Birla Institute of Technology & Science, Pilani
Hyderabad Campus

SECOND SEMESTER 2023-2024

Course Handout Part II

Date: 20-12-2023

In addition to part-I (General Handout for all courses appended to the timetable), this portion gives further specific details regarding the course.

Course No.	**:**	**CHE G556**
Course Title	**:**	**Electrochemical Engineering**
Instructor-in-Charge	**:**	**Dr. Ramendra Kishor Pal**

Course Description:
This course introduces basic principles and mathematical models of electrochemical systems. It provides the basics of galvanic cells, electrochemical Energy conversion, electrochemical energy storage, equivalent circuit dynamics, impedance spectroscopy, Impedance of electrodes, Nernst equation, fuel cells and batteries, Faradic equations in dilute solutions, Butler-Volmer equation, reactions in concentrated solutions, ion absorption and intercalation, concentration polarization, forced convection in fuel cells, transient diffusion, Warburg impedance, diffusion in concentrated solutions, transport in bulk electrolytes, ion concentration polarization, double-layer structure, transport on porous media, porous electrodes, supercapacitors, electrostatic correlations, experimental methods.

Scope & Objective:
The objective of the course is to provide students with the required fundamentals of electrochemical systems and engineering applications. By the end of the course, the students should be able to understand the theoretical and experimental understanding of important applications of electrochemical engineering such as batteries, fuel cells, electrodeposition and other electrochemical systems.

Learning objectives:
After completing this course students should be able to:
1) Explain and implement the modelling equations behind electrochemical systems.
2) Understand and perform the experimental techniques involved in electrochemical systems.
3) Explain and discuss important aspects and problems in modelling, design and use of some applications of electrochemical systems (*e.g.* PEM fuel cells and Li-ion batteries)

Text Book:
Thomas Fuller and John Harb, "Electrochemical Engineering", *Wiley*, 1st edition, 2018.

Reference Books:
- Allen J. Bard, Larry R. Faulkner, Henry S. White, "Electrochemical methods: Fundamentals and Applications", *Wiley*, 3rd edition, 2022
- John Newman and Karen Thomas, "Electrochemical Systems", *Wiley*, 3rd edition, 2012.

Course Plan:

Lec No.	Learning Objectives	Topics to be covered	TB Chapter No.
1-2	Introduction and Basic Principles	Scope and objectives of the course, Electrochemical cells, Faraday's law	1
3-5	Cell Potential & Thermodynamics	Electrochemical Reactions, Cell potential, Pourbaix diagrams, Equilibrium at electrode interface, Debye-Huckel theory, Activity Coefficients	2
6 – 10	Electrochemical Kinetics	Double Layer, Butler-Volmer Kinetics, Mass Transfer vs Reaction rate, Cell kinetics	3
11 – 15	Transport Equations	Fick's law, Nernst-Plank equation, Convective mass transport, Concentration overpotential	4
16 – 19	Electrode Structures & Configurations	Porous Electrodes, Three-phase electrodes	5
20 – 27	Electroanalytical Techniques	Electrode Kinetics, CV, SP, EIS, RRDE, iR compensation, Microelectrodes	6
28 – 32	Battery	Theoretical Capacity, State of charge, Cell characteristics, Efficiency, Capacity Fade, Battery layout, Electrode & Cell Design, Ionomers	7&8
33 – 35	Fuel Cell	I-V Characteristics, Polarizations, PEM Fuel Cell	9
36 – 38	Industry Applications	Electrochemical Reactors, Redox-flow battery	14
39 – 40	Photo-electrochemistry	Semiconductor-Electrolyte Interface, Photo-electrochemistry	15
41– 42	Bioelectrochemistry	Membrane Potential and Cellular Biology, Electrochemical Mechanisms of the Nervous System	Class notes

Planned Lab Experiments:

S. No.	Experiment Name
1	Introduction to potentiostat and various electrodes; preparation of Ag/AgCl reference electrode
2	Modelling the Butler-Volmer Equations
3	Performing Linear Sweep Voltammetry
4	Performing Cyclic Voltammetry, scan rate vs peak current
5	Performing Electrochemical Impedance Spectroscopy
6	Analyzing the Electrochemical Impedance Spectroscopy Data -I
7	Differential pulse voltammetry and sensing of an electroactive molecule
8	Electrochemical Deposition of Conducting Polymer; Calculation of the ECSA
9	Building a supercapacitor
10	Testing the supercapacitance; Calculating specific capacitance –I, Specific Energy vs Specific Power
11	Fabrication of a Redox Flow Battery
12	Testing of a Redox Flow Battery

Evaluation Scheme:

Component	Duration	Weightage (%)	Date & Time	Nature of Component
Quizzes (2 best of 3)	45 minutes	10%	TBA	Open Book
Group Project- Part A	TBA	5%	TBA	Open Book
Group Project- Part B	TBA	15%	TBA	Open Book
Mid Semester Exam	1.5 hours	20%	TBA	Open Book
Lab Component	TBA	20%	TBA	Open Book
Comprehensive Exam	3 hours	30%	14/05/23, FN	Open Book

Note:

- Students must wear PPEs (aprons, gloves, closed shoes, etc.) during lab sessions.
- Lab safety rules are noted outside the lab. More details will be provided during the first lab session.
- A total of three quizzes will be conducted. Two best of three will be considered.

Chamber Consultation Hour: Thursday, 5 to 6 PM (Chamber: **D 321**).

Notices: Will be updated via CMS

Make-up Policy: No make-up for the quizzes, group projects, and lab components. Make-up for mid-semester or comprehensive exams will be granted only for genuine cases with valid justification and only with prior permission from the Instructor-in-charge.

Academic Honesty and Integrity Policy: Academic honesty and integrity are to be maintained by all the students throughout the semester, and no type of academic dishonesty is acceptable.

Dr. Ramendra Kishor Pal
INSTRUCTOR-IN-CHARGE