

ME 408 Polymer Electrolyte Fuel Cell Engines

Fall, 2006

Text: A pre-draft of "Fuel Cell Engines", by M. Mench, will be provided
Optional: *Fuel Cell Systems Explained*, James Larminie and Andrew Dicks, 2nd Edition

Course URL: <http://angel.psu.edu> (logon and you will see the ME408 Webpage in your folder)

Prerequisites: ME 30, ME 33, Cmpsci 201 concurrent: ME31 and ME 412, or equivalent courses in other engineering majors.

Instructor: Dr. Matthew Mench, Assistant Professor of Mechanical Engineering
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The best way to get me outside office hours is by e-mail.

Office Hours: After class, Wednesday 2:00-3:00, after class and by appt.

COURSE DESCRIPTION:

This course serves as an introduction to the fundamental principles of electrochemistry applied to fuel cells, including an introduction to the thermodynamics and kinetics of electrode processes and mass transfer in electrochemical systems. The various types of fuel cell components and technologies are dissected in detail, with a vast majority of emphasis on the polymer electrolyte fuel cell systems includes direct inject alternative fuel systems. A survey of cutting-edge issues in fuel cell technology including the future direction of fuel cell technology will be presented if time permits. The student will also participate in a design project and visit a fuel cell research lab to aide in the understanding of these systems. Issues of specific interest to mechanical engineers, including water management and heat and mass transfer will be dealt with in greater depth.

WHO SHOULD CONSIDER:

This course is intended for the undergraduate or graduate engineering student interested in obtaining a fundamental background in the basic electrochemistry required for electrochemical system modeling and diagnosis. These fundamentals will be utilized to cover analysis of fuel cell systems with a special emphasis on polymer electrolyte fuel cell systems. Those students with interest in the basic design, operation, and characteristics of fuel cell systems should also benefit.

GRADING:

Homework:	28%
Quizzes (6):	30%
Lab session:	12%
Design project:	25%
Class Partic.	5%
Late drops prior to first exam	-WN
Late drops after first exam:	
With a score $\geq 60\%$	-WP
With a score $< 60\%$	-WF

OBJECTIVES: Upon completion of this course, students should be able to:

1. Apply fundamentals of electrochemistry, thermodynamics, fluid dynamics, and heat and mass transfer, as appropriate, to examine various issues of interest to mechanical engineers including electrode flooding, temperature, and species distribution.
2. Articulate the basic fundamentals of electrochemistry in terms of electrode processes, electrochemical potential, thermodynamics and kinetics of electrode reactions applicable to electrochemical systems.
3. Describe, explain, and model the various types of electrochemical overpotential occurring within the electrochemical system including ohmic, concentration, and activation overpotentials.
4. Describe, explain, and model the effects of mass transfer in electrochemical systems by migration, diffusion, and convection.
5. Describe and use Nernst equation to model cell EMF as a function of product and reactant activities.
6. Understand the meaning, use, and experimental derivation of the Tafel slope for determination of the transfer coefficient and the exchange current density.
7. Understand and use the Butler-Volmer model of electrode kinetics.

8. Understand the concepts and fundamentals behind basic experimental electrochemical methods used to determine various key parameters including, mass and ionic transport coefficients, exchange current density, and internal resistances.
9. Identify the main components, advantages, and limitations of gas-fed PEM, direct inject PEM, molten carbonate, alkaline, phosphoric acid, and solid oxide fuel cell systems.
10. Experimentally assemble, operate, and measure various parameters in an advanced PEM fuel cell system through hands-on laboratory operation.
11. Visualize current, temperature and species distributions in an operating fuel cell under various operating conditions.
12. Apply basic software tools to the analysis of experimental data and mathematical models.
13. Work more effectively in groups to work through open-ended design problems.
14. Demonstrate professionalism, and respectful interaction with faculty and colleagues.

GOALS:

It is my goal to help each person enrolled in this class achieve the following things:

- An enjoyable experience, in which the value added to the student in terms of education is long-lasting and transcends fuel cells. I want you to leave this class as better engineers.
- A firm and complete understanding of the topics covered in this course, especially including a firm grasp on the limiting factors and issues in the various fuel cell engines covered during the course of the semester.
- An ability to apply the background learned in this course confidently and systematically to new problems involving electrochemical systems.
- The basic training required to compete for entry-level jobs in the fuel cell industry.

ACADEMIC DISHONESTY:

Academic dishonesty will not be tolerated *at all*. I hope that everyone can develop enough pride in his or her own work and abilities that this will never be a problem. It is encouraged, however, to discuss problems solving techniques with classmates in study groups as long as each person does their own work. Absolutely no copying of homework/quizzes etc. will be tolerated. Evidence of academic dishonesty will be dealt with by University Policy 49-20, described at: <http://www.psu.edu/ufs/policies/47-00.html#49-20>

HOMEWORK FORMAT:

All homework should be in the following format, unless it is an open-ended question.

GIVEN: Include a sketch if possible.

ASSUMPTIONS: These need to be justified if they are atypical.

PROBLEM STATEMENT: What is unknown that we are asked to find.

SOLUTION: Solve the problem, step-by-step, and *always include units*. **Box the final answer.**

*COMMENT: At the end of each HW, you are required put in some brief comments to describe any thoughts or questions you have. This is your forum to ask questions, state opinions, and take some time to dig a little deeper into a problem than simple ‘plugging and chugging’. There is no ‘correct’ answer. I will take a look and reply to them as needed. Examples; explain some interesting trend you noticed in a particular problem, what you liked/disliked about the HW or class periods, or pose a question to me. This is worth 3% of each HW grade.

Note: The most important thing to me is that the solution method is coherent and systematic. One of the major tools you should leave this course with is enhanced engineering problem solving methodology.

Anticipated Schedule of Exams and Graded HW

Item	Anticipated date	Item	Anticipated Date
Quiz 1	Quizzes will be announced one week before in class	Homework 1/2	Approximately every other week
Quiz 2		Homework 3/4	
Quiz 3		Homework 5/6	
Quiz 4		Homework 7	
Quiz 5		Lab Project	TBD
Quiz 6		Design Project	Last Class

PROJECTS:

There will be two group projects assigned during the course of the semester. The first project will be an experimental laboratory-based session(s), in which each group will be responsible for operating a real fuel cell and applying principles learned in class to analyze results. The project will expose the student to a practical lab environment. For this laboratory session, a group written report will be required. The second project will be based around an open-ended question that will require the teams to utilize the skills learned in class as well as in the fundamentals of mechanical engineering thermal science. The project will require students to design a fuel cell system for a particular application and perform multiple calculations to predict operational performance.

QUIZZES:

There will be up to six quizzes during this course, and no final exam. They may be in-class or take-home in nature and will be announced one week before in class and on the web.

ATTENDANCE:

Due to the nature of this course and the fact that the quiz and test material will be discussed in class, it is assumed that those who regularly attend lectures will do better; therefore attendance is very important. Those who are habitually late or disruptive will forfeit the 2% class participation grade.

LATE HOMEWORK:

Homework turned in after the date due will have 15% taken off the grade per day it is late, including weekends, with no exceptions.

HOMEWORK SOLUTIONS:

Will be put available on Angel.

CLASS NOTES:

The student version of Electronically presented lectures will be available on the Angel web page. Due to the material covered, I will sometimes present overheads. *Every overhead presented in class will be available on Angel.*

WEB PAGE:

The course web page (<http://angel.psu.edu>) (logon and you will see the ME408 Webpage in your folder)) will provide updated information about schedule changes, course notes, HW assignments, grades, FAQs, exam/quiz reviews, links to useful sites, and contact information.

Anticipated Class Lecture Schedule

1. Overview of Fuel Cells and fuel cell systems
2. Basic Electrochemistry of Electrode Reactions in Polymer electrolyte fuel cells (PEFCs)
3. Thermodynamics of PEFCs
4. Efficiency and Open Circuit Voltage in PEFCs
5. PEFC Statics: systems overvoltages and losses- The polarization curve
6. Kinetics of Electrochemical Reactions in PEFCs
7. Kinetics of Electrochemical Reactions in PEFCs
8. Ohmic Losses of PEFC Electrolyte
9. Ohmic Losses of contacts and other components of PEFC
10. Mass Transfer Losses in PEFCs-diffusion
11. Mass Transfer Losses in PEFCs -convection
12. Psychrometrics of humid mixtures in PEFCs
13. Water management in PEFCs-basic calculations in single-phase regime
14. Water management in PEFCs- two-phase flow calculations
15. Water management in PEFCs- two-phase flow calculations
16. Heat Transport in PEFCs
17. Heat Transport in PEFCs
18. Heat and Mass Transport phenomena in PEFCs

19. CO Poisoning in PEFCs
20. CO Poisoning in PEFCs
21. Degradation in PEFCs -overview
22. Degradation in PEFCs -quantification methods
23. Midterm Exam
24. PEFC Modeling
25. PEFC Modeling
26. PEFC Modeling
27. Experimental Methods (distributed current and HFR)
28. Experimental Methods (distributed temperature and species)
29. Experimental Methods (lab session)
30. The Direct methanol fuel cell- overview
31. The Direct methanol fuel cell- kinetics and thermodynamics
32. The Direct methanol fuel cell- performance and water management
33. The Dimethyl Ether fuel cell for portable applications
34. PEFC Dynamics introduction.
35. Sensing and Control of PEFCs
36. PEFC MEA manufacture process
37. Overview of Solid Oxide Fuel Cells, materials, transport, heat transfer, and manufacturing issues
38. Alternative fuel PEFCs (Formic Acid, DMO, and other)
39. Presentations for group projects
40. Presentations for group projects
41. Presentations for group projects
42. Quizzes throughout Semester

STATEMENT ON ACADEMIC INTEGRITY

It is a simple matter of personal integrity, but unfortunately there are a few out there that have no personal pride in their own work. Earning a C is far more satisfying than stealing an A. Academic honesty and integrity is of utmost importance. Detailed information on this topic can be found at www.engr.psu.edu/undergrad/acad_int/students. Some examples are given below:

CHEATING: Using crib sheet; pre-programming a calculator; using notes or books during a closed book exam etc.

COPYING ON TEST: Looking at another unsuspecting student's exam and copying; copying in a complicit manner with another student; exchanging color-coded exams for the purpose of copying; passing answers via notes; discussing answers in exam, etc.

PLAGIARISM: The fabrication of information and citations; submitting others work from professional journals, books, articles and papers; submission of other students papers or lab results or project reports and representing the work as one's own; fabricating in part or total, submissions and citing them falsely, etc.

ACTS OF AIDING OR ABEADING: Facilitating acts by others; unauthorized collaboration of work; permitting another to copy from exam; writing a paper for another; inappropriately collaborating on home assignment or exam without permission or when prohibited, etc.

UNAUTHORIZED POSSESSION: Of examinations, through purchase or supply; stealing exams; failing to return exams on file; selling exams; photocopying exams; buying exams; any possession of an exam without the custodian's permission, etc.

SUBMITTING PREVIOUS WORK: Submitting a paper, case study, lab report or any assignment that had been submitted for credit in a prior class without the knowledge and permission of the instructor.

TAMPERING WITH WORK: Changing own or another students work product such as lab results, papers, or test answers; tampering with work either as a prank or in order to sabotage another work, etc.

GHOSTING: Taking a quiz, an exam, performing a laboratory exercise or similar evaluation in place of another; having another take a quiz, an exam, or perform an exercise or similar evaluation in place of the student, etc.

ALTERING EXAMS: When instructor returns graded exams for in class review and subsequently collects them, student changes incorrect answers and seeks favorable grade adjustment asserting that instructor made mistake in grading; other forms may include changing the letter or and/numerical grade on test; obtaining test in discretely, etc.

COMPUTER THEFT PROGRAM: Electronic theft of computer programs, data, or text belonging to another etc.