PHYS3130

Quantum Mechanics and Atomic Physics

Session 1, Special circumstances, North Ryde 2021

Archive (Pre-2022) - Department of Physics and Astronomy

Contents

Notice

As part of Phase 3 of our return to campus plan, most units will now run tutorials, seminars and other small group activities on campus, and most will keep an online version available to those students unable to return or those who choose to continue their studies online.

To check the availability of face-to-face activities for your unit, please go to timetable viewer. To check detailed information on unit assessments visit your unit's iLearn space or consult your unit convenor.

General Information

Unit convenor and teaching staff
Convenor and lecturer
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Lecturer
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Credit points
10

Prerequisites
(PHYS201 or PHYS2010) and (PHYS202 or PHYS2020) and (MATH235 or MATH2010)

Corequisites
PHYS301 or PHYS3010

Co-badged status

Unit description
This unit deals with the fascinating world of quantum physics, providing a modern introduction to quantum mechanics and its applications. 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. The material covered here provides an introduction to the basic physical principles of quantum mechanics and the mathematical language that is needed to describe the new physics. We will study the three most important exactly-solvable models in quantum theory: the potential well, harmonic oscillator, and hydrogen atom. The quantum mechanics of angular momentum is also introduced and explored. These principles are developed further in the context of atomic physics in the second half of the unit, demonstrating the origin of the unique energy-level diagrams for each atom in the periodic table, consequently the unique spectrum of frequencies of electromagnetic radiation that can be emitted and/or absorbed. Physics of multi-electron systems, origins of the periodic properties of the elements, and interactions with electromagnetic fields are explored, as well as current topics like laser manipulation of atoms, optical lattices, and cold atomic gases.

Important Academic Dates

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

Learning Outcomes

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

ULO1: use the mathematical formalism of quantum mechanics in terms of state vectors, operators and their vector/matrix representations.

ULO2: demonstrate knowledge of von Neumann measurements in quantum mechanics.

ULO3: solve the matrix form of the Schrodinger equation.

ULO4: identify and use standard solutions of Schrodinger wave equation [free, infinite well, step, harmonic oscillator, Coulomb potential].

ULO5: demonstrate basic proficiency with formalism of orbital angular momentum and spin in analysis of various physical problems.

ULO6: derive the excited states of simple atoms.

ULO7: discuss the basic rules of the atomic transitions and physical principles behind them, and apply them in spectral analysis.

General Assessment Information

The assessment for the unit is composed of weekly assignments, a mid session quiz and the final examination.

Assignments

Assignments will be set and marked for assessment purposes and issued approximately once a week. 11 or 12 weekly assignment sets will be released. The 8 best grades from all submitted assignments will contribute to the 20 marks for the assignment component of the unit. If less than 8 assignments are submitted, the missing assignments will be graded at zero for the purposes of the assignment mark calculation. Given the teaching constraints the assignments will often contain more problems than will have to be submitted. Solutions will be provided to all of them

Weekly assignments are excellent preparation for both the mid session test in week 7 and the final examination, and our strong experience is that students who engage with the assignment tasks do well in the unit overall. We strongly urge you complete as many as possible.

Informal group discussion regarding the material connected to assignment 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 assignment 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,

Extension for weekly assignments may be requested ***in advance*** with a suitable justification. Note that delay of the submission of a particular assignment delays publication of its solutions. No extensions to assignments will be granted after the due date.

Mid-session test

There will be one mid-session test, to be held (tentatively) during the SGTA timeslot on week 7.

Students can prepare their own hand written summary notes to take into the test. The summary notes and the test script will be collected and assessed to ensure the notes were independently prepared. Summary notes are limited to one A4 sheet (both sides) in text no smaller than 10 point.

End-of-session examination

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

Permitted material will be advised.

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
Weekly assignments	20%	No	Issued weekly on Tuesdays and due 10 days later
Final examination	50%	No	Final exam period
Midsession exam	30%	No	SGTA session in week 7

Weekly assignments

Assessment Type [1]: Problem set
Indicative Time on Task [2]: 39 hours
Due: **Issued weekly on Tuesdays and due 10 days later**
Weighting: **20%**

Short problem sets each week.

On successful completion you will be able to:

- use the mathematical formalism of quantum mechanics in terms of state vectors, operators and their vector/matrix representations.
- demonstrate knowledge of von Neumann measurements in quantum mechanics.
- solve the matrix form of the Schrodinger equation.
- identify and use standard solutions of Schrodinger wave equation [free, infinite well, step, harmonic oscillator, Coulomb potential].
- demonstrate basic proficiency with formalism of orbital angular momentum and spin in analysis of various physical problems.
- derive the excited states of simple atoms.
- discuss the basic rules of the atomic transitions and physical principles behind them, and apply them in spectral analysis.

Final examination

Assessment Type [1]: Examination

Indicative Time on Task [2]: 20 hours
Due: **Final exam period**
Weighting: **50%**

Examination in the university exam period, covering all the content from the unit.

On successful completion you will be able to:

- use the mathematical formalism of quantum mechanics in terms of state vectors, operators and their vector/matrix representations.
- demonstrate knowledge of von Neumann measurements in quantum mechanics.
- solve the matrix form of the Schrodinger equation.
- identify and use standard solutions of Schrodinger wave equation [free, infinite well, step, harmonic oscillator, Coulomb potential].
- demonstrate basic proficiency with formalism of orbital angular momentum and spin in analysis of various physical problems.
- derive the excited states of simple atoms.
- discuss the basic rules of the atomic transitions and physical principles behind them, and apply them in spectral analysis.

Midsession exam

Assessment Type [1]: Quiz/Test
Indicative Time on Task [2]: 10 hours
Due: **SGTA session in week 7**
Weighting: **30%**

Short exam covering the content from the first half of the unit.

On successful completion you will be able to:

- use the mathematical formalism of quantum mechanics in terms of state vectors, operators and their vector/matrix representations.
- demonstrate knowledge of von Neumann measurements in quantum mechanics.
- solve the matrix form of the Schrodinger equation.
- identify and use standard solutions of Schrodinger wave equation [free, infinite well, step, harmonic oscillator, Coulomb potential].

[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 Writing Centre 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

Content will be delivered through online lectures and a weekly on-campus SGTA .

The online lectures will be delivered as a mix of pre-recorded and synchronous to balance flexibility for students with direct contact time with the lecturers. The length of online videos each week will not exceed three hours but may be broken into a number of smaller blocks of related content to aid learning and revision.

A recommended textbook is:

- "Introduction to Quantum Mechanics" by David Griffiths (any edition)

Knowledge of the basic elements of classical analytical mechanics (particularly the Hamiltonian formalism) is helpful, but not required. A set of lecture notes for those who are interested will be posted on iLearn.

A recommended textbook for atomic physics

- "Atomic physics" by C. J. Foot

Supplementary textbook on quantum mechanics and atomic physics:

- "Introductory Quantum Mechanics" by R. L. Liboff (any edition)

Lecture materials, additional reading and assignments will be posted to iLearn.

A book by M. Zettili, "Quantum mechanics: concepts and applications" contains a large number of worked-out problems

Unit Schedule

The schedule of topics to be covered is as follows:

- State vectors
- Linear operators
- Measurements
- Time evolution, tensor products
- The Schrodinger equation, free particles and infinite wells

- Harmonic oscillator
- Angular momentum
- Hydrogen atom: Schrodinger equation
- Spin
- Addition of angular momentum
- Approximated solutions and perturbation theory
- Optical transitions in hydrogen atoms
- Multi-electron atoms: helium
- Fine structure, chemical properties, optical transitions
- External fields, Zeeman effect

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 Services and 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.

Student Enquiries

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

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.