Fuel Cell Systems
(MECH 445/545; 3 Credits)

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Course Description and Overview:

The focus of the Fuel Cell Systems course is to introduce fuel cell systems, fuel processing, hydrogen economy, transport processes in fuel cell, and analysis of fuel cells. A fuel cell is an electrochemical device which combines a fuel and an oxidant, typically oxygen from air, to deliver power. Unlike a battery, which is closed, a fuel cell is open on at least one side, the air side being invariably open. Like a battery, individual cells can be combined together to form a stack and hence delivering whatever power is needed for the given application. The fuel at point of use is commonly hydrogen, but can be a hydrocarbon or other hydrogen containing fuel, decomposed by heat, catalytically, or simply stored at pressure. The fuel cell stack combines fuel and air to form water and generate electricity, cleanly and efficiently.

Course Schedule:

Term 2 (Jan 06, 2020 to Apr 08, 2020)

Section	Activity	Days	Start Time	End Time	Classroom Location
MECH 445 201 MECH 545 201	Lecture	Mon Wed	10:00 am	11:00 am	Building: Frank Forward Room: 317
MECH 445 201 MECH 545 201	Lecture	Fri	10:00 am	11:00 am	Building: Earth Sciences Room: 2012
MECH 445 T2A MECH 545 T2A	Tutorial	Mon	8:00 am	9:00 am	Building: Food Nutrition and Health Room: 40

Course Website:

The primary point of contact outside the classroom will be through Canvas at www.canvas.ubc.ca. All assignments, course notes, and grades will be posted on Canvas as well as any announcements relevant to the course.

Instructor's Office Location and Office Hours:

My office is located at MCLD 451 and my office hours are: Wednesdays and Fridays from 1:00 pm to 2:00 pm. If you need to reach me, my email address is: **siamak.najarian@ubc.ca** (or **siamakn@ece.ubc.ca**).

Teaching Assistant's Contact Information:

Mr. Mohammad Reza Karimi will be your TA for this course and in charge of tutorial sessions, marking group assignments, and group quizzes and also the communications related to the formation of assignments groups. His email address is: **mohammadreza.karimi@ubc.ca**. For any issues related to tutorial sessions, marking of assignments, quizzes, and formation of assignments groups, please contact your TA directly.

Course Objectives:

This course provides fundamental understanding of performance characteristics of fuel cell systems and their components. It also outlines the design characteristics and operating issues for various fuel cells. Additionally, it discusses the design philosophy and challenges to make this system feasible. The design and analysis emphasis will be mostly on the thermodynamics and electrochemistry. Among the main objectives of the course are to: (a) develop a basic understanding of the electrochemical, thermodynamic and transport processes governing fuel cell operation; (b) acquire technical competence in fuel cell technology including design and quantitative analysis of various types of fuel cells and the parameters affecting their performance; and (c) develop an appreciation for some of the practical aspects of fueling and fuel cell system integration and operation.

Student Learning Outcomes:

By the conclusion of this course, each student should

- Apply know-how of thermodynamics, electrochemistry, heat transfer, and fluid mechanics principles to design and analysis of this emerging technology.
- Have thorough understanding of performance behavior, operational issues and challenges for major types of fuel cells.
- Identify, formulate, and solve problems related to fuel cell technology keeping in mind economic viability and sustainability.
- Use the techniques, skills, and modern engineering tools necessary for design and analysis of innovative fuel cell systems.
- Understand the impact of this technology in a global and societal context.
- Develop enough skills to design systems or components of fuel cells.
- Be ready and have sufficient knowledge to begin a career as an engineer in companies developing fuel cell components or R&D organization.

Prerequisites:

MECH 327 (Thermal System Design) and MECH 375 (Heat Transfer).

Requirements:

Regular lecture attendance, regular tutorial attendance, completing assignments on time and delivering them before the deadlines, and successfully taking various exams and quizzes. **Students are expected to come to lectures and tutorials regularly, and to be always on time**.

Textbook and Other Course Materials:

All the course materials will be posted online. They will be in the form of class lecture notes. Various textbooks and references can be used for this course, but the **major reference for the course will be my course materials that will be posted on Canvas.** All the assignments will be available on Canvas in a timely manner. A few optional useful textbooks for this course are:

1. Fuel Cell Fundamentals; 2016; by Ryan O'Hayre , Suk-Won Cha , Whitney Colella, Fritz B. Prinz; Publisher: Wiley.
2. Fuel Cells: Principles, Design, and Analysis; 2014; by Shripad T. Revankar (Author), Pradip Majumdar; Publisher: CRC Press.
3. Fuel Cell Engines; 2008; by Matthew M. Mench; Publisher: Wiley.

Grading System:

Assignments	10%
Quizzes (3 x 5% each)	15%
Tutorial Participation	10%
Midterm Exam	25%
Final Exam	40%

All students are required to attend the final exam. Not attending the final exam leads to a mark of zero for this course. So even if some students reach a mark of 50 (out of a total of 100) before the final exam, they must still take the final exam in order to pass the course. In other words, the above grading scheme is only valid for those who attend the final exam.

Group Assignments:

All the assignments have been prepared by the course instructor, but your TA will be in charge of uploading them on Canvas and marking them. Assignments will be given out periodically (6 sets) and form an important part of the course. Your solutions should be uploaded on Canvas before their deadlines. Each group should consist of about 5 members and the selection of the members will be decided by the students themselves. The electronic version of your group assignments solutions (one assignment solution per each group) should be submitted through Canvas before its due date. The names of the group members along with the name of the member in charge of correspondence with the TA (on behalf of your group) should be emailed to your TA. This should be done before the deadline set by your TA. If for any reason the list of assignments group members is not sent to your TA by the set deadline, he will set up the remaining group members himself and will let the students know the group arrangements a couple of days after the deadline is passed. Once a group is formed we encourage you not to change it. However, if for any reason you need to switch or change your group, you can do it only once by just informing your TA in advance. The same members who form the assignments groups also form the quiz groups. The assignments will cover the following topics:

- Set 1: Renewable and Non-Renewable Energy Sources
- Set 2: Fuel Cell Fluid Mechanics
- Set 3: Fuel Cell Heat Transfer
- Set 4: Fuel Cell Materials Science
- Set 5: Fuel Cell Thermodynamics
- Set 6: Fuel Cell Process Design and Kinetics

It should be noted that your TA will deduct 30% for up to 1-day late submission and then zero marks for later than 1 day late submission.

Group Quizzes:

All quizzes have been prepared by the course instructor, but your TA will be in charge of giving them during tutorial sessions and marking them. There will be three group quizzes in total with 5 members in each group. The quizzes will be mostly in the form of multiple choice tests. There will be no make-ups for missed quizzes. The same members who form the assignments groups also form the quiz groups.

Tutorial Sessions:

All the tutorial problems that will be discussed during the tutorials sessions have been prepared by the instructor. Your TA will be in charge of the TA sessions. The tutorial problems are very similar to your assignments problems. In some cases, I also incorporated more educational materials in both the tutorial problems and the assignments problems. They mostly cover the real-world design aspects of fuel cell systems. Tutorial participation will be measured based on taking attendance. It should be noted that there is a strong correlation between attendance and grades. In order to understand the material, you need to be present in class and tutorial sessions. Regular attendance is necessary in order to be most successful. Poor attendance will drastically affect a student's class participation grade. Please note that arriving late to a class is considered unprofessional.

Cell Phone Policy:

As a matter of courtesy, students are expected to turn off cell phones during class. If extraordinary circumstances require an exception to this policy, the student is expected to discuss this with the instructor or TA before class begins.

Summary of Important Dates:

Event	Date
Quiz 1	Monday, 10 February 2020
Midterm exam	Wednesday, 26 February 2020
Quiz 2	Monday, 16 March 2020
Quiz 3	Monday, 6 April 2020

Course Syllabus:

Energy system architecture and electrochemical energy conversion: fuel cell thermodynamics and electrochemistry; Proton Exchange Membrane Fuel Cells (PMFCs) and Solid Oxide Fuel Cells (SOFCSs); hydrogen production, storage, and distribution. This course consists of the following modules:

Module 1 (Non-Renewable Energy Sources)
Module 2 (Renewable Energy Sources)
Module 3 (Electrochemistry)
Module 4 (Fuel Cell Thermodynamics)
Module 5 (Fuel Cells – Green Power)
Module 6 (Hydrogen Production)
Module 7 (Hydrogen Distribution)
Module 8 (Hydrogen Storage)
Module 9 (Proton Exchange or Polymer Electrolyte Membrane Fuel Cell)
Module 10 (Solid Oxide Fuel Cell)