PHYS7909

Quantum Control

Session 2, In person-scheduled-weekday, North Ryde 2022

School of Mathematical and Physical Sciences

Contents

General Information

Unit convenor and teaching staff
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Credit points
10

Prerequisites
PHYS714 or PHYS7905

Corequisites

Co-badged status

Unit description
The aim of quantum control is to drive a quantum system to a desired state or more generally evolution through pulse-shaping. The unit begins with introducing control theory as a subject from engineering and a tool for solving inverse problems. We will discuss linear control and bilinear control, both are important in the quantum case. We then look at the Schrodinger equation as a bilinear control problem and aim to characterise what kind of states and operations can be reached in a given system. This leads us to an algebraic description of control, provided in the framework of Lie algebras. We will look at examples of how this works in practice in quantum computing. In such examples, one often encounters noise, and we will see how quantum control can help lowering noise, which leads us the control of open systems. A particular case of open system control is important in continuous variable quantum optics and known as the input-output formalism, which will bring us back to linear control. In the final part we introduce optimal control. The task here is to find the best way of controlling quantum system - shortest time, lowest energy, lowest noise. We look at examples from Nuclear Magnetic Resonance, from Ultrafast Laser Control, and from Quantum Computing. You will use the python library "QuTiP" to get experience with the beauty and the challenges of optimal control.

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: Distinguish linear, bilinear and general control systems and provide criteria for their controllability.

ULO2: Characterise the control properties of low-dimensional noiseless quantum systems.

ULO3: Explain basic concepts of the control of noisy systems and apply them to single qubit systems.

ULO4: Use the mathematical descriptions of input-output systems in quantum optics.

ULO5: Present physical arguments in quantum control through explanation of tutorial and assignment questions.

ULO6: Use the python library QuTiP to solve simple optimal control problems.

General Assessment Information

Late Assessment Submission Penalty: From 1 July 2022, Students enrolled in Session based units with written assessments will have the following university standard late penalty applied. Please see https://students.mq.edu.au/study/assessment-exams/assessments for more information. Unless a Special Consideration request has been submitted and approved, a 5% penalty (of the total possible mark) will be applied each day a written assessment is not submitted, up until the 7th day (including weekends). After the 7th day, a grade of '0' will be awarded even if the assessment is submitted. Submission time for all written assessments is set at 11:55 pm. A 1-hour grace period is provided to students who experience a technical concern. For any late submission of time-sensitive tasks, such as scheduled tests/exams, performance assessments/presentations, and/or scheduled practical assessments/labs, students need to submit an application for Special Consideration.

• Type of assessments in this unit and specific late policy

Problem sets – YES, Standard Late Penalty applies

Project reports - YES, Standard Late Penalty applies

Oral exam - not applicable

Assessment Tasks

Name	Weighting	Hurdle	Due
Problem sets	30%	No	to be determined
Project reports	30%	No	to be determined

Name	Weighting	Hurdle	Due
Oral Final Exam	40%	No	to be determined

Problem sets

Assessment Type [1]: Problem set
Indicative Time on Task [2]: 30 hours
Due: **to be determined**
Weighting: **30%**

A sequence of problem sets throughout the session.

On successful completion you will be able to:

- Distinguish linear, bilinear and general control systems and provide criteria for their controllability.
- Characterise the control properties of low-dimensional noiseless quantum systems.
- Explain basic concepts of the control of noisy systems and apply them to single qubit systems.
- Use the mathematical descriptions of input-output systems in quantum optics.

Project reports

Assessment Type [1]: Report
Indicative Time on Task [2]: 32 hours
Due: **to be determined**
Weighting: **30%**

Reports for numerical and computational projects

On successful completion you will be able to:

- Distinguish linear, bilinear and general control systems and provide criteria for their controllability.
- Characterise the control properties of low-dimensional noiseless quantum systems.
- Explain basic concepts of the control of noisy systems and apply them to single qubit systems.
- Use the mathematical descriptions of input-output systems in quantum optics.

- Use the python library QuTiP to solve simple optimal control problems.

Oral Final Exam

Assessment Type [1]: Viva/oral examination
Indicative Time on Task [2]: 20 hours
Due: **to be determined**
Weighting: **40%**

Oral examination in the University Examination period.

On successful completion you will be able to:

- Distinguish linear, bilinear and general control systems and provide criteria for their controllability.
- Characterise the control properties of low-dimensional noiseless quantum systems.
- Explain basic concepts of the control of noisy systems and apply them to single qubit systems.
- Use the mathematical descriptions of input-output systems in quantum optics.
- Present physical arguments in quantum control through explanation of tutorial and assignment questions.

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[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

The unit will be delivered exclusively online (via Zoom).

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
- Assessment Procedure
- Complaints Resolution 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

Academic Integrity

At Macquarie, we believe academic integrity – honesty, respect, trust, responsibility, fairness and courage – is at the core of learning, teaching and research. We recognise that meeting the expectations required to complete your assessments can be challenging. So, we offer you a range of resources and services to help you reach your potential, including free online writing and maths support, academic skills development and wellbeing consultations.

Student Support

Macquarie University provides a range of support services for students. For details, visit http://students.mq.edu.au/support/

The Writing Centre

The Writing Centre provides resources to develop your English language proficiency, academic writing, and communication skills.

- Workshops
- Chat with a WriteWISE peer writing leader
- Access StudyWISE

- Upload an assignment to Studiosity
- Complete the 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

Macquarie University offers a range of Student Support Services including:

- IT Support
- Accessibility and disability support with study
- Mental health support
- Safety support to respond to bullying, harassment, sexual harassment and sexual assault
- Social support including information about finances, tenancy and legal issues

Student Enquiries

Got a question? Ask us via AskMQ, or contact Service Connect.

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.