School of Nuclear Engineering, Purdue University
West Lafayette, IN 47907-1290

NUCL 47000 Fuel Cell Engineering
Fall 2018

This course will use **Blackboard Vista** to post information on this course, homework assignment, class notes and on campus emergency.

Instructor: Professor S. T. Revankar Office: NUCL 132E, Phone: 496-1782, e-mail: shripad@purdue.edu
Class Room: MWF 8:30am-9:20am GRIS 133 **Office Hours**: Friday 1:30pm -2:20pm and 3:30pm-4:30pm or by appointment

Course Objectives:

- To provide fundamental understanding of theory, analysis, performance, design and operation principles of various fuel cell components and systems and fuel processing.
- To understand the current state of technology of stationary and automotive fuel cell systems and components, and the challenges the industry faces today.
- Learn and perform qualitative analysis and quantitative calculations based on engineering and physical principles
- Enhance systematic problem solving skills and sharpen written communication skills through short technical project report.

Text: Fuel Cells-Principles, Design, and Analysis**,** Shripad Revankar and Pradip Majumadar, , CRC Press, ISBN 978-1-42-008968-4, June 2014.

Other references for free download: (1) Fuel Cell Handbook (7th Edition), EG&G Technical Services, Inc., U.S. Department of Energy, National Energy Technology Laboratory, November 2004. (free of cost –download)
www.netl.doe.gov/File%20Library/research/coal/energy%20systems/fuel%20cells/FCHandbook7.pdf or
http://www.netl.doe.gov/research/coal/energy-systems/fuel-cells/publications **(2)** Fuel Cells – Green Power, Thomas & Zalbowitz; Los Alamos National Laboratory. (free of cost –download)
http://www.lanl.gov/orgs/mpa/mpa11/Green%20Power.pdf
(3) Class Notes: *Additional material will be provided for class lectures*

Homework: Homework problems should be turned in at the beginning of the hour on the date due. They will be graded and returned as soon as possible. Problems turned in one day late will be graded on a one-half credit basis. Two days late will get ¼ credit and any later day submission will get zero credit. Since these problems are intended to show the application of lecture material and provide preparation for tests, individual work is essential. Solutions should make the approach followed clear to the grader. Collaboration on homework is limited to general discussion of the problems and approaches. Each student must independently complete their own written solution to each homework problem. Copying another person's homework or using old or other existing solutions is considered plagiarism. Each homework problem must contain the following header printed in the upper right corner of each page:

Last name, First name ***NUCL 402, Hwk Assignment #***

Team Design Project: A fuel cell system design problem is integral part of the course. Each team will work on the design part during next two months. Each team will work and prepare a complete engineering report documenting the work on this project. The format and further instructions for the project will be provided when the problem is assigned.
Homework and the Design Project report will be graded based on neatness and format (10%), clarity of presentation (20%), correctness of approach (50%), right answer or reasonable conclusions (20%).

Course Grading:	Hour exam (2)	60%
	Homework	20%
	Design Project	20%

Final Grade Scale: A = 85-100; B = 75-84; C = 65-74; D = 55-64; F < 55

Computer Usage: Knowledge of word processing and spreadsheet software will be necessary for laboratory report preparation and some homework assignments. Knowledge of a computer programming language may also be helpful for some assignments.

Attendance Policy:

Since many of the topics to be covered can only be adequately treated by class discussion, regular attendance is mandatory to meet the objectives of the course. Please see University attendance and grief absence policy at
https://www.purdue.edu/studentregulations/regulations_procedures/classes.html
Excessive unexcused absences will be reflected in the grade. Students are responsible for all material covered during class, including assignments and quizzes. If the instructor is late, students are required to wait 15 minutes before leaving.

Academic Integrity

http://www.purdue.edu/odos/osrr/academic-integrity/index.html
Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing integrity@purdue.edu or by calling 765-494-8778. While information may be submitted anonymously, the more information that is submitted provides the greatest opportunity for the university to investigate the concern.

Purdue Honors Pledge.

"As a boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together - we are Purdue." https://www.purdue.edu/provost/teachinglearning/honor-pledge.html

Diversity & Inclusion

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. Purdue's nondiscrimination policy can be found at: http://www.purdue.edu/purdue/ea_eou_statement.html.

CAPS Information

Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at (765)494-6995 and http://www.purdue.edu/caps/ during and after hours, on weekends and holidays, or by going to the CAPS office of the second floor of the Purdue University Student Health Center (PUSH) during business

Campus Emergency: *In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Here are ways to get information about changes in this course.* (i) Check on messages in for this course in Blackboard (ii) My email (shripad@purdue.edu), (iii) Phone: (765-496-1782)

Graduate Course Credit:

NUCL 597; One grad student complete the design project and report.

Part I Common Topic for NUCL 47000/59700

1. Introduction To Fuel Cells
    - 1.1. Introduction/History of Fuel Cells
    - 1.2. Basic Electrochemical Concepts and Definitions
    - 1.3 Principles of Electrochemical Energy Conversion
    - 1.4 Fuel Cell Types
    - 1.5 Bipolar Plates And Cell Stacks
    - 1.5 Fuel Cell Characteristics
    - 1.6 Advantages and Disadvantages
    - 1.7 Applications

2. Fuel Cell Performance
    - 2.1 EMF of the Hydrogen Fuel Cell
    - 2.2 Efficiency and Fuel Cell Voltage
        - A. Cell Efficiency
        - B. Gibbs Free Energy and Ideal Performance
    - 2.3 Cell Energy Balance
    - 2.4 Effect of Pressure and Gas Concentration
        - A. The Nernst Equation
        - B. System Pressure and Hydrogen Partial Pressure
    - 2.5 Fuel Cell Irreversibilities
    - 2.6 Activation Losses, Tafel equation
    - 2.7 Fuel Crossover
    - 2.8 Ohmic Losses
    - 2.9 The Charge Double Layer
    - 2.10 Fuel Cell Equations

3. Alkaline Electrolyte Fuel Cell (AFC)
    - 3.1 Types
    - 3.2 Cell Components
    - 3.3 Operation and Performance
    - 3.4 Application

4. Proton Exchange Membrane Fuel Cell (PEMC)
    - 4.1 Polymer Electrolyte, electrode structure
    - 4.2 Water Management
    - 4.3 Cell Cooling and Air Supply Methods
    - 4.4 Component Developments
    - 4.5 Direct Methanol Fuel Cell (DMFC)
    - 4.5 Cell Performance

5. Medium and High Temperature Fuel cells
    - 5.1 Common Features - Fuel Reforming, Fuel Utilization
    - 5.2 Phosphoric Acid Fuel Cell (PAFC)
        - 5.2.1 PAFC-Components
        - 5.2.2 PAFC-Thermodynamics
        - 5.2.3 PAFC- Performance
        - 5.2.4 PAFC-Recent Development
    - 5.3 Molten Carbonate Fuel Cell (MCFC)
        - 5.3.1 MCFC-Components
        - 5.3.2 MCFC-Thermodynamics
        - 5.3.3 MCFC- Performance
        - 5.3.4 MCFC-Recent Development
    - 5.4 Solid Oxide Fuel Cells (SOFC)
        - 5.4.1 SOFC-Components
        - 5.4.2 SOFC-Thermodynamics
        - 5.4.3 SOFC- Performance
        - 5.4.4 SOFC-Recent Development

6. Stack Engineering
    - 6.1 Basic considerations: bipolar, common gas, geometry, materials
    - 6.2 Flow field plate design: parallel, serpentine, inter-digitated

7. Fuel Cell Systems
    - 7.1 Fueling Fuel Cell
    - 7.2 Basic of Fuel Processing
    - 7.3 The Hydrogen Economy; Hydrogen Storage
    - 7.4 System Processes
    - 7.5 Systems Engineering Considerations (Balance of Plant)
    - 7.6 Fuel Cell Safety
    - 7.7 Codes and Standards for Fuel Cell Systems

NUCL 47000 Fuel Cell Engineering

Fall 2018 Class Schedule

Below is a tentative schedule for the semester. The first few weeks are firm, but some adjustments may be required later in the semester.

Week	Monday	Wednesday	Friday
1	08/20 Introduction to Fuel Cell	08/22 FC System Applications	08/24 Basic Electrochemistry for FC
2	08/27 Basic Electrochemistry FC	08/29 Electrochemistry for FC	08/31 *HW #1 Due* FC Performance
3	09/03 NO CLASS	09/05 FC Efficiency	09/07 *Project Proposal Due* *HW # 2 Due* Operation FC Voltage
4	09/10 Operation FC Voltage	09/12 Fuel Cell Equations	09/14 Proton Exchange Membrane FC (PEMFC)- Introduction
5	09/17 PEMFC- Membrane and Electrodes	09/19 PEMFC- Cooling and Air Supply	09/21 *HW # 3 Due* PEMFC- DMFC (methanol)
6	09/24 PEMFC- Cell Performance	09/26 Alkaline FC (AFC) -Types	09/28 *HW # 4 Due* AFC –Cell Components
7	10/01 AFC-Operation and Performance, AFC-Application Class Notes	10/03 Medium and High Temperature FC- Common Features, Phosphoric Acid FC (PAFC)-Components	10/05 PAFC-Thermodynamics, PAFC-Performance
8	10/08 NO CLASS October Break	10/10 PAFC-Recent Development	10/12 Review
9	10/15 ***Exam I***	10/17 Molten Carbonate FC (MCFC)-Components, Thermodynamics Class Notes	10/19 MCFC- Performance/ System
10	10/22 Solid Oxide FC (SOFC)-Components/Performance	10/24 , SOFC- Practical Systems	10/26 *HW # 5 Due* Fuels for Fuel Cells
11	10/29 Basics of Fuel Processing	10/31 Fuel Cell System Designs	11/02 Hydrogen and Storage
12	11/05 FC Safety Systems	11/07 Fuel Cell Status	11/09 Charge Transfer
13	11/12 Charge Transfer, Mass transfer	11/14 Mass transfer, Heat Transfer	11/16 Fuel cell Models
14	11/19 Electrochemical Measurements	11/21 NO CLASS Thanks Giving	11/23 NO CLASS Thanks Giving
15	11/26 Project Report Due	11/28 ***Exam 2***	11/30 *Project Reviews*

EMERGENCY PREPAREDNESS LECTURE

As we begin this semester I want to take a few minutes and discuss emergency preparedness. Purdue University is a very safe campus and there is a low probability that a serious incident will occur here at Purdue. However, just as we receive a "safety briefing" each time we get on an aircraft, we want to emphasize our emergency procedures for evacuation and shelter in place incidents. Our preparedness will be critical IF an unexpected event occurs!

Emergency preparedness is your personal responsibility. Purdue University is actively preparing for natural disasters or human-caused incidents with the ultimate goal of maintaining a safe and secure campus. Let's review the following procedures:

- For any emergency call 911.

- There are nearly 300 Emergency Telephone Systems throughout campus that connect directly to the Purdue Police Department (PUPD). If you feel threatened or need help, push the button and you will be connected to the PUPD.

- If we hear a fire alarm we will immediately evacuate the building and proceed to **Grissom Hall Basement rooms and hallways.**
    - **Do not use the elevator.**
    - Go over evacuation route…see specific Building Emergency Plan for GRISSOM Hall

- If we are notified of a Shelter in Place requirement for a tornado warning we will shelter in the lowest level of this building away from windows and doors. Our preferred location is **Grissom Hall Basement rooms and hallways.**

- If we are notified of a Shelter in Place requirement for a hazardous materials release we will shelter in our classroom shutting any open doors and windows.

- If we are notified of a Shelter in Place requirement for a civil disturbance such as a shooting we will shelter in a room that is securable preferably without windows. Our preferred location is **Grissom Hall Basement rooms and hallways.**

Attached to the syllabus is an "Emergency Preparedness for Classrooms" sheet that provides additional preparedness information. Please review the sheet and the Emergency Preparedness website for additional emergency preparedness information.

EMERGENCY PREPAREDNESS SYLLABUS ATTACHMENT

EMERGENCY NOTIFICATION PROCEDURES are based on a simple concept – if you hear a fire alarm inside, proceed outside. If you hear a siren outside, proceed inside.

- **Indoor Fire Alarms** mean to stop class or research and immediately **evacuate** the building.
  - Proceed to your Emergency Assembly Area away from building doors. **Remain outside** until police, fire, or other emergency response personnel provide additional guidance or tell you it is safe to leave.
- **All Hazards Outdoor Emergency Warning Sirens** mean to immediately seek shelter (**Shelter in Place**) in a safe location within the closest building.
  - "Shelter in place" means seeking immediate shelter inside a building or University residence. This course of action may need to be taken during a tornado, a civil disturbance including a shooting or release of hazardous materials in the outside air. Once safely inside, find out more details about the emergency*. **Remain in place** until police, fire, or other emergency response personnel provide additional guidance or tell you it is safe to leave.

**In both cases, you should seek additional clarifying information by all means possible…Purdue Emergency Status page, text message, email alert, TV, radio, etc…review the Purdue Emergency Warning Notification System multi-communication layers at http://www.pu-rdue.edu/ehps/emergency_preparedness/warning-system.html*

EMERGENCY RESPONSE PROCEDURES:

- Review the **Emergency Procedures Guidelines** https://www.purdue.edu/emergency_preparedness/flipchart/index.html
- Review the **Building Emergency Plan** (available on the Emergency Preparedness website or from the building deputy) for:
  - evacuation routes, exit points, and emergency assembly area
  - when and how to evacuate the building.
  - shelter in place procedures and locations
  - additional building specific procedures and requirements.

EMERGENCY PREPAREDNESS AWARENESS VIDEOS

- "Shots Fired on Campus: When Lightning Strikes," is a 20-minute active shooter awareness video that illustrates what to look for and how to prepare and react to this type of incident. See: http://www.purdue.edu/securePurdue/news/2010/emergency-preparedness-shots-fired-on-campus-video.cfm (Link is also located on the EP website)
- All Hazards Online Awareness training video (on Webcert & Blackboard.) A 30 minute computer based training video that provides safety and emergency preparedness information. See the EP website for sign up instructions.

MORE INFORMATION

Reference the Emergency Preparedness web site for additional information:
https://www.purdue.edu/ehps/emergency_preparedness/