Electrochemical Impedance Spectroscopy

ECH 6851/ECH4905 Section CHE1/CHE6
Class Periods: Tuesday, Periods 8-9, 3:00 PM – 4:55 PM, WEIM 1076
Thursday, Period 9, 4:05 PM - 4:55 PM, WEIM 1076
Academic Term: Fall 2025

Instructor
Mark E. Orazem
meo@che.ufl.edu
352-392-6207
Office Hours: Thursday, 1:00-3:00 PM RHN 210

Student Mentors
Zhikui Wang
wangzhikui@ufl.edu
Office Hours: Friday, 2:00-4:00 PM Zoom

Yunhan Chuai
yunhanchuai@ufl.edu
Office Hours: Thursday, 1:00-3:00 PM RHN 210

Course Description
3 credit hours. Intended for chemists, physicists, materials scientists, and engineers with an interest in applying electrochemical impedance techniques to study a broad variety of electrochemical processes.

Course Pre-Requisites / Co-Requisites
Prerequisites: familiarity with applications of differential equations.

Course Objectives
Impedance spectroscopy represents the confluence of a significant number of disciplines, and successful training in the use and interpretation of impedance requires a coherent education in the application of each of these disciplines to the subject. In addition to learning about impedance spectroscopy, the student will gain a better understanding of the general philosophy of scientific inquiry.
The topics include:

- Fundamentals of complex variables, electrical circuits, and electrochemistry needed to understand electrochemical impedance spectroscopy.
- Methods used to measure impedance and other transfer functions, including an understanding of frequency-domain techniques and the approaches used by impedance instrumentation. This understanding provides a basis for evaluating and improving experimental design.
- Methods for developing deterministic models of impedance response from physical and kinetic descriptions.
- Methods for interpretation of impedance data, ranging from graphical methods to complex nonlinear regression.
- Conceptual understanding of stochastic, bias, and fitting errors in frequency-domain measurements, including the Kramers-Kronig relations and their application to spectroscopy measurements.
- Philosophy for electrochemical impedance spectroscopy that integrates experimental observation, model development, and error analysis.

The coursework will include homework problems, exams, and a group project in which the concepts learned in the class will be applied to a specific set of impedance data. Students will use a free computer program developed in Prof. Orazem's group to identify the error structure of impedance data and to regress used-defined models to the data. The textbook for the course was co-authored by Prof. Orazem.

Materials and Supply Fees
None.

Required Textbooks and Software
M. E. Orazem and B. Tribollet, *Electrochemical Impedance Spectroscopy*, 2nd edition, John Wiley & Sons, Hoboken, New Jersey, 2017, ISBN: 9781118527399.
Note: Exams will be open-book, and use of computers and phones will be prohibited. Thus, a paper copy of the book will be required. The first edition is not an acceptable substitute.

W. Watson and M. E. Orazem, EIS: Measurement Model Program, Version 1.8, *ECSArXiv*, 2023, https://doi.org/10.1149/osf.io/g2fjm. This download is a Windows installation file, and the program is free for use. Mac users will need to use a Windows emulator.

Recommended Materials
Other materials will be made available on the course website.

Course Schedule
The tentative schedule for exams and materials covered is attached.

Important Dates

Sep. 25	Exam 1
Nov. 20	Exam 2
Dec. 9	Final Exam (3:00-5:00PM)

Evaluation of Grades
The nature of this material is that mastery can be obtained only through diligent solution of homework problems. Discussion with classmates is encouraged, but the final solution to homework problems should represent your own efforts.
The grading schedule used will depend on the size of the class. If the class is large, the grades will be based solely on exams. If the class size is moderate, homework and a group project may also be included in the calculation of the final grade. The tentative grading is:

Homework	10%
Mid-term exams (2)	50%
Final exam or Group Project	40%

The group project will involve application of regression analysis to impedance data. The manuscript should be of a quality sufficient for submission to relevant journals.

Grading Policy
Grades for this class are curved at the discretion of the instructor. Attendance and class participation will be considered.

Relevant Aspects of the Chemical Engineering Policy on Exams
a) All exams will include the honor pledge and students must sign their name by the pledge.
b) All students must leave backpacks, bags, etc., in the front of the classroom as they enter.
c) Students are asked not to bring cell phones in the exam. In case they do, they have to place the cell phones in the front of the classroom. The department and proctors have no responsibility in case of theft (cell phones should not be brought). A cell phone discovered on a student's person may result in a zero grade for the exam. If a student is expecting an important call, he or she must discuss this with the proctors before starting the exam.
d) Students are required to remove their hats during the exam and place them in the front of the classroom.

e) In open book exams no printed material other than the textbook is allowed. A solution manual or printouts from solution manuals will result in a zero grade for the exam and additional harsher penalties.
f) Any talking between students is strictly prohibited and will result in a zero grade for the exam.
g) Students may not leave the room before turning in the exam.

Academic Policies & Resources

To support consistent and accessible communication of university-wide student resources, instructors must include this link to academic policies and campus resources: https://go.ufl.edu/syllabuspolicies. Instructor-specific guidelines for courses must accommodate these policies.

Commitment to a Positive Learning Environment

The Herbert Wertheim College of Engineering values varied perspectives and lived experiences within our community and is committed to supporting the University's core values.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Coordinator
- HWCOE Human Resources, 352-392-0904, student-support-hr@eng.ufl.edu
- Pam Dickrell, Associate Dean of Student Affairs, 352-392-2177, pld@ufl.edu

Tentative Schedule

Date	Topics Covered
Aug. 21	Introduction to Impedance Spectroscopy / History of Impedance Spectroscopy (Front matter)
Aug. 26	Complex Variables (Chapter 1)
Aug. 28	Electrical Circuits (Chapter 4)
Sep. 2	Electrochemistry (Chapter 5)
Sep. 4	
Sep. 9	Experimental Methods (Chapters 7 and 8)
Sep. 11	Equivalent Circuit Analogs (Chapter 9)
Sep. 16	Kinetic Models (Chapter 10)
Sep. 18	
Sep. 23	Diffusion Impedance (Chapter 11)
Sep. 25	Exam 1
Sep. 30	Time-Constant Dispersion (Chapter 13)
Oct. 2	
Oct. 7	Constant-Phase Elements (Chapter 14)
Oct. 9	
Oct. 14	ECS Conference (Chicago) video lecture (overview of impedance)
Oct. 16	video lecture (measurement model program)
Oct. 21	Seminar at USF
Oct. 23	Complex Nonlinear Regression (Chapter 19)
Oct. 28	Error Structure of Impedance Measurements (Chapter 21)
Oct. 30	
Nov. 4	AIChE Meeting (Boston) video lecture (Graphical Methods (Chapters 17 and 18))
Nov. 6	Video lecture (The Kramers–Kronig Relations (chapter 22))
Nov. 11	UF Holiday (Veteran's Day)
Nov. 13	The Measurement Model
Nov. 18	
Nov. 20	Exam 2
Nov. 25	UF Holiday (Thanksgiving)
Nov. 27	
Dec. 2	Review
Dec. 9	Final Exam (3:00-5:00PM)