City University of Hong Kong
Course Syllabus

offered by Department of Physics
with effect from Semester A 2022/23

Part I Course Overview

Course Title:	**Modern Scattering Methods in Materials Science**
Course Code:	**PHY6180**
Course Duration:	**One semester**
Credit Units:	**3**
Level:	**P6**
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)*	**AP6180 Modern Scattering Methods in Materials Science**
Exclusive Courses: *(Course Code and Title)*	**AP8180/PHY8180 Modern Scattering Methods in Materials Science**

Part II Course Details

1. Abstract

This course covers a range of experimental and applied-physics topics and methods in materials science that involve X-ray and neutron scattering in the laboratory and as well as at large-scale facilities like at synchrotrons, at research nuclear-reactors, or at spallation neutron-sources. Its central aims are: (1) to describe the fundamentals of scattering by condensed matter, (2) to introduce the different commonly employed scattering techniques available in the laboratory and at large-scale facilities, (3) to show the possible applications in discovering advanced materials and (4) to motivate the students for discovery and innovation in applying scattering techniques in materials science.

2. Course Intended Learning Outcomes (CILOs)

(CILOs state what the student is expected to be able to do at the end of the course according to a given standard of performance.)

No.	CILOs	Weighting (if applicable)	Discovery-enriched curriculum related learning outcomes (please tick where appropriate)		
			A1	*A2*	*A3*
1.	Explain the importance of modern scattering techniques and their applications in material research.		√		
2.	Acquire the fundamental knowledge about different scattering techniques with special emphasis on neutron diffraction.		√		
3.	Clarify the similarities and differences between X-ray and neutron scattering.		√		
4.	Recognize the fundamental theory of scattering and its application to study the structures of different classes of materials.			√	
5.	Apply the kinematical diffraction theory to materials science problems.			√	√
6.	Master the basic knowledge of small-angle-X-ray-scattering (SAXS) and small-angle-neutron-scattering (SANS) for determining the large-scale structure of materials			√	√
7.	Describe the basics of inelastic-neutron-scattering (INS) and quasi-elastic-neutron-scattering (QENS) for being able to study the dynamics of liquids and soft materials			√	√
8.	Observe specific case-studies for better understanding the practical application of 1 to 7				√
		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, acquire research skills, synthesize knowledge across disciplines, or apply 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)

(TLAs designed to facilitate students' achievement of the CILOs.)

TLA	Brief Description	CILO No.								Hours/week (if applicable)
		1	2	3	4	5	6	7	8	
Lectures	Explain the basic principles of modern theories related to diffraction, small-angle, inelastic and quasi-elastic scattering techniques	√	√	√	√	√	√	√		2
Tutorials	Problem solving related to scattering	√	√	√	√	√	√	√		1
Project	Analysis of neutron scattering data of small-angle x-ray/neutron scattering and/or quasi-elastic neutron scattering								√	1

The "Lectures" will be in the form of 2-hrs lectures each week, while the "Tutorials" and/or the "Laboratory demonstrations" will always follow the lectures.

4. Assessment Tasks/Activities (ATs)

(ATs are designed to assess how well the students achieve the CILOs.)

Assessment Tasks/Activities	CILO No.								Weighting	Remarks
	1	2	3	4	5	6	7	8		
Continuous Assessment: 60%										
Assignments		√	√	√	√	√	√		10	
Project							√	√	20	
Midterm Test	√	√	√	√	√	√	√		30	
Examination: 40% (duration: 2 hours)	√	√	√	√	√	√	√		40	
									100%	

5. Assessment Rubrics

(Grading of student achievements is based on student performance in assessment tasks/activities with the following rubrics.)

Applicable to students admitted in Semester A 2022/23 and thereafter

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B)	Marginal (B-, C+, C)	Failure (F)
1. Assignments	Explain key concepts of modern scattering methods	High	Significant	Moderate	Not even marginal level
2. Project	Basic skills in data analysis of SAXS/SANS and QENS	High	Significant	Moderate	Not even marginal level
3. Midterm Test	Ability to explain concepts of different scattering methods	High	Significant	Moderate	Not even marginal level
4. Final examination	Understanding of fundamental concepts of different scattering methods, including diffraction, SAXS, SANS, INS, and QENS	High	Significant	Moderate	Not even marginal level

Applicable to students admitted before Semester A 2022/23

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B, B-)	Fair (C+, C, C-)	Marginal (D)	Failure (F)
1. Assignments	Explain key concepts of modern scattering methods	High	Significant	Moderate	Basic	Not even marginal level
2. Project	Basic understanding of data analysis of SAXS/SANS or QENS	High	Significant	Moderate	Basic	Not even marginal level
3. Midterm Test	Ability to explain concepts of different scattering methods	High	Significant	Moderate	Basic	Not even marginal level
4. Final examination	Ability to explain key concepts of diffraction, SAXS, SANS, INS, and QENS scattering methods	High	Significant	Moderate	Basic	Not even marginal level

Part III Other Information (more details can be provided separately in the teaching plan)

1. Keyword Syllabus

● Introduction

Basics of the structure of condensed materials: From atoms to the structures of crystalline, liquid and amorphous substances with showing materials of specific interest in modern life

● Fundamentals of scattering techniques: neutron diffraction, X-rays diffraction, scattering mechanisms, similarities and differences in X-ray and neutron scattering

● Fundamentals of the kinematical scattering theory, correlation between real and reciprocal space, and its relevance to understanding the structure of materials

● Small-angle-X-ray-scattering (SAXS) and small-angle-neutron-scattering (SANS), scattering by non-crystalline materials

● Inelastic-neutron-scattering (INS) and Quasi-elastic-neutron-scattering (QENS), atomic and molecular motion, and magnetic and crystal field excitations

● Specific case studies, atomic/molecular motion in liquids, the structure of bulk metallic glasses, magnetic shape-memory alloys, the dislocation density to strengthen metallic materials, internal stress measurements in engineering materials, interaction of water with biomolecules, etc.

2. Reading List

2.1 Compulsory Readings

(Compulsory readings can include books, book chapters, or journal/magazine articles. There are also collections of e-books, e-journals available from the CityU Library.)

1.	B. E. Warren, X-ray diffraction, Dover Books on Physics, 1964
2.	G. L. Squires, Introduction to the Theory of Thermal Neutron Scattering, Cambridge University Press, 1978

2.2 Additional Readings

(Additional references for students to learn to expand their knowledge about the subject.)

1.	L. H. Schwartz & J. B. Cohen, Diffraction from materials, Academic Press, 1977
2.	G. E. Bacon, Neutron diffraction, Clarendon Press, 1975
3.	Ilias Michalarias & Dr. Jichen Li, Neutron Scattering Experiments of Water in Biomolecules, University of Manchester, 2005
4.	F. H. Chung & D. K. Smith Eds. Industrial Applications of X-ray Diffraction, Marcel Dekker, Inc. USA, 2000
5.	M. Bee, Quasielastic Neutron Scattering, Principles and Applications in Solid State Chemistry, Biology and Materials Science, Taylor & Francis; 1 edition (January 1, 1988)
6.	Stewart F. Parker, Inelastic Neutron Scattering Spectroscopy, Wiley, 2006.
7.	T. Egami and S. J. L. Billinge, "Underneath the Bragg Peaks, Structure Analysis of Complex Materials," Elsevier, 2003.
8.	Linan Tian, A Kolesnikov and Jichen Li. Ab Initio Simulation of Hydrogen Bonding in Ices under Ultra-High Pressure. J. Chem. Physics. 2012
9.	D. Ma, A. D. Stoica, X.-L. Wang, Z. P. Lu, B. Clausen, D. W. Brown, "Moduli inheritance and the weakest link in metallic glasses," Phys. Rev. Lett., 108, 085501 (2012)
10.	S. Cheng, A.D. Stoica, X.-L. Wang, Y. Ren, J. Almer, J.A. Horton, C.T. Liu, B. Clausen, D.W. Brown, P.K. Liaw, and L. Zuo, "Deformation cross-over: from nano to meso

	scales," Physical Review Letters 103, 035502 (2009)
11.	P. Cordier, T. Ungar, L. Zsoldos, G. Tichy, Dislocation creep in $MgSiO_3$ perovskite at conditions of the Earth's uppermost lower mantle, Nature, 428 (2004) 837
12.	S. M. Chathoth, E. Mamontov, Y. B. Melnichenko and M. Zamponi, Diffusion and adsorption of methane confined in nano-porous carbon aerogel: a combined quasi-elastic and small-angle neutron scattering study, Mesoporous and Microporous Materials, 132, 148 (2010)