City University of Hong Kong
Course Syllabus

offered by Department of Physics
with effect from Semester A 2020/21

Part I Course Overview

Course Title:	**Energy Materials: Physics and Applications**
Course Code:	**PHY8526**
Course Duration:	**1 semester**
Credit Units:	**3**
Level:	**R8**
Medium of Instruction:	**English**
Medium of Assessment:	**English**
Prerequisites: *(Course Code and Title)*	**Nil**
Precursors: *(Course Code and Title)*	**Nil**
Equivalent Courses: *(Course Code and Title)*	**Nil**
Exclusive Courses: *(Course Code and Title)*	**PHY6526 Energy Materials: Physics and Applications**

Part II Course Details

1. 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. This course aims to provide students an introduction to the physics and applications of energy materials including semiconductor materials, photovoltaic materials, thermoelectric materials, as well as the materials for hydrogen technology. Emphasis will be put on the discussions of underlying physical mechanism, general performance, current limitations and challenges.

2. Course Intended Learning Outcomes (CILOs)

No.	CILOs#	Weighting* (if applicable)	Discovery-enriched curriculum related learning outcomes (please tick where appropriate)		
			A1	*A2*	*A3*
1.	Describe the physical concepts and principles of energy materials	30%		√	
2.	Relate the materials' properties with their applications	20%		√	
3.	Describe the intrinsic and practical limitations of various energy materials	10%	√		
4.	Identify challenges in current development of energy materials and technologies	20%		√	
5.	Develop possible solutions and designs for the generation and storage of renewable energies	20%			√
		100%			

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 self-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.

3. Teaching and Learning Activities (TLAs)

TLA	Brief Description	CILO No.						Hours/week (if applicable)
		1	2	3	4	5		
1	Lectures	√	√	√	√	√		26 hrs/13 wks
2	Tutorials	√	√	√				6 hrs/ 6 wks
3	Group project and presentation				√	√		6 hrs/ 6 wks

4. Assessment Tasks/Activities (ATs)

Assessment Tasks/Activities	CILO No.						Weighting*	Remarks
	1	2	3	4	5			
Continuous Assessment: 50%								
Assignment	√	√	√	√	√		10	
Presentation			√	√	√		20	Group project
Report			√	√	√		20	Group project
Examination: 50% (duration: 2 hours)								
Examination	√	√	√				50	
							100%	

5. Assessment Rubrics

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B, B-)	Fair (C+, C, C-)	Marginal (D)	Failure (F)
1. Assignment	Understanding the physical concepts related to common energy materials and their design principles	High	Significant	Moderate	Basic	Not reaching marginal level
2. Presentation	Understanding the physical mechanisms, applications, and limitations of selected energy material; Identify challenges and develop possible solutions	High	Significant	Moderate	Basic	Not reaching marginal level
3. Report	Having an in-depth understanding of the selected energy materials, including its properties, development and limitations	High	Significant	Moderate	Basic	Not reaching marginal level
4. Examination	Ability of solving problems related to physics of energy materials	High	Significant	Moderate	Basic	Not reaching marginal level

Part III Other Information

1. Keyword Syllabus

- Semiconductors physics
  - Review of quantum theory of solid, crystal structures, band theory, electron transport in solids
  - Charge carriers, doping, carrier concentrations, carrier transport phenomena (drift, diffusion, impurity distribution), carrier generation and recombination
  - Semiconductor junctions, pn junction, and heterojunctions
  - Optical processes in semiconductors, optical absorption

- 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

- Thermoelectric materials
  - The Kelvin relations, Thomson heat and thermoelectric power, Drude-Lorentz model, Boltzmann equation, phonon drag and phonon scattering, electron scattering by impurities, thermoelectric cooling, thermal conductivity, Seebeck coefficient, thermogalvanomagnetic effects
  - Materials for thermoelectric generators, low-dimensional thermoelectric materials
  - Thermionic refrigeration

- 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., $LiCoO_2$)
  - Materials for non-rechargeable batteries (e.g., alkaline battery)
  - Materials for rechargeable batteries (e.g., aluminium-ion battery, lithium-ion battery)

- 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 liquids

2. Reading List
2.1 Compulsory Readings

1.	"Semiconductor Physics and Devices: Basic Principles", D. A. Neamen, McGraw-Hill, 2011.
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.

2.2 Additional Readings

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 Li_xCoO_2", A. Van der Ven, M. K. Aydinol, and G. Ceder, Physical Review B 58, 2975-2987 (1998).
4.	"Electrochemical and i*n situ* X-ray diffraction studies of lithium intercalation in Li_xCoO_2", Jan N. Reimers and J. R. Dahn, Journal of The Electrochemical Society 139, 2091-2097 (1992).