Learning and Teaching Academic Standards

Physics Standards Statement

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This document has been prepared by adapting the work of the ALTC-supported projects on academic standards in Science[1] and in Chemistry[2], with the active input of:

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Physics Standards Statement

This Physics Standards Statement contains a description of the nature and extent of Physics, a statement of the Physics Standards expressed as threshold learning outcomes (TLOs), and some descriptive Notes that provide a framework for understanding, interpreting, and applying the TLOs. In conjunction with the Science Standards Statement[1], it provides a foundation for the evaluation of current physics degree programs, and for future curriculum development.

Nature and extent of physics

Physics is a science that explores the fundamental laws that govern the universe. It addresses issues such as the ultimate structure of matter, the origin of the universe, and the underpinnings of new technologies. It aims to understand the physical world by:

- using observed properties and relationships to identify integrating concepts,
- building models that incorporate those concepts,
- using the resultant conceptual frameworks to make predictions about new phenomena or observations, and
- using observations to test the predictions and, if necessary, modify the conceptual frameworks.

Bachelor Level Threshold Learning Outcomes for Physics

	Upon completion of a Major in physics, graduates will:
Understanding Science	1. *Demonstrate a coherent understanding of the nature of physics by:* 1.1 Articulating how physics uses observations of relationships between measurable quantities to create conceptual frameworks which can be used to explain, interpret and predict other observations. 1.2 Identifying the role of fundamental physics concepts (such as laws of conservation) in a variety of different contexts. 1.3 Acknowledging that there are physical reasoning processes characteristic of the discipline 1.4 Explaining the role and relevance of physics in society.
Scientific knowledge	*2. Exhibit depth and breadth of scientific knowledge by:* 2.1 Demonstrating well-developed knowledge in the subject areas of the physics discipline. 2.2 Demonstrating knowledge in the related disciplinary area of mathematics.
Inquiry and problem solving	*3. Critically analyse physical situations by:* 3.1 Gathering, documenting, organising, synthesising and critically evaluating information from a range of sources. 3.2 Designing, planning, carrying out and refining a physics experiment or investigation. 3.3 Selecting and critically evaluating practical, computational and/or theoretical techniques or tools in order to conduct an investigation. 3.4 Applying appropriate physics concepts to the interpretation of experimental or observational data and the drawing of conclusions from that data.
Communication	*4. Be effective communicators of physics by:* 4.1 Communicating physics data, results and analysis, to a range of audiences, for a range of purposes, and using a variety of modes. 4.2 Understanding and interpreting arguments or opinions based on physics, presented by others.
Personal and professional responsibility	*5. Be accountable for their own learning and scientific work by:* 5.1 Being independent and self-directed learners. 5.2 Working effectively, responsibly and safely in an individual or team context. 5.3 Exhibiting intellectual integrity and practising ethical conduct.

Notes on The Threshold Learning Outcomes

These Notes are intended to offer guidance on how to interpret the TLOs.
These threshold learning outcomes have been developed to describe a pass level graduate from a bachelor degree. A **bachelor degree** is defined according to the Australian Qualifications Framework.
The TLOs are not intended to be equally weighted across the degree program, nor does the numbering imply a hierarchical order of importance. However, the numbering may be used to provide easy reference to a specific TLO.

Understanding physics

A coherent understanding: Graduates will have developed an appreciation of physics as a discipline which seeks a unified understanding of physical phenomena. They will have a general understanding of how physics operates by abstracting the common features from various observations.

TLO 1.1
Observations of relationships: Graduates will understand that physics attempts to describe the physical world and so physical theories are constructed from and tested by observational data. In physics, data typically concern relationships, i.e. the way that one parameter varies as a result of variations in another parameter. Data include, but are not limited to, the results of controlled experiments, observation of uncontrolled physical objects and processes.
Measurable quantities: Graduates will recognise that a key characteristic of physics is a focus on measurable quantities, with relationships between them that can be expressed in mathematical form.
Creation of conceptual frameworks: Although physics is an empirical science, its primary goal is to create conceptual frameworks, consistent with specific observations, through a process of generalisation, inference and abstraction. The aim of physics is to create a coherent picture of the physical world that can be reliably used to explain past and current observations and predict new ones.

TLO 1.2
Fundamental physics concepts: Manifesting in a variety of contexts are underpinning concepts, such as conservation laws, the concept of potential, and the idea that all physical phenomena are the result of a limited number of interactions. Graduates will be able to identify and describe how the same concepts can be used to analyse a diverse range of contexts. For example, graduates will understand how conservation of energy and momentum can be used to describe the interactions of atomic radiation with matter, as well as macroscopic processes such as projectile motion. Similarly, they will understand how the concept of energy is critical in analysing thermal processes, fluid motion, mechanics and more.

TLO 1.3
Physical reasoning processes: First, this emphasises that graduates will look for physical causes of phenomena that they encounter. Second, there is a characteristic problem-solving or reasoning process used by physicists. This involves identifying key elements in a physical situation, focussing on them to create a simpler problem which can be solved, and subsequently making corrections or adjustments to account for the factors initially neglected. Graduates will be able to approach problems in this way, for example by initially neglecting air resistance in a projectile motion question, by treating extended objects as point masses, or by making order of magnitude estimates to use in a self-checking process.

TLO 1.4
Role and relevance of physics:
Physics graduates will have an overarching understanding of the role of physics - its impact, significance, and relevance. A physics graduate will understand that society includes one's fellow students and academic colleagues, the local community, the social, environmental, technological, and industrial sectors, and the worldwide community of scholars and others.
Physics has connections with and input into many fields of pure research, as well as applied fields such as technology development, engineering and medicine, and real-world situations. Physics graduates will appreciate the fundamental role of physics in connecting and underpinning the sciences. They will be able to place current scientific issues within the context of their understanding of physics. They will also be able to appreciate how physics is a continually evolving discipline and will be able to identify critical points in the development of physics as it is understood today.
Graduates will be able to identify specific ways in which physics has contributed to, and continues to contribute to, society and its development through both its own outputs and its support for other activities. They will understand that physics creates both challenges and opportunities for the community. Physics graduates will

be able to contribute to society by using their scientific literacy to understand and explain physics-related issues. For some graduates this might involve being an advocate for physics; however, all physics graduates should have some appreciation of physics in the larger context of society.

Scientific knowledge

This is the currently accepted body of facts and theories that has arisen from a systematic study of the physical world. Physics graduates will have acquired a coherent body of knowledge in physics (which may be equivalent to a major in a science degree).

TLO 2.1

Depth and breadth: Physics graduates will have command of the core knowledge of physics. They will have an understanding of the fundamental laws that govern the universe. Physics graduates will have a depth of knowledge in most of the identifiable traditional areas in physics such as mechanics, thermodynamics, optics, quantum physics and electromagnetism. Physics graduates will be able to understand how these subject areas relate to each other, and integrate their knowledge across the various physics areas in which they have studied. In addition, physics graduates will have a basic knowledge of closely-related fields of application. It is also expected that a Physics graduate will have some working knowledge of non-traditional physics areas such as biophysics or nanotechnology.

TLO 2.2

Mathematics: A Physics graduate will be expected to have at least a basic foundation of knowledge in one or more other related disciplinary areas. A graduate's knowledge of physics will be underpinned by a good foundation in mathematics, and he/she will have facility with mathematical techniques relevant to the disciplinary area of physics.

Inquiry and Problem solving

Approach: Graduates will be able to use critical thinking skills and a quantitative approach to analyse physical situations and solve complex problems.
Domain: Graduates will be able to apply physical principles in a range of contexts. They will have the skills to solve problems that lie within the domain of traditional physics, as well as tackle more open-ended research questions.

TLO 3.1

Gathering, documenting, organising and synthesising information: Physics graduates will be able to identify, access, record in appropriate format, collate and integrate information.
Critically evaluating information: Physics graduates will be able to assess the soundness of the information that they gather against the criteria of their knowledge and understanding of physics.
Range of sources: It is recognised that information about the physical world is available from a variety of sources, such as books, refereed and non-refereed journal articles, conference presentations, seminars, lectures, peers and the internet. Information processing also deals with data generated as a consequence of experimentation or observation, or the analysis of existing data.

TLO 3.2

Designing, planning and problem-solving: Physics graduates will be able to devise a sequence of data acquisition and analysis using methods based on accepted physical principles. They will be able to form hypotheses and then design activities or experiments to test these hypotheses. Physics graduates will use a systematic approach to problem-solving using the laws of physics. In addition, physics graduates will have an appreciation of how to frame a problem so that it might be solved in a creative or innovative way.
Refining: Physics graduates will be able to review the effectiveness of the methods they have used so as to improve their approaches and to acquire qualitatively and quantitatively superior data.

TLO 3.3

Techniques and tools: Physics graduates will be able to use a range of the tools of physics, including instruments, apparatus, mathematical and statistical approaches, including modelling, and information and communication technologies. They will be able to use a range of measurement and data analysis tools to collect data with appropriate precision. Through their undergraduate learning experiences, physics graduates will be knowledgeable of techniques used to solve different types of problems. Physics graduates will be able to use appropriate (combinations of) practical, theoretical and computational tools to solve problems in their discipline, and will have an appreciation of the techniques used in other areas of science.

TLO 3.4
Applying appropriate physics concepts: Physics graduates will be able to identify the physical concepts that apply to a particular situation or phenomenon being investigated. They will recognise the limits and boundaries of models.
Interpretation of experimental or observational data: Physics graduates will be able to analyse data to yield justifiable conclusions. They will evaluate quantitative evidence, to judge the quality of data and results, using one or more of the techniques of measurement uncertainty, reproducibility, precision, or statistical analysis.
Drawing conclusions Physics graduates will have the capacity to develop defensible arguments based on evidence and draw valid conclusions based on their interpretation of data. They will be able to explain the influence of theoretical or empirical models and measurement uncertainties when drawing conclusions from experimental, simulated or observational data.

Communication

Physics graduates will have developed skills in the communication of physics, both in the specialised forms characteristic of the discipline, and in the wider context.

TLO 4.1
Appropriate documentation: Physics graduates will be able to keep clear, accurate records of their work, including all relevant data and observations. Documentation should be of sufficient detail that the procedure could be replicated. Graduates will use appropriate formats such as notebooks, journals and databases, ranging from traditional media to emerging information technologies.
Presentation: Physics graduates will be able to convey their message in a clear and understandable manner. They will show clear evidence to support their arguments or from which conclusions are drawn.
They will be able to present quantitative and qualitative data in a variety of scientific formats, including tables, graphs, diagrams and symbols. They will use scientific language correctly and appropriately. They will be able to follow the conventions of discipline-specific nomenclature, such as the use of standard symbols, units, or key terms. Physics graduates will be aware of the need to communicate the details of their investigations according to conventions that are usually specific to their sub-discipline, and which may be defined by publishers, editors or professional associations.
A range of audiences: Physics graduates will be able to communicate with their peers, scientific non-experts, and the general community.
A range of purposes: Physics graduates will be able to present their findings in both a technical and non-technical manner.
A variety of modes: Physics graduates will communicate using a range of media, including both written and oral, and a variety of other techniques. They will be able to communicate physics in a range of formats (such as technical report, newspaper or journal article, poster presentation, and new media such as wikis, blogs and podcasts).

TLO 4.2
Understanding and interpreting: Physics concepts and laws are used to explain or make arguments about physical situations. Physics graduates will be able to recognise those concepts and laws (in whatever mode they are presented), understand their significance and interpret their relevance to a particular position or argument.
Arguments and opinions presented by others: Communication is a two-way activity that involves an ability to listen to and understand others.

Personal and professional responsibility

Physics graduates will be capable of taking responsibility for themselves and for others they interact with in physics-related activities.

TLO 5.1
Independence and self-directed learning: Physics graduates will be able to take responsibility for their own learning. This involves an ability to work autonomously and evaluate their own performance. Because physics knowledge is continually evolving, it is important that they are motivated to continue to learn after graduation.

TLO 5.2

Working effectively, responsibly and safely: Physics graduates will understand how to take responsibility for themselves and others during the conduct of physics investigations. This includes adhering to the relevant occupational/environmental health and safety and risk assessment requirements. It also includes an understanding of time management, and the onus on individuals to fulfil their role as part of team projects.

Relevant regulatory frameworks: Physics graduates will have an awareness of the regulatory frameworks that apply to their sub-disciplinary area, and the reasons for them. These might be the legal frameworks for experimentation and data collection, quality control procedures, appropriate safety procedures, or the necessity to obtain government permits for certain types of activity. They will be prepared to abide by these regulatory frameworks as they move into professional employment, and understand the consequences if they do not.

Individual context: Physics graduates will be able to work independently with limited supervision.

Team context: Physics graduates will have gained the skills to function effectively as members or leaders of physics or multidisciplinary teams. They will appreciate that physics is primarily a collaborative activity.

TLO 5.3

Intellectual integrity and ethical conduct: Physics graduates will recognise the ethical frameworks within which physics is practised. They will have learned to behave in an ethical manner during their undergraduate study, and are equipped to do so in the future. Aspects of ethics that graduates meet might include accurate data recording, secure data storage, proper referencing of the work of others, intellectual integrity, having an awareness of the impact on the environment of their activities, animal ethics, or human ethics. It is important that physics graduates have some understanding of their social and cultural responsibilities as they investigate the physical world.

References:

[1]Jones S, Yates B, and Kelder, J-A, (2011) *Learning and Teaching Academic Standards: Science Standards Statement, June 2011*, ALTC report.

[2]Buntine M, Price W, Separovic F, Brown T, and Twaites R, (2011) *Learning and Teaching Academic Standards: Chemistry Academic Standards Statement Consultation Paper, February, 2011,* ALTC report.