ME 482 / 682 Fuel Cell Science and Engineering (3 credits)
Fall 2023

Instructor: Dr. Oksana Zholobko
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Lecture Hours: Tuesday & Thursday, 2:00 – 3:15 PM
Office Hours: Tuesday & Thursday: 3:30 – 4:30 PM. Other hours by appointments
Course Website: https://bb.ndsu.nodak.edu
Prerequisites: Chemistry 121 (or 122) and ME 350 (or 351) or an equivalent physical chemistry or thermodynamics class.
Textbook (Recommended): R. O'Hayre, et al., *Fuel Cell Fundamentals* (3rd Ed.), Wiley, 2016. Instructor's lecture notes will be available to the students.

Additional references:

- Xiangguo Li, *Principles of Fuel Cells*, Taylor & Francis, 2006.
- Gregor Hoogers (Ed.), *Fuel Cell Technology Handbook* (Handbooks Series for Mechanical Engineering), CRC Press, 2002.
- Colleen Spiegel, *Design and Building Fuel Cells* (1st Ed.), McGraw Hill, 2007.
- *Fuel Cell Handbook* (5th Ed.), U.S. Department of Energy, 2015.
- *Hydrogen and Fuel Cell Annual Progress Reports*, DOE Hydrogen and Full Cell Technologies. Office https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cells-annual-progress-reports

Bulletin Description: Fundamental concepts and technology of state-of-the-art fuel cells and their applications.

Course Objectives: To provide students with a good understanding of the physics, chemistry, and engineering principles and applications of various fuel cells. To provide graduate students with advanced principles for solving practical issues relating fuel cells.

Course Outcomes:

1. Students will understand the definitions of fuel cells and how a fuel cell differs from a battery or a heat engine.
2. Students will grasp the basic principles of fuel cells, including thermodynamics and electrochemical kinetics.
3. Students will understand and learn how various types of fuel cells are designed and used for a range of applications, including portable, automotive, and stationary power sources.
4. Student will understand and learn the operational principles of various components in a polymer electrolyte member (PEM) fuel cell, direct methanol fuel cell, and other direct liquid fuel cells.
5. Students will understand and learn how to select, design, and fabricate electrode materials, gas diffusion layers, and electrolyte layers.
6. Students will have the opportunity to visit the research laboratory of low-temperature and intermediate-temperature fuel cells and their control systems.
7. Students will understand the applications and contemporary research and development topics in fuel cell systems.
8. Students will learn how to use the fundamental concepts and principles of fuel cells to find and resolve outstanding issues in existing or emerging fuel cell technologies.

Course Grading:
Students are expected to:

- Complete homework assignments on time;
- Take tests: Midterm and final exams;
- Submit project report (for graduate students) and presentation (for both graduate and undergraduate students);
- Participate in classroom discussions.

	Undergraduates	**Graduates**
Exam 1 (1 hour 15 min)	20 %	15 %
Exam 2 (1 hour 15 min)	20 %	15 %
Final Exam	20 %	20 %
Homework	20 %	20 %
Presentation	20 %	10 %
Project		20 %
Total	100 %	100 %

Final course grades will be assigned according to the following scale:

A	90% or greater
B	80% to less than 90%
C	70% to less than 80%
D	60% to less than 70%
F	Less than 60%

No scaling will be applied in this course

If a student needs a makeup exam due to a good reason, the student should contact the instructor at an earlier time. All the arrangements for makeup exams must be made in advance of the regularly scheduled exams.

Homework: Problems with due dates will be assigned during lectures and posted on the course website, and should be finished according to the format prescribed by the instructor.

Presentation:

Each undergraduate student is required to prepare and present a 15-minute presentation on a fuel cell issue, detailing the design of a specific type of fuel cells, durability of electrolytes and/or electrocatalysts, electrodes, gas diffusion layers, an outstanding technological issue and its resolution relevant to fuel cells, etc.

Each graduate student is required to prepare and present a 20-minute presentation on a fuel cell issue, detailing the design of a specific type of fuel cell, durability of electrolyte and/or electrocatalysts, electrodes, gas diffusion layers, an outstanding technological issue and its resolution relevant to fuel cells, etc.

The presentation format and requirements will be prescribed by the instructor. Dates of the presentation will be assigned at the beginning of the semester.

Each presentation will be graded according to instructor's and audiences' evaluations including the presentation content, preparation, effectiveness, and the presenter's style and responses to instructor's and/or audiences' questions.

Graduate Project (Term Paper): Each graduate student is required to conduct a literature review on one of selected topics related to fuel cells. Preferred topics are those related to new technological advancements in sub-fields of fuel cells, such as direct alcohol/ammonia/liquid fuel cells, proton exchange membranes, electrolyte materials, electrocatalysts, MEA fabrication technologies, bi-polar plate designs, fuel reformer technologies, and electro-chemical catalysts. The format and requirements for the project will be prescribed by the instructor. The project reports should be submitted two weeks before the end of the semester. The project will be graded according to the quality of the literature review including the content, depth, broadness, formulation, writing style, and language quality, among others.

Academic Honesty Statement: The academic community is operated on the basis of honesty, integrity, and fair play. NDSU Policy 335: Code of Academic Responsibility and Conduct applies to cases in which cheating, plagiarism, or other academic misconduct have occurred in an instructional context (available on the Web at http://www ndsu.nodak.edu/policy/335.htm). Students found guilty of academic misconduct are subject to penalties, up to and possibly including suspension and/or expulsion. Student academic misconduct records are maintained by the Office of Registration and Records. Informational resources about academic honesty for students and instructional staff members can be found at www.ndsu.edu/academichonesty.

Attendance: Students should realize that there are materials covered in class which are not discussed in the textbook. The student is responsible for **ALL** materials presented in class whether or not s/he is present in class. If a student misses a class, it is the student's responsibility to obtain notes from a classmate. Full credit can be received for work turned in late due to an excused absence. It is the student's responsibility to contact the instructor in such a case. If the student is going to miss a test for a good reason, s/he should provide the instructor a written **DOCUMENT** with authority's (or administrative) signature and contact information BEFORE the test in order to arrange for a make-up exam.

> *Veterans and student service members with special circumstances or who are activated are encouraged to notify the instructor as soon as possible and are encouraged to provide Activation Orders.*

American with Disabilities Act statement: Any students with disabilities or other special needs, who need special accommodations in this course are invited to share these concerns or requests with the instructor and contact the Disability Services Office as soon as possible.

Tentative Course Outline (Subject to change):

No.	Topics
1	**Introduction to Fuel Cells** 1.1 Fuel cell basics 1.2 Classification of fuel cells
2	**Fuel Cell Thermodynamics** 2.1 Engineering thermodynamics 2.2 Reversible voltage 2.3 Fuel cell efficiency
3	**Fuel Cell Reaction Kinetics** 3.1 Electrode kinetics 3.2 Activation energy 3.3 Butler-Volmer and Tafel equations 3.4 Exchange currents and electrocatalysis 3.5 Fuel cell reactions 3.6 Catalyst-electrode design
	Fuel Cell Charge Transport 4.1 Characteristics of charge transport

4	4.2 Conductivity 4.3 Fuel cell electrolytes
5	**Fuel Cell Mass Transport** 5.1 Flow structure 5.2 Diffusive transport 5.3 Convective transport
	Exam 1 (1 hour 15 minutes)-Thursday, September 28, 2023
6	**Fuel Cell Modeling** 6.1 Basic fuel cell model 6.2 1D fuel cell model
7	**Fuel Cell Characterization** 7.1 Characterization techniques 7.2 In-situ techniques 7.3 Ex-situ techniques
8	**Fuel Cell Types** 8.1 Phosphoric acid fuel cell 8.2 Polymer electrolyte membrane fuel cell 8.3 Alkaline fuel cell 8.4 Molten carbonate fuel cell 8.5 Direct alcohol fuel cell 8.6 Solid-oxide fuel cell
	Exam 2 (1 hour 15 minutes) –Thursday, November 2, 2023
9	**Fuel Cell Systems** 9.1 Fuel cell stack 9.2 Thermal management 9.3 Delivery/processing subsystem 9.4 Power electronic subsystem
10	**Environmental impact of fuel cell** 10.1 Life cycle assessment 10.2 Emissions for LCA 10.3 Emissions related to global warming 10.4 Emissions related to air pollution
11	**Laboratory visit**
	Presentations **Term Project due 12:00 PM, Monday, December 4, 2023** **Final Exam (1:00 PM, Tuesday, December 12, 2023)**