

**ME295.004-Special Topics in Mechanical Engineering**  
**ME320.003-Special Topics in Mechanical Engineering: Fuel Cells**  
Fall 2007  
TR 12:30-1:45pm UTEB 175



University of  
Connecticut

Department of Mechanical Engineering

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**Course Text**

F. Barbir, *PEM Fuel Cells: Theory and Practice*, Elsevier (2005). Limited number of copies is available at UConn-Co-Op.

**Reference Texts**

Fuel Cells:

J. Larminie and A. Dicks, *Fuel Cell Systems Explained-2<sup>nd</sup> Edition*, Wiley (2003).  
S. Srinivasan, *Fuel Cells: From Fundamentals and Applications*, Springer (2006).  
R. O'Hayre, S.-W. Cha, W. Colella and F.B. Prinz, *Fuel Cell Fundamentals*, Wiley (2005).  
X. Li, *Principles of Fuel Cells*, Taylor and Francis (2005).  
*Fuel Cell Handbook-5<sup>th</sup> Edition*, US Department of Energy, (2000). available at  
<http://www.osti.gov/bridge/servlets/purl/769283-sD4TGw/native/769283.PDF>

Electrochemistry:

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

Thermodynamics:

M.J. Moran and H.N. Shapiro, *Fundamentals of Engineering Thermodynamics-3<sup>rd</sup> Edition*, Wiley (1995).

Transport Phenomena:

R.B. Bird, W.E. Stewart and E.N. Lightfoot, *Transport Phenomena*, Wiley (1960).  
M. Kaviany, *Principles of Heat Transfer in Porous Media*, Springer-Verlag (1991).  
A. Faghri and Y. Zhang, *Transport Phenomena in Multiphase Systems*, Elsevier (2006).

Computational Fluid Dynamics:

S.V. Patankar, *Numerical Heat Transfer and Fluid Flow*, Taylor and Francis (1980).

**Course Objective**

Fossil fuels currently meet about 80% of the worldwide energy demand; however they are limited in supply and cause serious environmental problems. On the other hand, hydrogen is the cleanest and most efficient energy *carrier* and fuel cells provide a direct conversion of chemical energy of hydrogen into electricity. In this course, fuel cells will be introduced, along with theory, operating principles, materials, design and operation. Several fuel cell types will be discussed, and the fundamental electrochemistry and thermodynamics of fuel cell operation will be investigated in detail. Low temperature fuel cells based on polymer based electrolytes will be explored in depth, along with contemporary issues in design, operation, performance and reliability/durability of these systems. Charge, reactant and product transport phenomena will be a main focus of this course. The course has a substantial learn-by-doing component. You will explore various details of fuel cells through reading assignments from current literature.

**Pre-requisite**

Senior standing for ME 295 and graduate standing for ME 320. Undergraduate thermodynamics, heat transfer and fluid mechanics courses are prerequisite.

**Grading**

Homework: Approximately 5 homework sets will be assigned during the semester. You will have one to two weeks to complete each of the homework assignments. No late homework will be accepted without prior permission. Your homework is worth 30% of your course grade.

Mid-Term Exam: There will be 1 closed book exam worth 20% of your course grade. You may bring 1 crib sheet (1 side of a letter-size paper) to the exam.

Project: There will be one project, which may be an individual or group effort. This will constitute 30% of the grade.

Final: The final exam is closed book and is worth 20% of your course grade. You may bring 2 crib sheets (both sides of a letter-size paper) to the final.

Dates of the mid-term and final exams will be announced later.

**Academic Honesty**

All students are expected to maintain the highest level of academic integrity in accordance with the University of Connecticut's Student Code (<http://www.dosa.uconn.edu/AppendB.html>). Collaboration on homeworks is encouraged as long as it is limited to general discussions of the problems and approaches. However, anything that is turned in for a grade must be entirely your own work. Homework assignments that are copied from a classmate or other source and dishonesty of any sort on an exam are considered as serious breaches of academic honesty and will result in an F for the course.

## TENTATIVE OUTLINE

### INTRODUCTION

- Why does a mechanical engineer care about fuel cells?
- Hydrogen and hydrogen economy
- Benefits of fuel cells
- Principles of fuel cell operation

### FUEL CELL THERMODYNAMICS

- 2<sup>nd</sup> law analysis of fuel cells (Carnot myth)
- Efficiency of fuel cells

### FUEL CELL ELECTROCHEMISTRY

- Nernst principle
- Electrochemical kinetics-Butler-Volmer equations

### FUEL CELL TYPES

- Classification by operating temperature/electrolyte type

### Fuel Cell Performance

- Activation Overpotential
- Ohmic Overpotential
- Concentration Overpotential

### FUEL CELL DESIGN AND COMPONENTS

- Cell components
- Stack components
- System components

### OVERVIEW OF INTERMEDIATE/HIGH TEMPERATURE FUEL CELLS

- Solid Oxide Fuel Cells (SOFC)
- Molten Carbonate Fuel Cells (MCFC)
- Phosphoric Acid Fuel Cells (PAFC)

### POLYMER ELECTROLYTE FUEL CELLS (PEFC)

- Heat transfer in PEFC
- Mass transfer in PEFC
- Current issues in PEFCs
  - Water management in PEFCs
  - Durability/reliability in PEFCs

### DIRECT METHANOL FUEL CELLS (DMFC)

- Electrochemical kinetics methanol (MeOH) oxidation
- Current issues in DMFCs
  - Fuel crossover in DMFCs
  - Water management in DMFCs
  - High MeOH concentration operation, limiting current density