PHYS7909

Quantum Control

Session 2, Weekday attendance, North Ryde 2021

Department of Physics and Astronomy

Contents

Session 2 Learning and Teaching Update

The decision has been made to conduct study online for the remainder of Session 2 for all units WITHOUT mandatory on-campus learning activities. Exams for Session 2 will also be online where possible to do so.

This is due to the extension of the lockdown orders and to provide certainty around arrangements for the remainder of Session 2. We hope to return to campus beyond Session 2 as soon as it is safe and appropriate to do so.

Some classes/teaching activities cannot be moved online and must be taught on campus. You should already know if you are in one of these classes/teaching activities and your unit convenor will provide you with more information via iLearn. If you want to confirm, see the list of units with mandatory on-campus classes/teaching activities.

Visit the MQ COVID-19 information page for more detail.

General Information

Unit convenor and teaching staff Thomas Volz thomas.volz@mq.edu.au Daniel Burgarth daniel.burgarth@mq.edu.au	
Credit points 10	
Prerequisites PHYS714 or PHYS7905	
Corequisites	
Co-badged status PHYS8909	
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://students.mq.edu.au/important-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

Due dates for assessment tasks will be announced over the course of the semester.

Assessment Tasks

Name	Weighting	Hurdle	Due
Oral Final Exam	40%	No	to be announced
Problem sets	30%	No	weekly/bi-weekly
Project reports	30%	No	to be announced

Oral Final Exam

Assessment Type [1]: Viva/oral examination
Indicative Time on Task [2]: 20 hours
Due: **to be announced**
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.

Problem sets

Assessment Type [1]: Problem set
Indicative Time on Task [2]: 30 hours
Due: **weekly/bi-weekly**
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 announced**
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.

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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 Learning Skills Unit 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

We will have online lectures and tutorials via ZOOM.

ZOOM recordings and lecture notes will be made available via a shared Dropbox folder.

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
- Grade Appeal Policy
- Complaint Management 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

Student Support

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

Learning Skills

Learning Skills (mq.edu.au/learningskills) provides academic writing resources and study strategies to help you improve your marks and take control of your study.

- Getting help with your assignment
- Workshops
- StudyWise
- 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 Enquiry Service

For all student enquiries, visit Student Connect at ask.mq.edu.au

If you are a Global MBA student contact globalmba.support@mq.edu.au

Equity Support

Students with a disability are encouraged to contact the Disability Service who can provide appropriate help with any issues that arise during their studies.

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.