Mechanical Engineering
MECHENG 4ES3
Energy Storage
Winter 2025

Instructor Information

Keena Trowell
Email: trowellk@mcmaster.ca
Office Hours:
Wednesdays 2:30–3:30 or by appointment

TA Information

Name: Daniel Maestre
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Class Times

Lectures: Monday, Wednesday, and Thursdays 10:30–11:20
(check A2L for room location)

QUIZ DATES
Quiz 1 – Thursday, February 13th *(NO MAKE-UP DATE)*
Quiz 2 – 10% – Thursday, March 27th – Make-up for missing Quiz 2 with Associate Dean's (MSAF) approval will be on Tuesday, April 8th at 2:30PM

Midterms will take place during the normal lecture time (10:30–11:20AM)

Class Format

Course Dates: 01/06/2024 - 04/08/2024
Units: 3.00
Course Delivery Mode: In Person
Course Description: An overview of energy storage from the nanosecond scale to the seasonal scale. Concepts such as energy density, specific energy, thermodynamic losses, and cycle efficiency. Topics will include mechanical, thermal, electrochemical, and chemical energy storage. Three lectures; second term Prerequisite(s): one of MECHENG 2W04, ENGPHYS 2NE3, CHEMENG 3D04 or MATLS 2B03; and one of MECHENG 3O04, ENGPHYS 3O04, CIVENG 2O04 or CHEMENG 2O04

Important Links

- Mosaic
- Avenue to Learn
- Student Accessibility Services - Accommodations
- McMaster University Library
- eReserves

Course Learning Outcomes

1. Describe energy storage concepts such as energy density, specific energy, cycle efficiency, *etc.* and perform basic calculations
2. Identify and discuss inherent trade-offs of different energy storage techniques and technologies
3. Classify various storage techniques according to type (*i.e.* thermal, electrochemical, chemical, *etc.*) and duration
4. Identify and appraise appropriate energy storage techniques based on use case
5. Design an energy storage system with consideration given to technical, geographic, environmental, social, and economic aspects

Graduate Attributes

The Canadian Engineering Accreditation Board (CEAB) is a division of Engineers Canada and is responsible for accrediting undergraduate engineering programs across Canada. Accreditation by the CEAB ensures that the engineering programs meet a national standard of quality and cover essential educational requirements. Graduate Attributes are a set of qualities and skills that the CEAB expects engineering graduates to possess. These attributes are a benchmark for the learning outcomes of accredited engineering programs. This section lists the Graduate Attribute Indicators associated with the Learning Outcomes in this course.

3.1 Selects appropriately from relevant knowledge base to plan appropriate data collection methods and analysis strategies.
3.2 Synthesizes the results of an investigation to reach valid conclusions.
4.1 Defines the problem by identifying relevant context, constraints, and prior approaches before exploring potential design solutions.
4.4 Justifies and reflects on design decisions, giving consideration to limitations, assumptions, constraints and other relevant factors.
6.1 Actively contributes to the planning and execution of a team project.
7.2 Composes an effective written document for the intended audience.
9.1 Evaluates the environmental impact of engineering activities, identifies uncertainties in decisions, and promotes sustainable design.

Course Schedule

Section	Week*	Topics
Introduction	1	Review of basic thermodynamics and energy units
Mechanical Energy Storage	2	Flywheels, gravity storage, pumped hydro, compressed air energy storage
Thermal Energy Storage	3	Boreholes, thermal salts, phase change materials and thermochemical storage
Electric & Electrochemical Energy Storage	4	Capacitors and introduction to batteries ***(Individual Term Project, Part 1 Presentations)***
Electric & Electrochemical Energy Storage	5	Batteries and battery chemistry
Considerations of Energy Storage	6	Ragone Plots, Life Cycle Assessment ***Quiz 1***
Considerations of Energy Storage	7	Energy Economics ***(Individual Term Project, Part 2 Presentations)***
Chemical Energy Storage	8	Power–to–*X,* Metal fuels
Chemical Energy Storage	9	Metal–water reactions
Chemical Energy Storage	10	Hydrogen ***(Individual Term Project, Part 3 Presentations)***
Chemical Energy Storage	11	**Quiz 2** and Synthetic hydrocarbons
Conclusion	12	Group Presentations

*Schedule may be adjusted as needed

Required Materials and Texts

Textbook Listing: https://textbooks.mcmaster.ca
No required textbook
A useful, but not necessary, book is *Sustainable Energy Without the Hot Air* by David MacKay. It is available for free download here: https://www.withouthotair.com/

Course Evaluation

Individual Term Project – 45%
Group Project – 35%
Quiz 1 – 10% – Thursday, February 13th – There will be no make-up quiz for Quiz 1.
Quiz 2 – 10% – Thursday, March 27th – Make-up for missing Quiz 2 with Associate Dean's (MSAF) approval will be on Tuesday, April 8th at 2:30PM

Grading Scale

The McMaster 12 Point Grading Scale

Grade	Equivalent Grade Point	Equivalent Percentages
A+	12	90-100
A	11	85-89
A-	10	80-84
B+	9	77-79
B	8	73-76
B-	7	70-72
C+	6	67-69
C	5	63-66
C-	4	60-62
D+	3	57-59
D	2	53-56
D-	1	50-52
F	0	0-49

Late Assignments

Assignments are due at 11:59PM on the due date. Late assignments will be penalized at a rate of 20% per day:

The best possible grade is reduced by 20% for each day after the deadline.

Time since deadline	Best possible grade
1 minute to 24 hours (1 day)	80%
24–48hrs (2 days)	60%
48–72 (3 days)	40%
72–96 (4 days)	20%

If an assignment deadline falls during a period of absence with Associate Dean's (MSAF) approval, it is due 1 day after the end of the MSAF, then the late policy applies.

Absences, Missed Work, Illness

Missed quizzes

If Quiz 1 is missed with Associate Dean's (MSAF) approval, the weight is of Quiz 1 is shifted to Quiz 2. If Quiz 1 is missed for any other reason, the mark recorded will be zero. **There will be no make-up quiz for Quiz 1.**

There will be a make-up quiz if Quiz 2 for those who miss it with Associate Dean's (MSAF) approval. If Quiz 2 is missed for any other reason, the mark recorded will be zero. The make–up for Quiz 2 will be held 4 days after the original quiz date on Tuesday, April 8th at 2:30.

Note that Quiz 2 is cumulative and will cover the content of the whole course.

Missed assignments
All missed work that does not have Associate Dean's (MSAF) approval is given a grade of zero,

APPROVED ADVISORY STATEMENTS

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-proceduresguidelines/
The following illustrates only three forms of academic dishonesty:

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

Authenticity / Plagiarism

Some courses may use a web-based service (Turnitin.com) to reveal authenticity and ownership of student submitted work. For courses using such software, students will be expected to submit their work electronically either directly to Turnitin.com or via an online learning platform (e.g. Avenue to Learn, etc.) using plagiarism detection (a service supported by Turnitin.com) so it can be checked for academic dishonesty.
Students who do not wish their work to be submitted through the plagiarism detection software must inform the Instructor before the assignment is due. No penalty will be assigned to a student who does not submit work to the plagiarism detection software. **All submitted work is subject to normal verification that standards of academic integrity have been upheld** (e.g., on-line search, other software, etc.). For more details about McMaster's use of Turnitin.com please go to www.mcmaster.ca/academicintegrity.

Courses with an On-line Element

Some courses may use on-line elements (e.g. e-mail, Avenue to Learn, 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.

Online Proctoring

Some courses may use online proctoring software for tests and exams. This software may require students to turn on their video camera, present identification, monitor and record their computer activities, and/or lock/restrict their browser or other applications/software during tests or exams. This software may be required to be installed before the test/exam begins.

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.

Academic Advising

For any academic inquires please reach out to the Office of the Associate Dean (Academic) in Engineering located in JHE-Hatch 301.
Details on academic supports and contact information are available from:
https://www.eng.mcmaster.ca/programs/academic-advising

Requests for Relief for Missed Academic Term Work

In the event of an absence for medical or other reasons, students should review and follow the Policy on Requests for Relief for Missed Academic Term Work.

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. 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, Avenue to Learn and/or McMaster email.