

ENGPHYS 4QC3/6QC3
Introduction to Quantum Computing
Undergraduate Fall 2022
Course Outline

CALENDAR/COURSE DESCRIPTION

An introduction to quantum computing including qubits, entanglement, quantum key cryptography, teleportation, quantum circuits and algorithms, spin qubits.

Three lectures per week.

PRE-REQUISITES AND ANTI-REQUISITES

Prerequisite(s): ENGPHYS 2QM3 or PHYSICS 2C03

Antirequisite(s): N/A

INSTRUCTOR OFFICE HOURS AND CONTACT INFORMATION

Dr. R. LaPierre
lapierr@mcmaster.ca

Office Hours:
By appointment

TEACHING ASSISTANT OFFICE HOURS AND CONTACT INFORMATION

There are no TAs for this course. Please contact the instructor.

COURSE WEBSITE/ALTERNATE METHODS OF COMMUNICATION

<http://avenue.mcmaster.ca/>

COURSE INTENDED LEARNING OUTCOMES

By the end of this course, students should be able to understand:

- Qubits, Dirac notation, Bloch sphere
- Entanglement, EPR, Bell inequality
- Quantum communication, no cloning theorem
- Quantum gates, quantum circuits
- Tensor products
- Teleportation
- Quantum computing, multiple qubits, computational complexity
- Deutsch algorithm
- Grover algorithm

- Quantum Fourier transform, period finding, Shor algorithm
- Single-qubit gates, Rabi oscillations
- Two-state dynamics
- Two-qubit gates
- DiVincenzo criteria
- Nuclear magnetic resonance (NMR)
- Solid-state spin qubits
- Trapped ion quantum computing
- Superconducting qubits, D-Wave, adiabatic quantum computing
- Optical quantum computing
- Decoherence, quantum error correction
- Anyons, topological quantum computing, Majorana fermions

MATERIALS AND FEES

Required Texts:

R. LaPierre, Introduction to Quantum Computing, Springer, ISBN 978-3-030-69317-6, DOI 10.1007/978-3-030-69318-3, <https://www.springer.com/gp/book/9783030693176>

Calculator:

Only the McMaster Standard Calculator will be permitted in tests and examinations. This is available at the Campus Store.

Other Materials:

N/A

COURSE FORMAT AND EXPECTATIONS

The course is organized as 3 classroom-based in-person lectures per week
Details are provided in the course outline posted in Avenue.

COURSE SCHEDULE

Lecture	Topic
1	Course outline
2-3	Superposition
4-5	Schrodinger equation, quantization
6-7	Stern-Gerlach, spin, Pauli matrices
8-9	Qubits, Dirac notation, Bloch sphere
10-11	Entanglement, Bell inequality
12	Quantum key distribution, no cloning theorem
13-14	Quantum gates, circuit model
15	Teleportation
16	Tensor products

17	n qubits, computational complexity
18	Deutsch algorithm
19	Grover algorithm
20-21	Quantum Fourier transform, period finding, Shor algorithm
22-23	Single-qubit gates, Electron spin resonance (ESR), Rabi oscillations
24-25	Two-state dynamics
26	Two-qubit gates
27	DiVincenzo criteria
28	Nuclear magnetic resonance (NMR)
29-30	Solid-state spin qubits
31	Trapped ion quantum computing
32-33	Superconducting qubits, D-Wave, adiabatic quantum computing
34	Optical quantum computing
35	Decoherence, quantum error correction
36	Anyons, topological quantum computing, Majorana fermions

ASSESSMENT

Component	Weight
Exercises	35%
Report	25%
Final Exam*	40%
Total	100%

* The exam will be a written exam for undergraduates (4QC3) and oral for graduate students (6QC3).

ACCREDITATION LEARNING OUTCOMES

The Learning Outcomes defined in this section are measured for Accreditation purposes only and will not be directly taken into consideration in determining a student's grade in the course.

Outcomes	Indicators
N/A	N/A

For more information on Accreditation, please visit: <https://www.engineerscanada.ca>

EQUITY, DIVERSITY, AND INCLUSION

Every registered student belongs in this course. Diversity of backgrounds and experiences is expected and welcome. You can expect your Instructor to be respectful of this diversity in all aspects of the course, and the same is expected of you.

The Department of Engineering Physics is committed to creating an environment in which students of all genders, cultures, ethnicities, races, sexual orientations, abilities, and socioeconomic backgrounds have equal access to

education and are welcomed and treated fairly. If you have any concerns regarding inclusion in our Department, in particular if you or one of your peers is experiencing harassment or discrimination, you are encouraged to contact the Chair, Associate Undergraduate Chair, Academic Advisor or to contact the [Equity and Inclusion Office](#).

PHYSICAL AND MENTAL HEALTH

For a list of McMaster University's resources, please refer to the [Student Wellness Centre](#).

ACADEMIC INTEGRITY

You are expected to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity. **It is your responsibility to understand what constitutes academic dishonesty.**

Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university. For information on the various types of academic dishonesty please refer to the [Academic Integrity Policy](#), located at <https://secretariat.mcmaster.ca/university-policies-procedures-guidelines/>

The following illustrates only three forms of academic dishonesty:

1. plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
2. improper collaboration in group work.
3. copying or using unauthorized aids in tests and examinations.

COURSES WITH AN ON-LINE ELEMENT

McMaster is committed to an inclusive and respectful community. These principles and expectations extend to online activities including electronic chat groups, video calls and other learning platforms.

Some courses may use on-line elements (e.g. e-mail, Avenue to Learn (A2L), LearnLink, web pages, capa, Moodle, ThinkingCap, etc.). Students should be aware that, when they access the electronic components of a course using these elements, private information such as first and last names, user names for the McMaster e-mail accounts, and program affiliation may become apparent to all other students in the same course. The available information is dependent on the technology used. Continuation in a course that uses on-line elements will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure, please discuss this with the course instructor.

CONDUCT EXPECTATIONS

As a McMaster student, you have the right to experience, and the responsibility to demonstrate, respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the [Code of Student Rights & Responsibilities](#) (the "Code"). All students share the responsibility of maintaining a positive environment for the academic and personal growth of all McMaster community members, **whether in person or online.**

It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable

participation in University activities. Student disruptions or behaviours that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, WebEx or Zoom for delivery), will be taken very seriously and will be investigated. Outcomes may include restriction or removal of the involved students' access to these platforms.

ACADEMIC ACCOMMODATION OF STUDENTS WITH DISABILITIES

Students with disabilities who require academic accommodation must contact [Student Accessibility Services \(SAS\)](#) at 905-525-9140 ext. 28652 or sas@mcmaster.ca to make arrangements with a Program Coordinator. For further information, consult McMaster University's [Academic Accommodation of Students with Disabilities](#) policy.

COURSE POLICY ON MISSED WORK, EXTENSIONS, AND LATE PENALTIES

Late work will not be accepted, but please see the section below.

SUBMISSION OF REQUEST FOR RELIEF FOR MISSED ACADEMIC WORK

In the event of an absence for medical or other reasons, students should review and follow the Academic Regulation in the Undergraduate Calendar "Requests for Relief for Missed Academic Term Work".

1. **Relief for missed academic work worth less than 25% of the final grade resulting from medical or personal situations lasting up to three calendar days:**
 - Use the [McMaster Student Absence Form \(MSAF\)](#) on-line self-reporting tool. No further documentation is required.
 - Students may submit requests for relief using the MSAF once per term.
 - An automated email will be sent to the course instructor, who will determine the appropriate relief. Students must immediately follow up with their instructors. Failure to do so may negate the opportunity for relief.
 - The MSAF cannot be used to meet a religious obligation or to celebrate an important religious holiday.
 - The MSAF cannot be used for academic work that has already been completed attempted.
 - An MSAF applies only to work that is due within the period for which the MSAF applies, i.e. the 3-day period that is specified in the MSAF; however, all work due in that period can be covered by one MSAF.
 - The MSAF cannot be used to apply for relief for any final examination or its equivalent. See *Petitions for Special Consideration* above.

2. **For medical or personal situations lasting more than three calendar days, and/or for missed academic work worth 25% or more of the final grade, and/or for any request for relief in a term where the MSAF has been used previously in that term:**
 - Students must report to their Faculty Office to discuss their situation and will be required to provide appropriate **supporting documentation**.
 - If warranted, the Faculty Office will approve the absence, and the instructor will determine appropriate relief.

ACADEMIC ACCOMMODATION FOR RELIGIOUS, INDIGENOUS OR SPIRITUAL OBSERVANCES (RISO)

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the [RISO](#) policy. Students should submit their request to their Faculty Office **normally within 10 working days** of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

COPYRIGHT AND RECORDING

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright protected works. The Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, **including lectures** by University instructors

The recording of lectures, tutorials, or other methods of instruction may occur during a course with permission of the instructor. Recording may be done by either the instructor for the purpose of authorized distribution, or by a student for the purpose of personal study. Students should be aware that their voice and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

EXTREME CIRCUMSTANCES

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email.