Department of Physics **IIT Kanpur**

PHY 602 QUANTUM MECHANICS, 1-3-0-9

Course Objectives: This course is aimed at providing a comprehensive review of the core concepts of quantum mechanics through problem solving and introducing some advanced topics with illustrative examples

Course Contents: Problem-oriented review of basic quantum mechanics: Fundamental concepts, Hilbert space formalism for quantum mechanics; quantum dynamics, symmetries in quantum mechanics; theory of angular momentum; WKB approximation, perturbation theory; variation method; scattering; introduction to some advanced topics

Special Emphasis: Ability to solve problems and develop a holistic understanding of the subject

Instructor : Soumik Mukhopadhyay (soumikm@iitk.ac.in)

Course Organization: All notices for the course will be sent by email to the course email list. Regular Home Assignments will be given. The students are strongly advised to solve all the problems given in the home assignment.

Exams, Quizzes and Home Assignments: There will be one mid-semester examination of two hours and, an end-semester examination of three hours. These will be held during the prescribed examination period. There will be two quizzes of twenty minutes each. Besides, there will be home assignments. It should be possible to do reasonably well in this course by being involved and attentive during the lectures and solving problems given in the Home Assignment.

Attendance : It goes without saying that 100% attendance is compulsory. Any student who is granted leave by the Convener, DPGC also must inform the instructor regarding his/her absence.

References : This being a PG course there is no prescribed text. However, the following books are recommended.

1. J J Sakurai, Modern Quantum Mechanics, and Advanced Quantum Mechanics

2. R Shankar Principles of Quantum Mechanics

Phy604: Review of Statistical Physics:

1. Basics of ensembles, partition functions and derivation of thermodynamic quantities, **(10)**

2. Quantum statistical mechanics, density matrix, Bosons and Fermions **(10)**

3. Phase transitions, Ising model, mean field theory and critical exponents **(10)**

4. Landau theory, scaling relations and a brief idea of renormalization group **(10)**

Note: The basic concepts will be introduced followed by extensive problem solving sessions.

Books: Reif, Pathria, Huang, Chaikin and Lubensky, N. Goldenfeld.

There will be mid-semester and end-semester examinations.

Particle Physics — PHY680
Joydeep Chakrabortty

Prerequisites : Quantum Field Theory-I
Group Theory

Course Contents:

I. What is Particle Physics?

II. Basic development and its limitations.

III. Paving the path towards the Standard Model (SM).

- (a) Historical development of SM.
- (b) SM as a gauge theory.
- (c) Spontaneous symmetry breaking and mass generation.
- (d) Phenomenological exploration of the SM.
- (e) Parton model.
- (f) Higher order correction in SM.

IV. Shortcoming of SM — Beyond Standard Model.

V. Grand Unification.

References:

I. Gauge Theory of Elementary Particle physics — Cheng and Li.
II. Quarks and Leptons - Halzen and Martin
III. Gauge Theories in Particle Physics- I + II: Aitchison and Hey
IV. Classical Theory of Gauge Fields — Rubakov and Wilson

Course title: Concepts of plasma physics

Course Instructor: Sudeep Bhattacharjee

Course No. : PHY682

Plasma physics is one of the most active research areas in modern physics. Most of the visible universe is in the plasma state and plasma phenomena are of major importance in space, solar and ionospheric physics. Here on earth one of the most ambitious scientific and technological undertakings of the second half of the twentieth century has been the quest for controlled thermonuclear fusion – for which plasma physics is the key underlying scientific discipline. Plasma physics forms the basis of many technologies that have revolutionized areas of physics research, such as gaseous ion sources, generation of multielement focused ion beams which belongs to one of the major tools for research in nanotechnology, generation of electromagnetic radiation etc. Several industrial applications rely on plasma physics, to name a few semiconductor processing, sputtering for thin film deposition, plasma display panels, plasma based lighting technologies, production of nanoparticles and nanostructuring and more recently atmospheric pressure plasmas and plasmas in liquids for biomedical applications. The objective of this course is to lay the concepts of this exciting subject.

The course begins with a general introduction to plasma physics and is designed with the purpose of presenting a comprehensive, logical and unified treatment of the concepts of modern plasma physics. The course is primarily aimed for first year post graduate students and beyond or advanced undergraduate students meeting the subject of plasma physics for the first time and presupposes knowledge of vector analysis, differential equations, complex variables, as well as courses on classical mechanics and electromagnetic theory. As a part of the course, and to provide a flavor for experimental research to the students, the students will be introduced to plasma experiments current available in the Waves and Beams Laboratory.

<u>Course Contents:</u>

This course has been broadly divided into eight chapters.

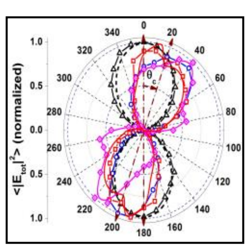
[1]. Introduction [2]. Charged particle motion in electromagnetic fields [3]. Some basic plasma phenomena [4]. Collisional processes in plasmas [5]. Fluid description of plasmas [6]. Diffusion and mobility [7]. Equilibrium and instabilities [8]. Introduction to waves in plasmas

<u>Reference Text Books:</u>

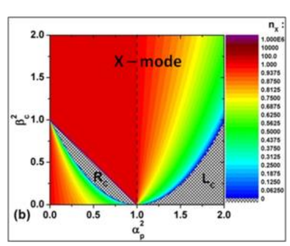
1. Introduction to plasma physics and controlled fusion (Vol. 1), F. F. Chen
2. Introduction to Plasma Physics, R. J. Goldston and P. H. Rutherford
3. Fundamentals of Plasma Physics, J. A. Bittencourt
4. Compact plasma and focused ion beams, Sudeep Bhattacharjee

Lightning

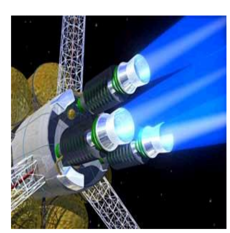
Nebula



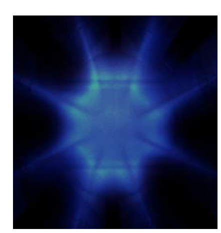
Laboratory observation of Cotton-Mouton effect



CMA model for wave dispersion in a plasma



Plasma thruster



Multicusp plasma

Course Announcement (2nd Semester, 2017-18)
Special Topics in Physics - PHY690N
Correlated Electrons and Quantum Magnetism
Instructor: Avinash Singh

Course Objective: Microscopic understanding of magnetic ordering and excitations in terms of correlated lattice fermion models. Focus will be on understanding detailed momentum dependence of magnetic and electronic excitations probed experimentally using Inelastic Neutron Scattering, Angle Resolved Photo Emission Spectroscopy, Spin Polarized Electron Energy Loss Spectroscopy, Resonant Inelastic X-ray Scattering.

Topics will include:

1. Quantum Antiferromagnetism and Hole Dynamics (Cuprates)

2. Quantum Corrections in a Metallic Ferromagnet (3d Transition Metals)

3. Ferromagnetism in Diluted Magnetic Semiconductors ($Ga_{1-x}Mn_xAs$)

4. Spin-Charge-Orbital Ordering in Doped Manganites ($La_{1-x}Sr_xMnO_3$)

5. 120^0 AFM Ordering in Triangular Lattice Systems ($HoMnO_3$, $YMnO_3$)

6. Magnetic Frustration and Excitations in FCC Lattice Systems (MnS_2)

7. Multi-Orbital Quantum Antiferromagnetism (Iron Pnictides)

8. Triplon Excitations in a Quantum Spin Liquid ($TlCuCl_3$)

9. Strongly Spin-Orbit-Coupled 5d Systems (Iridates and Osmates)

10. Spin-Orbital Entanglement and Magnetic Excitations (Sr_2IrO_4)

11. Spin-Orbit Coupling and Magnetic Anisotropy (bilayer Iridates)

12. Spin-Dependent Hopping and Kitaev-Heisenberg Model (Na_2IrO_3)

Prereq.: PHY431 / PSO201

PHY690 Astrophysics

Course outline:

Astronomical observations and Coordinate systems, Astrometry, Photometry, Stellar Classification, Interaction of Radiation with matter, Stellar structure and nuclear reactions, Star Formation and Stellar evolution, Interstellar medium, Compact stars, Sun and Solar system, Binary stars, Accretion, Milky Way, Extragalactic Astronomy, Active Galaxies, Plasma Astrophysics, brief introduction to cosmology and cosmological surveys.

References:

Astrophysics for Physicists by Arnab Rai Choudhuri
An Introduction to Astronomy and Astrophysics by Pankaj Jain
An Introduction to Modern Astrophysics, B. W. Carroll and D. A. Ostlie

Pankaj Jain

DEPARTMENTAL ELECTIVE PHY 690 M

Advanced General Relativity and Black Holes

Pre requisite: PHY 407 STR/GTR or equivalent.

Course Contents:

1. Differential Geometry and Summary of Connection, Curvature, Killing vectors and Symmetries. Energy Momentum Tensor.

2. Geodesic Congruences, Energy conditions, Frobenius Theorem and Raychuadhuri Equation.

3. Hypersurfaces, Gauss-Stokes Theorem and Gauss-Codazzi Equations. Israel Junction Conditions.

4. Lagrangian Formulation of General Relativity. Action and Einstein Field Equation.

5. Schwarzschild Black Holes, Horizon, Singularity, Eddington Finkelstein Cordinates and Kruskal Diagrams,

6. Carter-Penrose Diagrams, de-Sitter and Anti de Sitter (AdS) space time. Einstein Static Universe.

7. Reissner Nordstrom Black Holes: Horizon, Singularity, Killing Vectors and Penrose Diagrams.

8. Kerr and Kerr -Newman Black Holes: Horizon, Singularity, Killing Vectors and Penrose Diagrams.

9. Elements of Black Hole Thermodynamics. (If Time Permits)

INDIAN INSTITUTE OF TECHNOLOGY KANPUR
DEPARTMENT OF PHYSICS

Course Title	:	**Photonic Devices**
Course No.	:	**PHY 690V**
Proposed by	:	**Dr. R.Vijaya**
Prerequisite	:	**Background of Electromagnetic Theory** (as decided by instructor)
Level	:	**PG level**
Credits	:	L-T-P-D-[C] **3-0-0-0-[9]**

Course Contents:

S. No.	Broad theme	Contents	Lectures (of 50 min. duration)
1	Light-matter interaction – a review	Review of wave equation, dispersion, interference and diffraction effects	4
2	Light source	Need for lasers	2
3	Periodic structures as optical devices	Optical multi-layers, diffraction gratings, photonic crystals	6
4	Integrated-optic devices	Coupled-mode theory, waveguides and couplers in silicon platform	6
5	Fiber optic devices	Modal theory, devices for wavelength-, direction- and polarization-selectivity, Bragg gratings	6
6	Electro-optic and optoelectronic devices	Modulators, photodetectors and solar cells	6
7	Novel devices	Plasmonic sensors, slow light devices	5
8	Device characterization	Measurement techniques related to time- and spectral-domain	6

Short summary for including in the Courses of study booklet:

Light-matter interaction – a review, periodic structures such as Bragg reflectors, gratings and photonic crystals, fiber-optic devices, integrated-optic devices, active devices, sensors, measurement and characterization techniques.

Text books and References:

1. Thomas P.Pearsall, Photonics essentials, 2nd Edn, Mc-Graw Hill (2010)
2. R.Menzel, Photonics, Springer (2001)
3. Grote and Venghaus, Fiber optic communication devices, Springer (2001)
4. Zeev Zalevsky and Ibrahim Abdulhalim, Integrated nanophotonic devices, 2nd Edn, Elsevier (2014)
5. Larry A.Coldren, Scott W.Corzine and Milan L.Masanovic, Diode lasers and photonic integrated circuits, 2nd Edn, John-Wiley and Sons (2012)
6. Mark A.Mentzer, Applied optics fundamentals and device applications, CRC Press (2011)
7. A.Dmitriev (Ed.), Nanoplasmonic sensors, Springer (2012)
8. Jacob Khurgin and Rodney Tucker, Slow light, CRC Press (2008)

PHY606A

(3-0-0-0-[9]

Soft Matter: Concepts and Methods

Dr. Manas Khan

Course Content :

1	**Review of fundamentals** Colloids, polymers, amphiphiles, liquid crystals Forces, energies, timescales Brownian motion and related topics Fluctuation dissipation theorem Colloidal dispersions van der Waals attractions, electrostatics, ions, and DLVO Structure of maromolucules Viscoelasticity Surface tension, interfacial tension and capillary action Wetting, adhesion and friction	**10**
2	**Microscopy Techniques** Bright field, polarization, phase contrast microscopy Fluorescent and confocal microscopy Imaging, Image processing and particle tracking	**6**
3	**Rheology** Measuring stress-strain properties Different measurement geometries	**6**
4	**Microrheology** Passive microrheology Active Microrheology	**6**
5	**Optical Micromanipulations** Optical forces at different regimes Calibration of optical forces Measuring and applying forces using optical tweezers	**6**
6	**Scattering techniques** Dynamic light scattering Diffusive wave spectroscopy Small angle X-ray / neutron scattering (SAXS / SANS)	**6**
7	**Soft Matter Food Physics** (Additional lectures if time permits or in weekends) Physics of foodstuffs and cooking	**2**

Text books and References:

Textbook – “Soft Condensed Matter” by R.A.L. Jones.
References–“Soft Matter Physics” by M. Doi,
“Fundamentals of Soft Matter Science” by Linda S. Hirst;
Additional topic-specific references will be communicated to the class in time of teaching.

Signature of the

PHY781 (High Energy Physiscs-II)

Instructor: Dipankar Chakrabarti.[2017-18, 2nd semester]

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Basic knowledge of quantum field theory is essential. We'll assume that the students know the Feynman diagram and Feynman amplitude computations at the tree level. **Pre-requisite: PHY681**

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Course Contents:

1. Scattering Cross-sections: brief review of tree-level calculations of QED scattering processes.

2. Radiative corrections: electron self energy, vacuum polarization, Lamb shift. Infrared and ultraviolet divergences.

3. Renormalization: power counting, degree of divergence of a diagram, cutoff and dimensional regularization, Ward-Takahashi Identity, electron charge and mass renormalization.

4. Renormalization group, Callan-Symanzik equation.

5. Abelian and non-Abelian gauge theories, QCD

6. Path integral formalism.

Books:

1. Quantum Field Theory- Peskin and Schroeder.
2. Quantum Field theory- Mandl and Shaw.
3. Quantum Field Theory - Itzykson and Zuber.
4. Quarks and Leptons- Halzen and Martin.
5. Renormalization- John Collins.