Electrochemical Impedance Spectroscopy
ECH 6851 27778
ECH 4905 27590

Class Periods: M,W,F Period 6 (12:50–1:40 PM)
Location: MAEB 234
Academic Term: Fall 2021

Instructor
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392-6207
Office Hours: TBD

Teaching Assistant
None

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 a 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 project in which the concepts learned in the class will be applied to a specific set of impedance data.

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.

W. Watson and M. E. Orazem, EIS: Measurement Model Program, *ECSArXiv*, 2020, https://ecsarxiv.org/kze9x/. 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.

Attendance Policy, Class Expectations, and Make-Up Policy
Attendance is required. Attendance records will be used to guide determination of final grades. Cell phones and other distractions may not be used in class. Excused absences must be consistent with university policies in the undergraduate catalog (https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx) and require appropriate documentation.

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 may also be included in the calculation of the final grade. The tentative grading is:

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

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.

Students Requiring Accommodations
Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, https://www.dso.ufl.edu/drc) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be presented to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

Course Evaluation
Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at https://evaluations.ufl.edu/evals. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results/.

University Honesty Policy
UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code (https://www.dso.ufl.edu/sccr/process/student-conduct-honor-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Software Use
All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Student Privacy
There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: http://registrar.ufl.edu/catalog0910/policies/regulationferpa.html

Campus Resources

Health and Wellness

U Matter, We Care:
If you or a friend is in distress, please contact umatter@ufl.edu or 352 392-1575 so that a team member can reach out to the student.

Counseling and Wellness Center: http://www.counseling.ufl.edu/cwc, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Assault Recovery Services (SARS)
Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or http://www.police.ufl.edu/.

Academic Resources

E-learning technical suppor*t*, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml.

Career Resource Center, Reitz Union, 392-1601. Career assistance and counseling. https://www.crc.ufl.edu/.

Library Support, http://cms.uflib.ufl.edu/ask. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring. https://teachingcenter.ufl.edu/.

Writing Studio, 302 Tigert Hall*, 846-1138. Help brainstorming, formatting, and writing papers. https://writing.ufl.edu/writing-studio/.

Student Complaints Campus*: https://www.dso.ufl.edu/documents/UF_Complaints_policy.pdf.

On-Line Students Complaints*: http://www.distance.ufl.edu/student-complaint-process.

Tentative Schedule

Date	Topics Covered
Aug. 23	Introduction to Impedance Spectroscopy / History of Impedance Spectroscopy (Front matter)
Aug. 25	Complex Variables (Chapter 1)
Aug. 27	
Aug. 30	Electrical Circuits (Chapter 4)
Sep. 1	
Sep. 3	Electrochemistry (Chapter 5)
Sep. 6	
Sep. 8	
Sep. 9	
Sep. 13	Experimental Methods (Chapters 7 and 8)
Sep. 15	
Sep. 17	Exam 1
Sep. 20	Equivalent Circuit Analogs (Chapter 9)
Sep. 22	
Sep. 24	Kinetic Models (Chapter 10)
Sep. 27	
Sep. 29	
Oct. 1	Diffusion Impedance (Chapter 11)
Oct. 4	
Oct. 6	
Oct. 8	Homecoming (class not held)
Oct. 11	Impedance of Materials (Chapter 12)
Oct. 13	Time-Constant Dispersion (Chapter 13)
Oct. 15	
Oct. 18	
Oct. 20	Constant-Phase Elements (Chapter 14)
Oct. 22	
Oct. 25	
Oct. 27	
Oct. 29	Exam 2
Nov. 1	Graphical Methods (Chapters 17 and 18)
Nov. 3	
Nov. 5	Complex Nonlinear Regression (Chapter 19)
Nov. 8	
Nov. 10	
Nov. 12	Error Structure of Impedance Measurements / Measurement Model (Chapter 21)
Nov. 15	
Nov. 17	The Kramers–Kronig Relations (chapter 22)

Nov. 19	Application of Regression Analysis to Experimental Data
Nov. 22	
Nov. 24	Thanksgiving holiday (class not held)
Nov. 26	Thanksgiving holiday (class not held)
Nov. 29	
Dec. 1	
Dec. 3	
Dec. 6	
Dec. 8	
Dec. 16	**Final Exam (3:00-5:00 PM)**