PHYS2030

The Structure of Matter

Session 2, Weekday attendance, North Ryde 2021

Department of Physics and Astronomy

Contents

Session 2 Learning and Teaching Update

The decision has been made to conduct study online for the remainder of Session 2 for all units WITHOUT mandatory on-campus learning activities. Exams for Session 2 will also be online where possible to do so.

This is due to the extension of the lockdown orders and to provide certainty around arrangements for the remainder of Session 2. We hope to return to campus beyond Session 2 as soon as it is safe and appropriate to do so.

Some classes/teaching activities cannot be moved online and must be taught on campus. You should already know if you are in one of these classes/teaching activities and your unit convenor will provide you with more information via iLearn. If you want to confirm, see the list of units with mandatory on-campus classes/teaching activities.

Visit the MQ COVID-19 information page for more detail.

General Information

Unit convenor and teaching staff Convenor and lecturer Michael Steel michael.steel@mq.edu.au Contact via michael.steel@mq.edu.au 7WW 2.713 Mondays 2pm-3pm Lecturer Daniel Terno daniel.terno@mq.edu.au Contact via daniel.terno@mq.edu.au 7WW 2.243 Additional academic Alexei Gilchrist alexei.gilchrist@mq.edu.au Contact via alexei.gilchrist@mq.edu.au	
Credit points 10	
Prerequisites (PHYS201 or PHYS2010) and (MATH235 or MATH2010 or MATH2055)	
Corequisites	
Co-badged status	

Unit description

This unit provides a survey of the physics of the very small including atoms, the nucleus and the fundamental particles of the standard model, and their description in terms of quantum mechanics – the most successful and accurate theory in modern physics. As well as being the theory that underlies most of modern physics, it also provides a viewpoint about the nature of the physical world that is completely at odds with our everyday intuition. We develop the structure of quantum mechanics in terms of a set of basic principles and their expression in the mathematical language of vector spaces and operators and show how this picture encompasses the wave function picture we have met previously. We apply these principles and the quantum mechanics of angular momentum to discover the basic properties of the hydrogen atom and explain the general form of the periodic table and the nature of atomic spectra. Turning to the sub-atomic domain, we explore the basic structure of the nucleus, the nature of radioactivity and explain the phenomena of nuclear fission and fusion. Finally, we describe the particles and interactions which compose the current understanding of the standard model of particle physics and explain their division into different families on the basis of mass and spin.

Important Academic Dates

Information about important academic dates including deadlines for withdrawing from units are available at https://students.mq.edu.au/important-dates

Learning Outcomes

On successful completion of this unit, you will be able to:

ULO1: Explain key experiments and physical observations that have led to the modern formulation of quantum mechanics and phenomena such as superposition, commuting and non-commuting observables, entanglement and measurement.

ULO2: Discuss the interpretation and roles of state vectors, operators and observables in the Hilbert space formulation of quantum mechanics and apply these to pose and solve physical quantum problems

ULO3: Explain the commonalities and distinctions between the description of discrete and continuous quantum systems and how these are unified in the Hilbert space picture problems including the wave function in position representation

ULO4: Describe the procedure for solving the three-dimensional Schrödinger equation to explain the physics of single and multi-electron atoms including orbital and spin angular momentum and atomic wave functions, and so explain the form and simple trends of the periodic table and the basic rules of atomic transitions.

ULO5: Explain the structure of the atomic nucleus, the nature of radioactivity, and the roles of the strong and weak interactions in nuclear stability, and apply concepts such as binding energy to explain nuclear decay and the distribution of stable isotopes

ULO6: Describe the different families of fundamental particles in the standard model, their connection with particle spin, and explain how these account for the observed set of free particles and interactions

ULO7: Write, modify and apply python code to solve and visualise problems involving discrete and continuous 3D quantum systems.

General Assessment Information

The assessment for the unit is composed of fortnightly take-home problem sets, exercises in the computational laboratory and the final examination.

Take-home problem sets (30%)

Take-home problem sets will be set and marked for assessment purposes and issued approximately once every two weeks. Worked solutions will be provided to problem sets after the due date. These problem sets are excellent preparation for the final examination, and our strong experience is that students who engage with the problem-solving tasks do well in the unit overall. While this is not a hurdle task, we strongly urge you to complete all the problem-sets.

Academic integrity

Informal group discussion regarding the material connected to problem-set questions is encouraged, but **each student must independently develop and write up their own solutions**. Do not hesitate to seek help from the lecturing team if you are having difficulties with the assigned problems. All students must comply with the academic integrity policy by preparing and submitting their answers independently. To ensure compliance interviews with selected students may be conducted where there is undue similarity in submitted solutions.

Breaches of the academic integrity policy may lead to sanctions that may include, but not limited at, award of a failure grade for the unit and/or temporary suspension form studies. In cases determined by law the University has a legal obligation to disclose the applied sanctions to outside parties, including certain employers.

Extensions

Extension for the problem sets may be requested **in advance** with a suitable justification. No extensions to the problem sets will be granted after the due date.

Computational laboratory exercises (20%)

Similar to the procedure in PHYS2010, there will be six Python labs examining various aspects of quantum and atomic physics. Each lab will include a series of exercises to be submitted online via CoCalc.

Academic integrity

Discussion of programming and physics concepts with your peers during the PC workshops is encouraged, **but all solutions to the exercises must be formulated, typed up and submitted**

on your own. Staff will be on-hand during the labs to assist you in learning the material. All students must comply with the academic integrity policy by preparing and submitting their answers independently. To ensure compliance interviews with selected students may be conducted where there is undue similarity in submitted solutions.

Breaches of the academic integrity policy may lead to sanctions that may include, but not limited at, award of a failure grade for the unit and/or temporary suspension form studies. In cases determined by law the University has a legal obligation to disclose the applied sanctions to outside parties, including certain employers.

Final examination (50%, Hurdle task)

There will be a 3 hour end-of-session exam to be held in the University Examination Period.

Permitted materials will be advised in advance.

The final examination is a **hurdle task**. You must receive a mark of at least 45% on the final exam, as well an overall passing mark for all assessment tasks, in order to pass the unit. If you score between 35% and 44% in the final examination you may be given a second chance to reach the hurdle threshold. The mark from the second chance exam will be capped at 45%, and the second chance is only offered if this mark would be sufficient to pass the unit overall.

You are expected to present yourself for the final examination at the time and place designated in the University examination timetable (https://iexams.mq.edu.au/timetable). The timetable will be available in draft form approximately eight weeks before the commencement of examinations and in final form approximately four weeks before the commencement of examinations. If you receive special consideration for the final exam, a supplementary exam will be scheduled during the supplementary exam period. By making a special consideration application for the final exam you are declaring yourself available for a resit during the supplementary examination period and will not be eligible for a second special consideration approval based on pre-existing commitments. Please ensure you are familiar with the policy prior to submitting an application. Approved applicants will receive an individual notification one week prior to the exam with the exact date and time of their supplementary examination.

Assessment Tasks

Name	Weighting	Hurdle	Due
Problem sets	30%	No	Approx. 10 days after release of each problem set.
Computational lab reports	20%	No	4 days after the completion of each lab session.
Final exam in the University Examination Period	50%	Yes	As scheduled by exams office.

Problem sets

Assessment Type [1]: Problem set
Indicative Time on Task [2]: 24 hours
Due: **Approx. 10 days after release of each problem set.**
Weighting: **30%**

Problem-solving assignments, due spread through the session.

On successful completion you will be able to:

- Explain key experiments and physical observations that have led to the modern formulation of quantum mechanics and phenomena such as superposition, commuting and non-commuting observables, entanglement and measurement.
- Discuss the interpretation and roles of state vectors, operators and observables in the Hilbert space formulation of quantum mechanics and apply these to pose and solve physical quantum problems
- Explain the commonalities and distinctions between the description of discrete and continuous quantum systems and how these are unified in the Hilbert space picture problems including the wave function in position representation
- Describe the procedure for solving the three-dimensional Schrödinger equation to explain the physics of single and multi-electron atoms including orbital and spin angular momentum and atomic wave functions, and so explain the form and simple trends of the periodic table and the basic rules of atomic transitions.
- Explain the structure of the atomic nucleus, the nature of radioactivity, and the roles of the strong and weak interactions in nuclear stability, and apply concepts such as binding energy to explain nuclear decay and the distribution of stable isotopes
- Describe the different families of fundamental particles in the standard model, their connection with particle spin, and explain how these account for the observed set of free particles and interactions

Computational lab reports

Assessment Type [1]: Programming Task
Indicative Time on Task [2]: 12 hours
Due: **4 days after the completion of each lab session.**
Weighting: **20%**

Summary reports of computational lab tasks.

On successful completion you will be able to:

- Write, modify and apply python code to solve and visualise problems involving discrete and continuous 3D quantum systems.

Final exam in the University Examination Period

Assessment Type [1]: Examination
Indicative Time on Task [2]: 20 hours
Due: **As scheduled by exams office.**
Weighting: **50%**
This is a hurdle assessment task (see assessment policy for more information on hurdle assessment tasks)

Final exam in the University Examination Period covering the entire content of the unit.

On successful completion you will be able to:

- Explain key experiments and physical observations that have led to the modern formulation of quantum mechanics and phenomena such as superposition, commuting and non-commuting observables, entanglement and measurement.
- Discuss the interpretation and roles of state vectors, operators and observables in the Hilbert space formulation of quantum mechanics and apply these to pose and solve physical quantum problems
- Explain the commonalities and distinctions between the description of discrete and continuous quantum systems and how these are unified in the Hilbert space picture problems including the wave function in position representation
- Describe the procedure for solving the three-dimensional Schrödinger equation to explain the physics of single and multi-electron atoms including orbital and spin angular momentum and atomic wave functions, and so explain the form and simple trends of the periodic table and the basic rules of atomic transitions.
- Explain the structure of the atomic nucleus, the nature of radioactivity, and the roles of the strong and weak interactions in nuclear stability, and apply concepts such as binding energy to explain nuclear decay and the distribution of stable isotopes
- Describe the different families of fundamental particles in the standard model, their connection with particle spin, and explain how these account for the observed set of free

particles and interactions

---

[1] If you need help with your assignment, please contact:

- the academic teaching staff in your unit for guidance in understanding or completing this type of assessment
- the Learning Skills Unit for academic skills support.

[2] Indicative time-on-task is an estimate of the time required for completion of the assessment task and is subject to individual variation

Delivery and Resources

Mode of delivery

Content will be delivered through lectures (2 one-hour classes each week), weekly one-hour SGTA workshops, and fortnightly two-hour computational laboratories.

While all delivery modes are subject to change based on COVID-19 developments, the initial arrangements are that both lectures and SGTAs will be delivered purely online, while the computational classes will be conducted in a dual mode with simultaneous on-campus and online options.

All information about zoom links, assignment submission portals, etc will be provided on the ilear n page.

We know that it is challenging to maintain motivation and consistent study patterns during the pandemic. We **strongly urge** that attending all classes, online and on-campus, is the best way to stay engaged and on top of the material.

Recommended reading

There is no set textbook for the unit. If you would like to do further reading to complement your study of the unit materials, there are many good introductions to Quantum Mechanics available in the library or as online or hardcopy books. Some that we like are the following:

Quantum mechanics

- David A. B Miller, *Quantum mechanics for scientists and engineers*, (Cambridge University Press, 2008)
- David Griffiths, *Introduction to quantum mechanics*, (Cambridge University Press, 1995)

Atomic and particle physics

- C. J. Foot, *Atomic Physics*, (Oxford, 2004)
- R. Eisberg and R. Resnick, *Quantum physics of atoms, molecules, solids, nuclei, and particles*, (Wiley, 1985)

Unit Schedule

The expected schedule of topics to be covered (subject to possible modest change) is as follows:

- Review of wave mechanics
- Quantum mechanics with discrete systems
- State vectors, linear operators and the Dirac formulation of quantum mechanics
- Time evolution of quantum states and the Schrödinger equation
- The Schrödinger equation in three dimensions and angular momentum
- Solution of 3D problems including the harmonic oscillator and the hydrogen atom
- Perturbations in quantum physics
- Elements of nuclear physics and radioactivity
- Sub-atomic particles and the Standard Model

Policies and Procedures

Macquarie University policies and procedures are accessible from Policy Central (https://policies.mq.edu.au). Students should be aware of the following policies in particular with regard to Learning and Teaching:

- Academic Appeals Policy
- Academic Integrity Policy
- Academic Progression Policy
- Assessment Policy
- Fitness to Practice Procedure
- Grade Appeal Policy
- Complaint Management Procedure for Students and Members of the Public
- Special Consideration Policy

Students seeking more policy resources can visit Student Policies (https://students.mq.edu.au/support/study/policies). It is your one-stop-shop for the key policies you need to know about throughout your undergraduate student journey.

To find other policies relating to Teaching and Learning, visit Policy Central (https://policies.mq.edu.au) and use the search tool.

Student Code of Conduct

Macquarie University students have a responsibility to be familiar with the Student Code of Conduct: https://students.mq.edu.au/admin/other-resources/student-conduct

Results

Results published on platform other than eStudent, (eg. iLearn, Coursera etc.) or released directly by your Unit Convenor, are not confirmed as they are subject to final approval by the University. Once approved, final results will be sent to your student email address and will be made available in eStudent. For more information visit ask.mq.edu.au or if you are a Global MBA student contact globalmba.support@mq.edu.au

Student Support

Macquarie University provides a range of support services for students. For details, visit http://students.mq.edu.au/support/

Learning Skills

Learning Skills (mq.edu.au/learningskills) provides academic writing resources and study strategies to help you improve your marks and take control of your study.

- Getting help with your assignment
- Workshops
- StudyWise
- Academic Integrity Module

The Library provides online and face to face support to help you find and use relevant information resources.

- Subject and Research Guides
- Ask a Librarian

Student Enquiry Service

For all student enquiries, visit Student Connect at ask.mq.edu.au

If you are a Global MBA student contact globalmba.support@mq.edu.au

Equity Support

Students with a disability are encouraged to contact the Disability Service who can provide appropriate help with any issues that arise during their studies.

IT Help

For help with University computer systems and technology, visit http://www.mq.edu.au/about_us/offices_and_units/information_technology/help/.

When using the University's IT, you must adhere to the Acceptable Use of IT Resources Policy. The policy applies to all who connect to the MQ network including students.