ECE 789
Battery Testing, Modeling, and Pack Design
Graduate Course

COURSE OUTLINE

COURSE DESCRIPTION

This course will cover methodologies for testing, modeling, design, and state estimation of battery energy storage systems. There will be weekly lectures and hands on experimental labs. In the first six labs students will perform experiments to determine the characteristics of a battery cell. Experimental tests will include open circuit voltage, resistance, capacity, vehicle drive cycles or other application profiles, thermal characterization, and aging. From these tests state of charge, power capability, loss, vehicle range, and other characteristics will be determined via analytical and machine learning based methods. In the final five labs, students will work on an experimental based group project using a battery cell of their choice. Groups will select a creative way to present their results, such as through videos, a business plan, website, or open access datasets or algorithms. Overall, students will gain the skills and experience to allow them to design and manage state of the art energy storage systems for a wide range of applications.

PRE-REQUISITES AND ANTI-REQUISITES

Pre-requisite(s): None

SCHEDULE and MODE OF DELIVERY

The material for this course will be delivered through in person lectures and laboratories.

Lecture: Weekly 80-minute lectures

Lab:

- Weekly 2-hour teaching lab – Weeks 1 to 7
- Weekly 2-hour final group project lab – Weeks 8 to 12
- Each lab section will be limited to 12 students (3 students per bench - 4 benches)

INSTRUCTOR

Dr. Phillip Kollmeyer
E-mail: kollmeyp@mcmaster.ca
Website: https://battery.mcmaster.ca/
Office: ITB-113 Phone: 905-525-9140 ext. 22804
Office Hours: By appointment

COURSE WEBSITE/S

http://avenue.mcmaster.ca

COURSE MATERIALS

Weekly readings will be assigned at the beginning of the semester.

COURSE OBJECTIVES

The main objective of this course is to develop hands-on testing and analysis skills for battery energy storage systems. The course covers the most important battery area topics, providing students with the skills to quickly test cells and design packs using the latest advanced approaches including machine learning.

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

1. Conduct a comprehensive range of battery tests in hands-on laboratory sessions and present results in written reports.
2. Create high quality experimental datasets to parameterize equivalent circuit battery models and train the latest machine learning based state estimators.
3. Apply your understanding of the electrochemical and thermal behavior of lithium-ion batteries to determine how a cell will perform in challenging real-world applications.
4. Develop new approaches to testing, modeling, managing, or applying batteries through a collaborative group approach.

ASSUMED KNOWLEDGE

- Electrical circuit theory
- MATLAB or Python programming
- Microprocessor programming basics

COURSE OVERVIEW

Week	Topic
1	Battery Basics and Electrochemistry
2	Battery Modeling
3	Power Capability and State of Charge
4	Machine Learning Models and Algorithms
5	Determination of Battery Performance for an Application
6	Loss and Thermal Analysis
7	Special Testing Methods: GITT, EIS, ETIS, Float Voltage, Coulombic Eff., Ref. Electrodes, etc.
8	Aging and State of Health
9	Fast Charging and Thermal Management
10	Battery Management Systems and Pack SOx Estimation
11	Thermal Runaway and High Voltage Safety
12	Next Generation Chemistries and Packs
13	Final Project Presentations

TEACHING LABORATORY OVERVIEW

Week	Lab	Topic
1	1a	Introduction to Testing and Open Circuit Voltage: Part A
2	1b	Introduction to Testing and Open Circuit Voltage: Part B
3	2	Performance as a Function of C-rate
4	3	Equivalent Circuit Modeling and Power Capability
5	4	Temperature Dependence of Battery Characteristics
6	5	Vehicle Drive Cycle Testing and SOC Estimation
7	6	Thermal Characterization / Modeling and Aging

FINAL GROUP PROJECT LABORATORY OVERVIEW

Week	Lab	Topic
8	1	First group work session – preliminary proposal and battery cell selection
9	2	Five-minute project proposal presentation – fixture assembly and test preparation
10	3	Testing and analysis session 1
11	4	Testing and analysis session 2 – Mid-project update
12	5	Testing and analysis session 3

ASSESSMENT

Component	Weight
Pre-lecture readings	4 %
Lab participation points (6 labs, 1 point each)	6 %
Lab reports (6 reports, 5 points each)	30 %
Midterm project (individual)	20 %
Final project (group)	40 %
Total	100 %

Grading and Evaluation Policies

- Due dates and submission policies:
  - **Pre-lecture readings**
    - **Due**: Prior to each lecture
    - **Assessment Format:** Short answer avenue to learn quiz
    - **Grading:** Pass/fail
  - **Lab reports (first six labs)**
    - **Due**: One week after lab session, three-day grace period
    - **Format:** Written report following format described in lab manual
    - **Submission:**
      - Electronic submission via Avenue to Learn
      - One report per individual
    - **Grading:** Scored 0 to 10 based on quality of report
  - **Midterm Project**
    - **Due:** Date will be posted on avenue to learn, three-day grace period
    - **Format:** Written report (five pages)
    - **Submission:**
      - Electronic via Avenue to Learn
      - Individual submission by each student
    - **Grading:** Scored 0 to 100
  - **Group Project**
    - **Due:** Final week of course
    - **Format:** To be determined by group, can be a report, video, website, program, etc or combination of formats based on interest of group
    - **Grading:** Each group member's contribution scored 0 to 100
- Policy for missed exams/labs/projects with MSAF:
  - Lab (first six): Weight of missed lab transferred to remaining labs
  - Midterm Project: Late submission of project when student is able
  - Group Project: Exceeds 25% of grade so MSAF is not applicable

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 DETECTION

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. A2L, 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 (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.

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.

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.

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 ACCOMMODATIONS

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 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.

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.

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.

www.eng.mcmaster.ca/ece