Faculty of Engineering and Applied Science

CHEE 463 – ELECTROCHEMICAL ENERGY SYSTEMS

Course Syllabus – Winter 2021

This is your course syllabus. Please download the file and keep it for future reference.

TEACHING TEAM

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COURSE INSTRUCTOR

Brant Peppley, PhD, PEng
Department of Chemical Engineering
Queen's University
Dupuis Rm G09
613-533-3247
E-mail: brant.peppley@queensu.ca

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TEACHING ASSISTANTS

Yazan Bdour
Email: 16yb6@queensu.ca
Office hours: by appointment

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COURSE TIMINGS

Lecture – Monday 10:30-11:30 EST, MS Teams or Zoom
Active Learning Session – Tuesday 8:30-11:30 EST, MS Teams or Zoom
Question and Answer Period - Thursday 1:30-2:30 EST, MS Teams or Zoom

COURSE INFORMATION

COURSE DESCRIPTION

This engineering science and design course examines and analyzes electrochemical energy generation, conversion and storage technologies of emerging importance to modern society. Methods of generating electrical power will be examined in terms of efficiency, cost, environmental footprint, greenhouse gas emissions and current and potential applications. Integration of these power generation systems with energy conversion and storage technologies will be assessed in terms of their compatibility with the supply and demand model of the electricity grid and their potential for use in remote off-grid communities. The electrification of transportation technologies will also be examined. The design element of this course involves hands-on prototyping of an integrated energy system for a specified application.

The course will cover 5 major topics including:
1) Energy flows in society from primary source to end use, including the components and structure of the electricity grid, future smart grids and remote community power grids. Energy flows in the transportation sector and the potential for integration with the electrical grid will also be examined.
2) Technologies for power generation, energy storage and energy conversion. Technologies to be considered include solar photovoltaics, secondary batteries, super capacitors, flow batteries, water electrolysers, and fuel cells. This will be the major topic in the course and will include fundamental theory and governing equations for each technology.
3) Current performance specifications, key materials and research challenges, state of technical readiness, demonstrations and commercialization.
5) Strategies for energy sustainability and energy system design.

Prerequisites: CHEE270 (Electric Circuits), CHEE363 (Electrochemistry)

PRE-REQUISITE KNOWLEDGE

This course is designed for learners who need to acquire fundamental knowledge of energy systems, electrochemical energy storage and conversion devices and energy system design for grid applications and remote community application. The concepts are applied during active learning sessions which focus on their application in analytical chemistry instrumentation and other areas of engineering chemistry.

COURSE LEARNING OUTCOMES (CLO)

CLO	DESCRIPTION	INDICATORS
CLO 1	Utilizes knowledge of thermodynamics, electrochemistry and electrical circuits to analyze and design power generation and energy systems.	CHEE-KB-PROC
CLO 2	Utilizes knowledge of thermodynamics, electrochemistry and electrical circuits to analyze and design power generation and energy systems.	CHEE-KB-THE
CLO 3	Analyzes the influence of thermodynamic, equilibrium and second law limitations on the overall efficiency of power generation systems.	CHEE-KB-THE
CLO 4	Considers technical, financial, social, environmental and legal factors, safety and sutainability issues when solving engineering problems.	CHEE-IM-2
CLO 5	Develops equipment specifications, process or product design incorporating performance requirements and constraints such as quality, yield, reliability, economics, safety and standards and codes as appropriate	CHEE-DE-3

This course develops the following attributes at the 4th year level:

Knowledge Base: Process (CHEE-KB-PROC-1,2,3) Applies knowledge of electrochemistry and electrochemical engineering to analyze and design electrochemical systems and processes.

Knowledge Base: Thermodynamics (CHEE-KB-THE) Applies knowledge of electrochemistry and electrochemical engineering to analyze and design electrochemical systems and processes.

Knowledge Base: Design (CHEE-KB-DES-3) Develops a process or product design incorporating performance requirements and constraints such as quality, yield, reliability, economics, safety, and standards and codes as appropriate.

Impact (CHEE-IM-2) Considers technical, financial, social, environmental, and legal factors, safety and sustainability issues when solving engineering problems.

DESCRIPTION

Due to the COVID-19 pandemic, the course has been moved online. To ensure all students are progressing with the remote delivery format, all assignments (Quizzes, DSE reports, etc.) are due by Day 7 (Sunday) at 23:59 EST of the week they are assigned.

ASSESSMENT WEIGHTING

Assessment Tool	Due Date (before 23:59 EST)	Weight	Alignment with CLOs
Quizzes	**Weeks 1-12**	**20%**	**1, 2, 3, 4, 5**
Review Quiz	Day **7** of Week 12	4%	1 - 5
Quiz 1	Day **7** of Week 2	4%	4
Quiz 2	Day **7** of Week 5	4%	2
Quiz 3	Day **7** of Week 8	4%	2,3
Quiz 4	Day **7** of Week 10	4%	2,3,5

Demonstration Session Exploration and System Design Reports	**Weeks 3 - 12**	**50%**	**1, 2, 3, 4, 5**
DSE Report 1	Day **7** of Week 3	4%	4
DSE Report 2	Day **7** of Week 4	4%	3,4
DSE Report 3	Day **7** of Week 5	4%	3,4
DSE Report 4	Day **7** of Week 6	4%	3,4
DSE Report 5	Day **7** of Week 7	4%	3,4
DSE Report 6	Day **7** of Week 8	5%	3,4
DSE Report 7	Day **7** of Week 10	5%	3,4,5
System Design Report	Day 7 of Week 12	20%	1-5
Final Exam	**Date to be determined**	**30%**	**1, 2, 3, 4, 5**

Assessment Descriptions

Quizzes

There are five short quizzes in the course. The quizzes are comprised of multiple choice, calculations, and short answer questions that will help to identify gaps in conceptual understanding.

Demonstration Session Exploration and Data Analysis Reports

There are 7 Demonstration Session Reports. These reports will provide you with the opportunity to demonstrate your knowledge and understanding of the concepts and processes conducted in the DSE

Final Exam

The final exam will be a combination of multiple choice, calculations, and one or two paragraph answer questions.

GRADING

All assessments in this course will receive numerical percentage marks. The final grade you receive for the course will be derived by converting your numerical course average to a letter grade according to the established Grade Point Index.

Feedback on Assessments

The teaching team will provide feedback on graded activities. You can expect feedback on your assessments within seven days of the due date.

Accessing Your Final Grade

Your final grades will show on SOLUS. Official transcripts showing final grades will be available on the Official Grade Release Date. Please note that in official transcripts, a mark of IN (incomplete) is considered a grade, and your transcript is released with this grade.

COURSE MATERIALS

Websites and Online Videos

- Links to online instructional websites and videos will be provided.

Required Calculator

- A Casio 991 is required. **ONLY** this type of non-programmable, non-communicating calculator will be allowed during tests and exams.

All other course material is accessible via OnQ.

SUGGESTED TIME COMMITMENT

This course represents a study period of one semester. Each week will consist of 1 hour of synchronous lecture, 3 hours of synchronous Demonstration Video and discussion (All sessions will be recorded and posted for later review). Additionally learners can expect to invest on average 2 hours per week in online readings and quizzes and 3-4 hours working on Demonstration Session Exploaration (DSE) reports. Learners who adhere to a pre-determined study schedule are more likely to successfully complete the course on time.

WEEKLY COURSE OUTCOMES

Week	Learning Outcomes
	Module 1 – Energy Flows in Society from Primary Source to End Use
1	**Overview of the Structure of Energy Flows** By the end of week 1, learners will: • Understand the magnitude of energy flows globally, in developed countries, developing countries and underdeveloped countries [CLO 4] • Understand the implications of thermodynamic limitations and operational characteristics on the various primary sources of energy generation [CLO 3] • Learn what options are available for carbon free energy sources and their current level of deployment [CLO 1]
2	**Electrical Grids** By the end of this week, learners will be able to: • Become aware of the scale and importance of major electrical grids in North America and Europe. [CLO 4] • Understand the challenges of managing the deployment of the energy sources on the electrical grid that are dispatchable, intermittent and base-load. [CLO 3] • Understand how energy storage plays a key role in stabilizing the grid and enabling increased intermittent renewable power source penetration onto the grid [CLO 3] • Understand how the deployment of battery-powered vehicles will effect the management and stability of the electrical grid and increase the need for additional infrastructure [CLO 1,4]

Module 2 – Power Sources, Energy Storage and Energy Conversion	
3	**Power Sources - Thermal** By the end of this week, learners will have: • Reviewed how to calculate the efficiency of power-plants based on thermal cycles. [CLO 1,2] • Determined the approximate efficiency of the current thermal cycle power plants and estimated the associated emissions [CLO 1,2] • Considered the pros and cons of Nuclear Power Plants. [CLO 4] • Considered the pros and cons of Bio-Energy Power Plants [CLO 4]
4	**Power Sources – Renewable – Hydro-Electric, Solar PV and Wind** By the end of this week, learners will : • Be aware of the environmental pros, cons and limitations of hydro-electric power [CLO 4] • Know the types of solar PV, their characteristics and state of development [CLO 1,2] • Know the basic equations that govern the geographic variation of solar radiation [CLO 1,2] • Be able to calculate the effect of light intensity on Solar PV output [CLO 2] • Know the basic performance equation for wind turbines [CLO 1,2] • Understand the basic economics of wind and solar power [CLO 3]
5	**Power Sources Solar PV Performance Curves and Analysis** By the end of this week, learners will: • Be able to Generate an I-V curve for a Solar PV panel from experimental data [CLO 1,2] • Know how to measure the Open Circuit Voltage, Short Circuit Current and Fill Factor for Solar PV panels. [CLO 1,2] • Learn how basic silicon solar cells are manufactured and assembled into a solar panel [CLO 5] • Understand the process of assembling a multi-panel Solar PV installation [CLO 3] • Be aware of the issues arising from the materials used in current solar PV [CLO 4]

6	**Energy Storage** By the end of this week, learners will: • Know the options available for small-scale and large-scale energy storage [CLO 3] • Be aware of the opportunities, limitations and advantages of the various energy storage technologies. [CLO 3,4] • Understand the relative scale of energy storage systems compared to the energy demand on large grids and remote grids [CLO 3] • Understand the implications of increasing the amount of intermittent renewable power generation on energy storage requirements [CLO 3]
7	**Energy Storage – Batteries** By the end of this week, learners will: • Know the key types of batteries, the range of storage capacity and the applications for each type [CLO 1] • Know the basic chemistry of the major types of Lithium battery and the advantages and disadvantages of the various chemistries for specific applications [CLO 2] • Understand and be able to measure the storage efficiency of batteries [CLO 2] • Understand the economic, social and environmental impact of providing the basic materials for battery manufacture [CLO 4]
8	**Energy Storage – Water Electrolysis and Hydrogen Production and Storage** By the end of this week learners will: • Learn the various methods for producing hydrogen including electrolysis, steam reforming and photoelectrolysis. • Know the types of electrolysers available and being developed and their basic materials and chemistry [CLO 1] • Be able to apply the basic equations for determining electrolysis efficiency and rate of production. [CLO 2] • Understand the concept of an electrolyser polarization curve. [CLO 2] • Understand the pros and cons of energy storage using batteries versus hydrogen.

9	**Energy Conversion – Fuel Cells** By the end of this week learners will: • Know the types of fuel cells available and being developed and their basic materials and chemistry as well as their applications [CLO 1] • Understand the concept of a fuel cell polarization curve [CLO 2] • Be able to apply the basic equations for determining fuel cell efficiency and power output characteristics. [CLO 2]
Module 3 – Energy System Design	
10	**System Design and Analysis Project** By the end of this week, learners will: • Know the key components and be able to draw a simple schematic of an energy system. [CLO 5] • Utilize the knowledge of the various components to develop an energy flow diagram for a specific application that accounts for component efficiency and estimates size of the specified components. • Assess the functionality of the energy system. [CLO 6]
11	**System Scenario Testing and Final Report** By the end of this week, learners will: • Will have assessed the performance of their system given a specific scenario based on geographical, social and technological factors. [CLO 5] • Prepare a report on the overall predicted performance of their energy system design based on the performance of the various components. [CLO 5]
12	**System Design Summary and Overall Review** By the end of this week, learners will: • Have consolidated their understanding of clean energy systems and the role of electrochemical systems. • Have Reviewed the course content clarifying the importance and performance characteristics of the components of energy systems. • Have a clear picture of the content of the final examination.

Late Policy

Any applicable late penalties are described in the details for each assessment. In the event of extenuating circumstances, you may request an extension to an assignment due date without penalty. Requests must be made to your instructor prior to the original due date of the assignment, and some substantiating documentation is often required. Note that unacceptable reasons include malfunctioning computer, travel plans to go home for holidays, generally behind on schoolwork, etc. In the absence of substantiating documentation, the normal late penalty will apply as described in the assignment or departmental policies.

COURSE COMMUNICATION

Questions About Course Material

Questions or comments regarding the course material that can be of benefit to other students should be posted in the discussion forum in OnQ. The instructor, TAs, and students are encouraged to answer these questions directly in the discussion forum for the benefit of everyone in the course.

Course Announcements

The instructor will routinely post course news in the Announcements section on the main course homepage on OnQ. Please sign up to be automatically notified by email when the instructor posts new information in the Announcements section. Instructions on how to modify your notifications are found in the **Begin Here** section of the class website.

Office Hours

In addition to interaction in the Q&A discussion forums, you will have the opportunity to interact in a synchronous fashion with either a TA or the instructor during the Thursday Question and Answer session.

Netiquette

In this course, you may be expected to communicate with your peers and the teaching team through electronic communication. You are expected to use the utmost respect in your dealings with your colleagues or when participating in activities, discussions, and online communication.
Following is a list of netiquette guidelines. Please read them carefully and use them to guide your online communication in this course and beyond.

1. Make a personal commitment to learn about, understand, and support your peers.
2. Assume the best of others and expect the best of them.
3. Acknowledge the impact of oppression on the lives of other people and make sure your writing is respectful and inclusive.
4. Recognize and value the experiences, abilities, and knowledge each person brings.
5. Pay close attention to what your peers write before you respond. Think through and re-read your writings before you post or send them to others.

6. It's alright to disagree with ideas, but do not make personal attacks.
7. Be open to be challenged or confronted on your ideas and challenge others with the intent of facilitating growth. Do not demean or embarrass others.
8. Encourage others to develop and share their ideas.

Confidential Matters

If you have a confidential matter you would like to discuss with your instructor, their contact details are on the first page of this document. Expect email replies within 48 hours and in some cases within 24 hours.

COURSE POLICIES

Please review the following policies concerning copyright, academic integrity, absences and academic accommodations:

Copyright

Unless otherwise stated, the material on the course website is copyrighted and is for the sole use of students registered in CHEE 463. The material on the website may be downloaded for a registered student's personal use but shall not be distributed or disseminated to anyone other than students registered in this course.

Academic Integrity

As an engineering student, you have made a decision to join us in the profession of engineering, a long-respected profession with high standards of behaviour. As future engineers, we expect you to behave with integrity at all times. Please note that Engineers have a duty to:

•Act at all times with devotion to the high ideals of personal honour and professional integrity.

•Give proper credit for engineering work

The standard of behaviour expected of professional engineers is explained in the Professional Engineers Ontario Code of Ethics. Information on policies concerning academic integrity is available in the Queen's University Code of Conduct, in the Senate Academic Integrity Policy Statement, on the Faculty of Engineering and Applied Science website, and from your instructor. Departures from academic integrity include plagiarism, use of unauthorized materials or services, facilitation, forgery, falsification, unauthorized use of intellectual property, and collaboration, and are antithetical to the development of an academic community at Queen's. Given the seriousness of these matters, actions which contravene the regulation on academic integrity carry sanctions that can range from a warning or the loss of grades on an assignment to the failure of a course to a requirement to withdraw from the University. In the case of online exams, impersonating another student, copying from another student, making information available to another student about the exam questions or possible answers, communicating with another person during an exam or about an exam during the exam window, or accessing unauthorized materials, including smart devices, are actions in contravention of academic integrity.

Late Policy

Any applicable late penalties are described in the details for each assessment. In the event of extenuating circumstances, you may request an extension to an assignment due date without penalty. Requests must be made to your instructor prior to the original due date of the assignment, and some substantiating documentation is often required (see information below on absences). Note that unacceptable reasons include extra-curricular activities, travel plans, generally behind on schoolwork, etc. In the absence of substantiating documentation, the normal late penalty will apply as described in the assignment or departmental policies.

Absences (Academic Considerations) and Academic Accommodations

For absences and academic accommodations please review the information on the FEAS website.

ACADEMIC AND STUDENT SUPPORT

Queen's has a robust set of supports available to you including the Library, Student Academic Success Services (Learning Strategies and Writing Centre), and Career Services. Learners are encouraged to visit the Faculty of Engineering and Applied Science Current Students web portal for information about various other policies such as academic advisors, registration, student exchanges, awards and scholarships, etc.

Individual Needs and Support

If you have a disability or health-related condition that may require academic accommodations, please approach the Queen's Accessibility Services. The staff at Accessibility Services are available by appointment to develop individualized accommodation plans, provide referrals, and assist with advocacy. The sooner you let us know your needs, the better we can assist you in achieving your learning goals. For questions or assistance with requesting Academic Consideration or Accommodation, contact the FEAS Academic Accommodation Coordinator at engineering.aac@queensu.ca

Every effort has been made to provide course materials that are accessible. For further information on accessibility compliance of the educational technologies used in this course, please consult the links below.

Educational Technology	Accessibility Compliance Information
onQ (Brightspace Learning Management System by D2L)	https://www.d2l.com/accessibility/standards/
RocScience	https://www.rocscience.com/
Google Spreadsheets	https://www.google.com/accessibility/products-features/

If you find any element of this course difficult to access, please discuss with your instructor how you can obtain an accommodation.

Religious Observance

Students in need of accommodation for religious observance are asked to speak to their professor within a week of receiving their syllabus. Please note that Passover is Mar 28 to April 4 so students in need of accommodation should speak to their professors right away. Note also that alternative assignments are considered a "reasonable accommodation" under the Ontario Human Rights Code. Students with questions about their rights and responsibilities regarding religious accommodation should contact Chaplain Kate Johnson via Chaplain@queensu.ca.

Technical Support

Some basic comfort level with basic hardware and software skills are required for this course. If you require technical assistance, please contact Technical Support.

Supportive Personal Counselling

If at any time you find yourself feeling overwhelmed, anxious, sad, lonely, or distressed, consider confidential supportive counselling offered by the embedded counselors at the Student Wellness Service Faculty of Engineering and Applied Science.

Inclusivity Statement

Queen's students, faculty, and staff come from every imaginable background – small towns and suburbs, urban high rises, Indigenous communities, and from more than 109 countries around the world. You belong here: https://www.queensu.ca/inclusive/.