I. Course Identity, Teaching Staff, and Logistics

Instructor: Prof. Shannon Boettcher, email: swb@uoregon.edu, office: 435 LISB, Phone: 541-346-2543

Office hour: There will be two office hours per week, held in LISB 435. The times will be determined on the first day of lecture based on student availability.

Format: A blend of lecture and active learning in particular through think-pair-share activities.

Credits: 4

Location: Lectures will be held in Klamath 107 from 10:00 AM - 11:50 PM Tuesday and Thursday.

Required course materials:


Course website: Lecture notes, videos, homework solutions, and grades will be posted on the Canvas course site.

Prerequisites: Advanced Electrochemistry CH454/554.

II. Course Description

In CH454/554 students learn the fundamental theoretical concepts underlying electrochemical systems, but do not learn how these concepts govern the function of engineered electrochemical systems. CH692 electrochemical engineering combines the study of charge transfer at electrode/electrolyte interfaces with the development of practical materials and processes. The development of the technology involves the study of the electrochemical reactors, their voltage and current distribution, mass transport conditions, hydrodynamics, geometry as well as the quantification of overall performance in terms of reaction yield, conversion efficiency, and energy efficiency.

This course examines the operational principles of electrochemical energy storage devices (batteries and capacitors), energy conversion devices (fuel cells, electrolyzers), and bioelectrochemical interfaces. The emphasis is on materials and device design based on fundamental chemistry and physics concepts that govern the properties and performance of the materials/devices involved. The course makes use of numerical simulation to understand complex systems. Specific systems of study will include electrode and electrolyte materials for primary (non-rechargeable) and secondary (rechargeable) batteries including lithium ion batteries, electrochemical capacitors, proton exchange membrane fuel cells, solid oxide fuel cells, alloy electrocatalysts, mixed ionic-electric conductors, and biosensor development. Feedback from industry partners will drive the timely choice of specific example systems used to
support the curriculum.

### III. Expected Learning Outcomes

- Learn and critically apply foundational concepts in chemical thermodynamics, kinetics, and mass transport to analyze the operation of electrochemical devices including batteries, fuel cells, and electrochemical reactors
- Understand and evaluate device performance metrics
- Understand how to apply device optimization strategies
- Understanding of principles governing electrochemical deposition and corrosion reactions

### IV. Estimated Student Workload

Course participants will attend lecture, perform assigned reading, work assigned problem sets, and demonstrate the knowledge learned on exams. The table below shows the estimated workload.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Estimated hours per term</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lectures</td>
<td>40</td>
<td>4 h / wk</td>
</tr>
<tr>
<td>Assigned Reading</td>
<td>30</td>
<td>From Fuller and Harb</td>
</tr>
<tr>
<td>Problem Sets</td>
<td>50</td>
<td>Assigned Weekly</td>
</tr>
<tr>
<td>Projects</td>
<td>30</td>
<td>10 h / project</td>
</tr>
<tr>
<td>Exam Preparation</td>
<td>10</td>
<td>4 h for midterm, 6 h for final</td>
</tr>
<tr>
<td><strong>Total hours:</strong></td>
<td><strong>160</strong></td>
<td></td>
</tr>
</tbody>
</table>

### V. How Grades Will Be Determined

The grades will be determined based on the following percentage breakdown of the final total score:

**Problem Sets - 20%  Projects - 20%  Midterm Exam - 20%  Final Exam - 40%**

Problem sets will be graded for completion, students who complete each problem set and turn them in by the deadline will receive full credit. Each problem must be fully worked, with clear logical explanation of the approach to receive credit.

Projects will be graded based on the quality of the project report. Reports are expected to be concise formal documents with professional quality graphs and analysis and insightful discussion (5 pages of concise, single spaced, scientific writing for each). Each project assignment is accompanied by a document outlining project expectations. These projects will
include work-up of provided real-word data, simulation, and analysis of large data sets.

A = Clearly written, concise document, with high-quality figures. All required pieces of data are shown and discussed without major errors in the interpretation.

B = One or more issues with the items above.

C = Multiple issues with quality of the written document and interpretation/discussion.

D = Multiple issues and incomplete.

The midterm and final exams will be based largely on the content in the assigned problem sets, content emphasized in class discussion, and that emphasized in the projects. Letter grades will not be assigned on these exams, students will receive a percentage score for the exam.

A+ course grades will be given to the top-performing students in the course, provided they reach >95%. Students earning >90% in the course will earn at least and A, >80% at least a B, >70% at least a C, and >60% at least a D. The instructor may curve the course to increase the letter grades for a given percentage score to account for variations in difficulty of the exam questions from year-to-year. Students with a given percentage score will not, however, earn a grade lower than that indicated above.

VI. Course Schedule and Assignments

Assigned reading: Weekly reading from Fuller and Harb given after each topic. Reading should be started prior to the start of the weekly lectures and completed before the start of the following weeks lectures. Problem Sets are due on the 2nd lecture of the week following their assignment.

Week 1
- Lecture 1: Porous Electrode Structures
- Lecture 2: Electrochemical System Analysis
- Reading: Chapter 5: Electrode Structures and Configurations (pg. 93-108)
- Problem set 1: Selected problems from Fuller and Harb, Chapter 5 and 6.

Week 2
- Lecture 1: Battery Fundamentals: Cells, Classification, Theoretical Capacity and SOC
- Lecture 2: Cell Characteristics and Performance Metrics
- Reading: Chapter 7: Battery Fundamentals (pg. 151-169)
- Project 1: Li ion battery model and analysis.
- Problem set 2: Selected problems from Fuller and Harb, Chapter 7.

Week 3
- Lecture 1: Battery Cell Design, Layout, Capacity, Rate, Construction
Lecture 2: Battery Pack Design: Thermal, Mechanical, Performance Optimization
Problem set 3: Selected problems from Fuller and Harb, Chapter 8.
Reading: Chapter 8: Fuel Cell Stack and System Design (pg. 223-241)

Week 4
Lecture 1: Fuel Cell Fundamentals: Types, J-V characteristics, Operation
Lecture 2: Electrode Structures, Proton Exchange Membrane Fuel Cells, Solid Oxide Fuel Cells
Reading: Chapter 9: Fuel Cell Fundamentals (pg. 195-216)
Problem set 4: Selected problems from Fuller and Harb, Chapter 9.
Project 1 Due.

Week 5
Lecture 1: Fuel Cell System Overview, Stack Design Concepts, and Configurations
Lecture 2: Fuel Cell System construction and components, oxidant and fuel utilization, flow field design, water and thermal management
Reading: Chapter 10: Fuel Cell Stack and System Design (pg. 223-247)
Project 2: Fuel cell system model and analysis.

Week 6
Lecture 1: Catch-up and review for Midterm.
Lecture 2: Midterm exam covering all materials covered in week 1-5.

Week 7
Lecture 1: Electrochemical Double Layer Capacitors
Lecture 2: Energy Storage and Conversion for Electric Vehicles
Reading: Chapter 11 and Chapter 12 (pg. 251-277)
Project 2 due.
Problem Set 5: Selected problems from Fuller and Harb, Chapter 11-12.

Week 8
Lecture 1: Industrial Electrolysis: Performance, polarization curves, electrochemical reactor design
Lecture 2: Example processes, sustainable electrochemical reactors, thermal design
Reading: Chapter 14: Industrial Electrolysis, Electrochemical Reactors (pg. 323-350)
Project 3: Industrial electrolysis/electrosynthesis model and analysis.
Problem Set 6: Selected problems from Fuller and Harb, Chapter 14.

Week 9
Lecture 1: Electrodeposition: Faraday’s law, fundamentals, nucleation rates and growth
Lecture 2: Morphology, Additives, Current Distribution, Side reactions, substrates
Reading: Chapter 13: Electrodeposition (pg. 299-319)
Problem Set 7: Selected problems from Fuller and Harb, Chapter 13.
Week 10
Lecture 1: Corrosion: Thermodynamics, Kinetics, Localized Corrosion, and Corrosion Protection
Lecture 2: Catch up and review for Final Exam.
Project 3 due.

A review session will be scheduled during dead week to help students prepare for the exam.

Final Exam: TBD

VII. Course Policies

- Late or missed work will not generally be accepted without prior approval.
- Project reports must be your own work. You may share data across the class if it strengthens the quality of the report but the analysis and discussion of the data in the report must be your own work.
- There will be a zero-tolerance policy for plagiarism and or cheating on exams.
- Homework solutions must be your own work. You must clearly show your work and the reasoning used to obtain the answer to get credit.
- Academic Misconduct: The University Student Conduct Code (available at conduct.uoregon.edu) defines academic misconduct. Students are prohibited from committing or attempting to commit any act that constitutes academic misconduct. By way of example, students should not give or receive (or attempt to give or receive) unauthorized help on assignments or examinations without express permission from the instructor. Students should properly acknowledge and document all sources of information (e.g. quotations, paraphrases, ideas) and use only the sources and resources authorized by the instructor. If there is any question about whether an act constitutes academic misconduct, it is the students’ obligation to clarify the question with the instructor before committing or attempting to commit the act. Additional information about a common form of academic misconduct, plagiarism, is available at https://researchguides.uoregon.edu/citing-plagiarism.
- Accessibility: The University of Oregon is working to create inclusive learning environments. Please notify me if there are aspects of this course that result in disability related barriers to your participation. For more information or assistance, you are also encouraged to contact the Accessible Education Center, Suite 360 Oregon Hall, 346-1155 or uoaec@uoregon.edu; website: http://aec.uoregon.edu/content/about
- A graduate employee (GE) will serve as a teaching assistant for this course. The GE’s responsibilities will include assisting in the implementation of the project component of the course, including supervising students completing the projects and obtaining/distributing materials needed for the project. The GE may assist with grading, and will also be available for general assistance in preparing project reports, completing
homework assignments, and preparing for exams. Should graduate students enrolled in
the course perceive the course as leading to any conflict of interest, privacy concerns, or
unfairness related to having a GE in the above role please contact the instructor to
discuss paths of recourse. If the GE is involved in grading assignments, graduate
students may request that a faculty member, not the GE, grade their assignments. To do
this please make the request in writing via email to the instructor.