MSE6187: ELECTROCHEMICAL ENERGY STORAGE

Effective Term
Semester A 2026/27

Part I Course Overview

Course Title
Electrochemical Energy Storage

Subject Code
MSE - Materials Science and Engineering

Course Number
6187

Academic Unit
Materials Science and Engineering (MSE)

College/School
College of Engineering (EG)

Course Duration
One Semester

Credit Units
3

Level
P5, P6 - Postgraduate Degree

Medium of Instruction
English

Medium of Assessment
English

Prerequisites
Nil

Precursors
Nil

Equivalent Courses
Nil

Exclusive Courses
MSE6176

Part II Course Details

Abstract

This course offers a comprehensive introduction to electrochemical energy storage technologies, providing students with both foundational knowledge and practical insights into systems such as batteries, supercapacitors, and fuel cells. Designed for students in Materials Science and Engineering and related disciplines, it covers electrochemical principles, materials selection, and system-level design essential to modern energy storage.

Topics include thermodynamics, kinetics, and transport processes, along with the structure and function of device components like anodes, cathodes, and electrolytes. Students will explore both established technologies—such as lithium-ion batteries—and emerging systems including sodium-ion, solid-state, and lithium-sulfur batteries. Additional topics include supercapacitors, flow batteries, hydrogen fuel cells, and their role in renewable energy integration.

Through lectures, case studies, and projects, students will engage with innovations in materials science and sustainability for system optimization. The course also examines environmental impacts, recycling, and future challenges. Graduates will be prepared for roles in clean energy and sustainable technologies.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	Understand the fundamental principles of electrochemical energy storage devices, including batteries, supercapacitors, and fuel cells.	25	x		
2	Analyze the performance and efficiency of various energy storage systems through key metrics such as energy density, capacity, and stability.	25		x	
3	Investigate and assess the role of materials in determining the performance of energy storage technologies.	25	x		
4	Apply theoretical knowledge to real-world applications, such as energy storage integration with renewable energy sources, electric vehicles, and grid systems.	15			x
5	Assess the environmental impact, sustainability, and future technological challenges related to electrochemical energy storage systems.	10	x		

A1: Attitude
Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

A2: Ability
Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

A3: Accomplishments
Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

Learning and Teaching Activities (LTAs)

	LTAs	Brief Description	CILO No.	Hours/week (if applicable)
1	Lectures	Lectures	1, 2, 3, 4, 5	2 hrs
2	Tutorial	Tutorial	1, 2, 3, 4, 5	1 hr

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks ("-" for nil entry)	Allow Use of GenAI?
1	Assignments	2, 3, 4, 5	30	-	No
2	Midterm Tests	1, 2, 3	30	-	No

Continuous Assessment (%)

60

Examination (%)

40

Examination Duration (Hours)

2

Assessment Rubrics (AR)

Assessment Task

Assignments (students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

UNDERSTANDING concepts of energy storage materials and devices, their working principles, characterization techniques, and applications

Excellent

(A+, A, A-) High

Good

(B+, B, B-) Significant

Fair

(C+, C, C-) Moderate

Marginal

(D) Basic

Failure

(F) Not even reaching marginal levels

Assessment Task

Midterm Tests (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

CAPACITY to solve an engineering problem related to energy materials and device design

Excellent

(A+, A, A-) High

Good

(B+, B, B-) Significant

Fair

(C+, C, C-) Moderate

Marginal
(D) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Examination (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion
ABILITY to ANALYSE problems and EXPLAIN engineering concepts related to energy storage materials and devices

Excellent
(A+, A, A-) High

Good
(B+, B, B-) Significant

Fair
(C+, C, C-) Moderate

Marginal
(D) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Assignments (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
UNDERSTANDING concepts of energy storage materials and devices, their working principles, characterization techniques, and applications

Excellent
(A+, A, A-) High

Good
(B+, B) Moderate

Marginal
(B-, C+, C) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Midterm Tests (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion

CAPACITY to solve an engineering problem related to energy materials and device design

Excellent
(A+, A, A-) High

Good
(B+, B) Moderate

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Assessment Task
Examination (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
ABILITY to ANALYSE problems and EXPLAIN engineering concepts related to energy storage materials and devices

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(A+, A, A-) High

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(B-, C+, C) Basic

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Part III Other Information

Keyword Syllabus

1) Introduction to Electrochemical Energy Storage

- Overview of energy storage systems and their importance in modern society.
- Types of electrochemical energy storage devices (batteries, supercapacitors, fuel cells).
- Basic electrochemical principles: Redox reactions, electrochemical cells, and potentials.
- Nernst equation and its applications.
- Electrochemical potential and its relationship to voltage.
- Kinetic processes: Charge transfer, diffusion, and electrode reaction mechanisms.

2) Battery Technologies

- Basics of Lithium-Ion Batteries
- Advanced Lithium-Ion Batteries
- Sodium-Ion and Other Alkali-Ion Batteries
- Beyond Lithium-Ion – Magnesium, Zinc, and Aluminum Batteries

3)Supercapacitors and Electrochemical Capacitors

- Basics of supercapacitors: Capacitance, energy storage, and charge/discharge dynamics.
- Comparison with batteries: Advantages and limitations.
- Applications of supercapacitors in hybrid systems.

4) Flow Batteries

- Principles of flow batteries and their unique advantages.
- Types of flow batteries: Vanadium redox, all-vanadium, zinc-bromine, and others.
- Applications in grid storage and large-scale energy systems.

5) Fuel Cells and Hydrogen Storage

- Fundamentals of fuel cell operation (PEM, SOFC, etc.).
- Electrochemical reactions in fuel cells.
- Hydrogen storage: Methods and materials for efficient storage.

6) Advanced Topics in Electrochemical Energy Storage

- Emerging technologies: Solid-state batteries, lithium-sulfur batteries, and sodium-sulfur batteries, etc.
- The role of artificial intelligence and machine learning in energy storage optimization.
- Advances in materials science for electrochemical energy storage.

7) Energy Storage Systems Integration and Applications

- Integration of energy storage systems in renewable energy grids.
- Hybrid systems: Batteries and supercapacitors.
- Case studies: Energy storage in electric vehicles, portable electronics, and renewable energy systems.

8) Environmental Impact and Sustainability

- Recycling and second-life applications for batteries.
- Sustainability challenges and opportunities in electrochemical energy storage.

9) Future Trends and Challenges in Electrochemical Energy Storage

- Current limitations in energy density, cost, and performance.
- Technological advancements and the future of electrochemical energy storage.
- Policy, economic, and social considerations in the adoption of energy storage technologies.

Reading List

Additional Readings

	Title
1	"Electrochemical Energy Storage for Renewable Sources and Grid Balancing" – Patrick T. Moseley, Jürgen Garche
2	"Electrochemical Systems" – John Newman and Karen E. Thomas-Alyea
3	"Lithium-Ion Batteries: Science and Technologies" – Masaki Yoshio, et al.
4	"Advanced Batteries: Materials Science Aspects" – Robert A. Huggins.
5	Selected research papers and articles from journals such as Nature Energy, Journal of Power Sources, and Energy Storage Materials.