TELE9757

Quantum Communications

Term 1, 2022

Course Overview

Staff Contact Details

Convenors

Name	Email	Availability	Location	Phone
Robert Malaney	r.malaney@unsw.edu.au	Tuesday 6-10pm	R407	0293856580

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

This course is aimed at Engineers and Physicists wishing to understand the exciting new world of Quantum Communications. Quantum Communications and Quantum Networks are anticipated to be the core networking technologies of the 21st century. In fact, these communication systems have already appeared in the commercial world in many variations. This course introduces the keys concepts important for understanding, testing, analyzing, and improving the performance of quantum communication networks. It will have a particular focus on actual quantum networks currently being deployed and the use of such networks for secure information transfer. Designed from an engineering perspective the course will first introduce the basic quantum physics that underlies quantum communication principles. It will then introduce and explore the key concepts that drive quantum communications such as Quantum Entanglement, Quantum Teleportation, The No Cloning Theorem, Quantum Cryptography; Privacy Amplification, and Error Correction for Quantum Keys.

Course Aims

The main aim of this course is to develop amongst students from different backgrounds a solid understanding of the key concepts and principles that underpin the emerging and exciting new world of quantum communications. The course is particularly aimed at Graduate Engineers and Physicists wishing to understand Quantum Communications. Quantum Communications and Quantum Networks are anticipated to be the core networking technologies of the 21st century. In fact, these communication systems have already appeared in the commercial world in many variations. The course introduces the key concepts important for understanding, testing, analyzing and improving the performance of quantum communication networks. It will have particular focus on actual quantum networks currently being deployed and the use of such networks for secure information transfer. Designed from an engineering perspective the course will first introduce the basic quantum physics that underlies quantum communication principles. It will then introduce and explore the key concepts that drive quantum communications.

Course Learning Outcomes

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

Learning Outcome	EA Stage 1 Competencies
1. Explain the theory, concepts and challenges of quantum mechanics as applied to communications.	PE1.1, PE1.2, PE1.3, PE1.4
2. Explain the theory, concepts and challenges of transferring quantum information over a network.	PE1.1, PE1.2, PE1.3, PE1.4
3. Explain how applications operate over quantum communication channels.	PE1.4
4. Explain why quantum communications is a vital new technology that will only grow in importance within the engineering world.	PE2.1, PE2.2

Learning Outcome	EA Stage 1 Competencies
5. Explain and participate in discussions on the underlying principles of quantum networks, and be able to design and simulate the behaviour of quantum networks.	PE3.2, PE3.3
6. Carry out calculations which determine the performance of a quantum network.	PE1.2
7. Review and communicate via written reports the novelty and usefulness of quantum communication research papers appearing in engineering journals.	PE3.2

Teaching Strategies

Delivery Mode

The teaching in this course aims at establishing a good fundamental understanding of the areas covered using:

- Formal online (only) lectures and classes, which provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations to aid your understanding.
- Tutorials (during the regular online class), which allow for exercises in problem solving and allow time for you to resolve problems in understanding of lecture material.

Learning in this course

You are expected to attend all lectures online and mid-term exams in order to maximise learning. In addition to the lecture notes/video, you should read relevant sections of the recommended text. Reading additional texts will further enhance your learning experience. Group learning is also encouraged. UNSW *assumes* that self-directed study of this kind is undertaken in addition to attending face-to-face classes throughout the course.

Class attendance (virtual) at the online lectures is especially important for this class as you will be presented with brand new concepts that you have likely never come across before. This makes the class very interesting for you – but it does require your participation in class. There will be no formal notes handed out that covers all the class material in detail, There will be power-points put on the class web site for download but these will not be sufficient for you to cover the class material. The lectures will consist of some power-point presentations, discussion of material in prescribed texts, and discussion of case studies. You are strongly encouraged to participate in class by interacting through questions and discussions of class material, and to prepare before class by reading relevant work packages ahead of time. There will be plenty of problem sets that will be reviewed in class.

Each week we will go over a short tutorial problem set. Some of the tutorial set may be given to you during the class and worked on during the same class. Others may be done in class one week after being released. These tutorials are not compulsory, will not be marked and do not form any part of the final class mark. **You are strongly encouraged to attempt these tutorials - if you do not you will likely struggle in this class**.

Additional Course Information

Course Resources

Textbooks

Prescribed textbook

Protecting Information: From Classical Error Correction to Quantum Cryptography, S. Loepp & W. K. Wooters, Cambridge Press, 2006

Reference books

- Quantum Computation and Quantum Information, M. Nielsen and I. L. Chuang, Cambridge Press, 2006.

On-line resources

Moodle

As a part of the teaching component, Moodle will be used to disseminate teaching materials, host forums and occasionally quizzes. Assessment marks will also be made available via Moodle: https://moodle.telt.unsw.edu.au/login/index.php.

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).

Assessment

Assessment (details)

- **Final Examination (60%):** The examination is of two-hour duration, covering all aspects of the course that have been presented in lectures. This exam will assess both understanding and analytical skills. You must pass this exam to pass course.
- **Mid-Session Test (20%):** The mid-session test will last about 45 minutes and will be held in week 6. It will cover material covered in the course in week 1 to 5, and will test your conceptual understanding of this material, as well as your ability to apply the concepts to solving problems. This is a compulsory test.
- **Class Assignment (20%):** Student groups (maximum three) will be charged with reviewing a research paper chosen from a list (to be given in class), or choosing a substantial simulation project which covers some aspects of the class work (this substantial simulation needs to be agreed to by me). This assignment is related to the learning outcome of being able to comprehend current research papers in the area. A formal 10-page report on the research paper or the simulation will be required by week 11. The assignment will be marked on the following criteria; Presentation (15%) depth of technical content (30%), independent critical thinking (40%). technical writing (15%). Students may do both a review of a paper and add some small Matlab simulation related to that paper (generally reviews that include a small Matlab simulation obtain higher marks).The students may present a power-point presentation on his/her report (although encouraged to do so the presentation is optional). The assignment will be due by end of week 11 – delivery will be electronic. Each member of the group should be prepared for oral examination by me on any part of the report. Individual marks may be given for the assignment.
- **Bonus Marks**. A few bonus marks may be available for additional class participation – details in class. Note the combined bonus marks for any student will not exceed 5% of final class mark.
- **Late reports and missed tests.** There will be zero marks awarded for late reports or missed tests.

Assessment task	Weight	Due Date	Course Learning Outcomes Assessed
1. Mid-session Test	20%	Not Applicable	1, 2, 3, 6, 7
2. Project	20%	Not Applicable	4, 5, 7
3. Final Examination	60%	Not Applicable	1, 2, 3, 6

Assessment 1: Mid-session Test

Assessment length: 2 hours

Mid-session Test held online during class week 5 (tentative - as we may move to week 6).

Additional details

This exam will be multiple choice via Moodle, with marks returned next day.

Assessment 2: Project

Student groups (maximum three) will be charged with reviewing a research paper chosen from a list (to be given in class), or choosing a substantial simulation project which covers some aspects of the class work.

This assignment is submitted through Turnitin and students can see Turnitin similarity reports.

Additional details

This will be turned in via the Moodle web site at end of week 11.

Assessment 3: Final Examination

Assessment length: 2 hours

Final Examination

Assessment criteria

Full Marks: Full understanding of all course material and abilty to carry out relevant mathematical calculations.

Pass Marks: Substantial understanding of all course material and abilty to carry out at some level relevant mathematical calculations.

Additional details

The final exam in this course is a standard closed-book 2 hour written examination, comprising five compulsory questions. Calculators are not allowed. 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 unless specifically indicated otherwise by the lecturer. Marks will be assigned according to the correctness of the responses. *Please note that you must pass the final exam in order to pass the course.*

Attendance Requirements

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

Course Schedule

All classes will be online, 6pm-9pm Tuesday, Weeks 1 through 10.

View class timetable

Timetable

Date	Type	Content
Week 1: 14 February - 18 February	Lecture	**Introductory Lecture -** Who wants to be a "Quantum Engineer"? Why study Quantum Communications and Quantum networks? What's wrong with classical networks? What Quantum physics will we cover in the course? What "real engineers" are now building? Overview of current Quantum networks both deployed commercially and those currently in prototype.
Week 2: 21 February - 25 February	Lecture	**Photon Polarization -** Maxwell's equations revisited. Applications of polarization in Quantum Networks. **General Quantum Variables and Qubits** - Applications of quantum variables in Quantum Networks
Week 3: 28 February - 4 March	Lecture	**Composite Quantum Systems -** Applications of quantum systems in Quantum Networks.
Week 4: 7 March - 11 March	Lecture	**Quantum Entanglement -** Why Einstein was wrong and right at same time. Why entanglement important for Quantum Communications. **Quantum Teleportation -** An application of composite qubits and entanglement.
Week 5: 14 March - 18 March	Lecture	**Experimental Quantum Teleportation of Qubits -** Engineering sources of Entangled Photons. Why is this hard? **The No Cloning Theorem -** Copying classical information is easy but try copying quantum information.
Week 6: 21 March - 25 March	Lecture	Review of the story so far.
	Assessment	**Mid-term test**

Week 7: 28 March - 1 April	Lecture	**Review of Classical Cryptography -** Algorithms and why classical encryption is defeated by Quantum Computers. **Quantum Cryptography -** The Bennett-Brassard Protocol for Quantum key distribution. Eckert's Protocol for Quantum key distribution using entanglement.
Week 8: 4 April - 8 April	Lecture	**Video Lecture** **Review of Classical Error Correcting Codes -** Hamming distance, Linear Codes, Generator Matrices, and all that jazz.
Week 9: 11 April - 15 April	Lecture	**Error Corrections for Quantum Keys -** Error correcting codes once quantum physics is thrown in.
Week 10: 18 April - 22 April	Lecture	**Privacy Amplification -** Why error correction leaks information to a potential adversary and how to combat this with privacy amplification. **Video lecture** **Moving from Qubits to Lasers -** Continuous variable quantum communications – an overview.

Resources

Prescribed Resources

On-line resources

Moodle

As a part of the teaching component, Moodle will be used to disseminate teaching materials, host forums and occasionally quizzes. Assessment marks will also be made available via Moodle: https://moodle.telt.unsw.edu.au/login/index.php.

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).

Main Text: Protecting Information: From Classical Error Correction to Quantum Cryptography, S. Loepp & W. K. Wooters, Cambridge Press, 2006.

https://www.cambridge.org/core/books/protecting-information/C47D4C179628B6AA23297867ACC323E7

[Avialble Free Onlne via a UNSW Library Account]

Recommended Resources

Secondary Text: Quantum Computation and Quantum Information, M. Nielsen and I. L. Chuang, Cambridge Press, 2006.

(Not required - but a useful more detailed text)

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 via the myExperience process. 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.

Based on feedback from previous year, additional in class tutorial material has been added to this year's course.

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

Synergies in Sound 2016

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	