PHY6526: ENERGY MATERIALS: PHYSICS AND APPLICATIONS

Effective Term
Semester A 2025/26

Part I Course Overview

Course Title
Energy Materials: Physics and Applications

Subject Code
PHY - Physics

Course Number
6526

Academic Unit
Physics (PHY)

College/School
College of Science (SI)

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
PHY8526 Energy Materials: Physics and Applications

Part II Course Details

Abstract

Nowadays, economic development relies heavily on energy resources and energy technologies. Considerable efforts have been devoted to the design of novel materials for energy-related applications, especially the generation and storage of renewable energies such as solar energy and batteries. This course aims to provide students an introduction to the physics and applications of energy materials including battery materials, photovoltaic materials as well as the materials for fuel cell and hydrogen technology. Emphasis will be put on the discussions of underlying physical mechanism, general performance, current limitations and challenges.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	Describe the physical concepts and principles of energy materials	30		x	
2	Relate the materials' properties with their applications	20		x	
3	Describe the intrinsic and practical limitations of various energy materials	10	x		
4	Identify challenges in current development of energy materials and technologies	20		x	
5	Develop possible solutions and designs for the generation and storage of renewable energies	20			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	1	Lectures	1, 2, 3, 4, 5	26 hrs/13 wks
2	2	Tutorials	1, 2, 3	6 hrs/ 6 wks
3	3	Individual project and presentation	4, 5	6 hrs/ 6 wks

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks ("-" for nil entry)	Allow Use of GenAI?
1	Quizzes	1, 2	20	-	No
2	Presentation	1	40	Individual project	No
3	Final Report	1	40	Individual project	Yes

Continuous Assessment (%)

100

Assessment Rubrics (AR)

Assessment Task

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

Criterion

The student completes all assessment tasks and activities, including answering questions and simulating representative systems related to the taught topics on the class. Understanding the physical concepts related to common energy materials and their design principles.

Excellent

(A+, A, A-) High(Excellent accomplishment with creativity and correct understanding)

Good

(B+, B, B-) Significant(Good accomplishment with mostly correct understanding)

Fair

(C+, C, C-) Moderate(fair accomplishment with some correct understanding)

Marginal

(D) Basic (essential accomplishment with basic understanding)

Failure

(F) Not reaching marginal level

Assessment Task

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

Criterion

Understanding the physical mechanisms, applications, and limitations of selected energy material; Identify challenges and develop possible solutions.

Excellent

(A+, A, A-) High(Excellent accomplishment with creativity and correct understanding)

Good

(B+, B, B-) Significant(Good accomplishment with mostly correct understanding)

Fair

(C+, C, C-) Moderate(fair accomplishment with some correct understanding)

Marginal

(D) Basic(Essential accomplishment with basic understanding)

Failure

(F) Not reaching marginal level

Assessment Task

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

Criterion

Having an in-depth understanding of the selected energy materials, including its properties, development and limitations. Also, the student’s report should demonstrate clear original thinking, backed by a diverse range of properly cited information sources beyond the provided course materials.

Excellent

(A+, A, A-) High(Excellent accomplishment with creativity and correct understanding)

Good

(B+, B, B-) Significant(Good accomplishment with mostly correct understanding)

Fair

(C+, C, C-) Moderate(fair accomplishment with some correct understanding)

Marginal

(D) Basic(Essential accomplishment with basic understanding)

Failure

(F) Not reaching marginal level

Assessment Task

Quizzes (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion

The student completes all assessment tasks and activities, including answering questions and simulating representative systems related to the taught topics on the class. Understanding the physical concepts related to common energy materials and their design principles.

Excellent

(A+, A, A-) High(Excellent accomplishment with creativity and correct understanding)

Good

(B+, B) Significant(Good accomplishment with mostly correct understanding)

Marginal

(B-, C+, C) Basic(fair accomplishment with some correct understanding)

Failure

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Assessment Task

Presentation (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion

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Assessment Task

Final Report (for students admitted from Semester A 2022/23 to Summer Term 2024)

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Part III Other Information

Keyword Syllabus

Battery materials
- Electrochemical fundamentals, electrochemical cell, charging and discharging, phase transition, order-disorder transition, electrode processes at equilibrium, energy efficiency, cycle life
- Materials for electrode (e.g., $LiCoO_2$, $LiFePO_4$, graphite)
- Materials for non-rechargeable batteries (e.g., alkaline battery)
- Materials for rechargeable batteries (e.g., aluminium-ion battery, lithium-ion battery)

Photovoltaic (PV) materials
- Electrodynamic basics, electromagnetic waves, optics of flat interfaces, light absorption
- Solar radiation, solar spectra, solar energy concentration, solar cell parameters, losses and efficiency limits
- Crystalline silicon solar cells, thin-film solar cells, and other types
- PV modules and systems (components, design, and fabrication)
- PV system economics and ecology

Fuel cell applications

- Overview of fuel cell types, charge transfer and mass transport in fuel cells
- Thermodynamics and reaction kinetics in Fuel cell
- Proton exchange membrane and solid oxide fuel cell materials
- Fuel cell system design and characterization

Materials for hydrogen technology
- Hydrogen production (e.g., electrolytic production, thermal decomposition of water, chemical extraction), hydrogen from the decomposition of materials containing hydride anions
- Hydrogen storage in solids: metal hydrides, ammonia and related materials, reversible organic

Reading List

Compulsory Readings

	Title
1	Fuel Cell Fundamentals, O' Hayre Cha, Colella, and Prinz, Wiley, any Edition
2	"Solar Energy: The Physics and Engineering of Photovoltaic Conversion, Technologies and Systems", A. Smets K. Jäger O. Isabella, R. V. Swaaij M. Zeman, UIT Cambridge, 2016.
3	"Thermoelectrics: Basic Principles and New Materials Developments", G.S. Nolas J. Sharp, J. Goldsmid Springer, 2001.
4	"Energy Storage: Fundamentals, Materials and Applications", Robert Huggins, Springer, 2nd ed. 2016.

Additional Readings

	Title
1	"Energy Materials", D. W. Bruce, D. O'Hare, R. I. Walton, Wiley, 2011."
2	"Thermoelectricity: An Introduction to the Principles", D. K. C. MacDonald, Dover Publications, 2006.
3	"First-principles investigation of phase stability in LixCoO2", A. Van der Ven, M. K. Aydinol and G. Ceder Physical Review B 58, 2975-2987 (1998).
4	"Electrochemical and in situ X - ray diffraction studies of lithium intercalation in LixCoO2", Jan N. Reimers and J. R. Dahn, Journal of The Electrochemical Society 139, 2091-2097 (1992).