

# Electrochemical Engineering: Fundamentals and Design

ECH 6709 Section 15E1

ECH 4905 Section 1A96

**Class Periods:** W, F, Period 8-9 (3:00–4:55 PM)

**Location:** WEIL 234

**Academic Term:** Spring 2017

## **Instructor**

Mark E. Orazem

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392-6207

Office Hours: 2:00–3:55 PM Room ChE 327

## **Teaching Assistant**

None

## **Course Description**

3 credit hours. Electrochemical phenomena and processes are covered from an engineering perspective. This course introduces electrochemical engineering as an extension to the fields of transport phenomena, thermodynamics, reaction and design that encompass Chemical Engineering. The course has the following organization:

A. Fundamentals: Thermodynamics, electrode kinetics, interfacial phenomena, and transport processes as applied to electrochemical systems. This section will encompass as well the influence of coupled kinetic, interfacial, and transport phenomena on current and potential distributions in a variety of electrochemical systems.

B. Applications of Electrochemical Principles: The emphasis will be on applying a fundamental understanding to electrochemical topics of current interest. The students will help decide which topics will be presented. The list of subjects may include: fuel cells, fundamentals of electrochemical measurements, applications of electrokinetic phenomena, semiconductor electrochemistry, porous electrodes, corrosion, cathodic protection, and transport in such media as membranes, concentrated suspensions, and solid-state ionic and electronic conductors.

## **Course Pre-Requisites / Co-Requisites**

Graduate-level understanding of transport phenomena, thermodynamics, and reaction kinetics – or permission of instructor.

## **Course Objectives**

The subjects to be covered will follow the content of the course textbook.

### Fundamentals

Chapter 11	Infinitely Dilute Solutions
Chapter 2	Thermodynamics in Terms of Electrochemical Potentials
Chapter 3	The Electric Potential
Chapter 4	Activity Coefficients
Chapter 5	Reference Electrodes
Chapter 6	Potentials of Cells with Junctions
Chapter 7	Structure of the Electric Double Layer
Chapter 8	Electrode Kinetics
Chapter 1	Introduction

### Current and Potential Distributions

Chapter 15	Fluid Mechanics
Chapter 17	Convective-Transport Problems
Chapter 18	Applications of Potential Theory
Chapter 19	Effect of Migration on Limiting Currents
Chapter 21	Currents below the Limiting Current

### Special Topics

- Chapter 9 Electrokinetic Phenomena
- Chapter 10 Electrocapillary Phenomena

### Optional Topics

- Chapter 20 Concentration Overpotential
- Chapter 12 Concentrated Solutions
- Chapter 22 Porous Electrodes
- Chapter 23 Semiconductor Electrodes
- Instructor Measurement Techniques

The tentative schedule for exams and materials covered is attached.

### **Materials and Supply Fees**

None.

### **Required Textbooks and Software**

John Newman and Karen Thomas-Alyea, *Electrochemical Systems*, 3rd edition, John Wiley & Sons, New York, 2004. The previous edition (John Newman, *Electrochemical Systems*, 2nd edition, Prentice Hall, Englewood Cliffs, NJ, 1991) is an acceptable substitute.

Note: Exams may be open-book, and use of computers and phones will be prohibited. Thus, a paper copy of the book will be required.

Other materials will be made available on the course website.

### **Recommended Materials**

J. O.'M. Bockris, A. K. N. Reddy, and M. Gamboa-Aldeco, *Modern Electrochemistry 2A: Fundamentals of Electrode Processes*, 2nd Edition, Springer, 2008.

M. E. Orazem and B. Tribollet, *Electrochemical Impedance Spectroscopy*, 2<sup>nd</sup> edition, John Wiley & Sons, Hoboken, New Jersey, 2017.

A. J. Bard and L. R. Faulkner, *Electrochemical Methods: Fundamentals and Applications*, Wiley & Sons, 2<sup>nd</sup> Edition, 2000.

G. A. Prentice, *Electrochemical Engineering Principles*, Prentice Hall, 1990.

D. Pletcher and F.C. Walsh, *Industrial Electrochemistry*, 2nd Edition, Springer, 1990.

### **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:

Mid-term exams (2)	60%
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](mailto: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 support**, 352-392-4357 (select option 2) or e-mail to [Learning-support@ufl.edu](mailto: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](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. Chapter 11. Infinitely Dilute Solutions
Aug. 25	Chapter 11. Infinitely Dilute Solutions (continued)
Aug. 30	ISE Annual Meeting, Providence, RI
Sep. 1	
Sep. 6	Chapter 2. Thermodynamics in Terms of Electrochemical Potentials
Sep. 8	Chapter 2. Thermodynamics in Terms of Electrochemical Potentials (continued)
Sep. 13	International Workshop on Green Energy Conversion, Kofu, Japan
Sep. 15	
Sep. 20	Chapter 3. The Electric Potential
Sep. 22	Chapter 4. Activity Coefficients
Sep. 27	Chapter 5. Reference Electrodes / Review
Sep. 29	Exam 1
Oct. 4,	ECS Meeting, National Harbor, MD
Oct. 6,	Homecoming
Oct. 11	Chapter 6. Potentials of Cells with Junctions
Oct. 13	Chapter 7. Structure of the Electric Double Layer
Oct. 18	Chapter 8. Electrode Kinetics
Oct. 20	
Oct. 25	Chapter 1. Introduction / Review
Oct. 27	Exam 2
Nov. 1	Chapter 17. Convective-Transport Problems
Nov. 3	Chapter 18. Applications of Potential Theory
Nov. 8	Chapter 19. Effect of Migration on Limiting Currents
Nov. 10	Veteran's Day
Nov. 15	Chapter 21. Currents below the Limiting Current
Nov. 17	Workshop on Corrosion, Santiago, Chile
Nov. 22	Thanksgiving holiday (class not held)
Nov. 24	
Nov. 29	Topics to be chosen by the class
Dec. 1	
Dec. 6	
Dec. 15	<b>Final Exam (7:30-9:30 AM)</b>