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DP physics—Sample unit planner 1: Nuclear and quantum physics

Teacher(s)		**Subject group and course**	Sciences: Physics		
Course part and topic	Nuclear and quantum physics: Radioactive decay (E.3), Fission (E.4) and Fusion and stars (E.5)	**SL or HL/Year 1 or 2**	SL Year 2	**Dates**	

Unit description and content	**DP assessment(s) for unit**
This unit covers parts of topics E.3 Radioactive decay, E.4 Fission and E.5 Fusion and stars. The unit starts by considering the binding energy of the nucleons and the stability of the nucleus. It then addresses the different ways in which a nucleus may decay to a lower energy state (radioactive decay). Fission and fusion are also reviewed as mechanisms through which the energy of a nucleus may change.	• Paper 1: Multiple-choice questions and data analysis • Paper 2: Short-answer and extended-response questions • Internal assessment

Establishing the purpose of the unit

Transfer goals *prompt students to "transfer" or apply their knowledge, skills and concepts from the unit to new/different circumstances, on their own without scaffolding from the teacher.* *The* Physics guide *describes two ways to integrate topics.* • *Concepts and themes* • *Guiding and linking questions* *List one to three big transfer goals for this unit. The transfer goals list will depend on the sequence of units.*
Transfer goals 1. When direct observation is not possible (like in studying the atomic nucleus), indirect observation may provide evidence for the success of a model or theory. 2. The energy of a system can determine the transitions that it can undergo.

Teaching and learning through inquiry

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Concepts, skills and nature of science—essential understandings

Students will develop the following understandings in relation to concepts, application of skills and nature of science (NOS).

(Refer to the specific sections of the Physics guide *for details.)*

Note: This unit includes a selection of linking questions from the Physics guide*, chosen for their relevance in the teaching sequence. Further linking questions are specified in the* Physics guide*, but they do not all need to be addressed because they are not specifically assessable. Teachers and students may wish to write their own linking questions to make meaningful links between topics.*

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Learning process (in order of teaching sequence)

Check the boxes for any pedagogical approaches used during the unit. Aim for a variety of approaches to help facilitate learning.

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Students will know the following content.

- Isotopes
- Nuclear binding energy and mass defect
- The binding energy curve
- The strong nuclear force
- The random and spontaneous nature of radioactive decay
- The equations for α, β^+, β^- and γ decays
- Activity and count rate of a radioactive sample
- The effect of background radiation in count rate
- Energy release in fission and fusion reactions

Students will develop the following skills.

- Calculate the energy liberated in nuclear reactions using the mass energy equivalence
- Determine the half-life of a radioactive element from data
- Explain the shape of the binding energy curve

Students will grasp the following concepts.

- Binding energy
- Decay

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Learning experiences and strategies/planning for self-supporting learning

☒ Lecture

Some content is more easily introduced in a lecture and class discussion, such as the different decay types.

☐ Socratic seminar

☒ Small group/pair work

Students will work in several worksheets. Pair and small group work is encouraged in this kind of work, since discussion among peers is key for the deepening of learning.

☐ Multimedia presentation/notes

☐ Individual presentations

☐ Group presentations

☐ Student lecture/leading

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Students will deal with the following guiding questions. • Why are some isotopes more stable than others? (E.3) • In what ways can a nucleus undergo change? (E.3) • How do large, unstable nuclei become more stable? (E.3) • How can the random nature of radioactive decay allow for predictions to be made? (E.3) • In which form is energy stored within the nucleus of the atom? (E.4) **Students will deal with the following linking questions.** • Would a nucleus be able to exist if only gravitational and electric forces were considered? (E.3) • In which form is energy released as a result of nuclear fission? (E.4) • How is fusion like—and unlike—fission? (E.5)	☐ Interdisciplinary learning Details ☒ Other(s) **Practical work** Students will use experimental evidence to draw and confirm conclusions from the unit. **Guided inquiry** Guided inquiry worksheets can be used, allowing students to reach their own conclusions on some of the contents, skills and concepts of the unit.
	Formative assessment • Guided inquiry worksheets: Although these worksheets are not necessarily to be handed in after completion, they may serve as a useful formative assessment • Paper 1 questionnaire: At the end of the unit students will answer a paper 1 style questionnaire, and then complete a metacognitive exercise
	Summative assessment • Paper 1 and paper 2 style test. Teachers should create their own using past paper questions or Questionbank • Laboratory report on radioactive decay
	Differentiation ☐ Affirming identity and building self-esteem ☒ Valuing prior knowledge New concepts, such as binding energy, will be introduced from previous knowledge, making a

	connection with different topics and valuing prior learning. ☒ Scaffolding learning While students are working on the guided inquiry worksheets, the teacher will act as a facilitator, being able to give more time to students that need it. ☐ Extending learning Details

Approaches to learning *Check the boxes for any explicit approaches to learning connections made during the unit. For more information on approaches to learning, refer to the* Diploma Programme Approaches to teaching and learning *website*.
☒ Thinking Students will use creative thinking skills to solve the guided inquiry worksheets. Students will use critical thinking skills to evaluate the methodology used in the laboratory work. ☒ Social Students will reach agreements and negotiate with peers when working in small groups to solve the guided inquiry worksheets. ☐ Communication ☒ Self-management Students will have to manage their time when completing the worksheets and the laboratory experience. Students will have to address their results in the end-of-unit questionnaire. ☐ Research Details

Theory of knowledge (TOK) connections *Describe any explicit TOK connections made during the unit.*	Creativity, activity, service (CAS) connections *Check the boxes for any explicit CAS connections. If you check any of the boxes, provide a brief note explaining how students engaged in CAS for this unit.*
☐ Core theme ☒ Optional themes • Knowledge and technology Technology has a close relationship to modern physics. Modern sensors, detectors and other instruments are needed to make measurements, and the knowledge produced through these measurements often drives us to new technology. Can we think of science and technology as separate things? ☒ Areas of knowledge • Scope Physics is first and foremost an experimental science. The idea of describing something that cannot be directly seen or observe may at first seem outside the scope of physics. However, indirect observation and theoretical work are tools that allow the study of such topics. • Methods and tools Modern physics often relies on models that are tested through indirect observation and their predictive power. This can provide enough evidence to consider a particular model as “true”. • Ethics	☒ Creativity The radioactive decay laboratory centres itself in the idea that random occurrence follows an exponential function. Students can be asked to think of and create new experiences that, based on random behaviour, could result in behaviour that models an exponential function. ☐ Activity ☐ Service

Physics develops new knowledge constantly. However, physicists are not usually concerned with what is done with that knowledge. The discovery and description of nuclear fission was the root of the development of nuclear weapons. Should we concern ourselves with what can be done with the knowledge we are developing? ☒ Key concepts • Interpretation When making indirect observation, the way that observation is interpreted is key to determining the validity of the model behind it. How reliant is theory on interpretation? • Evidence Can an indirect observation be considered evidence?	
Skills in the study of physics	**Nature of science**
Technology Students will use a spreadsheet to graph data and show that the found relationship follows an exponential function. Mathematics Students will process and graph data and use equations to draw conclusions. Collecting and processing data Students will collect data and process it to reach conclusions. Concluding and evaluating Students will draw conclusions from the radioactive decay laboratory experience, and evaluate their methodology.	☒ Observations The discovery of radioactive decay is a good example of how an indirect observation can provide information about a phenomenon. ☐ Patterns ☒ Hypotheses The electron emitted in beta decay was originally thought to reside inside the nucleus before emission. Further observations, and the study of special relativity and quantum physics, showed that this was impossible and the electron had to be “created” at the moment of the decay. ☐ Experiments

	☐ Measurement ☐ Evidence ☐ Theories ☒ Models The theoretical model to explain radioactive decay is quite descriptive initially. The actual understanding of what is happening for the decays to occur comes much later. However, the first model that introduces concepts like the half-life of an element is extremely useful and allows us to make predictions. ☐ Falsification ☐ Science as a shared endeavour ☒ Global impact of science The knowledge developed around fission and fusion was the basis for the development of nuclear weapons. The further understanding of nuclear physics and radioactive decay was the basis for radiotherapy treatment, which has saved countless lives. How can we know or predict what will be done with the knowledge we develop?

Resources

Handouts. These are suggested worksheets that teachers could develop.

- Binding energy worksheet
- Binding energy curve worksheet
- Mass defect worksheet
- Fusion and fission worksheet
- Formative assessment questionnaire
- Radioactive decay worksheet

• Radioactive decay laboratory worksheet Laboratory materials • Dice

Reflection: Considering the planning, process and impact of the inquiry

What worked well *List the portions of the unit (content, assessment, planning) that were successful.*	**What did not work well** *List the portions of the unit (content, assessment, planning) that were not as successful as hoped.*	**Notes/changes/suggestions** *List any notes, suggestions or considerations for the future teaching of this unit.*