# TELE9781 Special Topics
## Quantum Communications II

Course Outline – Term 3, 2019

Never Stand Still | Faculty of Engineering | School of Electrical Engineering and Telecommunications

## Course Staff

Course Convener: A/Prof Robert Malaney, Room 407 EE&T , r.malaney@unsw.edu.au

**Consultations:** You are encouraged to ask questions on the course material, after the lecture class times in the first instance, rather than via email. Lecturer consultation times will be advised during lectures. ALL email enquiries should be made from your student email address with TELE9781 in the subject line.

**Keeping Informed:** Announcements may also be made during classes, via email (to your student email address) and/or via online learning, class website, and teaching platforms – in this course, we will use Moodle to post marks https://moodle.telt.unsw.edu.au/login/index.php. Please check the class web site prior to sending a general administrative email as this website is updated weekly and important administrative matters will be posted there (https://subjects.ee.unsw.edu.au/tele9781).

## Course Summary

### Contact Hours

The course consists of 1 hours of lectures and 2 hours of Matlab Project work

| Lectures | Day | Time | Location |
|---|---|---|---|
| | Monday | 9am - Noon | Elec Eng 108 |

### Context and Aims

This course is designed to be built on the expertise gained in Tele9757 Quantum Communications. In this advanced version of quantum communications, we will move much closer to real working quantum communication systems. Going deeper into the details of how quantum communication systems work in practice, the course will expose you to many issues not covered in Tele9757. The course will also introduce the use of-the shelve technology in the form of continuous variables (weak laser beams) as a means to enable quantum communications. The mode of learning will be largely 1 hour lectures followed by a 2 hour laboratory in which you will carry out simulation exercises using Matlab. Additional online lectures may be used to assist with the needed theoretical background. A pre-requisite for this class is a Credit Pass in Tele9757. Those with just a Pass from Tele9575 will need special permission from the course convener A/Prof Robert Malaney, and such students should contact him directly. The tentative curriculum is below.

## Part I - Single Photon (Discrete Variable) Technology

**Lecture 1**: Reviewing Tele9757 and recalling the "known unknowns" (2 hours). ***Matlab Laboratory* 1:** Matlab and quantum communications – a brief overview (1 hour)

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**Lecture 2**: Quantum Error Correction I - How to make a quantum communication *link* work (1 hour). ***Matlab Laboratory 2*** - A point-to-point quantum communication link with error correction (2 hours).

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**Lecture 3**: Quantum Error Correction II - How to make quantum a communication link *really* work (1 hour). ***Matlab Laboratory 3*** - A point-to-point quantum communication link with advanced error correction (2 hours).

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**Lecture 4**: Quantum Teleportation - Teleporting in practice, it will work! (1 hour). ***Matlab Laboratory 4***: An operational teleoperation scheme with error correction (2 hours).

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**Lecture 5**: Quantum Key Distribution: The six steps to perfect security (1 hour). ***Matlab Laboratory 5***:– An operational QKD communication link (2 hours).

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**Lecture 6**: Quantum Repeaters: Connecting point-to-point links (1 hour). ***Matlab Laboratory 6*:** – A fully operational QKD communication network (2 hours).

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## Part II – Multi Photon (Continuous Variable) Technology

**Lecture 7:**- Quantising the Electromagnetic Field: Not as hard as it sounds (1 hour). ***Matlab Laboratory 7*:** Beyond the four degrees of freedom of a photon (2 hours).

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**Lecture 8:**- **Continuous Variable** QKD (CV-QKD). ***Matlab Laboratory 8*:** CV-QKD using lasers (2 hours).

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**Lecture 9:**- CV-QKD in Lossy Channels (1 hour). ***Matlab Laboratory 9*:** QKD when real communication channels are used (2 hours).

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**Lecture 10:**- Multiplexing Quantum Communications (1 hour). ***Matlab Laboratory 10*:** Improving communications via multiplexing spatial modes of the Electromagnetic Field (2 hours).

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**Offline learning Mode –** Additional video lectures may be provided for additional theoretical background.

## Assessment

| | |
|---|---|
| MATLAB work in class | 50% |
| Final Exam | 50% |

# Course Details

## Credits

This is a 6 UoC course and the expected workload is 10–12 hours per week throughout term.

## Relationship to Other Courses

This is an elective postgraduate course in the School of Electrical Engineering and Telecommunications.

## Pre-requisites and Assumed Knowledge

A Credit Pass in Tele9757 is a prerequisite. It is assumed that all students have qualifications equivalent to an Electrical Engineering undergraduate degree from UNSW.

## Learning outcomes

After successful completion of this course, you should be able to:

1. Understand at a deeper level than Tele9757 the theory, concepts and challenges and implementations of quantum mechanics as applied to communications.
2. Learn implementations of transferring quantum information over a network.
3. Understand how quantum protocols applications are implemented over a quantum communication channel.
4. Be able to design and implement in Matlab the behavior of quantum networks.

This course is designed to provide the above learning outcomes which arise from targeted graduate capabilities listed in ***Appendix A***. The targeted graduate capabilities broadly support the UNSW and Faculty of Engineering graduate capabilities (listed in ***Appendix B***). This course also addresses the Engineers Australia (National Accreditation Body) Stage I competency standard as outlined in ***Appendix C***.

## Syllabus

Designed from an engineering perspective the course will build on your current understanding of quantum physics that underlies quantum communication principles. We will do this largely by a series of numerous projects in Matlab that will be carried out in class.

# Teaching Strategies

## Delivery Mode

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

- Formal face-to-face lectures, which provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations to aid your understanding;
- Matlab tutorials in which you are required to implement various aspects of quantum communication protocols. Learning in this course

You are expected to attend <u>all</u> lectures and laboratory work. This is compulsory for this course You must prepare well for your laboratory classes and your lab work will be

assessed. 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.

### Tutorials

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**.

### Assessment (details)

- **Final Examination (50%):** 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.
- **Class Assignment (50%):** You will be asked in each class to carry out a Matlab project. This Matlab project will be assessed and you will be given a mark for each class as you progress through the course.

### Final Exam

The 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.*

### Relationship of Assessment Methods to Learning Outcomes

| | **Learning outcomes** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Assessment** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| Assignments | - | - | - | ✓ | ✓ | - | ✓ |
| Final exam | ✓ | ✓ | ✓ | - | - | ✓ | - |

## 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).

## Other Matters

### 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.

### Student Responsibilities and Conduct

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

### Workload

It is expected that you will spend at least **ten to twelve hours per week** studying a 6 UoC course, from Week 1 until the final assessment, including both face-to-face classes and *independent, self-directed study*. In periods where you need to 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.

### 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.

### 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 should seek assistance early if you suffer illness or misadventure which affects your course progress. All applications for special consideration must be **lodged online through myUNSW within 3 working days of the assessment**, not to course or school staff. For more detail, consult https://student.unsw.edu.au/special-consideration.

### Continual Course Improvement

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 years course.

### 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:
http://www.engineering.unsw.edu.au/electrical-engineering/policies-and-procedures
https://my.unsw.edu.au/student/atoz/ABC.html

## Appendix A: Targeted Graduate Capabilities

Electrical Engineering and Telecommunications programs are designed to address the following targeted capabilities which were developed by the school in conjunction with the requirements of professional and industry bodies:

- The ability to apply knowledge of basic science and fundamental technologies;
- The skills to communicate effectively, not only with engineers but also with the wider community;
- The capability to undertake challenging analysis and design problems and find optimal solutions;
- Expertise in decomposing a problem into its constituent parts, and in defining the scope of each part;
- A working knowledge of how to locate required information and use information resources to their maximum advantage;
- Proficiency in developing and implementing project plans, investigating alternative solutions, and critically evaluating differing strategies;
- An understanding of the social, cultural and global responsibilities of the professional engineer;
- The ability to work effectively as an individual or in a team;

- An understanding of professional and ethical responsibilities;
- The ability to engage in lifelong independent and reflective learning.

## Appendix B: UNSW Graduate Capabilities

The course delivery methods and course content directly or indirectly addresses a number of core UNSW graduate capabilities, as follows

- Developing scholars who have a deep understanding of their discipline, through lectures and solution of analytical problems in tutorials and assessed by assignments and written examinations.
- Developing rigorous analysis, critique, and reflection, and ability to apply knowledge and skills to solving problems. These will be achieved by the laboratory experiments and interactive checkpoint assessments and lab exams during the labs.
- Developing digital and information literacy and lifelong learning skills through assignment work.
- Developing independent, self-directed professionals who are enterprising, innovative, creative and responsive to change, through challenging design and project tasks.

## Appendix C: Engineers Australia (EA) Professional Engineer Competency Standard

| | **Program Intended Learning Outcomes** | |
|---|---|---|
| **PE1: Knowledge and Skill Base** | PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals | ✓ |
| | PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing | ✓ |
| | PE1.3 In-depth understanding of specialist bodies of knowledge | ✓ |
| | PE1.4 Discernment of knowledge development and research directions | ✓ |
| | PE1.5 Knowledge of engineering design practice | ✓ |
| | PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice | |
| **PE2: Engineering Application Ability** | PE2.1 Application of established engineering methods to complex 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 | |
| **a n d P** | PE3.1 Ethical conduct and professional accountability | |

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|---|---|---|
| | PE3.2 Effective oral and written communication (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 | ✓ |