Department of Physics

Indian Institute of Technology Kanpur

PHY601 : Review of Classical Mechanics

Course content:

S. No.	Topics	No. of Lecture and Tutorial Hours
1	Problem oriented review of Classical Mechanics, Newton's laws of motion, Galilean transformations, Particle mechanics, System of particles, Non-inertial frames, Pseudo-forces. Small oscillations and normal modes.	8
2	Lagrangian formulation, Configuration space, Hamilton's principle of least action, Symmetries and conservation laws, Rigid body motion, Hamiltonian formulation.	10
3	Phase space, Liouville's theorem, Canonical transformations, Poisson brackets, Hamilton-Jacobi theory, Action-angle variables.	10
4	Integrability, Perturbation theory, Time dependent Hamiltonian, Introduction to chaos, Chaotic attractor (and repeller), Lyapunov exponent, Special relativity.	12

Reference books:

1. J. V. Jose & E. J. Saletan, Classical Dynamics, Cambridge University Press (1998).

2. I. C. Percival & D. Richards, Introduction to Dynamics, Cambridge University Press (1982).

3. L. D. Landau & E. M. Lifshitz, Mechanics, Butterworth-Heinemann (1976).

4. H. Goldstein, Classical Mechanics, Addison-Wesley (1980).

5. S. H. Strogatz, Nonlinear Dynamics and Chaos, Westview Press (2001).

6. M. Tabor, Chaos and Integrability in Nonlinear Dynamics, Wiley-Interscience (1974).

Department of Physics

Indian Institute of Technology Kanpur

PHY603 : Review of Classical Electrodynamics

Course content:

S. No.	Topics	No. of Lecture and Tutorial Hours
1	Problem oriented review of Classical Electrodynamics. Electrostatics and Magnetostatics: Methods of solving electrostatic problems in cartesian, spherical and cylindrical coordinates, Green's function and Boundary value problems, both analytical and numerical solutions. Multipole expansion, Macroscopic media, Dielectrics and Magnetic media.	12
2	Electrodynamics: Faraday's law, Displacement current, Poynting Vector, Conservation laws. Electromagnetic waves in free space and different media, waveguides.	10
3	Radiation: Retarded potential, electric and magnetic dipole fields, linear antenna. Special Relativity: Transformation of electromagnetic fields.	10
4	Scattering and diffraction, Resonant cavities, Optical fibers, Dispersion.	8

Reference books:

1. J. D. Jackson, Classical Electrodynamics.

2. Landau and Lifshitz, Electrodynamics of continuous media.

3. Griffiths, Electrodynamics.

4. Zangwill, Electrdynamics.

5. Reitz, Christy and Millford, Electrodynamics.

Department of Physics

Indian Institute of Technology Kanpur

PHY605 : Review of Mathematical Methods in Physics

Course content:

S. No.	Topics	No. of Lecture and Tutorial Hours
1	Problem oriented review of Mathematical Methods in Physics. Vector spaces - Discrete and continuous: orthogonality, operator algebra. Hermitian and unitary operators, projection operators, matrices and applications in Physics. Calculus of variations, function spaces and Hilbert spaces, Orthogonal polynomials, expansions in orthogonal polynomials, generating functions. Integral transforms (e.g Fourier, Laplace, etc.) and applications to physics.	12
2	Differential equations: General introduction to ordinary differential equations, linear first and second order ordinary differential equations, singular points, series solutions-Frobenius method, second solution, inhomogeneous equations-Green's function, Sturm-Liouville theory, partial differential equations, characteristics, Boundary conditions. Special functions and applications in Physics.	16
3	Complex analysis: Cauchy-Riemann conditions, Cauchy-Goursat theorem, Cauchy integral formula, Contour integrals, Taylor and Laurent Series, The residue theorem. Applications of complex analysis to physics problems.	12

Reference books:

1. Sadri Hassani, Mathematical Physics: a modern introduction to its foundations (Springer)
2. Arfken, Weber- Mathematical Methods for Physicists (Academic Press)
3. Tulsi Dass and S. K. Sharma, Mathematical methods in Classical and Quantum Physics (University Press)
4. A. K. Kapoor, Complex variables (World Scientific)
5. Mathews, Walker - Mathematical Methods of Physics (Addison-Wesley)
6. Schaum Series - Vector Analysis
7. A. W. Joshi, Matrices and Tensors in Physics (New age international)

Indian Institute of Technology, Kanpur

Department of Physics

PHY 615: Non–equilibrium Statistical Mechanics

Part: I : Thermodynamics of irreversible processer near equilibrium

Entropy production, coupled processes and energy transduction; endo-reversible Thermodynamics; Thermal and chemical engines with finite cycle time; modes of operation; efficiency at maximum power.

Part II : Equations for describing time evolution of non-equilibrium systems:

(1) Fokker- Planck equation: Diffusion equation, examples of solutions with different initial and boundary conditions, diffusion equation with drift; relation with Schrödinger equation and exact solutions in one –dimension.

(2) Master equation: Random walk and diffusion; relation between Liouville equation and master equation –illustration with Kac ring model; relation with quantum master equation- Pauli equation

(3) Langevin equation: theory of Brownian motion; derivation of generalized Langevin equation form Hamilton's equation.

Part III: Time evolution form non –equilibrium initial states to equilibrium final state:

(1) Critical slowing down: illustration with interacting Ising model.

(2) Kramers' theory of the decay of metastable states- reaction rate theory; Application of WKB approximation.

(3) Becker – Doering theory: homogeneous nucleation in metastable state.

(4) Domain growth and phase ordering form unstable initial states: dependence on symmetry and conservation; Allen-Cahn and Cahn-Hilliard laws; formation of ordered patterns.

(5) RG for dynamic exponent & for domain growth.

Part IV : Cyclic processes and non –equilibrium steady-states far from equilibrium:

Stochastic resonance and Brownian ratchet; beating second law with energy pumping.

Interacting self –driven particles: TASEP; boundary- induced phase transitions; application to intracellular molecular motor transport.

Part V: Modern fluctuation theorems, foundations of statistical mechanics and applications: Taming Maxwell's DEMON!!

Instructor : Prof . D. Chowdhury.

PHY622: Condensed matter Theory II (2016: August-December)

Instructor*:* Amit Agarwal, Physics Department, IIT Kanpur

Prerequisite: PHY 543 (Condensed matter Physics)

Basic background in quantum mechanics, statistical mechanics, and condensed matter theory.

Course Objective:

The aim of this course is to survey various ground states of "condensed matter" many particle systems and explore their excitations and other properties. In doing this, we will also review the appropriate theoretical framework for understanding and exploring "what is out there", with the possibility of being able to predict new stuff that "may be out there".

Official Syllabus: Fermi liquid, second quantization, interaction picture, electron-electron interaction; plasmons; electron-phonon interactions; polarons, advanced methods of band structure calculations. Cooperative phenomena; magnetism and paramagnetism, superconductivity: experimental background, cooper pairs, BCS and Ginzburg- Landau theories.

Possibilities:

Models, hamiltonians and symmetries, Periodic potentials/tight-binding models (fixed lattice approximation), Many particles, second quantization and field theoretic formulation, Metals and insulators, Physics of metals: transport theory, Phonons and electron-phonon interactions, Metal physics revisited, Disorder – ideas of localization, Anderson transition, Electron-electron interactions (HF, RPA, Fermi liquid theory) , Interaction effects in semiconductors: excitons (time permitting), Instabilities of fermi liquid (magnetism, CDW, superconductivity), Superconductivity, GL and BCS theories, Magnetism (insulating magnets, itinerant magnets, spin waves), Charge density wave systems (time permitting), Strong correlations, ideas of Mott transition, Short discussion on (interacting) bosons (time permitting),

References (to start with):

1) C. Kittel, Introduction to Solid State Physics.
2) C. Kittel, Quantum Theory of Solids
3) Henrik Bruus, Karsten Flensberg, Many-Body Quantum Theory in Condensed Matter Physics: An Introduction.

Physics of Turbulence
PHY672

Instructor: Mahendra K. Verma, Physics Dept., IITK

Units: 3 lectures, 9 credits

Timing: MF: 8-9 AM, T 9-10AM (subject to change depending on students' convenience)

Prequisite: None, yet basic knowledge of Navier-Stokes equation and programming is required.

Who can take the course: Ph. D., M. Sc., M. Tech., Advanced UG (final year) students.

Course Contents: Review of Navier-Stokes equations, Spectral descriptions, Homogeneity and isotropy in turbulence, Kolmogorov's theory of turbulence, Two-dimensional turbulence, Higher-order structure functions and intermittency, Application of renormalization groups to turbulence and renormalized (eddy) viscosity. Large-eddy simulations.

Magnetohydrodynamic Turbulence, Magnetic field generation in turbulent flows (Dynamo), Liquid metal flows, Astrophysical applications, Buoyancy-driven turbulence, Rotating turbulence

Direct numerical simulation of turbulence. Hands on experience with some of the codes

Selected Readings: (1) S. B. Pope, Turbulent Flows, Cambridge University Press (2000).
(2) M. Lesieur, Turbulence in Fluids, Springer (2008).
(3) P. A. Davidson, Turbulence, Oxford University Press (2004).
(4) P. Sagaut and C. Cambon, Homogeneous Turbulence Dynamics, Cambridge University Press (2008).
(5) Course notes

PHY 681 Quantum Field Theory
Instructor: Gautam Sengupta

1. Lorentz and Poincare Group and Representations. Relativistic Quantum Mechanics. Klein Gordon and Dirac Equation. Particles and Antiparticles. Dirac spinors.

2. Review of Classical Field Theory. Canonical Quantization of Scalar Fields. Propagators. Creation and Annihilation Operators. Fock space.

3. Quantization of Electromagnetic Field. Propagator and Gauge Invariance. Indefinite Metric and Gupta Bleuler Quantization.

4. Quantization of the Dirac Field. Dirac propagator.

5. Interacting Field Theory. Schroedinger, Heisenberg and Interaction Representation. Perturbation expansion, Dyson Series and Feynman Rules. $\lambda\,\phi^4$, Yukawa Interactions. Tree level processes and S Matrix.

6. Quantum Electrodynamics. Tree level processes and S Mastrix.

*7. Idea of higher loop diagrams and Renormalization.

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.

Course Contents:

This course has been broadly divided into eight chapters.

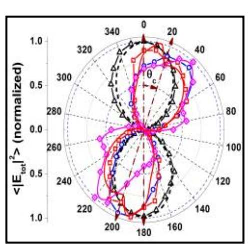
[1]. Introduction [2]. Charged particle motion in electromagnetic fields [3]. Some basic plasma phenomena [4]. Collisional processes in plasmas [5]. Fluid description of plasmas [6]. Diffusion and mobility [7]. Equilibrium and instabilities [8]. Introduction to waves in plasmas

Reference Text Books:

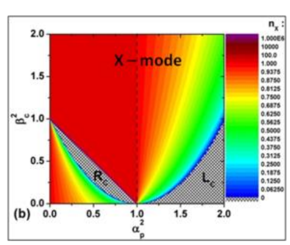
1. Introduction to plasma physics and controlled fusion (Vol. 1), F. F. Chen
2. Introduction to Plasma Physics, R. J. Goldston and P. H. Rutherford
3. Fundamentals of Plasma Physics, J. A. Bittencourt
4. Compact plasma and focused ion beams, Sudeep Bhattacharjee

Lightning

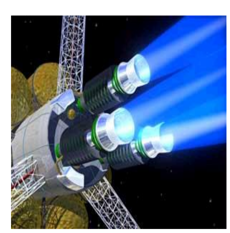
Nebula



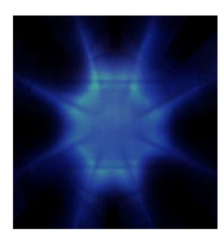
Laboratory observation of Cotton-Mouton effect



CMA model for wave dispersion in a plasma



Plasma thruster



Multicusp plasma

ELECTIVE FOR SEMESTER 2016-17-I

Course Name: PHY690D, DENSITY FUNCTIONAL THEORY (DFT)

Instructor: Manoj K. Harbola

Prerequisite: Introductory Quantum Mechanics (at the level of Phy431)

Course contents (tentative number of lectures):

- Review of Basic quantum mechanics (4)
- Many-electron Schrodinger equation, Variational method for many-electron system (1)
- Self-consistent field method, Hartree theory and Hartree-Fock theory (5)
- Slater's treatment of Hartree-Fock theory, Xα method (2)
- Beyond Hartree-Fock ; correlation enery, dielectric constant analysis, collective oscillations (3)
- Many-electron theory in terms of the density – Thomas Fermi and Thomas-Fermi-Dirac methods (2)
- Modern density-functional theory – Hohenberg-Kohn theorem and Kohn-Sham method (3)
- Constrained-search method (2)
- Chemical potential and related quantities (3)
- Treatment of exchange-correlation in density-functional theory (3)
- Approximate functionals (3)
- Applications to atoms, molecules, and solids; perturbation theory in DFT (2)
- Time-dependent density-functional theory, Runge-Gross theorem, time-dependent Kohn-Sham theory (3)
- Time-dependent linear response theory , RPA and beyond; application to excited-states (3)
- Quantum-fluid dynamics(3)

Course Title: Coherence and Quantum Entanglement
Course Number: PHY690 G; Semester-I, 2016-17

Instructor:

Anand Kumar Jha
Office: Faculty Building 351; Lab: CL 104 D/E
Ph: (+91)512-259-7014(Off); (+91)962-142-3993(Mobile)
Email: akjha@iitk.ac.in ; akjha9@gmail.com

Course content:

This course will have two main parts. The first part, which will cover about 1/3rd of the course, will discuss the concept of coherence; the remaining part of the course will focus on Quantum Entanglement.

(1) Coherence: Spectral properties of stationary random processes, Wiener-Khintchine theory, Angular spectrum representation of wavefields, Introduction to the second-order coherence theory, Propagation of coherence, The van Cittert-Zernike theorem, Coherent mode representation of sources and fields.

(2) Quantum Entanglement: Basics of nonlinear optics, Two-photon field produced by parametric down-conversion, EPR paradox, Bell inequalities and its experimental violations, Quantum theory of higher-order correlations, Two-photon coherence and two-photon interference effects. Two-photon entanglement in the following variables: time-energy, position-momentum, and angle-orbital angular momentum; Introduction to Quantum Information: Quantum Cryptography, Quantum Dense Coding, Quantum Teleportation, Quantum Imaging.

(3) Additional topics (may be covered during the course or given out as small projects): Photoelectric detection of light, The Hanbury Brown-Twiss experiment, Photon-bunching and antibunching, Photon Statistics, Squeezed states of light.

Reference books:

1. L. Mandel and E. Wolf, Optical Coherence and Quantum Optics (Cambridge university press, New York, 1995).
2. R. W. Boyd, Nonlinear Optics, 3rd ed. (Academic Press, New York, 2008).
3. R. Loudon, *The Quantum Theory of Light*, 3rd ed. (Oxford University Press, New York, USA, 2000).
4. M. Born and E. Wolf, *Principles of Optics*, 7th expanded ed. (Cambridge University Press, Cambridge, 1999).
5. Feynman R, Leighton R, and Sands M. *The Feynman Lectures on Physics*, Volume III.

Evaluation:

20% Homework (5/6 homeworks); 30% Mid-sem exam; 50% End-sem exam.

PHY690K Quantum Dynamics: Computation and Information

Prerequisites: PHY431, PHY412, Computer Programing.

Course Outline:

1. Quantum Dynamics of Discrete Systems: Two-level atoms, Spins, Density Matrix, Entangled states, Schmidt Decomposition.
2. Quantum Dynamical Process: Open systems, Completely positive maps, Superoperator, Kraus representation, many-particle systems, Schroedinger evolution of initial states, master equation approach to equilibrium, decoherence, and entanglement.
3. Quantum Information: Information processing, communication and computation protocols, algorithms.
4. Quantum Dynamics of Continuous-variable systems: Interacting harmonic oscillators, Guassian states, evolution of one-mode and two-mode guassian states, entanglement in multi-mode pure states, and mixed states.

Reference Books:

Quantum Mechanics: J. J. Sakurai
Quantum Theory: Concepts and Methods A. Peres
Quantum Computation and Quantum Information: Nielsen and Chuang
Quantum Inforamtion Theory: M. M. Wilde
Classical and Quantum Information Theory: E. Desurvire

V. Subrahmanyam
3 April 2016

PHY690M: Advanced General Relativity and Black Holes

The course will deal with advanced topics in General Relativity and black hole physics. Basic familiarity with GR will be assumed. Topics to be covered are :

1) Lagrangian formulation of GR [6]
2) Hamiltonican formulation of GR [6]
3) Basic definitions of mass and angular momentum : Komar formulae. [6]
4) Black holes : Schwarzschild, Reissner Nordstrom, Kerr. AdS generalizations. [12]
5) Elementary introduction to black hole thermodynamics. [8]

The basics of differential geometry as relevant to GR will also be discussed.

References :

Eric Poisson : A relativist's toolkit – the mathematics of black hole mechanics.
Robert Wald : General Relativity.
Black Holes : Lecture notes by Paul Townsend.

Course Title: **Principles of Lasers and Detectors**

Course Number: **PHY690P/PSE 602**
Units: **3-0-0-0-9**
Pre-requisite: **None**
Level: **PG**
Course Description:
This course provides an introduction to the fundamental principles governing the operation and design of coherent light sources and detection tools.
Course Topics:
Introduction to light sources, Lasers, principle of lasing
Optical cavities, longitudinal, transverse modes, Stability
Interaction of radiation with matter, Spontaneous emission
Absorption and stimulated emission, line broadening mechanisms
Population inversion, absorption and gain coefficients
Pumping schemes (Rate equation based Lasing model)
Three- and four- level lasers
CW and pulsed lasers, Q-switching and mode-locking
Detection of optical radiation:
photomultiplier tubes, semiconductor photodiodes, avalanche photodiodes, Single photon detectors,dark current, thermal noise, shot noise
Measurement systems: Spectroscopy (Spectral and Temporal measurement systems),
CCD, monochromater, pulse width measurement

References:

1. Laser Physics, Peter W. Milonni and Joseph H. Eberly, Wiley, 2nd edition, 2010

2. Lasers, Anthony E. Siegman, University Science Books; 1st edition, 1986

3. Laser Electronics, Joseph T. Verdeyen, Prentice Hall; 3rd edition, 1995

4. Laser spectroscopy, W. Demtroder, 3rd edition, 2004

5. Lasers, Theory and Applications, K. Thyagarajan and A.K. Ghatak, Macmillan India Ltd., 2010

6. Principles of Lasers, O. Svelto and D. C. Hanna,5th edition, 2010