Special/Select Topics in Classical and Quantum Physics
SWAYAM Prabha course S8

PROFESSOR'S NAME	P. C. Deshmukh
DEPARTMENT	Physics
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COURSE OUTLINE	Special/Select Topics in Classical and Quantum Physics are presented in this lecture course. These lectures supplement, and complement, earlier lectures by PCD for NPTEL on Classical Mechanics, Atomic Physics, and Atomic Collisions and Spectroscopy. The course is organized in two modules (4 lectures) on classical mechanics, five modules (10 lectures) on electrodynamics, and seven modules (32 lectures) on quantum physics. New topics added in the domain of classical mechanics include further discussion on the variational principle in classical mechanics, rotations and angular momentum, laws of electrodynamics, and a primary introduction to the special and general theory of relativity. Topics added in the domain of quantum physics include EPR paradox, Bell's theorem, Feynman's path integral approach to quantum physics, Aharonov-Bohm effect, Quantum entanglement, quantum gates, introduction to quantum computing, and several aspects of Quantum Optics, including Rabi oscillations and the Jaynes-Cummings model.

Course Details: Classical Mechanics (Module 1 and 2)

Sr. No.	Module No.	Subject	Topic
01	1	Classical Variational Principle	Brachistochrone
02	1	Classical Variational Principle	Isochronous Pendulum
03	1	Classical Variational Principle	More Applications of Variational Principle
04	2	Rotations in Classical Mechanics	Rotations; Moment of Inertia Tensor

Course Details: Electrodynamics (Module 1 to 5)

Sr. No.	Module No.	Subject	Topic
01	1	Semi-empirical Electrodynamics	Semi-empirical Classical Electrodynamics
02	1	Semi-empirical Electrodynamics	Energy of a Charge Distribution
03	2	Steady State Electromagnetism	Biot, Savart, Ampere Laws
04	2	Steady State Electromagnetism	Multipole Expansions
05	3	Semi-empirical to Theoretical Electrodynamics:	Uniqueness Theorem

06	3	Semi-empirical to Theoretical Electrodynamics:	Helmholtz Theorem
07	3	Semi-empirical to Theoretical Electrodynamics:	Maxwell's Equations and Interface Boundary Conditions
08	4	Electromagnetic Waves	EM Waves, Energy, and Momentum; Poynting Vector
09	5	STR & EM theory	Electromagnetic Field Tensor
10	5	STR & EM theory	Invariance of Maxwell's equations under Lorentz transformations

Course Details: Quantum Physics (Module 1 to 7)

Sr. No.	Module No.	Subject	Topic
01	1	Inadequacy of Classical Physics	The Necessity to Supersede Classical Mechanics by Quantum physics
02	2	Uncertainty Principle and Schrodinger Equation	Linear Vector Spaces; Mathematical Formalism of Quantum Physics
03	2	Uncertainty Principle and Schrodinger Equation	Hermitian Operators; Observables.
04	2	Uncertainty Principle and Schrodinger Equation	CSCO: Complete Set of Compatible Observables; Commuting Operators
05	2	Uncertainty Principle and Schrodinger Equation	Uncertainty principle and the Schrodinger Equation
06	2	Uncertainty Principle and Schrodinger Equation	Quantum Tunnelling
07	3	Evolution of a quantum state	Generators of Translations and Rotations; Linear and Angular Momentum
08	3	Evolution of a quantum state	Evolution of a Quantum State
09	3	Evolution of a quantum state	Schrodinger, Heisenberg, and Dirac Picture of Quantum Evolution
10	4	Feynman Path Integrals	Feynman Path Integral Approach to Quantum Physics
11	4	Feynman Path Integrals	Sum Over all Paths/Histories; Nested Gaussian Integrals
12	4	Feynman Path Integrals	Free Particle Path Integrals
13	4	Feynman Path Integrals	Superposition States of Feynman Particles
14	4	Feynman Path Integrals	Dynamic and Geometrical Phase. BERRY PHASE.
15	4	Feynman Path Integrals	Feynman Path Integral analysis of BERRY PHASE
16	4	Feynman Path Integrals	Path Integral analysis of AHARONOV-BOHM effect.
17	5	EPR paradox, Bell's Theorem	Einstein-Podolsky-Rosen Paradox
18	5	EPR paradox, Bell's Theorem	Classical vs. Quantum Uncertainty

19	5	EPR paradox, Bell's Theorem	Quantum Entanglement
20	5	EPR paradox, Bell's Theorem	Correlations in Results of Measurements: Bell Inequality
21	6	Introduction to Quantum Computing	Revisiting classical computers
22	6	Introduction to Quantum Computing	Computing: from Classical to Quantum
23	6	Introduction to Quantum Computing	Quantum Logic Gates
24	6	Introduction to Quantum Computing	Physical Qubits – spin half systems
25	6	Introduction to Quantum Computing	Quantum Algorithms.
26	6	Introduction to Quantum Computing	"No Clone Theorem" of quantum information science.
27	7	Light-Atom interactions	Semi-classical Rabi oscillations
28	7	Light-Atom interactions	Generalized Rabi Oscillations
29	7	Light-Atom interactions	Need for Quantum Electrodynamics (QED)
30	7	Light-Atom interactions	Jaynes Cummings Model
31	7	Light-Atom interactions	Cavity QED
32	7	Light-Atom interactions	Haroche experiment. Collapse and Revival of Rabi oscillations.

References:

(1) P.C.Deshmukh *Foundations of Classical Mechanics* (Cambridge University Press, 2019)
(2) J.J.Sakurai and Jim Napolitano *Modern Quantum Mechanics* (Cambridge University Press, 2017)
(3) David Harrison *Bell's inequalities and quantum correlations* Am. J. Phys. 50(9) p.811-816 (Sept.1982)
(4) A.O.Barut and S.Basri *Path integrals and quantum interference* Am.J.Phys. 60(10) 896-899 (1992)
(5) John S Townsend A modern approach to quantum mechanics
(6) M.A.Nelsen and I.L.Chuang *Quantum Computation and Quantum Information* (Cambridge University Press, 2010)
(7) C.C.Gerry and P.L.Knight - INTRODUCTORY QUANTUM OPTICS Cambridge Univ. Press, (2005)
(8) Mark Fox: *QUANTUM OPTICS – an introduction* (Oxford University Press, 2006)
(9) Matteo Bina *The coherent interaction between matter and radiation - A tutorial on the Jaynes-Cummings model* Eur. Phys. J. Special Topics 203, 163–183 (2012)

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