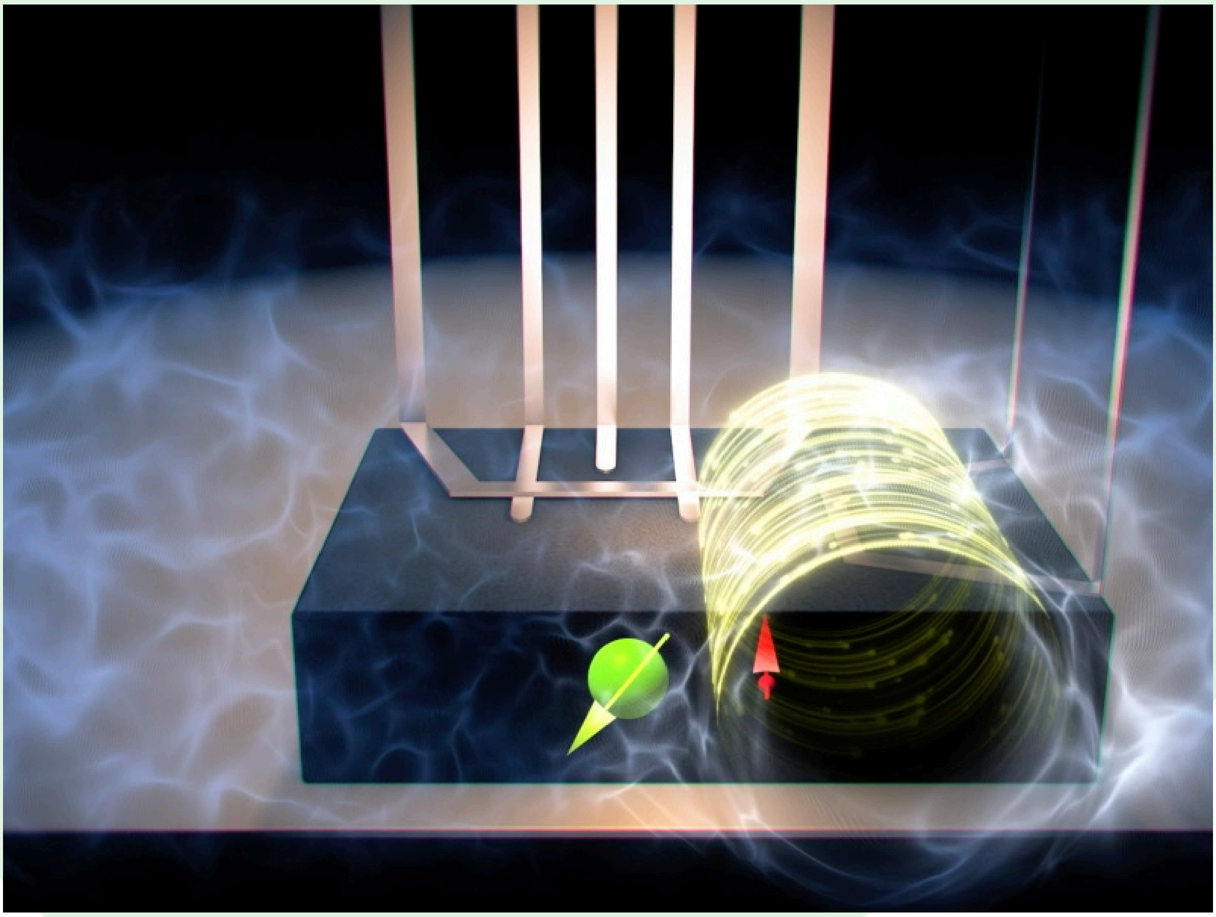
ELEC3705

Fundamentals of Quantum Engineering

Term 3, 2021



Course Overview

Staff Contact Details

Convenors

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Demonstrators

Name	Email	Availability	Location	Phone
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School Contact Information

Consultations: Lecturer consultation times will be advised during the first lecture. You are welcome to email the tutor or laboratory demonstrator, who can answer your questions on this course and can also provide you with consultation times. ALL email enquiries should be made from your student email address with ELEC/TELExxxx in the subject line; otherwise they will not be answered.

Keeping Informed: Announcements may be made during classes, via email (to your student email address) and/or via online learning and teaching platforms – in this course, we will use Moodle https://moodle.telt.unsw.edu.au/login/index.php. Please note that you will be deemed to have received this information, so you should take careful note of all announcements.

Student Support Enquiries

For enrolment and progression enquiries please contact Student Services

Web

Electrical Engineering Homepage

Engineering Student Support Services

Engineering Industrial Training

UNSW Study Abroad and Exchange (for inbound students)

UNSW Future Students

Phone

(+61 2) 9385 8500 – Nucleus Student Hub

(+61 2) 9385 7661 – Engineering Industrial Training

(+61 2) 9385 3179 – UNSW Study Abroad and UNSW Exchange (for inbound students)

Email

Engineering Student Support Services – current student enquiries

- e.g. enrolment, progression, clash requests, course issues or program-related queries

Engineering Industrial Training – Industrial training questions

UNSW Study Abroad – study abroad student enquiries (for inbound students)

UNSW Exchange – student exchange enquiries (for inbound students)

UNSW Future Students – potential student enquiries

- e.g. admissions, fees, programs, credit transfer

Course Details

Units of Credit 6

Summary of the Course

The progress of nanotechnology allows the fabrication of devices whose physical dimensions are approaching the atomic scale. At that scale, the laws of Quantum Mechanics become important. For classical electronics, an understanding of quantum phenomena and their impact on nanoscale devices is essential to further improve their performance. On the other hand, quantum effects can also be deliberately harnessed and exploited to create unprecedented functionalities.

The course "Fundamentals of Quantum Engineering" provides a modern, accessible, engineering-oriented introduction to the laws of Quantum Mechanics, and their relevance and applications in the emerging field of quantum technologies. The course teaches Quantum Mechanics using a matrix-oriented approach, which allows the students to write simple computer code to simulate the behaviour of surprisingly complex quantum devices.

The key learning outcomes of the course is the ability to understand and quantitatively describe the behaviour of quantum mechanical systems and devices, and to appreciate the potential of quantum phenomena to be applied for the construction of revolutionary systems such as quantum computers, quantum-enhanced sensors, and secure quantum communication channels. The course has a rather minimal set of prerequisities, and provides the necessary knowledge base to attend more advanced courses on the theory and applications of Quantum Mechanics.

Course Aims

The course aims to:

- Teach students the fundamental principles of quantum mechanics, with no prior assumed knowledge of the topic.
- Equip students with the tools required to simulate simple quantum systems with a numerical software package.
- Provide students with the background knowledge necessary to understand the operating principles of the quantum devices driving today’s technology.

Course Learning Outcomes

After successfully completing this course, you should be able to:

Learning Outcome	EA Stage 1 Competencies
1. Explain the fundamental concepts in quantum mechanics (e.g. wave-particle duality, Schrodinger’s equation, Heisenberg’s uncertainty principle, quantum tunneling and entanglement).	PE1.1, PE1.2
2. Apply the mathematics behind quantum mechanics to calculate the basic properties (e.g. energy and wavefunction) of a quantum system, as well as their time evolution.	PE1.1, PE1.2, PE1.3, PE2.1

Learning Outcome	EA Stage 1 Competencies
3. Develop code to simulate a quantum system using numerical software packages, such as Python	PE1.2, PE1.3, PE2.1, PE3.4
4. Demonstrate knowledge of the various physical systems with which it is possible to observe and exploit quantum phenomena.	PE1.1, PE1.3, PE1.4, PE1.5, PE2.1, PE2.2
5. Recognise the impact of quantum engineering on the creation of innovative technology industries, and demonstrate the conceptual knowledge to participate and contribute in these industries.	PE1.3, PE1.4, PE2.2, PE3.3
6. Possess some insight into how quantum mechanics underpins the physical properties of semiconductors and superconductors.	PE1.1, PE1.2, PE1.3, PE1.4

Teaching Strategies

Delivery Mode

The course will be delivered through the following methods:

- Lectures: Face-to-face lectures will be used to present students with core material essential for an understanding of quantum mechanics and engineered quantum systems.
- Tutorial/Laboratory: A two-hour laboratory session will provide students with experience in simulating quantum systems using the numerical software package Python. The laboratory will also be used to solve tutorial problems assigned in the lectures.

Online resources

Microsoft Teams

All the lecture materials, lecture recordings, and laboratory materials will be shared through the MS Teams course page. MS Teams also provides a natural platform for discussion threads, sharing information, and creating a collaborative student experience.

The Teams page will be structured in Channels, each one covering a section of the lecture material, or one of the laboratory sessions. All discussions should be posted and answered in the pertinent MS Teams channel, so that the topics remain self-contained

Moodle

Moodle will be used as the platform through which we host gradable assignments and quizzes. Assessment marks will also be made available via Moodle: https://moodle.telt.unsw.edu.au/login/index.php.

All non-assessable teaching materials (lectures, labs, discussion forums) will be posted through MS Teams instead.

Mailing list

Announcements concerning course information will be given in the lectures and/or on Moodle and/or via email (which will be sent to your student email address).

Additional Course Information

Credits

This is a 6 UoC course and the expected workload is 15 hours per week throughout the 10-week trimester.

Relationship to Other Courses

This is a 2nd / 3rd year course in the School of Electrical Engineering and Telecommunications. It is offered in 3rd year as an elective course for students following a BE (Electrical) or (Telecommunications), and in 2nd year as a core course for students enrolled in the BE (Quantum).

Pre-requisites and Assumed Knowledge

The pre-requisites for this course are PHYS1231 and MATH2099 (or equivalent). We assume only a basic understanding of Physics and Mathematics. In particular, the student should have had some exposure to linear algebra (vector spaces, matrices, matrix operations, eigenvalues and eigenvectors). It is highly beneficial if the students have already attended ELEC3115, because the description of wave propagation in electromagnetism is very similar to particle propagation in quantum mechanics. Please contact the lecturer if you are unsure whether you have the required background knowledge.

Assessment

Assessment task	Weight	Due Date	Course Learning Outcomes Assessed
1. Quizzes	10%	Not Applicable	1, 2, 4, 5, 6
2. Assignments	40%	Not Applicable	1, 2, 3, 4
3. Final Exam	50%	Not Applicable	1, 2, 4, 5

Assessment 1: Quizzes

Several online quizzes will be given throughout the session, to help the students receiving timely feedback on their understanding of the course material.

The quizzes will be organized by topic, where a "topic" is defined as the contents of a particular channel within the MS Teams course page. After having covered the specified material, a quiz will be opened in Moodle, and will close before the start of the subsequent topic. Exact dates and deadline for the quizzes will be communicated through both Moodle and MS Teams throughout the session.

The quizzes are assessable activities that will contribute to 10% of the final course mark.

Assessment 2: Assignments

Two take-home assignments will be given, with submission deadlines in week 7 and week 11 (5pm, Friday). The assignments will be based on numerical calculations to predict the dynamics and the properties of some quantum system. They will constitute extended versions of the Python exercises taught during the Laboratory sessions. The assignments will also have a pedagogical value, in the sense that the students will discover highly non-trivial and intellectually profound results by examining the outcomes of their calculations.

The assignment submission will be handled through the Moodle portal. You will be expected to upload a pdf file that summarizes your answers to all the questions, plus every Python file you have used to arrive at the solutions. *Late reports will attract a penalty of 10% per day* (including weekends).

The two assignments contribute to 40% of the final course mark (20% from each assignment).

Assessment 3: Final Exam

The exam will be administered through the Inspera online platform. It will be an open-book digital assessment.

The examination tests analytical and critical thinking and general understanding of the course material in a controlled fashion. Questions may be drawn from any aspect of the course (including laboratory), unless specifically indicated otherwise by the lecturer. Marks will be assigned according to the correctness of the responses.

The final exam contributes to 50% of the final course mark.

Attendance Requirements

Students are strongly encouraged to attend all classes and review lecture recordings.

Course Schedule

The schedule below is indicative and subject to change.

View class timetable

Timetable

Date	Type	Content
Week 1: 13 September - 17 September	Lecture	Introduction to fundamental concepts in quantum mechanics (wave-particle duality, Heisenberg's uncertainty principle and Schrodinger's equation)
Week 2: 20 September - 24 September	Lecture	Postulates of quantum mechanics (observables, measurements and time evolution) and their application to spins
	Laboratory	Introduction to Python coding relevant to quantum systems
Week 3: 27 September - 1 October	Lecture	Quantum mechanics in real space: Potential well, quantum confinement
	Laboratory	Matrix formalism of quantum systems
Week 4: 4 October - 8 October	Lecture	Quantum tunnelling, ammonia molecule; position and momentum operators
	Laboratory	Time evolution of an electron spin
Week 5: 11 October - 15 October	Lecture	General description of quantum two-level systems (qubits)
	Laboratory	Bouncing particles in a potential well
	Assessment	Assignment 1 released
Week 6: 18 October - 22 October	Homework	Flexibility week: individual revision and consultations
Week 7: 25 October - 29 October	Lecture	Qubit coupling and entanglement
	Laboratory	Dynamical control of a qubit
	Assessment	Assignment 1 due
Week 8: 1 November - 5 November	Lecture	Quantum statistics of identical particles
	Laboratory	Quantum tunneling and evanescent waves

Week 9: 8 November - 12 November	Lecture	From atoms to solids
	Laboratory	Defining and quantifying entanglement
	Assessment	Assignment 2 released
Week 10: 15 November - 19 November	Lecture	Quantum transport of charge; single-electron quantum devices
	Laboratory	Qiskit - advanced Python packages for quantum engineering
Study Week: 20 November - 25 November	Assessment	Assignment 2 due

Resources

Prescribed Resources

Textbooks

Prescribed textbook

- There is no formally prescribed textbook for the course. The course materials constitute sufficient resources.

Reference books

Students are encouraged to inspect the reference books in order to deepen their understanding of the subject (including more extensive mathematical treatments) and expand the scope of topics beyond the ones covered in the course.

- Claude Cohen-Tannoudji, Bernard Diu & Frank Laloe. *Quantum Mechanics*. Edn. 1 Vol. 1 (Wiley, 1991).
- Supriyo Datta. *Quantum Transport: Atom to Transistor*. Edn. 2 (Cambridge University Press, 2005).
- David A. B. Miller. *Quantum mechanics for scientists and engineers*. Edn. 1 (Cambridge University Press, 2008).
- Dennis M. Sullivan. *Quantum mechanics for electrical engineers*. Edn. 1 (IEEE Press, 2012)

Course Evaluation and Development

This course is under constant revision in order to improve the learning outcomes for all students. Please forward any feedback (positive or negative) on the course to the course convener or via the online student survey myExperience. You can also provide feedback to ELSOC who will raise your concerns at student focus group meetings. As a result of previous feedback obtained for this course and in our efforts to provide a rich and meaningful learning experience, we have continued to evaluate and modify our delivery and assessment methods.

For T3 2021, we have converted from Matlab to Python as the chosen software for the laboratory and assignments. Python is the de-facto standard for coding in quantum information systems. It is adopted by all quantum computer platforms available online, and widely supported in the quantum engineering community. It is also entirely free and open source.

Laboratory Workshop Information

The laboratory schedule is deliberately designed to provide practical, hands-on exposure to the concepts conveyed in lectures soon after they are covered in class. The practical component is achieved by learning how to write Python code to simulate the behavior of the quantum systems described during the lectures.

This component of the course will be delivered through **live online Python laboratory sessions** that coincide with the time slot allocated in the calendar. Prior to each laboratory, you will be given a set of problems to solve. It is essential that you attempt these problems BEFORE attending your laboratory, as you may require the solutions to complete your exercise.

Python is a free software. It used through a package manager called Anaconda. A video explaining how to install and use Anaconda can be found here:

https://www.youtube.com/watch?v=uOwCiZKj2rg

Academic Honesty and Plagiarism

Academic Honesty and Plagiarism

Plagiarism is the unacknowledged use of other people's work, including the copying of assignment works and laboratory results from other students. Plagiarism is considered a form of academic misconduct, and the University has very strict rules that include some severe penalties. For UNSW policies, penalties and information to help you avoid plagiarism, see https://student.unsw.edu.au/plagiarism. To find out if you understand plagiarism correctly, try this short quiz: https://student.unsw.edu.au/plagiarism-quiz.

General Conduct and Behaviour

Consideration and respect for the needs of your fellow students and teaching staff is an expectation. Conduct which unduly disrupts or interferes with a class is not acceptable and students may be asked to leave the class.

Academic Information

COVID19 - Important Health Related Notice

Your health and the health of those in your class is critically important. You must stay at home if you are sick or have been advised to self-isolate by NSW health or government authorities. Current alerts and a list of hotspots can be found here. **You will not be penalised for missing a face-to-face activity due to illness or a requirement to self-isolate**. We will work with you to ensure continuity of learning during your isolation and have plans in place for you to catch up on any content or learning activities you may miss. Where this might not be possible, an application for fee remission may be discussed.

If you are required to self-isolate and/or need emotional or financial support, please contact the Nucleus: Student Hub. If you are unable to complete an assessment, or attend a class with an attendance or participation requirement, please let your teacher know and apply for special consideration through the Special Consideration portal. To advise the University of a positive COVID-19 test result or if you suspect you have COVID-19 and are being tested, please fill in this form.

UNSW requires all staff and students to follow NSW Health advice. Any failure to act in accordance with that advice may amount to a breach of the Student Code of Conduct. Please refer to the Safe Return to Campus guide for students for more information on safe practices.

Dates to note

Important Dates available at: https://student.unsw.edu.au/dates

Student Responsibilities and Conduct

Students are expected to be familiar with and adhere to all UNSW policies (see https://student.unsw.edu.au/policy), and particular attention is drawn to the following:

Workload

It is expected that you will spend at least **15 hours per week** studying a 6 UoC course, from Week 1 until the final assessment, including both formal classes and *independent, self-directed study*. In periods where you need to complete assignments or prepare for examinations, the workload may be greater. Over-commitment has been a common source of failure for many students. You should take the required workload into account when planning how to balance study with employment and other activities.

Attendance

Regular and punctual attendance at all classes is expected. UNSW regulations state that if students attend less than 80% of scheduled classes they may be refused final assessment.

Work Health and Safety

UNSW policy requires each person to work safely and responsibly, in order to avoid personal injury and to protect the safety of others.

Special Consideration and Supplementary Examinations

You must submit all assignments and attend all examinations scheduled for your course. You can apply for special consideration when illness or other circumstances beyond your control interfere with an assessment performance. If you need to submit an application for special consideration for an exam or assessment, you must submit the application **prior to the start** of the exam or before the assessment is submitted, except where illness or misadventure prevent you from doing so. Be aware of the “fit to sit/submit” rule which means that if you sit an exam or submit an assignment, you are declaring yourself well enough to do so and cannot later apply for Special Consideration. For more information and how to apply, see https://student.unsw.edu.au/special-consideration.

Administrative Matters

On issues and procedures regarding such matters as special needs, equity and diversity, occupational health and safety, enrolment, rights, and general expectations of students, please refer to the School and UNSW policies:

https://student.unsw.edu.au/guide

https://www.engineering.unsw.edu.au/electrical-engineering/resources

Image Credit

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CRICOS

CRICOS Provider Code: 00098G

Acknowledgement of Country

We acknowledge the Bedegal people who are the traditional custodians of the lands on which UNSW Kensington campus is located.

Appendix: Engineers Australia (EA) Professional Engineer Competency Standard

Program Intended Learning Outcomes	
Knowledge and skill base	
PE1.1 Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline	✓
PE1.2 Conceptual understanding of the mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline	✓
PE1.3 In-depth understanding of specialist bodies of knowledge within the engineering discipline	✓
PE1.4 Discernment of knowledge development and research directions within the engineering discipline	✓
PE1.5 Knowledge of engineering design practice and contextual factors impacting the engineering discipline	✓
PE1.6 Understanding of the scope, principles, norms, accountabilities and bounds of sustainable engineering practice in the specific discipline	
Engineering application ability	
PE2.1 Application of established engineering methods to complex engineering problem solving	✓
PE2.2 Fluent application of engineering techniques, tools and resources	✓
PE2.3 Application of systematic engineering synthesis and design processes	
PE2.4 Application of systematic approaches to the conduct and management of engineering projects	
Professional and personal attributes	
PE3.1 Ethical conduct and professional accountability	
PE3.2 Effective oral and written communication in professional and lay domains	
PE3.3 Creative, innovative and pro-active demeanour	✓
PE3.4 Professional use and management of information	✓
PE3.5 Orderly management of self, and professional conduct	
PE3.6 Effective team membership and team leadership	