School of Physics

Course Outline 2022

PHYS4141

Quantum Mechanics (Honours)

School of Physics

Faculty of Science

T1, 2022

1. Staff

Position	Name	Email	Consultation times and locations	Contact Details
Course Coordinator	A/Prof Julian Berengut	julian.berengut@unsw.edu.au	Consultation times: by arrangement via email	
Lecturer	Professor Oleg Sushkov	sushkov@phys.unsw.edu.au	Consultation times: by arrangement via email	
Teaching Support Officer	Zofia Krawczyk-Bernotas	z.krawczyk-bernotas@unsw.edu.au	School of Physics office G06, Old Main Building	(02) 9065 5719

2. Course information

Units of credit: 6

Pre-requisite(s): PHYS3111 Quantum Mechanics and PHYS3114 Electrodynamics

http://timetable.unsw.edu.au/2022/PHYS4141.html

2.1 Course summary

This advanced Quantum Mechanics course is designed to provide students with a solid foundation needed to understand relativistic quantum mechanics, quantum electrodynamics, the standard model, and quantum information and computation. Topics include: The spin-statistics relationship; second quantisation; angular momentum; the density matrix; relaxation and decoherence; the Klein-Gordon equation; the Dirac equation; second quantisation of the Dirac field.

2.2 Course aims

This is the highest undergraduate course in quantum mechanics and will provide students with a broad and comprehensive understanding and a foundation for further study and research.

2.3 Course learning outcomes (CLO)

Learning outcomes:

1. Recall and demonstrate understanding of core principles of quantum mechanics.
2. Develop an understanding of, and ability to solve, a wide range of problems in quantum mechanics
3. Understand and develop facility with all syllabus material as a foundation for future research and professional activity.

2.4 Relationship between course and program learning outcomes and assessments

Course learning outcomes 1-3 are assessed by the midsession test, assignment and final exam. These assessments are largely of a problem-solving nature designed to determine students' ability to deploy acquired knowledge to new situations, which is a key graduate attribute for successful physics-trained graduates.

3. Strategies and approaches to learning

3.1 Learning and teaching activities

Lecture: This course is taught by two lecturers teaching 20 hours each.

Day	***Time***	***Location***	***Weeks***
Tuesday	0900-1100	OMB G32	1-5, 7-10
Friday	1100-1200	OMB G32	1-5, 7-8,10

Seminar (Journal Club)

Day	***Time***	***Location***	***Weeks***
Friday	1400-1500	OMB G32	2,4,6,8

3.2 Expectations of students

Students are expected to attend at least 80% of all classes.

Academic misconduct will not be tolerated in any form in this course. Substantiated instances of cheating, plagiarism or copying of answers may result in a failure grade or significant deduction of marks. Please ensure you are fully familiar with the University's requirements and rules on plagiarism, which are detailed at http://student.unsw.edu.au/plagiarism. Claims of being unaware of the rules and/or the requirement for you to meeting them will not be accepted as mitigating circumstances.

The School endorses interactive group learning and fully understands that you may discuss the content of your courses including tutorial and assignment problems during your studies. However, submitted assignments should be your own work outlining your own reasoning and demonstrating your own knowledge related to the assessment. Copying will not be tolerated (we are good at spotting it); please ensure you know where the line between studying together and cheating on assessments lies. We will expect you to stay firmly on the correct side of that line.

4. Course schedule and structure

Detailed Syllabus

Part	Topic	Time
Part 1. Spin-statistics	Identical particles, fermions and bosons, spin statistics relation, Slater determinant. He atom, variational approach. Multielectron atoms, effective potential. Exchange interaction.	**2 hours**
Part 2. Second quantization	Heisenberg representation of quantum mechanics. Algebraic method for harmonic oscillator, creation and annihilation operators. Second quantization for bosons, creation and annihilation operators, Hamiltonian for bosons in the second quantization representation. Weekly interacting boson gas. Coherent states, phase - number of particles uncertainty relation. Macroscopic occupation numbers, example of the laser field. Second quantization for fermions, creation and annihilation operators, Hamiltonian for fermions in the second quantization representation. Example of the ideal Fermi gas.	**4 hours**
Part 3. Density matrix, relaxation and decoherence	Density matrix, pure and mixed states (Liboff 11.11). Spin polarisation density matrix (Blum Ch. 1). Liouville equation, time evolution, interaction picture, Larmor precession (Blum 2.3 – 2.6) 4 – Irreversibility, Markoff processes. Master equation, stimulated emission and absorption (Blum 8.2 – 8.3). Magnetic resonance, Bloch equations, spin echo (Blum 8.4). Spin dephasing due to noise – beyond Fermi's golden rule.	**6 hours**
Part 4. Angular momentum	Commutation relations, ladder operators, spin-orbit coupling, LS and JJ schemes	**2 hours**
Part 5. Relativistic Klein Gordon equation	Klien Gordon equation for spinless particles, relativistic invariance, gauge invariance, physical interpretation and nonrelativistic limit. Second quantization of the Klein Gordon field, vacuum energy and Casimir effect.	**3 hours**
Part 6. Relativistic Dirac equation	Dirac equation for spin 1/2, relativistic invariance, gauge invariance, physical interpretation. Difference between spin and pseudospin/isospin. Differences and similarities with graphene. Pauli equation, g-factor of electron. Dirac equation in Coulomb field, spin orbit interaction.	**4 hours**
Part 7. Second quantization of Dirac field	Dirac sea, positrons, problem with the vacuum energy, analogy with particles/holes in a band insulator. Pauli spin-statistics theorem.	**3 hours**

5. Assessment

5.1 Assessment tasks

Assessment task	Length	Weight	Mark	Due date *(normally midnight on due date)*
Assessment 1:		20%		Friday 4 March (Week 3)
Assessment 2:		20%		Thursday 14 April (Week 9)
Assessment 3: Final Exam	2 hours	60%		See Exam Schedule (TBA)

Journal Club
Each student will be assigned a paper (the papers will represent key advances in physics that will be of interest to any serious physicist.). Students will make a 20 minute presentation that covers the background, the advance and its implications. Every member of the class will be expected to at least read the paper. The presenter will then lead a discussion (~20 minutes) of the work. This component is compulsory but does not count towards the final grade.

Further information

UNSW grading system: student.unsw.edu.au/grades

UNSW assessment policy: student.unsw.edu.au/assessment

Information about Special Consideration is available from

https://student.unsw.edu.au/special-consideration

5.2 Assessment criteria and standards

Please see Moodle for a marking rubric for each assessment task

5.3 Submission of assessment tasks

Unless otherwise specified, assignments should be submitted to your lecturer by 5pm on the due Unless otherwise specified, assignments should be submitted to your lecturer or posted in the School of Physics assignment box by 5pm on the due date. Assignments will not be accepted by email. Marks will be deducted for late assignments, at a rate of 10% of the maximum possible mark for the assignment per day. A weekend will count as two days. An assignment submitted after the solutions have been posted will automatically receive 0%.

A downloadable assignment cover sheet is available from
https://www.physics.unsw.edu.au/current-students/cover-sheet

5.4. Feedback on assessment

Please see Moodle for details on how feedback will be provided for each assessment task

6. Academic integrity, referencing and plagiarism

Referencing is a way of acknowledging the sources of information that you use to research your assignments. You need to provide a reference whenever you draw on someone else's words, ideas or research. Not referencing other people's work can constitute plagiarism.

Further information about referencing styles can be located at student.unsw.edu.au/referencing

Academic integrity is fundamental to success at university. Academic integrity can be defined as a commitment to six fundamental values in academic pursuits**:** honesty, trust, fairness, respect, responsibility and courage.[1] At UNSW, this means that your work must be your own, and others' ideas should be appropriately acknowledged. If you don't follow these rules, plagiarism may be detected in your work.

Further information about academic integrity and **plagiarism** can be located at:

- The *Current Students* site student.unsw.edu.au/plagiarism*,* and
- The *ELISE* training site subjectguides.library.unsw.edu.au/elise

The *Conduct and Integrity Unit* provides further resources to assist you to understand your conduct obligations as a student: student.unsw.edu.au/conduct.

7. Readings and resources

Textbooks

Stephen Gasiorowicz, Quantum Physics.

J. J. Sakurai, Modern Quantum Mechanics.

L. D. Landau, E. M. Lifshitz. Nonrelativistic Quantum Mechanics (vol 3).

L. D. Landau, E. M. Lifshitz. Relativistic Quantum Mechanics (vol. 4).

R. Liboff, Quantum Mechanics

K. Blum, Density matrix theory and applications

Other Resources

Lecture notes will be posted on Moodle.

[1] International Center for Academic Integrity, 'The Fundamental Values of Academic Integrity', T. Fishman (ed), Clemson University, 2013.

8. Administrative matters

Communications

Students should check their UNSW email account regularly as all official university communication will be sent to that address. Students should use their university email account when writing to UNSW staff and should always include their name and student number.

Health and Safety

The School of Physics is actively committed to the health, safety and welfare of its staff and students. Information on relevant UNSW Occupational Health and Safety policies and expectations is available at: www.ohs.unsw.edu.au and https://www.physics.unsw.edu.au/about/safety

Recommended Internet Sites

The School of Physics website is www.physics.unsw.edu.au. Under the “Current Students” link students will find information about degrees, courses, and assessment.

The University website my.unsw.edu.au provides links to the UNSW Handbook, Timetables, Calendars and other student information.

Student Complaint Procedures

UNSW has procedures for dealing with complaints. These aim to solve grievances as quickly and as close to the source as possible. Information is available here: student.unsw.edu.au/complaints. Staff who can assist include:

School Contacts:

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9. Additional support for students

- The *Current Students* Gateway: student.unsw.edu.au
- Academic Skills and Support: student.unsw.edu.au/skills
- Student Wellbeing, Health and Safety: student.unsw.edu.au/wellbeing
- Disability Support Services: student.unsw.edu.au/disability
- UNSW IT Service Centre: www.it.unsw.edu.au/students