

ENGPYHS 4QC3/6QC3
Introduction to Quantum Computing
Winter 2020
Course Outline

CALENDAR/COURSE DESCRIPTION

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

PRE-REQUISITES AND ANTI-REQUISITES

Prerequisite(s): ENGPYHS 2QM3 or PHYSICS 2C03
Antirequisite(s): N/A

INSTRUCTOR OFFICE HOURS AND CONTACT INFORMATION

Dr. Ray LaPierre
JHE A315
lapierr@mcmaster.ca
ext. 27764

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 OBJECTIVES

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, n 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:

N/A

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 OVERVIEW

Date/Week	Topic	Readings
1	Double slit experiment	
2-3	Schrodinger equation, quantization	
4-5	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%

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 actual grade in the course.

Outcomes	Indicators
N/A	N/A

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

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.

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.

It is your responsibility to understand what constitutes academic dishonesty. For information on the various types of academic dishonesty please refer to the Academic Integrity Policy, located at <http://www.mcmaster.ca/academicintegrity>

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.

ACADEMIC ACCOMMODATIONS

Students who require academic accommodation must contact Student accessibility Services (SAS) to make arrangements with a Program Coordinator. Academic accommodations must be arranged for each term of study. Student Accessibility Services can be contact by phone at 905.525.9140 ext. 28652 or e-mail at sas@mcmaster.ca. For further information, consult McMaster University's Policy for [Academic Accommodation of Students with Disabilities](#).

NOTIFICATION OF STUDENT ABSENCE AND SUBMISSION OF REQUEST FOR RELIEF FOR MISSED ACADEMIC WORK

1. The [McMaster Student Absence Form](#) is a self-reporting tool for Undergraduate Students to report absences DUE TO MINOR MEDICAL SITUATIONS that last up to 3 days and provides the ability to request accommodation for any missed academic work. Please note this tool cannot be used during any final examination period.
2. You may submit a maximum of 1 Academic Work Missed request per term. It is YOUR responsibility to follow up with your Instructor immediately (NORMALLY WITHIN TWO WORKING DAYS) regarding the nature of the accommodation. Relief for missed academic work is not guaranteed.
3. If you are absent for reasons other than medical reasons, for more than 3 days, or exceed 1 request per term you MUST visit the Associate Dean's Office (JHE/H301). You may be required to provide supporting documentation.
4. This form must be submitted during the period of absence or the following day, and is only valid for academic work missed during this period of absence.
5. It is the prerogative of the instructor of the course to determine the appropriate relief for missed term work in his/her course.
6. You should expect to have academic commitments Monday through Saturday but not on Sunday or statutory holidays. If you require an accommodation to meet a religious obligation or to celebrate an important religious holiday, you may submit the Academic Accommodation for Religious, Indigenous and Spiritual Observances (RISO) Form to the Associate Dean's Office. You can find all paperwork needed here: <https://www.eng.mcmaster.ca/programs/academic-advising>

NOTICE REGARDING POSSIBLE COURSE MODIFICATION

The instructor and university reserve the right to modify elements of the course during the term. The university may change the dates and deadlines for any or all courses in extreme circumstances. If either type of modification becomes necessary, reasonable notice and communication with the students will be given with explanation and the opportunity to comment on changes. It is the responsibility of the student to check their McMaster email and course websites weekly during the term and to note any changes.

TURNITIN.COM STATEMENT

In this course we will be using a web-based service (Turnitin.com) to reveal plagiarism. Students will be expected to submit their work electronically to Turnitin.com and in hard copy so that it can be checked for academic dishonesty. Students who do not wish to submit their work to Turnitin.com must still submit a copy to the instructor. No penalty will be assigned to a student who does not submit work to Turnitin.com. All submitted work is subject to normal verification that standards of academic integrity have been upheld (e.g., on-line search, etc.). To see the Turnitin.com Policy, please go to <http://www.mcmaster.ca/academicintegrity/>.

ON-LINE STATEMENT FOR COURSES REQUIRING ONLINE ACCESS OR WORK

In this course, we will be using Avenue to Learn. Students should be aware that, when they access the electronic components of this course, 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 this course will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure, please discuss this with the course instructor.

REFERENCE TO RESEARCH ETHICS

The two principles underlying integrity in research in a university setting are these: a researcher must be honest in proposing, seeking support for, conducting, and reporting research; a researcher must respect the rights of others in these activities. Any departure from these principles will diminish the integrity of the research enterprise. This policy applies to all those conducting research at or under the aegis of McMaster University. It is incumbent upon all members of the university community to practice and to promote ethical behaviour. To see the Policy on Research Ethics at McMaster University, please go to <http://www.mcmaster.ca/policy/faculty/Conduct/ResearchEthicsPolicy.pdf>.