Course Code	PHYS8202 (RPG)		
Title	Special Topics in Physics		
Credit Weighting	6		
Offering Department	Physics		
Course Co-ordinator	Prof. Zi Yang Meng Physics		
Course Co-ordinator Email	zymeng@hku.hk		
Teachers Involved	Name	Department	Percentage
	Prof. Zi Yang Meng	Physics	100
Course Objectives	Modern computational approaches are playing increasingly important roles in the advances of condensed matter physics and quantum material research, particularly in quantum many-body systems, where strong correlations among multiple degrees of freedom, including electronic, spin, lattice, and orbital, have rendered conventional methods inadequate. In recent years, a new trend of research, combining modern computational methods, such as exact diagonalization, quantum Monte Carlo, tensor network, neural network and artificial intelligence, and modern theoretical approaches such as quantum field theory and symmetry analysis as well as topological techniques, has emerged and enabled scientists to thoroughly and in an interdisciplinary manner, investigate the highly entangled quantum phases of matter, 2D moire materials, light-matter interaction, quantum simulators and Rydberg atom arrays, etc. Considering these rapid developments and their lack of systematic introduction and education to senior undergraduate and graduate students and researchers in HKU and even the GBA area, this course is designed to cover the advanced topics in quantum many-body computation and theoretical understanding in strongly correlated electron systems and quantum materials. Based on the frontier research type exercises, course projects and group discussion, as well as the platform-free cloud computing environment offered by the teacher https://quantummc.xyz/teaching/, we plan to teach senior undergraduate and graduate students and junior researchers in HKU and other institutions in Hong Kong, in condensed matter, quantum material, particle physics as well as astrophysics, the basic and live knowledge of modern quantum many-body computation, such that they can apply them into their research works in the corresponding areas.		
Course Contents & Topics	Topics include: Basic data analysis methods such as error analysis, chi-square analysis and regression approaches; basic random number generators and stochastic processes; basic introduction of application of AI in quantum physics research. Hartree-Fock mean-field theories for quantum many-body models such as Hubbard model and Heisenberg model on different lattices, to understand the various Landau-Ginzburg-Wilson types of symmetry-breaking phases and phase transitions (with algorithm note and platform-free cloud computation code under the path https://quantummc.xyz/teaching/mean-field/); Exact Diagonalization with symmetry and quantum number implemented for quantum spin systems and field theory with topological term, to understand the basics of modern quantum phase transitions. (with algorithm note and platform-free cloud computation code under the path https://quantummc.xyz/ed/);		

	Quantum Monte Carlo algorithms for interacting fermion and spin/boson lattice models and quantum entanglement measurements, to understand the basic concept of quantum phase transitions and gradually cover the unconventional quantum matter beyond Landau-Ginzburg, and to teach how to implement the modern computational algorithm in 2D material and quantum simulator research (with the algorithm note and platform-free cloud computation code under the path https://quantummc.xyz/dqmc/); Density Matrix Renormalization Group and Tensor network methods, dynamic and thermodynamic computations for quantum many-body systems, to teach how to compute the experimentally relevant quantities such as transport, specific heat and spectroscopies in quantum magnetism and 2D materials. (with the algorithm note and platform-free cloud computation code under the path https://quantummc.xyz/teaching/dmrg/)
Course Learning Outcomes (CLO)	On successful completion of this course, students should be able to: CLO 1 understand the basic computational knowledge in the research of condensed matter, quantum material, particle physics as well as astrophysics. CLO 2 comprehend the mathematical and physical considerations behind these modern computational approaches. CLO 3 apply these quantum many-body computation techniques into his/her own research activities. CLO 4 design and improve the existing numerical algorithms in his/her research works.
Pre-requisites (and Co-requisites and Impermissible combinations)	Nil
Offer in 2025 - 2026	Y 1st sem / Examination: No Exam
Course Grade	Pass or Fail
Grade Descriptors	Pass: Demonstrate thorough mastery at an advanced level of extensive knowledge and skills required for attaining all the course learning outcomes. Show strong analytical and critical abilities and logical thinking, with evidence of original thought, and ability to apply knowledge to a wide range of complex, familiar and unfamiliar situations. Apply highly effective organizational and presentational skills. Fail: Demonstrate little or no evidence of command of knowledge and skills required for attaining the course learning outcomes. Lack of analytical and critical abilities, logical and coherent thinking. Show very little or no ability to apply knowledge to solve problems. Organization and presentational skills are minimally effective or ineffective.
Course Type	Lecture with laboratory component elective course

Course Teaching & Learning Activities	Activities	Details	No. of Hours
	Lectures		36
	Laboratory (code practise)		12
	Tutorials		8
	Reading/Self study		80

Assessment Methods and Weighting	Methods	Details	Weighting in final course grade (%)	Assessment Methods to CLO Mapping
	Assignments		40	CLO 1,2,3
	Presentation		20	CLO 1,2,3,4
	Project reports		40	CLO 1,2,3,4
Quota	9999 (9999 if no quota)			
Required/recommended reading and online materials	Lecture notes provided by Course Coordinator Please follow my teaching page https://quantummc.xyz/teaching/			