STAWA DEPTH and BREADTH of CONTENT: Teacher Support Documents

Senior Secondary Science WACE 2015 – 2016: Year 11 Physics Unit 1

The STAWA Depth & Breadth of Content documents have been developed through the collaboration of teachers working in Department of Education, Catholic Education and Independent Schools.

Purpose

The STAWA Depth & Breadth of Content documents are intended to promote a shared understanding of the course content that improves moderation across schools, regions and systems/sectors.

Caution

The Depth and Breadth points of elaboration are interpretations. The ATAR syllabus content statements are the only parts of these documents that are mandated. Examiners are required to address the mandated statements only.

The STAWA Depth & Breadth of Content documents are a great example of teachers helping teachers for the benefit of all students.

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Leadership in Science Education

PHYSICS
ATAR Year 11
Unit 1 – Thermal, nuclear and electrical physics

Unit description

An understanding of heating processes, nuclear reactions and electricity is essential to appreciate how global energy needs are met. In this unit, students explore the ways physics is used to describe, explain and predict the energy transfers and transformations that are pivotal to modern industrial societies. Students investigate heating processes, apply the nuclear model of the atom to investigate radioactivity, and learn how nuclear reactions convert mass into energy. They examine the movement of electrical charge in circuits and use this to analyse, explain and predict electrical phenomena.

Contexts that can be investigated in this unit include technologies related to nuclear, thermal, or geothermal energy, the greenhouse effect, electrical energy production, large-scale power systems, radiopharmaceuticals, and electricity in the home; and related areas of science, such as nuclear fusion in stars and the Big Bang theory.

Through the investigation of appropriate contexts, students understand how applying scientific knowledge to the challenge of meeting world energy needs requires the international cooperation of multidisciplinary teams and relies on advances in ICT and other technologies. They explore how science knowledge is used to offer valid explanations and reliable predictions, and the ways in which it interacts with social, economic, cultural and ethical factors.

Students develop skills in interpreting, constructing and using a range of mathematical and symbolic representations to describe, explain and predict energy transfers and transformations in heating processes, nuclear reactions and electrical circuits. They develop their inquiry skills through primary and secondary investigations, including analysing heat transfer, heat capacity, radioactive decay and a range of simple electrical circuits.

Learning outcomes

By the end of this unit, students:

1. understand how the kinetic particle model and thermodynamics concepts describe and explain heating processes
2. understand how the nuclear model of the atom explains radioactivity, fission, fusion and the properties of radioactive nuclides
3. understand how charge is involved in the transfer and transformation of energy in electrical circuits
4. understand how scientific models and theories have developed and are applied to improve existing, and develop new, technologies

5. 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
6. use algebraic and graphical representations to calculate, analyse and predict measurable quantities associated with heating processes, nuclear reactions and electrical circuits
7. evaluate, with reference to empirical evidence, claims about heating processes, nuclear reactions and electrical technologies
8. communicate physics understanding using qualitative and quantitative representations in appropriate modes and genres.

Unit content

This unit includes the knowledge, understandings and skills described below.

Science Inquiry Skills

1. identify, research, construct and refine questions for investigation; propose hypotheses; and predict possible outcomes
2. design investigations, including the procedure(s) to be followed, the materials required, and the type and amount of primary and/or secondary data to be collected; conduct risk assessments; and consider research ethics
3. conduct investigations, **including using temperature, current and potential difference measuring devices,** safely, competently and methodically for the collection of valid and reliable data
4. represent data in meaningful and useful ways, including using appropriate Système Internationale (SI) units and symbols, and significant figures; organise and analyse data to identify trends, patterns and relationships; identify sources of random and systematic error and estimate their effect on measurement results; identify anomalous data and calculate the measurement discrepancy between experimental results and a currently accepted value, expressed as a percentage; and select, synthesise and use evidence to make and justify conclusions
5. interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments
6. select, construct and use appropriate representations, **including text and graphic representations of empirical and theoretical relationships, flow diagrams, nuclear equations and circuit diagrams**, to communicate conceptual understanding, solve problems and make predictions
7. select, use and interpret appropriate mathematical representations, including linear and non-linear graphs and algebraic relationships representing physical systems, to solve problems and make predictions
8. communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports

Green: specific content related to Unit 1. The rest of the statements are the same generic ones across the units.

Science Understanding: Thermal

Syllabus Statement	Elaboration	Activities	Assessment opportunities
Heating processes			
1. The kinetic particle model describes matter as consisting of particles in constant motion, except at absolute zero	Particle theory • movement of particles • straight line motion and vibratory motion • change in phase • diffusion and expansion Temperature scales • absolute zero • Celsius and Kelvin	Absolute zero demonstration and determination (Pressure/Temp) Triple point experiment	
2. All substances have internal energy due to the motion and separation of their particles	Internal energy • kinetic energy and temperature • potential energy and changes of state	Brownian motion	
3. Temperature is a measure of the average kinetic energy of particles in a system	Temperature scales. • calibration and testing of thermometers	Bath and Hot Cup demonstration, Sand temperature	
4. provided a substance does not change state, its temperature change is proportional to the amount of energy added to or removed from the substance; the constant of proportionality describes the heat capacity of the substance *This includes applying the relationship* $Q = m c \Delta T$	Specific heat capacity • energy vs time graphs • specific heat capacity can be determined experimentally and through calculations • applications - cookware • water is a good coolant because of high c • applications and understanding of house design, passive solar, heat reservoirs, hot water systems, air masses inside the home - not definitions	Calorimetry, Practicals on determining c for a range of metals. hot pies burning your mouth Sugars	Practical tests on determination of c Use calorimeter to determine SHC of a metal
5. change of state involves separating particles which exert attractive forces on each other; latent heat is the energy required to be added to or removed from a	Latent heat of fusion and vaporisation • Temp/Thermal energy graphs • Hidden heat, latent (potential)	Determination of L for a fusion/vaporisation of ice -> water	Practical tests on determination of L

system to change the state of the system *This includes applying the relationship* $Q = mL$	• do calculations • heating curves (graphical analysis)	Digital temperature probes (eg : PASCO, Vernier) Cooling curve for naphthalene.	
6. Two systems in contact transfer energy between particles so that eventually the systems reach the same temperature; that is, they are in thermal equilibrium. This may involve changes of state as well as changes in temperature	Heat Energy • Heating/Cooling curves, condition for thermal equilibrium • Q loss = Q gained • mixtures of cold and hot substances • calculations of final temperature at thermal equilibrium • Calculations of final T using heat lost = heat gained • conditions for thermal equilibrium in a closed system	Demonstration of Temp probes (Hot/Cold), Thermal disequilibrium different coloured water (eg : blue for cold and red for hot) mixing together Measure temperature changes if varying masses of ice melting in water.	Video capture for change in Temp analysis Heating cooling curves activities.
7. a system with thermal energy has the capacity to do mechanical work [to apply a force over a distance]; when work is done, the internal energy of the system changes	Heat pumps • Steam engines and turbines, basic heat pumps (define what is meant by this) • steam to water potential • increased temperature and flow to low temperature (kinetic energy) • descriptive only	Demonstration of putt-putt boats, Stirling engine, Heros' engine. Convection spiral	
8. because energy is conserved, the change in internal energy of a system is equal to the energy added by heating, or removed by cooling, plus the work done on or by the system	Q loss = Q gained • method of mixture calculations • explain heat pumps, air con, refrigerators • Δ Q = Q gain + work done	Practicals of ice in a range of solutions. Comparison of theoretical/actual temperature Practicals of ice in a range of solutions. Comparison of theoretical/actual temperature Ice cube in hot water activities.	Practical tests on determination of heat loss
9. heat transfer occurs between and within systems by conduction, convection and/or radiation	Conduction, convection and radiation in terms of particles • processes of heat transfer	$KMnO_4$ in cold water, bath crystals, conduction of different metals prac, application infrared –	

	• examples of application : solar hot water systems, car radiators, sea breezes, refrigerators, in homes (windows, insulation design)	helicopters and night vision goggles. Insulating materials – lagging of pipes, roof insulation.	
10. energy transfers and transformations in mechanical systems always result in some heat loss to the environment, so that the usable energy is reduced and the system cannot be 100 percent efficient *This includes applying the relationship* $\text{efficiency } \eta = \frac{energy\ output}{energy\ input} \times \frac{100}{1}\ \%$	Efficiency in a heat transfer system • useful energy • degradation of energy • Range of strategies to limit heat loss. High and low grade energies • do the above in terms of specific examples : thermos flask, space blanket, wetsuits, internal combustion engine	thermos flasks efficiency of an electric kettle clothing for desert and polar conditions eskys practical : electrical energy to mechanical energy, observe E loss to heat Practical – temp probe measurements inside cans painted different colours.	Practical test on determination of efficiency
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11. passive solar design for heating and cooling of buildings	• Energy efficient homes, other methods of heating and cooling, • Green energy inclusions for all new homes Star Rating of 6 and over • house design within the Australian context	Use of solar heater/ demo house, survey of impact of different colour staff cars on internal temperatures excursion to energy efficient dwellings building design based on termite mounds, air flow, igloos	Assignment on House design
12. the development of the refrigerator over time	• 19th century refrigerators 1906, Ice factories, Coolgardie safe • compressor & design/purpose and power requirements within the context of evaporation and heat transfer and phase change • P = rate of energy use	Piezoelectric cooler and Solar Eskies	
13. the use of the sun for heating water	• Tibetan oven, concentration of solar energy	solar water	
14. engine cooling systems in cars	• Radiator design, evaporative AC, refrigeration, air cooled vs water cooled, motor with fin • Thermostat and expansion valves		

Science Understanding: Nuclear

Syllabus Statement	Elaboration	Activities	Assessment opportunities
Ionising radiation and nuclear reactions			
1. 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	Understanding of historical development. • JJ Thomson, Rutherford, Chadwick, Fermi • Bohr's model of the atom, electron cloud • diagrammatic representation of Thomson, Rutherford, Chadwick atom • standard model of matter (quarks, leptons) • determine the structure different atoms from atomic number and mass number Modern development • quarks and sub-nuclear particles that result in strong nuclear forces may be appropriate at this stage	Simulations available on phet.colorado website	
2. 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	Categories of weak and strong forces and distinguish between weak and strong forces. • name the 4 force (gravitation, electrostatic, strong nuclear force, weak nuclear force) Introduction to other subatomic particles. • boson particles (standard model) • charge • charge law of attraction and repulsion and role of neutrons		
3. some nuclides are unstable and spontaneously decay, emitting alpha, beta (+/-) and/or gamma radiation over time until they become stable nuclides	Many different mechanisms available (specific examples) • Focus on alpha, beta, positron, gamma, neutron, proton, neutrino • definition of a nuclide symbols for each • nuclear decay equations • nuclear reactions (alpha, beta and gamma particles) • Absorbed dose and dose equivalence.	Alpha/Beta/Gamma demonstrations FAR LABS (optional La Trobe) writing and balancing these equations SPICE	Geiger counter usage

4. each species of radionuclide has a half-life which indicates the rate of decay *This includes applying the relationship* $N = N_0 \left(\frac{1}{2}\right)^n$	• Analysis of Carbon dating, dating of rocks using quartz, Age of Earth - Zircon • graphical display of decay curves (half- life's)	M and M experiment	
5. alpha, beta and gamma radiation have different natures, properties and effects	Medical, industrial and geophysical use. • Flight/altitude dosimeters • Earth's magnetic field diverts charged particles • define quality factor • define the gray and the sievert • thickness of materials • quality control (weak/imperfect structures) • irradiation of food • Sterilisation of disposable medical equipment.	Penetrating power demonstrations	SKG, Radiology
6. the measurement of absorbed dose and dose equivalence enables the analysis of health and environmental risks *This includes applying the relationships* absorbed dose = E/m dose equivalent = absorbed dose x quality factor	• Ionising effect, health risks, waste management on humans $DE = \frac{energy}{mass} \times QF$	Research Chernobyl to Fukushima. Demo of lead shielding, videos on the latest on Chernobyl as in Current Affairs 60 mins OPAL in Sydney disposing of medical waste disposing of waste from power stations	Research assignments
7. Einstein's mass/energy relationship relates the binding energy of a nucleus to its mass defect *This includes applying the relationship* $\Delta E = \Delta m c^2$	Binding Energy per nucleon • calculations and their relation to isotope stability	Far labs remote control radiation pracs funded by government	
8. Einstein's mass/energy relationship also applies to all energy changes and enables the energy released in nuclear reactions to be determined from the mass change in the reaction	Energy released/absorbed in decay mechanisms and fission/fusion. • Using MeV or J. • Manhattan Project and Einstein.		
9. alpha and beta decay are examples of spontaneous	Mass difference		

transmutation reactions, while artificial transmutation is a managed process that changes one nuclide into another	• Calculations of mass difference and energy released, energy released per kg of fissile materials in a nuclear reaction equation • change in mass = energy mass differences between products and reactants		
10. neutron-induced nuclear fission is a reaction in which a heavy nuclide captures a neutron and then splits into smaller radioactive nuclides with the release of energy	1930s nuclear transmutation and fission • Fermi		
11. a fission chain reaction is a self-sustaining process that may be controlled to produce thermal energy, or uncontrolled to release energy explosively if its critical mass is exceeded	Define a chain reaction. Design of a nuclear reactor • Fukushima and Chernobyl. • Critical mass. • Linking to heating and cooling. • cooling systems and the process by which they remove energy from the reactor • Critical mass as a density change to increase probability of a neutron hitting a nucleus. • Manhattan project	Reactor simulations, chain reaction with matchsticks in a box of sand atom bomb	Assessing different reactor types.
12. nuclear fusion is a reaction in which light nuclides combine to form a heavier nuclide, with the release of energy	Fusion • Energy determinations. • ITER and JET reactors. • need to find a realistic context for fusion reactions • risks, limits, hurdles • Temperature and pressure required	Research based investigations. 500 TW Laser Fusion. ITER	
13. more energy is released per nucleon in nuclear fusion than in nuclear fission because a greater percentage of the mass is transformed into energy	Fusion vs Fission • The bomb • nuclear waste, environmental application		

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14. Ionising radiation and nuclear reactions	Role of cosmic radiation and ionosphere		
15. Qualitative and quantitative analyses of relative risk (including half-life, absorbed dose, dose equivalence) are used to inform community debates about the use of radioactive materials and nuclear reactions for a range of applications and purposes, including:			
16. radioisotopes are used as diagnostic tools and for tumour treatment in medicine			
17. nuclear power stations employ a variety of safety mechanisms to prevent nuclear accidents, including shielding, moderators, cooling systems and radiation monitors			
18. The management of nuclear waste is based on the knowledge of the behaviour of radiation.			

Science Understanding: Electricity

Syllabus Statement	Elaboration	Activities	Assessment opportunities
1. there are two types of charge that exert forces on each other	Dynamic and static electricity • Faradays early work. • current defined as movement of positive charges • magnetic fields associated with electric current • basic electrical power distribution (power loss) and efficiency • quantify charges • define potential • quality of conductors	Practicals on length of conductors electric field/force fuses Van der Graph Static electricity	
2. electric current is carried by discrete charge carriers; charge is conserved at all points in an electrical circuit *This includes applying the relationship* $I = \frac{q}{t}$	Charge • Exploration of what charge is. • What are responsible for charge • movement of electrons through a conductor • conventional vs electron current • operation of ammeter – very low resistance	Simple current and time calculations. Determining total number of electrons flowing.	Practical test on total charge and number of electrons
3. energy is conserved in the energy transfers and transformations that occur in an electrical circuit	Work and Energy • Understanding of Work as change in energy in a system. • energy transfer in an electrical context • energy transformation		
4. the energy available to charges moving in an electrical circuit is measured using electric potential difference, which is defined as the change in potential energy per unit charge between two defined points in the circuit *This includes applying the relationship* $V = \frac{W}{q}$	Voltage • Exploration of what potential difference is • V = E/q • operation of a voltmeter and potential difference • voltmeters have high internal resistance • define voltage and current	Use of Amp/Volt meters	

5. energy is required to separate positive and negative charge carriers; charge separation produces an electrical potential difference that drives current in circuits	Electrostatic forces. • non-calculation based • draw electrostatic fields • uniform electrostatic fields • non-uniform electrostatic fields • electron acceleration - kinetic energy (transfer) and potential energy	Drawing basic electric field	
6. power is the rate at which energy is transformed by a circuit component; power enables quantitative analysis of energy transformations in the circuit *This includes applying the relationship* $P = \frac{W}{t} = V\,I$	Power • Power explored as rate at which work is done. P = W/t = VI. Linked to power rating on common appliances • ohms law • power efficiency = useful power/input power	Determination of power rating for a range of components. Power rating of a human climbing up a flight of stairs	Practical test on Power of a simple motor. Links to motion and Potential energy/Kinetic energy
7. resistance depends upon the nature and dimensions of a conductor	Resistance • Resistivity in a qualitative context • Length, area and effects on R		
8. resistance for ohmic and non-ohmic components is defined as the ratio of potential difference across the component to the current in the component *This includes applying the relationship* $R = \frac{V}{I}$	Exploration of Ohmic/Non-ohmic resistors • resistors in parallel and use of formulae • resistors in series and use of formulae • internal resistance • V = IR • super conductors • temperature effects • V/I graphs for a range of components.	Gradient of a V/I graph used to determine R. Possible use of V/I graph to determine P. graphical analysis	Practical test on determination of R Ohm's Law
9. circuit analysis and design involve calculation of the potential difference across the current in, and the power supplied to, components in series, parallel, and series/parallel circuits *This includes applying the relationships*	Simple circuits • Determination of R Total for a range of circuits. Determination of V/I for all components • circuit diagrams and calculations	application to electric circuits in the home	Practical test on theoretical/actual V/I

series components, I = constant, $V_t = V_1 + V_2$ $R_t = R_1 + R_2$ parallel components, V = constant, $I_t = I_1 + I_2$ $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2}$			
SHE			
10. there is an inherent danger involved with the use of electricity that can be reduced by using various safety devices, including fuses, residual current devices (RCD), circuit breakers, earth wires and double insulation	Discussion on danger levels of electricity and how these devices provide protection.		
11. electrical circuits enable electrical energy to be transferred and transformed into a range of other useful forms of energy, including thermal and kinetic energy, and light			
12. Electrical circuits 13. The supply of electricity to homes has had an enormous impact on society and the environment. An understanding of electrical circuits informs the design of effective safety devices for the safe operation of: lighting, power points, stoves other household electrical devices.			