ChE 331 – Electrochemical Engineering

Winter 2024

Instructor: Michael Fowler; E6-1110, Ext. 33415; mfowler@uwaterloo.ca
Office hours: Primary: Monday 10:00-13:00
Secondary (you will likely find me there) Monday or Friday 11:00 – 14:30
Note – Just before Class on Tuesday and Thursday afternoon is not good for meeting for me at this time.
For visits to my office please 'mask' prior to coming to my office.

Teaching Assistants:
Marking the Assignments
"Yasmin Shabeer" yshabeer@uwaterloo.ca Extra Help E6 1108 – 9 am to 12 pm on Fridays.

Lectures: Tuesday 3:30 - 5:30, E6 - 2024
Thursday 3:30 - 5:30, E6 - 2024
Quizzes and Tutorials During the Lecture Periods

Textbook and Reference material:
Required: ChE 331 Course Notes – Found on D2L Course Web site
(You must Print them from the Web Site)
There are also Course POWER POINT presentations that cover the course notes, but additional materials also. Other required readings (Articles) will be posted on D2L
Optional References can be found in the library:
Electrochemical Engineering, Thomas F. Fuller, John N. Harb, Wiley, 2018,
ISBN: 978-1-119-00425-7
Electrochemical Engineering Principles, G. Prentice, Prentice-Hall, 1991. (Old now, still but good)
Industrial Electrochemistry 2nd., by D. Pletcher. F. Walsh, Chapman and Hall, 1990. (Older Book)

Mark Breakdown*	Homework Assignments	24%
	Quizzes	12%
	Design Group Project	5% (10 Group Students–due 12 March)
Design 3-Minute Pitch	Electrochemical Applications	4% (Individual Oral Presentation)
	Midterm Examination	15% (TBA – likely in Class – 15 Feb)
	Final Examination	40%
		100% (maximum is 100%)

Bonus – Pre-Assignment 9 Jan 2024 – 3:25 – 1%
Bonus Design of Electrochemical Application Report – 5 - 10 pages (1.5 spacing) - 1%-5%
Assignments, Solutions and Notes will be posted on D2L. In-class lecture problem solutions will not be posted on D2L. Quizzes and Quiz Solutions will not be posted.

***IMPORTANT:** You cannot fail both the midterm and final exams and still be given a passing mark in the course. If you fail both the midterm and final exams, your overall mark in the course will be the average of your midterm and final exam marks.

Exams/quizzes/assignments/sample problems in class:

Tests are open book in that you may consult your textbook, course notes, and materials posted in the course LEARN site. Use of any other resource (including file-sharing services such as chegg.com, coursehero.com, stackexchange.com, ...) is prohibited. Assignments and Quizzes may be used in Sample Problems, Midterm and Final Exam in only your 'handwritten' problems. You may not communicate directly or indirectly with any person except the course instructor.

Quizzes will be conducted in 'grading'. The exam rules first 30 minutes (approx.), hints will provide 30-60 minutes period, working with other students/TA/Instructors 60 – 110 period. Students may review with questions on the Assignments once their Quiz is submitted (students/TA/Instructor).

Design 3-Minute Pitch Electrochemical Applications 4% (Individual Oral Presentation) – Pass/Fail Milestone
FIRM – 3 Minutes (2-3 minute presentations)
ChE 331 – Electrochemical Application

This 'Electrochemical Applications' helps develop students to:

- Develop width understanding of the electrochemical field;
- Research skills of 'design content'; and,
- Present oral presentation skills.

This is an individual milestone presentation. Every 'Electrochemical Application' must be unique. Students can add their own 'Electrochemical Applications' or select one of the ideas that I have put on the list now.

This will fit into the end of classes starting is 10 Jan. These are 'flex' dates for Presentations. So students can start 12 Jan up to 3 Students will have their presentation for each day. Some students will have 'ready' to present on a selected date (i.e. Tuesday or Thursday), however, I may have 'flex' the presentation to the next day depending on how long the presentation lector take for specific 'problems'.

Course milestone case studies of Electrochemical Applications (e.g. daily life experience, particular industrial scenarios, applications of electrochemical). To encourage students to think critically and energize the on-line learning/teaching environment, each student can make an in-class presentation of their case studies (2-3min), finishing presentation in the 13^{th} week (email ppt slides to the Instructor one day ahead). The 3-Minute Electrochemical Pitch will 'fit' into the class period at the end of class (or the start of the class). Students can present when ready and have sent into a Presentation.

Bonus case studies:

The optional bonus of 1-5% marks for the Electrochemical Applications Report. This application can use the 3-minute topic or any other topic presented in the class (Due 10 April 2022). Normally to 5 to 15 pages, 1.5 spacing, plus references.

For a Design Report on the Electrochemical Applications Report an report will be outline below.

Reference: https://www.linkedin.com/pulse/guideline-engineering-design-report-writing-pankaj-khandelwal/

A report is an integral part of any engineering design where an engineer needs to document the design process and its outcome and it helps the reader to understand the Electrochemical Engineering. A design report should consist of the following items.

1. Front Cover Page

Cover page should consist of project title, course and instructor name, date, report title as appropriate.

2. Table of Contents (Not needed if the Report is less than 20 pages and/or has Appendices)

Index should reflect all the sections/ chapters used in report with page numbers. It should also consist index of tables, sketches, figures, drawings, appendices etc used in report.

3. Executive Summary (not needed for reports less than 15 pages)

An Executive Summary should be written in such a way that if a person reads, he/she can understand the broad aspects of the report. The report goes into many hands including technical persons, authorities, administrators, the public etc. and not all of them have enough time to go through the report and understand the details of engineering design. Executive summary helps them to understand the requirement and implications on their interest areas.

4. Introduction

Details of Electrochemical Engineering background. Scope of the electrochemical application, purposes of report should include in Introduction with sketches illustrating above mentioned items.

5. Electrochemical Engineering Applications of Aspects & Design Details

Provide details various component used in design in terms of their applicability, engineering logic, availability etc. Discuss about how these components includes the design of the features of the Electrochemical Applications. Discuss about the overall picture of project and how the proposed design components integrated with other components. The 'Pros and Cons' should

discuss of the application. The student should make critical and analysis comments on the Applications as appropriate.

6. Design Options (not needed in ChE 331)

Mention available opportunities and limitations in detail and present design options as an outcome. Add details about each option by mentioning advantages and disadvantages. The 'Pros and Cons' should discuss of the application. Mention all the important design decisions made during design development and add references. Present results/ outcome graphically, tabular format or in the text as appropriate. Mention what could be achieved or not achieved through each design feature of Electrochemical Applications. As appropriate the feasibility should be discussed. Prepare enough information such that Electrochemical Application could see all the available/ feasible options. Provide commentary about how the outcome/ results match with design philosophy and criteria.

7. Environment Impact Assessment and Safety

Every change in nature brings an impact on the environment and safety needs to be assessed.

8. Comparisons of Options (not needed in ChE 331)

The various option prepared in the earlier section need to be compared preferably in tabular format for easy decision-making, the option should be compared against important parameters like interface issues, cost, health and safety, constructability, environment impact, time requirement to implement, advantages and disadvantages, stakeholder approvals etc.

9. Conclusion & Recommendation

Provide a conclusion of the design developed by highlighting the fulfilment of design criteria. Add commentary about how the design will help in achieving client requirements, and how it fits in bigger picture. Add a recommendation about the preferred option and write why it has been chosen. Mention recommendation what would be the next course of actions and who will be responsible.

10. References

Add references which been referred to throughout the design process

<u>Quizzes in class:</u>

Jan 18, Feb 1 Feb 8, Mar 7, Mar 21 and April 4 (due in a week by 11:30 pm at that day, submit a copy to the Dropbox or on Learn): otherwise, it will be announced in the class with changes. ; otherwise, it will be announced in the class.

<u>Assignment posting: (</u>submit a copy to the Dropbox submitted on Learn)
Jan 19, Feb 2, Feb 9, Mar 8, Mar 22 and April 5 (due in a week by 11:30 pm at that day, submit a copy to the on Learn): otherwise, it will be announced in the class with changes.

Reading week: Feb 19, 2024 to Feb 23, 2024

Final Exam Date: TBD

Course support on the internet

All online materials for ChE can be at UW-D2L. All Assignments can be found on this site. Due Dates for Lab Assignments can be found on this site. Submit a Dropbox on Learn.
Assignments 19 Jan, 2 Feb, 9 Feb, 8 Mar, 22 Mar, 5 Apr, and the course will announced in the class with changes.

Course Objectives and Outline

ChE 331 is concerned with the principles and applications of electrochemistry and electrochemical engineering. The course is intended to provide the students with the information, and knowledge to address electrochemical issues in the industry. The basic physical chemistry of REDOX reactions is covered. These issues include corrosion of metals, metal plating and processing, basic metallurgy, environmental contaminants that involve REDOX reactions, battery design and selection, and fuel cell design and selection.
The course is covered in 6 units with each unit taking about 2 weeks to cover, including:

1. Introduction
    - basics of electrochemical reactions and processes
    - overview of applications
    - some basic concepts and conventions
    - Faraday's law

2. Transport Phenomena in Electrolytes
    - electrolytic conduction
    - diffusion, migration and convection

3. Electrode Reactions (Equilibrium)
    - reversible electrode potential, Nernst equation
    - cell emf
    - applications of equilibrium potentials (reference electrodes, specific ion electrodes)

4. Electrode Reactions (Non-Equilibrium)
    - electrode kinetics, overpotentials
    - transport-controlled electrode reactions
    - electrolytic and galvanic cells
    - potential distribution across cells
    - applications

5. Electrochemical Engineering
    - reactor design of electrochemical reactors (CSTR)
    - current efficiency of cells

6. Applications
    - materials, corrosion, batteries, fuel cells

Course Learning Outcomes

After successful completion of this course, students will be able to:

- Identify and solve electrochemical problems relevant to technology in society.
- Calculate rates of mass transfer by different mechanisms for practical processes.
- Understand and analyze electrochemical voltage, current, mixed current, including applications of Pourbaix Diagrams.
- Understand the analogy between ions and current transfer.
- Learn to use a Tafel plot is a graphical plot (usually logarithmic) showing the relationship between the current generated in an electrochemical cell and the electrode potential of a specific metal. These plots are usually generated based on the kinetics of electrochemical experiments performed under controlled conditions.
- Use the application to the Butler–Volmer equation which is one of the most fundamental relationships in electrochemical kinetics. It describes how the electrical current through an electrode depends on the voltage difference between the electrode and the bulk electrolyte for a simple, unimolecular redox reaction, considering that both a cathodic and an anodic reaction occur on the same electrode.
- Configuration of batteries, electrolysers, battery packs, hydrogen economy, and fuel cells.
- Develop width understanding of the electrochemical field;
- Research skills of ‘design content’,
- Present oral presentation skills.
- Understand and use correlations for electrochemical transfer coefficients in applications.
- Analyze and design batteries, corrosion and various equipment/application for Electrochemical Engineering.

Assignment Marking Matrix

Assignment Marking for ChE 331	
	Assignments are to be submitted to the appropriate 'drop box' outside of the main Chem Eng office E6 – 5th Floor
	LATE assignments, will not be marked, and will not receive any credit on the final course grade.
	There will be a quiz every two weeks based on the current materials. Exact date and time will be announced in class and posted on D2L. If you have a valid reason (e.g. medical, away for competition etc.) for missing a quiz this information must be presented to the instructor immediately upon your return so that arrangements can be made.
	Generally, each problem in the assignment and/or quiz will have a unique marking scheme, however, the general format/principles are shown below.
3	The solution is Correct and it is very well presented · Well written (*i.e.* language, grammar, spelling – no errors) · Report format is consistent, and very well presented · Technically correct - Significant figures are appropriate - All work is clearly labelled and outlined so that the solution is easily followed · Understanding and discussion of results in correct and well presented
2.5	The solution is generally Correct – EXCEPT: · Not well presented, · Understanding and discussion of results mostly correct, · Poor or inconsistent format, · Poor language, grammar, or spelling, · Hard to follow, · Incorrect units, or · Improper use of significant figures.
2	The solution is mostly correct or one critical synthesis flaw or format and presentation is poor. For example: · Simple math errors, · Poor report format; · Simple synthesis flaw.
1	The solution demonstrates some limited understanding of the principles.
0	The solution does not demonstrate an understanding of the principles involved.

Marked assignments will be kept for no longer than two weeks and returned in class. Students who prefer an alternative return method must so advise Dr. Fowler by e-mail by 21 Jan, and may pick up their assignments during Dr. Fowler's office hours.

Note for Students with Disabilities: The Office for Persons with Disabilities (OPD), located in Needles Hall, Room 1132, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with the OPD at the beginning of each academic term.

Academic Integrity

The University of Waterloo requires that all course descriptions contain material related to plagiarism. Please review the information on the following URL prior to the course. http://www.eng.uwaterloo.ca/~ugoffice/course_responsibilities.html

Acceptable rules for group work:
Students may consult other students for assistance, but each student must submit his/her own version of the work, assignments, spreadsheets, and/or results. Completion of the assignment is the principal method to learn the material in the course.

Academic Integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. [Check www.uwaterloo.ca/academicintegrity/ for more information.]

Grievance: A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4, www.adm.uwaterloo.ca/infosec/Policies/policy70.htm. When in doubt please be certain to contact the department's administrative assistant who will provide further assistance.

Discipline: A student is expected to know what constitutes academic integrity [check www.uwaterloo.ca/academicintegrity/] to avoid committing an academic offence, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate Associate Dean. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline, www.adm.uwaterloo.ca/infosec/Policies/policy71.htm. For typical penalties check Guidelines for the Assessment of Penalties, www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm.

This course includes the independent development and practice of specific skills, such as **ChE 331 Electrochemical Engineering lectures, Class lecture problems, Quiz, Midterm, Design Problems and Design Electrochemical Application 3 minute pitches.**. Therefore, the use of Generative artificial intelligence (GenAI) trained using large language models (LLM) or other methods to produce text, images, music, or code, like Chat GPT, DALL-E, or GitHub CoPilot, is not permitted in this class. Unauthorized use in this course, such as running course materials through GenAI or using GenAI to complete a course assessment is considered a violation

of Policy 71 (plagiarism or unauthorized aids or assistance). Work produced with the assistance of AI tools does not represent the author's original work and is therefore in violation of the fundamental values of academic integrity including honesty, trust, respect, fairness, responsibility and courage (ICAI, n.d.).
You should be prepared to show your work. To demonstrate your learning, you should keep your rough notes, including research notes, brainstorming, and drafting notes. You may be asked to submit these notes along with earlier drafts of their work, either through saved drafts or saved versions of a document. If the use of GenAI is suspected where not permitted, you may be asked to meet with your instructor or TA to provide explanations to support the submitted material as being your original work. Through this process, if you have not sufficiently supported your work, academic misconduct allegations may be brought to the Associate Dean.
In addition, you should be aware that the legal/copyright status of generative AI inputs and outputs is unclear. More information is available from the Copyright Advisory Committee: https://uwaterloo.ca/copyright-at-waterloo/teaching/generative-artificial-intelligence
Students are encouraged to reach out to campus supports if they need help with their coursework including:

- Student Success Office for help with skills like notetaking and time management
- Writing and Communication Centre for assignments with writing or presentations
- AccessAbility Services for documented accommodations
- Library for research-based assignments

Appeals: A decision made or penalty imposed under Policy 70 (Student Petitions and Grievances) (other than a petition) or Policy 71 (Student Discipline) may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72 (Student Appeals) www.adm.uwaterloo.ca/infosec/Policies/policy72.htm.