nuclear physics to explore how the use of electromagnetic radiation and particle radiation are applied in medical diagnosis and treatment. They learn about the production and simple interpretation of images of the human body produced by a variety of imaging techniques used to observe or monitor the functioning of the human body. **Key Knowledge:** • Radiation and the human body • distinguish between electromagnetic radiation and particle radiation • describe how X-rays for medical use are produced including the distinction between soft and hard X-rays • describe how medical radioisotopes may be produced by neutron bombardment and high energy collisions • analyse decay series diagrams of medical radioisotopes with reference to type of decay and stability of isotopes • compare ionising and non-ionising radiation with reference to how each affects living tissues and cells • explain the effects of α, β and γ radiation on humans, including: ▪ different capacities to cause cell damage ▪ short- and long-term effects of low and high doses ▪ ionising impacts of radioactive sources outside and inside the body ▪ calculations of absorbed dose (gray), equivalent dose (sievert) and effective dose (sievert) • The use of radiation in diagnosis and treatment of human illness and disease • compare the processes of, and images produced by, medical imaging using two or more of X-rays, computed tomography (CT), γ radiation, magnetic resonance imaging (MRI), single photon emission computed tomography (SPECT) and positron emission tomography (PET) • describe applications of medical radioisotopes in imaging and diagnosis • explain the use of medical radioisotopes in therapy including the effects on healthy and damaged tissues and cells

	- relate the detection and penetrating properties of α, β and γ radiation to their use in different medical applications - analyse the strengths and limitations of a selected contemporary diagnostic or therapeutic radiation technique **Assessment:** - a modelling activity - a summary report of selected practical investigations - a test comprising multiple choice and/or short answer and/or extended response. - Practical work is a central component of learning and assessment. As a guide, between 3½ and 5 hours of class time should be devoted to student practical work and investigations in each of Areas of Study 1 and 2 and to investigations in Area of Study 3 involving the use of secondary data and/or modelling. **Key Skills (Outcome 2.6/2.7):** - Develop aims and questions, formulate hypotheses and make predictions - determine aims, hypotheses, questions and predictions that can be tested - identify independent, dependent and controlled variables - Plan and undertake investigations - determine appropriate type of investigation: conduct experiments; design-build-testevaluate a device; explore operation of a device; solve a scientific or technological problem; perform simulations; access secondary data, including data sourced through the internet that would otherwise be difficult to source as raw or primary data through a laboratory or a classroom - select and use equipment, materials and procedures appropriate to the investigation, taking into account potential sources of error and uncertainty - Comply with safety and ethical guidelines - apply ethical principles when undertaking and reporting investigations - apply relevant occupational health and safety guidelines while undertaking practical investigations - Conduct investigations to collect and record data - work independently and collaboratively as appropriate and within identified research constraints - systematically generate, collect, record and summarise both qualitative and quantitative data - Analyse and evaluate data, methods and scientific models - process quantitative data using appropriate mathematical relationships, units and number of significant figures - organise, present and interpret data using tables, line graphs, correlation, line of best fit, calculations of mean and fitting an appropriate curve to graphical data, including the use of error bars on graphs

	• take a qualitative approach when identifying and analysing experimental data with reference to accuracy, precision, reliability, validity, uncertainty and errors (random and systematic) • explain the merit of replicating procedures and the effects of sample sizes to obtain reliable data • evaluate investigative procedures and possible sources of bias, and suggest improvements • explain how models are used to organise and understand observed phenomena and concepts related to physics, identifying limitations of the models • Draw evidence-based conclusions • determine to what extent evidence from an investigation supports the purpose of the investigation, and make recommendations, as appropriate, for modifying or extending the investigation • draw conclusions consistent with evidence and relevant to the question under investigation • identify, describe and explain the limitations of conclusions, including identification of further evidence required • critically evaluate various types of information related to physics from journal articles, mass media and opinions presented in the public domain • discuss the implications of research findings and proposals • Communicate and explain scientific ideas • use appropriate physics terminology, representations and conventions, including standard abbreviations, graphing conventions and units of measurement • discuss relevant physics information, ideas, concepts, theories and models and the connections between them • identify and explain formal physics terminology about investigations and concepts • use clear, coherent and concise expression • acknowledge sources of information and use standard scientific referencing conventions

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