PHYS7910

Engineering Quantum Matter

Session 2, In person-scheduled-weekday, North Ryde 2024

School of Mathematical and Physical Sciences

Contents

General Information

Unit convenor and teaching staff
Lecturer & Convenor
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Credit points
10

Prerequisites
PHYS714 or PHYS7905

Corequisites

Co-badged status
PHYS8910

Unit description
This unit teaches fundamentals and emerging topics in engineered quantum materials. As originally envisioned by Feynman, quantum simulation is a process where one set of controllable quantum systems can be made to simulate a complex quantum system that is too hard to model classically. In this unit we will explain how quantum simulators work to mimic natural and unnatural, or synthetic, materials. Theoretical skills taught will be standard techniques from condensed matter, as well as tools used in quantum information. You will learn how a quantum system can be programmed to simulate another either via an analogue simulation using an engineered Hamiltonian, or via a digital gate-based quantum simulation. We will cover the physics of experimental quantum simulation architectures including trapped ions and neutral atoms, and colour centres in diamond. Applications of synthetic quantum matter for quantum error correction and sensing will be covered. To better understand the physics of many body quantum systems you will learn numerical techniques including quantum simulation code and approximation methods known as tensor networks in order to simulate ground states and dynamics of many body quantum systems.

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: Apply essential skills for solving problems in quantum many body physics.

ULO2: Model quantum simulations using Hamiltonian based and gate based approaches.

ULO3: Explain how to use the toolbox of interactions in an experimental architecture to perform a quantum simulation.

ULO4: Numerically model the physics of entangled many body systems via tensor network algorithms and quantum simulation software.

ULO5: Effectively communicate ideas in quantum engineering.

General Assessment Information

The assessment for the unit is composed of four problem sets, a written report, and the final examination. Regular attendance is expected, with exceptions granted for valid reasons communicated in advance.

Written Assignments (40%)

Four take-home assignments of problem sets will be set and marked for assessment purposes and issued approximately once every two weeks. Worked solutions will be provided to problem sets after the due date. These problem sets are excellent preparation for the final examination, and our strong experience is that students who engage with the problem-solving tasks do well in the unit overall.

Academic integrity

Informal group discussion regarding the material connected to problem-set questions is encouraged, but **each student must independently develop and write up their own solutions**. Do not hesitate to seek help from the lecturing team if you are having difficulties with the assigned problems. All students must comply with the academic integrity policy by preparing and submitting their answers independently. To ensure compliance interviews with selected students may be conducted where there is undue similarity in submitted solutions.

Breaches of the academic integrity policy may lead to sanctions that may include, but are not limited to, award of a failure grade for the unit and/or temporary suspension form studies. In cases determined by law the University has a legal obligation to disclose the applied sanctions to outside parties, including certain employers.

Extensions

Extension for the assignments may be requested **well in advance** with a suitable justification. No extensions to the assignment due dates will be granted within 48 hours of the original due date.

Report (20%)

A wriiten report should be produced that involves numerical computation on some topic in quantum many body information relevant to the course content. Examples of reports from prior offerings will be provided as will example topics. For numerical comptuation you may use any software package you prefer but the report should be completed using Latex.

Final examination (40%)

There will be a 3 hour end-of-session exam to be held online. It is open book but no collaboration with other students is allowed.

You are expected to make yourself available for the final examination at the time designated in the University examination timetable. If you receive special consideration for the final exam, a supplementary exam will be scheduled during the supplementary exam period. By making a special consideration application for the final exam you are declaring yourself available for a resit during the supplementary examination period and will not be eligible for a second special consideration approval based on pre-existing commitments. Please ensure you are familiar with the policy prior to submitting an application. Approved applicants will receive an individual notification one week prior to the exam with the exact date and time of their supplementary examination.

Late Assessment Submission Penalty

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. Assessments where Late Submissions will be accepted In this unit, late submissions will accepted as follows:

• Assessment Written assignments – YES, Standard Late Penalty applies

• Assessment Report – YES, Standard Late Penalty applies

• Assessment Final exam - NO, unless Special Consideration is Granted

Requirements to Pass this Unit

To pass this unit you must: Achieve a total mark equal to or greater than 50%.

Assessment Tasks

Name	Weighting	Hurdle	Due
Final exam	40%	No	As scheduled during formal examination period

Name	Weighting	Hurdle	Due
Written assignments	40%	No	Four homework assignments due as advised on iLearn.
Report	20%	No	Week 14

Final exam

Assessment Type [1]: Examination
Indicative Time on Task [2]: 20 hours
Due: **As scheduled during formal examination period**
Weighting: **40%**

An examination in the University Examination period covering all of the course content.

On successful completion you will be able to:

- Apply essential skills for solving problems in quantum many body physics.
- Model quantum simulations using Hamiltonian based and gate based approaches.
- Explain how to use the toolbox of interactions in an experimental architecture to perform a quantum simulation.
- Effectively communicate ideas in quantum engineering.

Written assignments

Assessment Type [1]: Problem set
Indicative Time on Task [2]: 24 hours
Due: **Four homework assignments due as advised on iLearn.**
Weighting: **40%**

Four problems sets spread throughout the session.

On successful completion you will be able to:

- Apply essential skills for solving problems in quantum many body physics.
- Model quantum simulations using Hamiltonian based and gate based approaches.
- Explain how to use the toolbox of interactions in an experimental architecture to perform a quantum simulation.

- Effectively communicate ideas in quantum engineering.

Report

Assessment Type [1]: Report
Indicative Time on Task [2]: 16 hours
Due: **Week 14**
Weighting: **20%**

Report on computational project

On successful completion you will be able to:

- Apply essential skills for solving problems in quantum many body physics.
- Model quantum simulations using Hamiltonian based and gate based approaches.
- Numerically model the physics of entangled many body systems via tensor network algorithms and quantum simulation software.
- Effectively communicate ideas in quantum engineering.

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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

Classes

Classes are schedule Mondays 3-5pm and Thursdays 3-5pm (subject to change as best suits the students and lecturer).

Mode of delivery

Content will be delivered through online lectures and online SGTA (Small Group Teaching Activities) (two 2 hour sessions per week)

Recommended reading

Notes for the course and recommended reading will be available on iLearn. There is no recommended text. Lectures will be delivered online and recorded with links provided.

Technologies Used

Zoom for online lectures and SGTA (Small Group Teaching Activities). For the written report with numerical comptuation you may use any software package you prefer for the numerics but the report should be completed using Latex.

Covid Information

For the latest information on the University's response to COVID-19, please refer to the Coronavirus infection page on the Macquarie website: https://www.mq.edu.au/about/coronavirus-faqs. Remember to check this page regularly in case the information and requirements change during semester. If there are any changes to this unit in relation to COVID, these will be communicated via iLearn

Unit Schedule

Week 1: Stabilizer states, graph states

Week 2: Properties of quantum mechanical entropy, methods of calculation

Week 3: Area law behaviour, topologically ordered matter

Week 4: Bosonic systems 1

Week 5: Bosonic systems 2

Week 6: Fermionic systems 1

Week 7: Fermionic systems 2

Week 8: Majorana fermions

Week 9: Anyonic systems, topological quantum computing

Week 10: Finitely correlated states

Week 11: Tensor networks 1

Week 12: Tensor networks 2

Week 13: Summary

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 connect.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 Advocacy provides independent advice on MQ policies, procedures, and processes

Student Enquiries

Got a question? Ask us via the Service Connect Portal, 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.

Unit information based on version 2024.03 of the Handbook