SYLLABUS

Integrated M.Sc. in Physics

National Institute of Science Education and Research
Bhubaneswar

Course Structure for Integrated M.Sc. in School of Physical Sciences

Year/Semester	Course No.	Credits	Course Name
1/Semester-I	P101	6	Introductory Physics I
	P141	3	Physics Laboratory I
1/Semester-II	P102	6	Introductory Physics II
	P142	3	Physics Laboratory II
2/Semester-III	P201	8	Classical Mechanics I
	P202	8	Mathematical Methods I
	P207	4	Linear Optics
	P241	3	General Physics Laboratory
	P245	5	Basic Electronics theory and Laboratory
2/Semester-IV	P204	8	Electromagnetism I
	P205	8	Mathematical Methods II
	P206	8	Quantum Mechanics I
	P246	4	Advanced Electronics theory and Laboratory
3/Semester-V	P302	8	Statistical Mechanics
	P303	8	Quantum Mechanics II
	P304	8	Special Theory of Relativity
	P346	6	Computational Physics Laboratory
	P345	3	Optics Laboratory
	P343	3	Modern Physics Laboratory
3/Semester-VI	P301	8	Electromagnetism II
	P306	8	Introduction to Condensed Matter Physics
	P307	8	Nuclei and Particles
	P341	6	Nuclear Physics & Instrumentation Laboratory
	P347	6	Solid State Physics Laboratory
4/Semester-VII	P401	8	Classical Mechanics II
	P405	8	Atoms, Molecules and Radiation
	P445	8	Integrated Physics Laboratory I
	*	8	Elective 1
	*	8	Elective 2
4/Semester-VIII	P446	8	Integrated Physics Laboratory II
	*	8	Elective 3
	*	8	Elective 4

	*	8	Elective 5
	*	8	Elective 6
5/Semester – IX	P598	20	Physics Dissertation project I
	*	8	Elective 7
	*	8	Elective 8
5/Semester – X	P599	20	Physics Dissertation project I
	*	8	Elective 9
	*	8	Elective 10

Note: * against elective courses in the above list, stands for any physics in-stream elective in the new syllabus.

List of Elective courses

Year/Semester	**Course name**	**Credits**	**Course Name**
4&5/Semester all	P451	8	Advanced Solid State Physics
4&5/Semester all	P452	8	Computational Physics
4&5/Semester all	P453	8	Quantum Field theory I
4&5/Semester all	P454	8	Particle Physics
4&5/Semester all	P455	8	Introduction to Phase Transition and Critical Phenomena
4&5/Semester all	P456	8	Nonlinear Optics and Lasers
4&5/Semester all	P457	8	General Theory of Relativity and Cosmology
4&5/Semester all	P458	8	Soft Condensed Matter
4&5/Semester all	P459	8	Applied Nuclear Physics
4&5/Semester all	P460	8	Many Particle Physics
4&5/Semester all	P461	8	Physics of Mesoscopic Systems
4&5/Semester all	P462	8	Introduction to Quantum Optics
4&5/Semester all	P463	8	Astronomy and Astrophysics
4&5/Semester all	P464	8	Plasma Physics and Magneto-hydrodynamics
4&5/Semester all	P466	8	Quantum and Nano-electronics
4&5/Semester all	P467	8	Nonlinear Dynamics sand Chaos
4&5/Semester all	P468	8	Magnetism and Superconductivity

4&5/Semester all	P469	8	Density Functional Theory of Atoms, Molecules and Solids
4&5/Semester all	P470	8	Quantum Field Theory II
4&5/Semester all	P471	8	Quantum Information and Quantum Computation
4&5/Semester all	P472	8	Experimental High Energy Physics
4&5/Semester all	P473	8	Experimental Techniques
4&5/Semester all	P474	4	Introduction to Cosmology
4&5/Semester all	P475	8	Relativistic Nucleus-Nucleus collision and Quark-Gluon Plasma
4&5/Semester all	P476	8	Non-equilibrium Statistical Mechanics
4&5/Semester all	P477	8	Special topics in quantum mechanics

Course Structure for a Minor in Physics

Excluding first year courses, the student has to take the following courses from physics to earn the minor

1. P201 - Classical Mechanics I (8 credits)
2. P202 - Mathematical Methods I (8 credits)
3. P204 - Electromagnetism I (8 credits)
4. P206 - Quantum Mechanics I (8 credits)
5. P302 - Statistical Mechanics (8 credits)
6. Any one of the other theory courses with 8 credits.

Course Structure for earning a Major in Physics

Compulsory Theory Courses

P101: Introductory Physics I (28 Lectures + 14 Tutorial)
Prerequisite: None

Outcome of the Course:

Builds understanding of basic classical mechanics and thermodynamics.

Mechanics (12 Lectures)
Newton laws, work-energy theorem, line integrals, conservative forces
Simple harmonic motion, forced oscillator, damping, resonance
Rotational motion
General properties of matter (Elasticity, viscosity, surface tension)

Kinetic theory of gases (4 Lectures)

Thermodynamics (12 Lectures)
Principles of thermodynamics, thermodynamic states, extensive/intensive variables
Heat, work, internal energy and first law of thermodynamics
Heat engines, second law of thermodynamics, entropy
Thermodynamic potentials

References:

1. Introduction to mechanics by Daniel Kleppner & Robert Kolenkow. New York: McGraw-Hill Book Co., Inc
2. Heat and thermodynamics: an intermediate textbook by Mark W. Zemansky & Richard H. Dittman. 7th ed., New York: McGraw-Hill Book co., Inc., 1997
3. Fundamentals of Physics by David Halliday, Robert Resnick, & Jearl Walker. 8th ed., New Jersey: John Wiley, 2008
4. University Physics by Francis W. Sears, Mark Zemansky, & Hugh D. Young. 7th ed. Massachusetts: Addison Wesley, 1987
5. Mechanics by Keith R. Simon. 3rd ed. Massachusetts: Addison Wesley pub. Co., 1971
6. Thermodynamics, kinetic theory, & statistical thermodynamics by Francis W. Sears, \& Gerhard L. Salinger, 3rd ed., Norosa 1998
7. Mechanics by Charles Kittel, Walter D. knight & Malvin A. Ruderman. 2nd ed., New York: McGraw-Hill Book Co., Inc., 1973

P102: Introductory Physics II (28 Lectures + 14 Tutorial)
Prerequisite: None

Outcome of the Course:
Builds basic understanding of electro and magneto static phenomena and processes. Introduces important concepts of polarization, electromagnetic waves, interference and diffraction and basic ideas in special relativity and quantum mechanics.

Overview of Electromagnetism (10 lectures)
1. Coulombs law, Gauss law
2. Biot-Savart law, Ampere law
3. Lorentz force, Faraday law
4. Maxwell equation and EM wave equation

Introduction to relativity (6 lectures)
1. Michelson Morley experiment, Bradley & Fizeau experiment (ether-drag hypothesis)
2. Galilean non-invariance of EM wave equation; postulates of SR
3. Lorentz transformation: length contraction / time dilation / simultaneity
4. Discussion of muon-decay problem

Introduction to quantum physics (12 lectures)
1. Black body radiation, photo-electric effect, Compton effect, atomic spectra, Planck postulate, Bohr atom
2. de Broglie hypothesis and Davisson-Germer experiment
3. Franck-Hertz experiment, Quantization of energy & qualitative discussion on laser
4. 1D Schroedinger equation, particle in an infinite potential well
5. (Time permitting: step and barrier problems)

References:
1. Concepts of Modern Physics, Sixth Ed. By Arthur Beiser
2. Fundamentals of Physics by David Halliday, Robert Resnick & Jearl Walker, 8th ed. New York: John Wiley & Sons Inc., 2004
3. Foundations of Electromagnetic theory by John R. Reitz, Fredrick Milford & Robert Christ. 4th ed. Massachusetts: Addison Wesley, 1993
4. Electricity and magnetism (Berkeley Physics Course; vol.2) by Edward M. Purcell. 2nd ed. New York McGraw Hill Book Company Inc.
5. Introduction to Electrodynamics by David J. Griffiths, 3rd ed. New Jersey: Prentice Hall
6. Introduction to Quantum Mechanics 2nd ed. by David J. Griffiths.

P201: Classical Mechanics I (42 Lectures + 14 Tutorial)
Prerequisite: None

Outcome of the Course:
Training in basic classical mechanics, prepares the student for advanced mechanics courses.

1. Principle of virtual work; constraints; D'Alemberts principle.
2. Generalized coordinates, velocities and momenta; Euler-Lagrange formulation.
3. Two-body central force problem (reduced mass); planet orbits; virial theorem.
4. Collisions and scattering, CM and Lab frames, scattering cross section.
5. Motion in non-inertial frames; Coriolis force.
6. Principle of least action; formulation by Maupertuis, Euler, Hamilton; Liou- villess theorem.
7. Hamiltons equations; Poisson brackets.
8. Canonical transformations; Hamilton-Jacobi equation; generating functions; Symmetries and conservation laws.
9. Small oscillations; normal modes

References:
1. Classical Mechanics, by Keith R. Symon, Pearson Education Dorling Kinderslay, 3rd Ed.
2. Classical Mechanics, by W. B. Kibble & F. H. Berkshire, Imperial college press, 5th Ed. By Kibble
3. Classical Mechanics by N. C. Rana & P. S. Joag, Mc Graw Hill Education
4. Classical Mechanics by H. Goldstein, C. P. Poole, J. Safko, Pearson Education Dorling Kinderslay, 3rd Ed.

P202: Mathematical Methods I (42 Lectures + 14 Tutorial)
Prerequisite: None

Outcome of the Course:
Provides training in basic mathematical methods needed in all areas of physics

1. Vector Calculus, curvilinear coordinates
2. Linear vector spaces, linear operators in linear vector spaces, Hermitian, projection and Unitary operators, normal matrices and diagonalisation
3. Fourier series, Fourier and Laplace transforms

4. 1st & 2nd order differential equations, power series solution, special functions (Hermite, Legendre, Bessel, Laguerre, hypergeometric)
5. Partial differential equations, separation of variables

References:
1. Mathematical Methods in the Physical Sciences by M. L. Boas
2. Mathematical Methods for Physicists by G. B. Arfken and H. J. Weber
3. Mathematical Methods for Physics by H. W. Wyle
4. Mathematical Methods of Physics by J. Mathews and R. L. Walker
5. Mathematical Physics I and II by S. D. Joglekar
6. Introduction to Mathematical Physics by C. Harper
7. Mathematical Methods for Physics and Engineering by K. E. Riley, M. P. Hobson & S. J. Bence

P204: Electromagnetism I (42 Lectures + 14 Tutorial)
Prerequisite: None

Outcome of the Course:
Trains the student in detailed computations involved in electrostatics and magnetostatics, solving Maxwell's equations. Introduces to the idea of energy momentum tensor and Gauge invariance.

1. Introduction to electrostatics and Green function formalism
2. Laplace and Poisson equations, boundary value problems
3. Dielectrics, Polarization, electric displacement
4. Steady currents, Lorentz force; magnetostatic (including vector potentials), magnetic materials
5. Time-varying fields, Faraday's law, displacement current
6. Maxwell's equations, electromagnetic waves

References:
1. Classical Electrodynamics by J. D. Jackson (3rd Edition)
2. Classical Electromagnetic Radiation by Mark Heald, J. B. Marion
3. Introduction to Electrodynamics by D. J. Griffiths (3rd Edition)
4. Foundations of Electromagnetic Theory by J. R. Reitz, F. J. Milford & R. W. Christy
5. Electricity and magnetism (Berkeley Physics Course; vol.2) by Edward M. Purcell (2nd Edition)

P205: Mathematical Methods II (42 Lectures + 14 Tutorial)
Prerequisite: None

Outcome of the Course:
Prepares the student in important advanced mathematical concepts and tools. This is needed for advanced physics courses such as applications of quantum mechanics in solid state physics quantum field theory and particle phenomenology

1. Functions of a complex variable, analytic functions, residue theorem and applications, conformal mapping, Taylor and Laurent series, analytic continuation, special analytic functions, Gamma functions, method of steepest descent
2. Hilbert space, Differential operators and Sturm-Liouville theory

3. Greens functions
4. Generalized functions
5. Cartesian tensors, 4-vectors and 4-tensors
6. Elements of Group theory

References:

1. Mathematical Methods for Physicists by G. B. Arfken & H.J. Weber
2. Complex Variables and Applications (9th Edition) by James Ward Brown, Ruel V Churchill
3. Mathematical Methods for Physics by H.W. Wyld
4. Mathematical Methods of Physics by J. Mathews and R. L. Walker
5. Mathematics for Physicists by P. Dennery and A. Krzywicki

P206: Quantum Mechanics I (42 Lectures + 14 Tutorial)
Prerequisite: None

Outcome of the Course:
First in-depth introduction of basic ideas and methods in quantum mechanics. This is necessary across almost all advanced modern physics courses.

1. Schroedinger equation, one-dimensional problems
2. Central potentials, Hydrogen atom, 3D harmonic oscillator
3. Hilbert space formalism (introductory level), operator method for simple harmonic oscillator
4. General treatment of angular momentum, spin, addition of angular momentum
5. Approximation methods: Time-independent perturbation theory, degenerate perturbation theory; Ritz variational method, WKB

References:

1. Introduction to Quantum Physics by A. P. French & Edwin F. Taylor
2. Quantum Mechanics by L. L. Schiff
3. Introduction to Quantum Mechanics by D. J. Griffiths
4. Principles of Quantum Mechanics by R. Shankar
5. Modern Quantum Mechanics by J. J. Sakurai
6. Quantum Mechanics by N. Zettili

P207: Linear Optics (21 Lectures +7 Tutorials)
Prerequisite: None

Outcome of the Course:
Provides introduction is slightly advanced topics in classical optics. The course also helps build up basics for experiential wok in advanced laboratory work.

1. Plane waves, Spherical waves, relation of wave optics and ray optics
2. Interference: Single & multiple-beam interference, Fabry-Perot, Mach-Zehnder, Michelson interferometer, Spatial & temporal coherence
3. Diffraction: Introduction to Fourier transform, Fresnel and Fraunhoffer integral, Fourier analysis and angular spectrum. Examples of single-slit, multiple-slit, circular aperture; Lens as Fourier transforming element
4. Gaussian Beam propagation, Laguerre-Gaussian and Hermite Gaussian beam propagation
5. Optional topics: Spatial filtering/Image formation/Holography

References:
1. Fundamentals of Photonics (2nd Edition) by B. E. A. Saleh, Malvin Carl Teich
2. Optics by Ajoy Ghatak (5th Edition), Tata McGraw Hill
3. Optics by Eugene Hecht (5th Edition), Pearsons
4. Modern Optics by B. D. Guenther (2nd Edition), Oxford University Press

P301: Electromagnetism II (42 Lectures + 14 Tutorial)
Prerequisite: P204 (Electromagnetism I), P202 (Mathematical Methods I)

Outcome of the Course:
Provides training in advanced concepts and methods for understanding advanced electromagnetic phenomena. Important concepts of radiation retardation, multipole expansions, covariant formulation of classical mechanics and relativistic kinematics are taught.

1. Review of Maxwell's equations, Poynting's theorem, electromagnetic energy momentum tensor
2. Wave propagation in conductors and dielectrics, Reflection, Refraction, Polarization, Total internal reflection, Attenuation of waves in metals, Brewster's angle, Lorentz theory of dispersion, wave-guides, fibers and plasma
3. Gauge transformations and gauge invariance, electromagnetic potentials
4. Lienard-Weichert potentials, radiation from an accelerated charge, Larmor formula, bremsstrahlung and synchrotron radiation
5. Multipole radiation, scattering by free charges
6. Time permitting introduction to magnetohydrodynamics/covariant formulation

References:
1. Classical Electrodynamics by J. D. Jackson (3rd Edition)
2. Classical Electromagnetic Radiation by Mark Heald & J. B. Marion
3. Foundations of Electromagnetic Theory by J. R. Reitz, F. J. Milford & R. W. Christy
4. Classical Theory of Fields by L. Landau and E. Lifshitz
5. Introduction to Electrodynamics by D. J. Griffiths (3rd Edition)

P302: Statistical Mechanics (42 Lectures + 14 Tutorial)
Prerequisite: P201 (Classical Mechanics I), P206 (Quantum Mechanics I)

Outcome of the Course:
The course trains the student in basics of statistical mechanics, introduces important concepts like the density matrix, different kinds of quantum statistics and the idea of fluctuation dissipation theorem.

1. Basics of Probability Theory: Probability distribution, cumulants, central limit theorem; laws of large numbers
2. Fundamentals of statistical mechanics: Phase space and Liouville theorem; microscopic definition of entropy, ergodic hypothesis
3. Ensembles theory: Microcanonical, canonical and grand canonical ensembles,
4. Gibbs Paradox, Energy and density fluctuations. Application to ideal gases, spin and non-interacting systems
5. Review of thermodynamics: Laws of thermodynamics and entropy, Thermodynamic potentials and thermodynamic stability
6. Quantum Statistical Mechanics: Ideal quantum gases; Bose and Fermi distribution; phonons, photons;

Fermi sea; density matrix formulation. Examples: electrons in metal, black body radiation, Bose-Einstein condensation and white dwarf
7. Deviations from ideal gas law behavior: Van der Waals equation, liquid-gas transition, Maxwell construction, phase diagram of water

References:

1. Statistical Physics by F. Reif
2. Introduction to Statistical Physics by Kerson Huang
3. Statistical Mechanics by R. K. Pathria and P. D. Beale
4. Statistical Physics of Particles by M. Kardar
5. Introduction to Modern Statistical Mechanics by D. Chandler
6. Statistical Mechanics by R.P. Feynman
7. Statistical Physics (Vol. I) by L. Landau and E. Lifshitz

P303: Quantum Mechanics II (42 Lectures + 14 Tutorial)
Prerequisite: P206 (Quantum Mechanics I)

Outcome of the Course:
Prepares the student in intermediate level of quantum mechanics needed across many advanced disciplines. Introduces important concepts for time evolution in quantum mechanics, propagators and path integrals and relativistic quantum mechanics.

1. Review of Hilbert space formalism for quantum mechanics
2. Review of time independent perturbation theory, bound state perturbation theory
3. Time dependence in QM and Time-dependent perturbation theory
4. Scattering theory
5. Greens function methods, Path integral in non-relativistic theory
6. Relativistic wave equations: Klein-Gordon and Dirac Equations, Dirac particle in presence of an electromagnetic field leading to g = 2
7. Identical particles, Pauli exclusion principle

References:

1. Modern Quantum Mechanics by J. J. Sakurai
2. Advanced Quantum Mechanics by J. J. Sakurai
3. Principles of Quantum Mechanics by R. Shankar
4. Quantum Mechanics by E. Merzbacher
5. Quantum Mechanics (volumes 1 and 2) by A. Messiah
6. Quantum Mechanics (Vol. I & Vol. II) by C. Cohen-Tannoudji, B. Diu & F. Laloe

P304: Special Theory of Relativity (42 Lectures + 14 Tutorial)
Prerequisite: P205 (Mathematical Methods II) & P204 (Electromagnetism I)

Outcome of the Course:
Trains the student in basic and advanced concepts in special relativity and introduces the basic ideas up on which General relativity is based on. Also provides in depth training in applications of group theory in relativity. Prepares the student for studying general relativity in future.

1. Review: Galilean relativity, Newtonian mechanics, Electrodynamics and inconsistency with Galilean relativity, ether and experiments for its detection, failure to detect ether. Measurement of velocity of

light in moving frames. Lorentz, Poincare and developments towards relativity
2. Einstein's special theory: Constancy of velocity of light as a postulate. Derivation of Lorentz transformation. Length contraction and time dilation. Mass- energy relation, Doppler shift. Minkowski space-time diagram, boosts as complex rotations in Minkowski space
3. Four dimensional space-time continuum, Lorentz transformations as coordinate transformations, vectors, scalar product, scalars, tensors, contravariant and covariant objects, laws of physics as tensor equations, Mechanics, hydro-dynamics and electrodynamics as tensor equations
4. Beyond special relativity: Inertial and gravitational mass, Equivalence principle, Introducing gravitational field as general coordinate transformation, Principle of general covariance, Metric tensor and affine connection, Gravitational potential as metric tensor, Laws of physics in presence of gravitation, gravitational time dilation and red shift, Experimental observation of gravitational red shift
5. Lorentz and Poincare groups: abelian and non-abelian groups, Rotations in two and three dimensions, generators of rotations, Representations (finite dimensional), Casimir operators, Lorentz transformations as a group, Generators for translations, rotations and boosts, Finite and infinite dimensional representations

References:

1. Introduction to Special Theory of Relativity by R. Resnick
2. Relativity by A. Einstein
3. Classical Electrodynamics by J. D. Jackson
4. Electrodynamics by W. K. H. Panofsky & M. Phillips
5. Classical Mechanics by H. Goldstein
6. GTR and Cosmology by S. Weinberg
7. Classical Theory of Fields by L. Landau & E. Lifshitz

P306: Introduction to Condensed Matter Physics (42 Lectures + 14 Tutorial)
Prerequisite: P206 (Quantum Mechanics I), P301 (Statistical Mechanics)

Outcome of the Course:
This is the first course in condensed matter physics and draws on quantum and statistical mechanics to provide a foundation in basic concepts and techniques required to tackle advanced courses in the area of solid state physics.

1. General introduction, Drude and Sommerfeld model
2. Crystal structure; x-ray diffraction
3. Cohesive energy
4. Blochs theorem; Band theory nearly free electrons; tight binding approximation; semi-classical dynamics of electrons in a band; motion of electrons in super-lattices
5. Semiconductors
6. Thermal properties of insulators; phonons
7. Landau levels - de Hass van alphen effect and integer quantum hall effect
8. Magnetism
9. Superconductivity

References:

1. Introduction to Solid State Physics by C. Kittel
2. Solid State Physics by N. Ashcroft and N. D. Mermin,

3. Solid-State Physics by M. N. Rosenberg
4. Solid State Physics by G. Burns

P307: Nuclei and Particles (42 Lectures + 14 Tutorial)
Prerequisite: P302 (Quantum Mechanics II) & P202 (Mathematical Methods I)

Outcome of the Course:
Provides training in basic concepts and methods in nuclear physics, stability of nucleons and classification of interactions. The course prepares the student to begin working in experimental and theoretical high energy physics.

1. Nuclear systematics and stability (masses, sizes, spins, magnetic moments, quadrupole moments, energetics and stability against particle emission, beta decay)
2. Nucleon-nucleon interaction, space-time symmetries, conservation laws, iso-spin symmetry, low energy interactions (effective range, shape independence, meson exchange picture)
3. Liquid drop model, compound nucleus and fission, nuclear vibrations and rotations
4. Shell model, introduction to Hartree-Fock, spins and magnetic moments
5. Direct nuclear reactions
6. Mesons and baryons, resonances, SU(3) classification, iso-spin and strangeness, quark model, color
7. Weak interactions (nuclear and particle decays, neutrinos)

References:
1. Introduction to Nuclear Physics by R. R. Roy and B. P. Nigam
2. Structure of Nucleus by M. A. Preston and R. K. Bhaduri
3. Introduction to Particle Physics by D. J. Griffith
4. Introduction to Particle Physics by D. J. Perkins

P401: Classical Mechanics II: Mechanics of Continuous Media (42 Lectures + 14 Tutorial)
Prerequisite: P201 (Classical Mechanics I)

Outcome of the Course:
This is an advanced course introducing the students to concepts and techniques in mechanics of continuous media. It prepares them to tackle a variety of problems in many areas such as fiber optics, fluid dynamics and structural stability of materials.

1. Rigid body dynamics; Euler angle, Euler equations (should solve up to nutation of a top).
2. Elastic Continua: Small deformations, stress tensor, elastic energy, equation of motion. Mechanics of continuous media.
3. Strings: Euler Lagrange equation for continuous medium, Bernoullis and D'Alemberts solutions, Sturm-Liouville theory.
4. Membranes: Scalar Helmholtz equation and its solution in various geometries.
5. Fluids: Newtons second law for an ideal fluid, continuity equation, Euler equation, Bernoullis theorem, sound waves in fluids.
6. Surface waves on Fluids: Tidal waves (long waves on shallow water), surface waves on deep water, solitary waves.
7. Viscous Fluids: Viscous stress tensor, Navier Stokes equation, examples of incompressible flow, sound waves in viscous fluids.

References:

1. Classical Mechanics by N. C. Rana & P. S. Joag
2. Classical Mechanics by H. Goldstein, C. P. Poole, J. Safko
3. Classical Mechanics by A. L. Fetters and J. D. Walecka
4. Fluid Mechanics by L. Landau and E. Lifshitz
5. Theory of Elasticity by L. Landau and E. Lifshitz

P405: Atoms, Molecules and Radiation (42 Lectures + 14 Tutorial)
Prerequisite: P302 (Quantum Mechanics II), P204 (Electromagnetism I)

Outcome of the Course:
Important topics in atomic physics, selection rules, atomic and molecular spectroscopy is taught. The training is imperative to work in the area of applied solid state physics and optics.

1. Hydrogen atom including l.s coupling and hyperfine interaction.
2. Helium atom introduction to exchange and correlation; variational calculation of ground and excited-states.
3. introduction to the idea of effective potentials for electrons in many-electron atoms (Hartree theory and idea of self- consistency); use of Clementi-Roetti wave-functions.
4. One-electron atomic systems in an electromagnetic field; dipole approximation and associated selection rules; Stark and Zeeman effect (note: instructor will have to introduce the students to time-dependent perturbation theory here).
5. Einstein's A and B coefficients, population inversion, laser action, derivation of A and B coefficients from semi-classical treatment of light-atom interaction.
6. Molecular formation: Discussion of atom-atom interaction, van der Waals force, ionic interaction and covalent bond.
7. Molecular structure: Hydrogen molecule MO and VB pictures; importance of correlations.
8. Molecular spectra (restricted to two atom molecules) electronic, rotational and vibrational.
9. Some lectures left for interesting current topics.

References:
1. Elementary Atomic Structure by G. K. Woodgate
2. Atomic Physics by C. J. Foot
3. Atoms, Molecules and Photons by W. Demtroeder
4. The Theory of Atomic Spectra by E. U. Condon and G. H. Shortley
5. Topics in Atomic Physics: C. E. Butkhardt and J. L. Leventhal
6. Physics of Atoms and Molecules by B.H. Bransden and C. J. Joachain

Elective Theory Courses

P451: Advanced Solid State Physics (42 Lectures + 14 Tutorial)
Prerequisite: P302 (Quantum Mechanics II), P306(Introduction to condensed matter Physics), P475 (Special topic in Quantum Mechanics)

Outcome of the Course:
This is a course which aims to prepare students with advanced concepts, techniques and knowledge of solid state physics that allows them to start working on basic research problems in the broad area of condensed matter theory, materials theory or solid state experiments.

1. Introduction to Fermi liquid theory, quasiparticle, spectral function properties and metal to insulators transitions. Idea of non Fermi liquid metals.
2. Local moment formation and suppression in metals.
3. Collective excitations: screening and plasma oscillations, spin waves and magnons.
4. Electrical and optical properties of Fermi liquid metals and Mott insulators
5. Charge impurity in a metal and Friedel oscillation
6. Magnetic impurity in a metal: quenching of local moments (Kondo effect)
7. Electron phonon interaction: electrical conduction, sound propagation and ultrasonic attenuation.
8. Quantum Hall Effect: Landau levels, role of disorder, Laughlin states and composite fermions (time permitting), introduction to topological protection and Chern insulators.
9. Band theory and simple topological insulators.
10. Quantum phase transition: Quantum rotor model, mean field solution, scaling and transport properties.

References:

1. Concepts in Solids by P. W. Anderson
2. Advanced Solid State Physics by P. Philips
3. Elementary Excitations in Solids by D. Pines
4. Introduction to Many-Body Physics by P. Coleman
5. Lecture Notes on Electron Correlation and Magnetism by P. Fazekas
6. Condensed Matter Physics by M. P. Marder
7. Strong Fermion Interactions in Fractional Quantum Hall States: Correlation Functions by S. Mulay, J. J. Quinn, M. Shattuck
8. Composite Fermions by Jainendra K. Jain
9. Quantum phase transition by Subir Sachdev

P452: Computational Physics (42 Lectures + 14 Tutorial)
Prerequisite: P206 (Quantum Mechanics I) & P301 (Statistical Mechanics)

Outcome of the Course:
This course provides training in computation tools required in research across a wide variety of fields including condensed matter, high energy phenomenology and lattice field theories.

1. Introduction to theory of computation and Random numbers.
2. Monte Carlo: Importance sampling, Markov chain, Metropolis algorithm, Ising Model and other applications.
3. Molecular Dynamics: Integration methods (e.g Verlet and Leap frog algorithms), extended ensembles, molecular system.
4. Variational methods for Schrodinger Equation, Hartree and Hartee-Fock methods.
5. Quantum Monte Carlo methods.
6. Special Topics Like: QMD, Ideal fluids, matrix inversions, Numerical solution of Poisson’s equation: Finite difference method. Particle-Mesh Methods, radiative transfer etc.

References:

1. Computational Physics by Joseph Marie Thijssen, Cambridge University Press
2. An Introduction to Computational Physics by Tao Pang, Cambridge University press
3. Computer Simulation of Liquid by M. P. Allen and D. J. Tildesley, Clarendon press
4. A Guide to Monte Carlo Simulations in Statistical Physics by L. Landau and K. Binder

5. Quantum Monte Carlo Methods by M. Suzuki (Editor) Springer-Verlag
6. New Methods in Computational Quantum Mechanics by I. Prigogine and Stuart A. Rice
7. Understanding Molecular Simulation by D. Frankel and B. Smit, Second edition, academic press.
8. Computational Methods in Field Theory by H. Gausterer and C.B. Lang (Lecture notes in physics 409)
9. Density Functional Theory of Atoms and Molecules by R. G. Parr and W. Yang
10. F. Jensen, introduction to Computational Chemistry by F. Jensen
11. Essentials of Computational Chemistry by C. J. Crammer
12. Dynamical mean field theory by Jean-Marc Robin
13. Quantum Monte Carlo Methods by James Gubernatis, Naoki Kawashima, Philipp Werner
14. Computer Simulations using Particles - R. W. Hockney and J. W. Eastwood

P453: Quantum Field Theory I (42 Lectures + 14 Tutorial)
Prerequisite: P304 (Electromagnetism II), P302 (Quantum Mechanics II)

Outcome of the Course:
This first course on quantum field theory prepares the student for tackling future advanced courses in the area of high energy physics.

1. Relativistic quantum mechanics - Klein-gordon equation, Dirac equation, free- particle solutions
2. Lagrangian formulation of Klein-Gordon, Dirac and Maxwell equations, Symmetries (Noether's theorem), Gauge field, actions
3. Canonical quantization of scalar and Dirac fields
4. Interacting fields - Heisenberg picture, perturbation theory, Wicks theorem, Feynman diagram
5. Cross-section and S-matrix
6. Quantization of gauge field, gauge fixing
7. QED and QED processes
8. Radiative corrections - self-energy, vacuum polarization, vertex correction
9. LSZ and optical theorem
10. Introduction to re-normalization

References:
1. An Introduction to Quantum Field Theory by M. Peskin and D. V. Schroeder
2. Quantum Field theory: From Operators to Path Integrals, 2nd edition by Kerson Huang
3. Quantum Field Theory by Mark Srednicki
4. Quantum Field Theory by Claude Itzykson and Jean Bernard Zuber
5. Notes from Sidney Coleman's Physics 253a, arXiv: 1110.5013

P454: Particle Physics (42 Lectures + 14 Tutorial)
Prerequisite: P306 (Nuclei & Particles), P303 (Special Theory of Relativity)

Outcome of the Course:
This course teaches the basics of particle physics and allows the student to start beginning research work in high energy phenomenology

1. Elementary particles, discrete symmetries and conservation laws.
2. Symmetries and Quarks.
3. Klein-Gordon equation, concept of antiparticle.

4. Lorentz symmetry and scalar / vector / spinor fields.
5. Dirac equation
6. Scattering processes of spin-1/2 particles, Feynmans rules as thumb rule QFT course, propagators.
7. Current-current interactions, weak interaction, Fermi theory.
8. gauge symmetries, spontaneous symmetry breaking, Higgs mechanism
9. Electroweak interaction, Glashow-Salam-Weinberg model.
10. Introduction to QCD, structure of hadrons form factors, structure functions, parton model, Deep inelastic scattering.

References:

1. Gauge Theories in Particle Physics, Vol I & II by Aitchison and Hey
2. Foundations of Quantum Chromodynamics by T. Muta
3. Modern Particle Physics by Mark Thomson
4. Introduction to Elementary Particle by David Griffiths
5. Quarks and Leptons by F. Halzen and A.D. Martin
6. Introduction to High Energy Physics: D.H. Perkins
7. Introduction to Elementary Particle Physics: A. Bettini
8. Particle Physics by B. R. Martin and G. Shaw

P455: Introduction to Phase Transitions and Critical phenomena (42 Lectures + 14 Tutorial)
Prerequisite: P301 (Statistical Mechanics)

Outcome of the Course:
This course teaches the students advanced concepts and methods in statistical mechanics crucial for the student to take up basic research work.

1. Introduction to critical phenomena and first order phase transition. Survey of experimental results and scaling hypothesis, introduction to critical exponents and universality.
2. Review of thermodynamic potentials, introduction to order parameter and response functions.
3. Introduction to interacting systems: study of one dimensional Ising model via transfer matrix, lack of phase transition in one dimension, study of Ising model in two dimensions, XY and Heisenberg model.
4. Mean field theory: calculation of order parameter, response functions and correlation functions using Curie-Weiss mean field theory and Landau-Ginzberg theory, calculation of critical exponents for mean field systems, range of validity of mean field theory.
5. Introduction to re-normalization group (RG): Kadanoff block spins and real space RG methods, Perturbative RG in momentum space: Wilson-Fisher RG and epsilon expansion, broken continuous symmetry: Mermin Wagner theorem, Goldstone modes and Kosterlitz Thouless phase transition, introduction to non-linear sigma models, quantum critical phenomena and quantum phase transitions, introduction to 1D Transverse Field Ising Model and introduction to Bose- Hubbard model.

References:

1. Introduction to phase Transitions and Critical phenomena by H. Eugene Stanley
2. Modern approach to Critical phenomena by Igor Herbut
3. Statistical physics: Statics, Dynamics and Renormalization by Leo p. Kadanoff
4. The Theory of Critical phenomena by J. J. Binney, a. J. Fisher, M. E. J. newman
5. Modern Theory of Critical phenomena by Shang-keng Ma
6. Statistical Mechanics of phase Transitions by J. Yeomans
7. Field Theory, the Renormalisation group and Critical phenomena by Daniel J. Amit

P456: Nonlinear Optics and Lasers (42 Lectures + 14 Tutorial)
Prerequisite: P204 (Electromagnetism I)

Outcome of the Course:
This course teaches the students advanced concepts and methods in modern topics in laser optics and non-linear optics necessary for the student to take up basic research work in optics.

1. Introduction to general lasers and their types, emission, absorption processes and rate equations, population inversion, gain, optical cavities, three and four level lasers, CW and pulsed lasers, Q-switching and mode-locking, physics of gas discharge, atomic, ionic, molecular, liquid, and excimer lasers, optical pumping, Holography
2. Overview of non- linear Optics, nonlinear polarization, nonlinear optical susceptibility, Symmetry considerations
3. Wave propagation in nonlinear media
4. Electro optical and magneto optical effects
5. Higher harmonic generations, phase matching and quasi phase matching, Sum and difference frequency generation, Optical parametric amplification and oscillation
6. Kerr effect, Cross-Phase Modulation, Self phase modulation, Multi-photon processes , Self focusing, Four-Wave Mixing
7. Laser Spectroscopy, wave front conjugation Stimulated Raman Scattering, Stimulated Brillouin Scattering, Optical solitons and Optical pulse compression

References:

1. Lasers by P. W. Milonni and J. H. Eberly
2. Lasers by A. E. Siegman
3. Principles of Lasers by Orazio Svelto
4. The Principles of Nonlinear Optics by Y. R. Shen
5. Nonlinear Optics by Robert W. Boyd
6. Nonlinear Optics: Basic Concepts by D.L. Mills
7. Optical waves in crystals by Amnon Yariv and Pochi Yeh

P457: General Theory of Relativity and Cosmology (42 Lectures + 14 Tutorial)
Prerequisite: P303 (Special Theory of Relativity)

Outcome of the Course:
This course teaches the students, advanced concepts and methods in general relativity crucial for the student for building their background for research work in general relativity and cosmology.

1. Review of Newtonian Mechanics. Special theory of relativity. prelude to general relativity, historical developments
2. 4-Vectors and 4-tensors, examples from physics
3. Principle of Equivalence, Equations of motion, gravitational force
4. Tensor analysis in Riemannian space, Effects of gravitation, Riemann-Christoffel curvature tensor, Ricci Tensor, Curvature Scalar
5. Einstein Field Equations, Experimental tests of GTR
6. Schwartzchild Solution, gravitational lensing
7. Gravitational waves: generation and detection
8. Energy, momentum and angular momentum in gravitation
9. Cosmological principle, Robertson-Walker metric, Redshifts
10. Big-Bang Hypothesis, CMB

11. Issues in Quantum gravity

References:

1. A first course in General Relativity by Bernard Schutz
2. Gravity by James B. Hartle
3. The Classical Theory of Fields by L. D. Landau and E. M. Lifshitz
4. Gravitation and Cosmology by Steven Weinberg
5. Introducing Einstein's Relativity by Ray D'Inverno
6. General Relativity by P. Dirac

P458: Soft Condensed Matter (42 Lectures + 14 Tutorial)
Prerequisite: P301 (Statistical Mechanics)

Outcome of the Course:
This course teaches the students advanced concepts and methods in soft matter physics, with the aim to build their background for future research work in this area.

1. Introduction: Basic phenomenology of soft condensed matter systems, intermolecular forces, viscoelasticity, ordering in softmatter, glass transition, phase separation
2. Diffusion processes: Fick's laws, Diffusion Equation, Random walks, Brownian motion, Langevin and Fokker-Plank equations
3. Colloids: Stability of colloidal systems, Poisson-Boltzmann theory, DLVO theory, Depletion interactions, Electro-kinetic effects
4. Polymers: model systems and chain statistics, polymers in solvents and melts, viscoelasticity, gelation
5. Liquid crystals: Introduction, liquid crystal phases and transitions, Distorted nematic ordering, response to electric and magnetic fields
6. Amphiphiles: Introduction, microphase separation in block copolymers and in solutions of amphiphiles, aggregation and self-assembly of amphiphiles

References:

1. Principles of Condensed Matter Physics by P. M. Chaikin and T. C. Lubensky
2. Soft Condensed Matter by R. A. L. Jones
3. Structured Fluids: Polymers, Colloids, Surfactants by T. Witten
4. Introduction to Soft Matter: Polymers, Colloids, Amphiphiles and Liquid Crystals by I. W. Hamley
5. Soft Matter Physics by M. Klemanand and O. D. Lavrentovich
6. Colloidal Dispersions by W. B. Russel, D. A. Saville and W. R. Showalter
7. Dynamics of Colloids by J. K. G. Dont
8. Intermolecular and Surface Forces: With Applications to Colloidal and Biological Systems by J. Israelachvili
9. Introduction to Liquid Crystals by P. J. Collings and M. Hird
10. Polymer solutions -- an introduction to physical properties by I. Teraoka

P459: Applied Nuclear Physics (42 Lectures + 14 Tutorial)
Prerequisite: P303 (Quantum Mechanics II)

Outcome of the Course:
This course teaches the students advanced concepts and methods in applied nuclear physics, with the aim to build their background for future research work in this area.

1. Basis of nuclear structure and reactions
2. Radioactivity and radioactive decays: Detecting nuclear radiations, Alpha decay, beta decay, gamma decay
3. Passage of charged particle through matter.
4. Detectors and accelerators.
5. Applications: Effects of radiation on biological systems and Nuclear medicine, Industrial Applications
6. Power from Fission and Fusion: Characteristics of Fission, Nuclear Reactors, Thermonuclear fusion

References:

1. Nuclear Physics: Principles and Applications, John Lilley, Wiley Publications
2. The Atomic Nucleus, Robley D. Evans, Tata McGraw-Hill Publishing.
3. Fundamentals of Nuclear Reactor Physics, Elmer Lewis, Elsevier Publishing.
4. An Introduction to the Passage of Energetic Particles through Matter, N. J. Carron, CRC Press
5. Accelerator Physics, S. Y. Lee, World Scientific

P460: Many Particle Physics (42 Lectures + 14 Tutorial)

Prerequisite: P301 (Statistical Mechanics), P302 (Quantum Mechanics II) and P475 (Special topic in Quantum Mechanics)

Outcome of the Course:

This course teaches the students advanced concepts and methods in many particle physics, with the aim to build their background for future research work in this area.

1. Review of second quantisation, one and two body operators, mean field solutions of interacting systems.
2. Canonical Transformation: Jordan-Wigner, Bogoliubov-Valetin, SchriefferWolf, etc.
3. Green's function formalism at zero & finite temperatures, observables and their relationship to one and two body Greens functions.
4. Thermodynamic potential, spectral functions, analytic properties of Green's function.
5. Linear Response, correlation function, sum rules.
6. Green's functions equation of motion.
7. Diagrammatic perturbation theory for Green function and the thermodynamic potential. Interacting fermions: Hartree-Fock, Random phase and ladder approximation, Goldstone theorem, Luttinger Ward identities. Interacting bosons: condensate depletion.
8. Functional methods: Imaginary time and coherent state path integrals, many particle partition function and perturbation theory in path integral approach. Stationary phase approximation. Hubbard-Stratonovich transformation and auxiliary field representation of time evolution operator and the partition function. Saddle point approximation and small fluctuation corrections.

References:

1. Statistical Physics part 2 by E.M.Lifshitz & L.P. Pitaevskii
2. Quantum Theory of Many body particle systems by Fetter Walecka
3. Introduction to Many-Body Physics by Piers Coleman
4. Many particle physics by Ben Simon
5. Green's Function for Solid State Physics by S. Doniach & E.H. Sondheimer
6. Quantum Mechanics R. Shankar

7. Quantum many particle systems J. W. Negele and H. Orland
8. Techniques and Application of Path-integration by S.Schulman

P461: Physics of Mesoscopic Systems (42 Lectures + 14 Tutorial)
Prerequisite: P306 (Introduction to Condensed Matter Physics)

Outcome of the Course:
This course teaches the students advanced concepts and methods in mesoscopic physics, with the aim to build their background for future research work in this area.

1. Effects of magnetic fields: The Aharonov Bohm effect; 2D electron gas; Landau levels; Transverse modes in 2D quantum wire; Shubnikovde Haas oscillations; Magnetic edge states; integer Quantum Hall effect, Fractional Quantum Hall effect
2. Electron transport: Boltzmann semiclassical transport; Onsager reciprocity relations; Conventional Hall effect; Drude conductivity; Einstein relation; Electronic states in quantum confined systems; Conductance from transmission; Ballistic transport; Quantum of conductance; Landauer formula; Quantum point contact; T-matrices; S-matrix and green functions; Current operator; Landauer Buttiker formalism; Linear response and Kubo formula; nonequilib- rium green's function approach to transport; Scattering: Breit Wigner resonance and Fano resonance; Delay time for resonances; Friedel sum rule; Levin- son.s theorem; Singleelectron tunneling: Coulomb blockade and Kondo effect
3. Quantum information: Josephson Junctions and Cubits; Metastable states and escape dynamics
4. Disordered conductors: Weak localization; Mesoscopic fluctuations; Random Matrices; Anderson localization; Quantum Chaos; Dephasing; Decoherence

References:
1. Electronic Transport in Mesoscopic Systems by S. Datta, Cambridge University press.
2. Introduction to Mesoscopic Physics by Y. Imry
3. Mesoscopic Electronics in Solid State Nanostructures by T. Heinzel
4. Quantum Transport in Mesoscopic Systems: Complexity and Statistical Fluctuations by P. Mello and N. Kumar

P462: Introduction to Quantum Optics (42 Lectures + 14 Tutorial)
Prerequisite: P204 (Electromagnetism I), P206 (Quantum Mechanics I)

Outcome of the Course:
This course teaches the students important concepts and methods in quantum optics, with the aim to build their background for future research work in this area.

1. Electromagnetic field quantization: Quantum fluctuation and Quadrature operators of a single mode field, Thermal fields, Vacuum fluctuation and zero point energy, Quantum phase
2. Coherent and squeezed states of radiation field: Properties and phase space picture of coherent state, Generation of a coherent state, Squeezed state physics, generation and Detection of squeezed light, Schrodinger cat states, Multi- mode squeezing, Broadband squeezed light, Squeezing via non-linear process
3. Atom-field interaction: Rabi model (Semi-classical model for atom-field interaction), Jaynes-Cummings model (fully quantum mechanical model for atom- field interaction), Dressed states, Density operator approach, Hanle effect, Coherent trapping, electromagnetically induced transparency, Four wave mixing
4. Quantum coherence function: photon detection and quantum coherence functions, First order

coherence and Youngs type double source experiment, Second order coherence, physics of Hanbury-Brown-Twiss effect, Experiments with single photon, Quantum mechanics of beam splitter, interferometry with single photon
5. Optical test of quantum mechanics: photon sources: spontaneous parametric down-conversion, Hong-Ou-Mandel interferometer, Superluminal tunneling of photons, EpR paradox and optical test of Bell.s theorem
6. atom Optics: Mechanical effects of light, Laser cooling, atom interferometry, atoms in cavity, Experimental realization of Jaynes-Cummings model
7. Heisenberg-limited interferometry and quantum information: Entanglement and interferometric measurements, Quantum teleportation, Quantum cryptography, an optical realization of some quantum gates.

References:

1. Introductory Quantum Optics by C. C. Gerry and P. L. Knight, Cambridge University press
2. Quantum Optics by M. O. Scully and M. S. Zubairy, Cambridge University press
3. Quantum Optics by M. Fox, Oxford Master series in atomic, Optical and Laser physics
4. Quantum Theory of Light by R. Loudon, Oxford science publication

P463: Astronomy and Astrophysics (42 Lectures + 14 Tutorial)
Prerequisite: P201 (Classical Mechanics I), P204 (Electromagnetism I) & P303 (Special Theory of Relativity)

Outcome of the Course:
This course teaches the students important concepts and methods in astronomy and astrophysics, with the aim to build their background for future research work in this area.

Part I: Introduction and Tools
1. Tools - astronomical objects, scales, distance ladder, astrometry, magnitude scale
2. Gravity - Kepler's law, Virial theorem
3. Radiation physics - radiative flux, transfer function, absorption, scattering and emission, Einstein coefficient, local thermodynamic equilibrium, source function and line formation, concept of opacities

Part II: Stars
1. Stars and stellar structures - stellar spectra, HR diagram • Equilibrium in stars
2. Star formation and Protostar
3. Stellar evolution
4. Supernovae
5. Black holes and gravitational waves

Part III : Interstellar medium

Part IV: Galaxies
1. The Milky way Galaxy - distribution of matter, differential rotation, formation of the spiral arms
2. Elliptical and Spiral Galaxies
3. Evidence for dark matter
4. Active Galaxies - Active Galactic Nuclei, Seyfert Galaxies, Quasars, Blazers

Part V: Magnetic fields
1. Astrophysical phenomena where magnetic fields are critical
2. Galactic magnetic fields - dust and synchrotron polarization, Faraday rotation, Zeeman measurements

Part VI: Gravitational Lensing

Part VII: Clusters and Superclusters (optional)

Part VIII: Cosmology (optional)

- Cosmological Observations and the Cosmological Principle - Newtonian Cosmology and Cosmological Models
- Cosmic Microwave Background

References:

1. Fundamental Astronomy by H. Karttunen, P. Kröger, H. Oja, M. Poutanen, K. J. Donner
2. Introduction to Modern Astrophysics by B. W. Carroll and D. A. Ostlie
3. An invitation to Astrophysics by T. Padmanabhan
4. Astrophysical Concepts by Martin Harwit
5. Introductory Astronomy and Astrophysics by Zelike and Gregory
6. Universe by Roger Freedman
7. Physical Universe by F. Shu
8. Astrophysics Processes by Hale Bradt
9. Radiative processes in Astrophysics by Rybicki and Lightman
10. An introduction to Astronomy and Astrophysics by Pankaj Jain
11. Quasars and Active Galactic Nuclei by Kembhavi and Narlikar

P464: Plasma Physics and Magneto-hydrodynamics (42 Lectures + 14 Tutorial)
Prerequisite: P304 (Electromagnetism II)

Outcome of the Course:
This course teaches the students important concepts and methods in plasma physics and magnetohydrodynamics, with the aim to build their background for future research work in this area.

1. Introduction to plasmas, applications: in fusion, space and astrophysics, semi- conductor etching, micro- wave generation, characterisation of the plasma state, Debye shielding.
2. Plasma and cyclotron frequencies, collision rates and mean-free paths, atomic processes, adiabatic invariance, orbit theory, magnetic confinement of single charged particles.
3. Two-fluid description, magneto-hydrodynamic waves and instabilities, heat flow, diffusion, kinetic description, and Landau damping.
4. Ideal magneto-hydrodynamic (MHD) equilibrium, MHD energy principle, ideal and resistive MHD stability, drift-kinetic equation, collisions, classical and neoclassical transport, drift waves and low-frequency instabilities, high frequency micro instabilities, and quasi-linear theory.

References:

1. Plasma physics by Peter Andrew Sturrock
2. Principles of Magnetohydrodynamics by J. P. Hans Goedbloed, Stefaan Poedts
3. Hydrodynamic and Hydromagnetic Stability by S. Chandrasekhar
4. The Physics of Plasmas by T. J. M. Boyd, J. J. Sanderson
5. Fundamentals of Plasma Physics by Paul M. Bellan,
6. Introduction to Plasma Physics by R. J. Goldston, P. H. Rutherford
7. An Introduction to Magnetohydrodynamics by P. A. Davidson
8. An Introduction to Plasma Astrophysics and Magnetohydrodynamics by M. Goossens

P466: Quantum and Nanoelectronics (42 Lectures + 14 Tutorial)
Prerequisite: P302 (Quantum Mechanics II), P301 (Statistical Mechanics)

Outcome of the Course:

This course teaches the students important concepts and methods in nanoelectronics, with the aim to build their background for future research work in this area.

1. Introduction and review of electronic technology
2. From electronics to nano-electronics: particles, waves and Schrodinger equation, quantum description of atoms and molecules, quantum description of metals, semiconductors, junction devices, some newer building blocks for nano-electronic devices
3. Fabrication and characterization methods for nano-electronics
4. The field effect transistor FET: size limits and alternative forms
5. Devices based on electron tunneling, resonant tunnel diodes, single electron transistors, molecular electronics, hybrid electronics
6. Devices based on electron spin and ferromagnetism
7. Qubits vs. binary bits in a quantum computer, applications of nano-electronic technology to energy issues
8. Summary and brief comment on the future of nano-electronic techniques

References:

1. Quantum nano-electronics: An Introduction to Electronic Nanotechnology and Quantum Computing by Edward L. Wolf
2. Quantum Electronics by Amnon Yariv
3. Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience by Edward L. Wolf
4. Fundamentals of Nanoelectronics by George Hanson
5. Introduction to Nanoelectronics: Science, Nanotechnology, Engineering and Applications by Vladimir Mitin, Viatcheslav, A. Kochelap, Michael, A. Stroscio

P467: Nonlinear Dynamics, Chaos and Turbulence (42 Lectures + 14 Tutorial)
Prerequisite: P201 (Classical Mechanics I)

Outcome of the Course:
This course teaches the students important concepts and methods in classical nonlinear dynamics, with the aim to build their background for future research work in this area.

1. General introduction and motivation: examples of linearity and nonlinearity in physics and the other sciences; modelling systems using iterated maps or differential equations, nonautonomous systems
2. General features of dynamical systems : Systems of differential equations with examples; control parameters; fixed points and their stability; phase space; linear stability analysis; numerical methods for nonlinear systems; properties of limit cycles; nonlinear oscillators and their applications; the impossibility of chaos in the phase plane; bifurcations: their classification and physical examples; spatial systems, pattern formation and the Turing mechanism; strange attractors and chaotic behaviour
3. The logistic map: Linear and quadratic maps; graphical analysis of the logistic map; linear stability analysis and the existence of 2-cycles; numerical analysis of the logistic map; chaotic behaviour and the determination of the Lyapunov exponent; universality and the Feigenbaum numbers; other examples of iterated maps
4. Hamiltonian Sytems: Phase space; Constants of motion and integrable Hamiltonians; Nonintegrable systems, the KAM theorem and period-doubling; applications
5. Fractal geometry: dimension of an object, Mandelbrot set, Julia set, iterated function systems
6. Spatio-temporal dynamics: Spatio-temporal chaos

7. Quantum Chaos: Quantum analogies to Chaotic behaviour, Correaltions in wave functions, chaos and Semi-classical approaches to Quantum mechanics

References:

1. Nonlinear Dynamics and Chaos: With Applications in Physics, Biology, Chemistry and Engineering by S. H. Strogatz
2. Chaos and Nonlinear Dynamics by Robert C. Hilborn
3. Exploring Chaos: Theory and Experiment by Brian Davies
4. An Introduction to Dynamical Systems by K. T. Alligood, T. D. Sauer and J. A. Yorke, Chaos
5. Chaos in Dynamical Systems by Edward Ott
6. Chaos and Integrability in Nonlinear Dynamics: An Introduction by M. Tabor

P468: Magnetism and Superconductivity (42 Lectures + 14 Tutorial)
Prerequisite: P306 (Introduction to Condensed Matter Physics)

Outcome of the Course:
This course teaches the students important concepts and applications of many particle quantum mechanics, with the aim to build their background for future research work in this area.

1. The phenomenon of Superconductivity: historical perspective, characteristics, occurrence
2. London Equations, Thermodynamics
3. Ginzburg Landau Theory, Abrikosov Vortices
4. Josephson Effect
5. Cooper instability, BCS wave function, gap equation, thermodynamics and magnetic response, Nambu-Gorkov formalism, idea of BCS-BEC crossover.
6. Conventional and non-conventional superconductors
7. Diamagnetism paramagnetism Ferromagnetism characteristics, Occurrence
8. Orbital magnetism, de Haas van Alfen effect, Meissner Effect in superconductor
9. Heisenberg Model: ground state, spin waves
10. Hubbard Model and itinerant exchange

References:

1. Theory of Superconductivity by J. R. Schrieffer
2. Superconductivity of Metals and Alloys by P. G. De Gennes
3. Introduction to Superconductivity by M. Tinkham
4. Quantum Theory of Magnetism by R.M.White
5. The theory of Magnetism by D. C. Mattis

P469: Density Functional Theory of Atoms, Molecules and Solids (42 Lectures + 14 Tutorial)
Prerequisite: P302 (Quantum Mechanics II)

Outcome of the Course:
This course teaches the students important concepts and methods in density functional theory, with the aim to build their background for future research work in this area.

1. Many-body problem: QM of electrons and nuclei, approximation methods for many electron systems, Born-Oppenheimer approximation, Hartree and HF theory, tight binding method, greens functions, electron correlation, Ci & many-body and Moller-plesset theory, complete active space methods, coupled cluster theory, density matrices, time-dependent approach to all the above formalism

2. Foundations of Density Functional Theory(DFT): Hohenberg-Kohn (HK) theo-rem, degenerate ground states, variational DFT, N − and v− representability problem, Levy-Lieb constrained search, fractional particle number & derivative discontinuity, spin polarized systems, Exited states part i: Effective Single particle picture: Kohn-Sham (KS) construction, non-interacting v− representability, degenerate KS DFT, KS equations for spin polarized systems, interpretation of KS eigenvalues
3. Exchange-Correlation (XC) Energy Functional: exact exchange formalism within DFT, exact representations of the energy functional, LDa, gga, meta-gga, weighted density approximation, self interaction correction (SiC), virial theorems, exact exchange formalism (OpM, KLi, HS), where DFT goes wrong, strengths of DFT, strong correlation: DFT+U, Rpa, gW, DFpT, DMFT, orbital free DFT, DFT- hybrid
4. Crossover to Excited-States: time-dependent DFT: Runge-gross theorem, time- dependent KS equations, adiabatic LDa & TD XC potentials, linear response TDDFT, Excited states part ii, spin polarized TDDFT, frequency dependent XC kernel, TDCDFT, TDOEp, relativistic DFT, molecular orbital theories

References:
1. Density Functional Theory of atoms and Molecules by Robert G. Parr and Weitao Yang
2. Density functional Theory by R.M. Dreizler and E.K.U. Gross
3. Density Functional Theory by Eberhard Engel
4. Primer in Density Functional Theory by C. Fiolhais, F. nogueira, Miguel and A. L. Marques
5. Fundamentals of TDDFT by Miguel A. L. Marques et al.
6. Time-dependent Density Functional Theory by Miguel A. L. Marques et al.
7. Time-dependent Density Functional Theory by Carsten Ullrich
8. Quantal Density Functional Theory I & II by Viraht Shani
9. Recent advances in Density Functional Methods (Part I, II & III) by Delano P Chong
10. Atomic and Electronic Structure of Solids by Ethimios Kaxiras
11. Electronic Structure: Basic Theory and Practical Methods by Richard M. Martin
12. Many-Body Quantum Theory in Condensed Matter Physics by H. Bruus and K. Flensberg
13. Quantum Theory of the Electron Liquid by Gabriele Giuliani and Giovanni Vignale
14. Molecular Electronic Structure Theory by T. U. Helgaker, P. Jorgensen and J. Olsen
15. Electronic Structure Calculations for Solids and Molecules by J. Kohanoff
16. Methods of Electronic Structure Calculations by M. Springborg
17. Self Consistent Fields in Atoms by Norman March
18. Computational Materials Science by J. G. Lee
19. Density Functional Theory in Quantum Chemistry by Takao Tsuneda
20. Material Modeling using DFT by Feliciano Giustino

P470: Quantum Field Theory II (42 Lectures + 14 Tutorial)
Prerequisite: P453 (Quantum Field Theory I)

Outcome of the Course:
This course teaches the students important concepts and methods in advanced quantum field theory, with the aim to build their background for future research work in this area.

1. Path-integral formulation of quantum mechanics
2. Path-integral for scalar fields, generating functional, connected Greens functions, Feynman rules, 1 loop diagrams
3. Grassmann variable, path-integral for Dirac field

4. Path-integral for Electromagnetic field, gauge fixing
5. QED, symmetries and Ward identity
6. Renormalization divergences and power counting, Φ4 theory, QED, spontaneous symmetry breaking, Renormalization group basics (running of coupling).
7. Yang-Mills theory, gauge fixing and ghosts, BRST, asymptotic freedom

References:

1. An Introduction to Quantum Field Theory by M. Peskin and D. V. Schroeder
2. Quantum Field theory:From Operators to Path Integrals, 2nd edition by Kerson Huang
3. Quantum Field Theory by Mark Srednicki
4. Quantum Field Theory by Claude Itzykson and Jean Bernard Zuber
5. Notes from Sidney Coleman's Physics 253a, arXiv: 1110.5013

P471: Quantum Information & Quantum Computation (42 Lectures + 14 Tutorial)
Prerequisite: P206 (Quantum Mechanics I)

Outcome of the Course:
This course teaches the students important concepts and methods in quantum information and computation, with the aim to build their background for future research work in this area.

1. Introduction to Classical information: Shannon entropy, Mutual Information
2. Quantum Information I: Hilbert space, density matrices, quantum entropy and Holevo bound
3. Quantum Information II: Entanglement, Teleportation, super dense coding & Bell inequalities
4. Quantum dynamics:Two level systems, decoherence and Rabi oscillations
5. Quantum computation: single qubit gates-phase, swap, Hadamard, two qubit gates-CNOT
6. Quantum algorithms: Deutsch, Grover, Introduction to Shor's algorithm
7. Quantum error correction
8. Applications: Quantum simulation and Adiabatic quantum computation
9. Solid state quantum information & computation: Introduction to entanglement in nanostructures, quantum computation with superconducting devices and topological quantum computation

References:

1. Introduction to Quantum Information Science by V. Vedral (Oxford U. Press)
2. Quantum Information & Computation by M. A. Nielsen & I. L. Chuang (Cambridge U. Press)
3. An Introduction to quantum computing Kaye by P. R. Laflamme and A. M. Mosca (Oxford U. press)

P472: Experimental High Energy Physics (42 Lectures + 14 Tutorial)
Prerequisite: P206 (Quantum Mechanics I), P303 (Special Theory of Relativity)

Outcome of the Course:
This course teaches the students important concepts and methods in experimental high energy physics, with the aim to build their background for future research work in this area.

1. The interaction of high-energy particles with matter: specific applications related to EHEP. Relativistic kinematics: Detailed derivation of kinematic variables and their transformations whenever needed. Decay kinematics. Rapidity, pseudo-rapidity, space-like and time-like. Some examples where relativistic kinematics play important role for understanding of data.

2. Detectors in High Energy physics: general concept of building a HEp experiment, coverage and option
3. Gas detectors; Semiconductor detector; Scintillator and Cerenkov detectors Specific to EHEP
4. Calorimeter and Pre-shower detectors: principle of electromagnetic and hadronic shower generation. Detector Simulation: need of simulation, various techniques, MC, some general
5. Concepts. Data analysis in HEp: general approach of data cleanup, calibration, track reconstruction, reconstruction of events Error analysis in EHEp. Computing in EHEp: Basics of OO programming using C++, few applications in EHEpdata analysis.

References:

1. Relativistic Kinematics; aguide to the kinematic problems of High Energy physics by R. Hagedorn
2. The Experimental Foundations of particle physics by R. N. Cahn and G. Goldhaber
3. Techniques for nuclear and particle physics experiments: aHow to approach by W. R. Leo (Springer)
4. Experimental Techniques in Hugh Energy Nuclear and Particle physics by T. Ferbel (World Scientific)
5. Introduction to Experimental particle physics by R. C. Fernow
6. Data Reduction and Error analysis for the physical sciences by P. Bevington and D. K. Robinson
7. Data analysis Techniques for High Energy physics by R. Frunwirth, M. Regler, R. K. Bock and H. Grote

P473: Experimental Techniques (42 Lectures + 14 Tutorial)
Prerequisite: P306 (Introduction to Condensed Matter Physics) & P242 (Basic Electronics Theory & Lab)

Outcome of the Course:
This course teaches the students important concepts and methods in experimental techniques, with the aim to build their background for future research work in this area.

1. Mechanical drawing and designs: Mechanical drawing tools, basic principles of mechanical drawing, dimensions, tolerances, from design to working drawings
2. Basics tools: hand tools, machines for making holes, lathe & milling machines, grinders, casting
3. Vacuum technology: gases, gas flow, pressure and flow measurement, vacuum pumps, pumping mechanisms, ultrahigh vacuum, leak detection
4. Optical systems: optical components, optical materials, optical sources
5. Charge particle optics: electrostatic lenses, charged-particle sources, energy and mass analyzer
6. Detectors: optical detectors, photoemission detectors, particle and ionizing radiation detectors, signal to noise ration detection, surface barrier detector, Particle detector: interactions of charged particles and photons with matter; gaseous ionization detectors, scintillation counter, solid state detectors
7. Electronics: electronic noise, survey of analog and digital I/Cs, signal processing, data acquisition and control systems, data analysis evaluation
8. Nano- and micro-fabrication: various lithography techniques such as photolithography, nanoimprint lithography, e-beam lithography, ion-ball milling
9. SEM, TEM, X-ray diffraction, SQUID Magnetometry, Magnetotransport, PL/CL time resolved spectroscopy, Rutherford Backscattering spectrometry (RBS), RBS-Channeling, UV-ViS-iR spectrometry.

References:
1. The art of Measurement, by Bernhard Kramer (V. C. H. Publication)

2. Building Scientific Apparatus by J. H. Moore et al.
3. Experiments in Modern Physics, Second Edition by Adrian C. Melissinos and Jim Napolitano
4. The art of Experimental Physics by Daryl W. Preston,
5. Vacuum Technology by A. Roth (North-Holland publisher)
6. Charge particle Beams by Stanley Humphries (John Wiley and Sons)
7. Principles of Charged Particles Acceleration, by Stanley Humphries (John Wiley and Sons)
8. Radiation Detection and Measurements by G. Knoll (3rd Edition)
9. Techniques for Nuclear and Particles Physics Experiments by W. R. Leo (2nd edition, Springer)

P474: Introduction to Cosmology (42 Lectures + 14 Tutorial)
Prerequisite: P457 (General Theory of Relativity & Cosmology)

Outcome of the Course:
This course teaches the students important concepts and methods in introductory cosmology, with the aim to build their background for future research work in this area.

1. The cosmic history and inventory
2. A sketch of general Relativity.
3. The expanding Universe
4. Friedmann Equations and Cosmological Models
5. The Standard cosmological model.
6. The inflationary Universe.
7. Primordial nucleosynthesis and the thermal history of the Universe.
8. Perturbations in an expanding Universe.
9. Ggrowth of perturbations
10. Dark Matter Halos.
11. Statistical description of gravitational clusteing
12. Special Topics: Fluctuations in the CMB, Lensing, Cluster Cosmology, The Lyman-alpha Forest, Re-ionization, Halo Model, Redshift Space Distortions.

References:
1. Introducing Einstein's General Relativity by Ray D'inverno
2. The Early Universe by E. W. Kolb and M. S.Turner
3. Introduction to Cosmology by Barbara Ryden
4. Modern Cosmology by Scott Dodelson
5. Principles of Physical Cosmology by P. J. E. Peebles
6. Large Scale Structure of the Universe by P. J. E. Peebles
7. Structure Formation in the Universe by T. Padmanabhan

P475: Relativistic Nucleus-Nucleus collision & Quark-Gluon Plasma (42 Lectures + 14 Tutorial)
Pre-requisite: P306 (Nuclei and Particle Physics), P303 (Special theory of Relativity), P301 (Statistical Mechanics), P201 (Classical Mechanics-I)

Outcome of the Course:
This course provides the basic background for relativistic nuclear scattering processes and physics of quark gluon plasma.

1. Introduction to high energy heavy ion collisions and Quark-Gluon-Plasma, comparison of big bang

and the little bang

2. Thermodynamics: Relativisticgas (hadrons, quarks and gluons) and its statistical and thermodynamical properties, MIT Bag model, Hagedorn gas, phase diagram of QCD
3. Relativistic Kinematics: four vectors notation, rapidity variables, pseudo rapidity variables, light cone variables, relativistic invariants, Dalitz plot, cross sections
4. Collision Dynamics: initial state of nuclear collisions, fluid dynamical evolution, kinetic transport model, freeze-out and particle production
5. Experiments: a general overview of different experimental setup related to search for QGP and relevant observables
6. Signatures of QGP: collective flow, J/Ψ suppression, strangeness enhancement, jet quenching, electromagnetic probes, Hanbury-Brown-Twiss measurement
7. Recent progress

References:

1. Hadrons and QGP by Letterssier and Rafelski
2. Introduction to High Energy Heavy Ion Collissions by C. Y. Wong
3. Phenomenology of Ultra Relativistic Heavy Ion Collissions by W Florkowski
4. Ultra relativistic heavy ion collisions by R. Vogt
5. Introduction to relativistic heavy ion collisions, by L. P. Csernai
6. A Short Course On Relativistic Heavy Ion Collission by A. K. Chaudhuri
7. Extreme states of matter in strong interaction physics by Helmut Satz
8. Relativistic Hydrodynamics by L. Rezzolla and O. Zanotti
9. Finite Temperature Field Theory by J. I. Kapusta and C. Gale
10. The Early Universe by Kolb and Turner
11. Fantastic Realitis by Frank Wilczek
12. Research Reports in Physics, Quark Gluon Plasma, Invited lectures of Winter School, Published by Springer Verlag, Editors - B. Sinha, S. Pal and S. Raha
13. The Physics of Quark Gluon Plasma, Introductory lectures, Lecture Notes in Physics 785, Publisher - Springer, Editor - S. Sarkar, H. Satz and B. Sinha
14. Quark Gluon Plasma - From big bang to little bang, K. Yagi, T. Hatsuda, Y. Miake, Cam- bridge Monograms on Particle Physics, Nuclear Physics and Cosmology
15. Quark Gluon Plasma: Theoretical Foundations, An annotated reprint collection - J. Ka- pusta, B. Muller and J. Rafelski, Publisher - Elsevier Science

P476 Non-equilibrium Statistical Mechanics (42 Lectures + 14 Tutorial)

Pre-requisite: P301 (Statistical Mechanics)

Outcome of the Course:

This course provides the basic background of non-equilibrium statistical mechanics and out of equilibrium dynamics.

1. Kinetic theory of gases, Bolzmann distribution and its implications.
2. Bolzmann equation, H Theorem, Conservations laws and Hydrodynamics
3. Linear response, fluctuation dissipation theorem,Green-Kubo formula
4. Markov Processes: Conditional probabilities, Markov processes, Chapman-Kolmogorov equation, Master equation, Fokker Planck equation, Random walk processes,Ising Glauber Model
5. Stochastic differential equations: Langevin equation, stochastic integration, Ito calculus, Stratonvich integrals
6. Diffusion equations, first passage problems, driven diffusive systems

7. Applications: Aggregation,Fragmentation,Phase ordering Kinetic,Exclusion processes

References:

1. Stochastic Methods by C. Gardiner
2. A Kinetic View of Statistical Physics by P. L. Kaprivsky, S. Redner and E. Ben Naim
3. Statistical Physics 2- Nonequilibrium Statistical Mechanics by R. Kubo, M. Toda and N. Hashitsume
4. Stochastic Processes in Physics and Chemistry by N. G. Van Kampen.
5. Theory and Applications of Stochastic Processes by Z. Schuss
6. A Guide to First Passage Processes by S. Redner

P477 Special Topics in Quantum Mechanics (42 Lectures + 14 Tutorial)

Pre-requisite: P302 (Quantum Mechanics II)

Outcome of the Course:

This course teaches advanced topics in quantum mechanics which provides the much needed background in concepts and technique in present day research in interface of the area of quantum mechanics, many body physics and information theory.

PART I: Quantum entanglement & applications:

1. Density matrices
2. Tensor product and entangled states coherent and squeezed states; Bell basis
3. Quantum teleportation
4. EPR and Bells inequalities
5. Shannon entropy: Qbits, introduction to quantum computing principles; measurement and decoherence

References:

1. Entangled systems by Jurgen Audretsch
2. Density Matrix Theory and Applications by Karl Blum
3. Quantum Mechanics by Leonard Susskind
4. Modern Quantum Mechanics by J. J Sakurai

PART II: Introduction to many particle QM:

1. Creation/ Annihilation operators; Symmetization/Antisymertization; many body operators, Boson/Fermion coherent states, Grassmann algebra and Gaussian integrals using coherent states.
2. Dynamical variables and dynamics of identical particles
3. Applications to many body systems: Angular momentum of system of identical particles, first order perturbation in many body systems, introduction to Hartree-Fock methods.

References:

1. Quantum Mechanics Merzbacher (Chapters 21 and 22)
2. Quantum many particle systems J. W. Negele and H. Orland (Chapter 1)
3. Quantum Mechanics Schiff (Chapter 14)
4. Elements of Advanced Quantum Theory by J. M. Ziman (Chapters 1,2 and 5)
5. Modern Quantum Mechanics by J. J Sakurai

PART III: Symmetries in QM

1. Group representation, Point group symmetry, Lie Groups; Schur lemma, orthogonality theorems, irreducible representations, accidental degeneracies; Irreducible tensor operators and direct product representations, Wigner Eckart theorem;

2. Applications including molecular orbitals, space time symmetries of Bloch states; normal model of vibrations; characters of angular momentum states; SU(2), SU(3) representations

References:

1. Group Theory by M Tinkham
2. Group Theory by Hamermesh
3. Lie Algebras in Particle Physics: from Isospin To Unified Theories by Howard Geogie
4. Group theory and Chemistry by Bishop
5. Topics in Condensed Matter Theory by Michele Cini
6. Elements of Advanced Quantum Theory by J. M. Ziman (chapters 7)
7. Solid State Physics by Ashcroft and Mermin

Laboratory Experiments

P141: Physics Laboratory I

Outcome of the Course:
Introduces the students to basic methods in experimental techniques, statistics and error analysis. The focus is on basic mechanics and little amount of solid state physics experiments.

1. Compound pendulum
2. Moment of Inertia
3. Young's modulus
4. Soft massive spring and standing waves
5. Specific heat of graphite
6. Electrical Equivalent of Heat
7. Measurement of Thermal Conductivity
8. Viscosity
9. Surface tension by capillary rise
10. Velocity of Sound

P142: Physics Laboratory II

Outcome of the Course:
Expands on the training provided in P141 with further basic experiments focused on electromagnetism and optics.

1. Conversion of Voltmeter to Ammeter and vice-versa.
2. Study of Electromagnetic Damping
3. Tangent Galvanometer
4. Magnetic field variation along the axis of a circular coil and a Helmholtz coil
5. Determination of the resolving power of a telescope
6. Dispersive Power of Prism
7. Study of Newton’s rings.
8. Laser Diffraction and Interference
9. Malus's law
10. Thermal conductivity of a good conductor

P241: General Physics Laboratory

Outcome of the Course:
Expands the training of the students, building on P141 and P142 to train them in experimental methods in basic solid state experiments.

1. Verification of Coulomb's law
2. Coefficient of linear expansion by Fizeau's method
3. Magnetic susceptibility of a paramagnetic material.
4. Young's modulus of glass by Cornu's method
5. Specific charge (e/m) of electron
6. Magnetic hysteresis
7. Dielectric constant

P245: Basic Electronics Theory and Laboratory

Outcome of the Course:
This final basic training in experimental physics equips the student with concepts and methods for doing advanced experiments in electronics.

PART I (Theory) (14 Lectures)
1. Foundations, passive elements, sources – dependent sources
2. Survey of network theorems and network analysis
3. Transient response of R-L circuit, R-C circuits, sinusoidal steady state response
4. Diodes and diode circuits, power supply – rectifiers, full wave rectifier without center tapped transformer
5. Bipolar junction transistors, constant current source, constant voltage source, field effect transistors, basic differential amplifier circuit

PART II (Experiments) (9 Practicals)
1. Diode characteristics (Si/Ge & Zener)
2. Half wave rectifier circuit
3. Fullwave bridge rectifier circuit
4. Zener regulated power supply
5. Passive RC filters and phase shifting network
6. LCR series resonance circuit
7. Transistor characteristics
8. Single and two stage RC coupled amplifier
9. Characteristics of Metal-oxide semiconductor field-effect transistor (MOSFET)

References:

1. The art of electronics by Paul Horowitz and Winfield Hill, Cambridge University Press
2. Electronics by Allan R. Hambley, Prentice Hall
3. Electronics Fundamentals by Thomas L. Floyd, Prentice Hall
4. Introduction to Electronics by Earl Gates, Cengage Learning
5. Op-amps and linear integrated circuits by R.A. Gayakwad, Prentice Hall of India
6. Microelectronics by Millman, Grabel, McGraw-Hill

P246: Advanced Electronics Theory and Laboratory

Outcome of the Course:
In this course the students learn advanced electronic experimentations. This includes transistors, operational amplifiers digital circuits and counters and are crucial to carrying our future experimental research.

PART I (Theory) (14 Lectures)
1. Operational amplifiers, feedback circuits and operations
2. Digital electronics, gates, universality of certain gates
3. Boolean expressions, Other ways of realising logic functions
4. Multiplexers, flip-flops and latches, counters, sequential circuits – master slave flip-flop (S-R), edge triggered flip-flops
5. Transducers, signal averaging, lock-in amplifier
6. D/A & A/D converter, multi-channel analyzer, introduction to microcomputers and microprocessors

PART II (Experiments) (9 Practicals)
1. Study of basic configuration of OPAMP (IC-741), simple mathematical operations and its use as comparator and Schmitt trigger
2. Differentiator, Integrator and active filter circuits using OPAMP (IC-741)
3. Phase shift oscillator using OPAMP (IC-741)
4. Study of various logic families (DRL, DTL and TTL)
5. Study of Boolean logic operations using ICs
6. Design and study of full adder and subtractor circuits
7. Design and study of JK flip flop and counter circuits
8. Design and study of astable multivibrators using IC 555
9. Basic experiments using Lock-in amplifier (Signal and noise, Phase sensitive detection, measurement of low resistance and mutual inductance using lock in amplifier)

References:

1. The art of electronics by Paul Horowitz and Winfield Hill, Cambridge University Press
2. Electronics by Allan R. Hambley, Prentice Hall
3. Electronics Fundamentals by Thomas L. Floyd, Prentice Hall
4. Introduction to Electronics by Earl Gates, Cengage Learning
5. Op-amps and linear integrated circuits by R.A. Gayakwad, Prentice Hall of India
6. Microelectronics by Millman, Grabel, McGraw-Hill

P346: Computational Physics Laboratory (24 Practicals)

Outcome of the Course:
The course provides a basic training in numerical and statistical methods used in all branches of physics though programming and hands on tutorial sessions.

1. Introduction to C/C++ or Python
2. Representation of numbers on the computer, integers and floating point number, finite precision
3. Statistical description of data: Mean, Variance etc. Statistical inference, Error propagation
4. Curve fitting : Introduction to least squares, Straight line fitting, General linear and non-linear

function fitting
5. Numerical Differentiation
6. Numerical Integration
7. Random number generators and random walk
8. Differential equations - Euler and Runge Kutta methods
9. Introduction to solving Partial Differential Equations
10. Finding roots of polynomials and transcendental equations
11. Minimisation of functions - golden section search, multivariable minimisation, gradient descent, conjugate gradient methods for quadratic and general functions
12. Solving system of linear equations using matrix algebra
13. Fast Fourier Transforms
14. Monte Carlo – Markov chain, Metropolis algorithm, Ising Model
15. Solving system of linear equations using matrix algebra
16. Fast Fourier Transforms
17. Monte Carlo – Markov chain, Metropolis algorithm, Ising Model

References:

1. Learning Python, 5th Edition by Mark Lutz, O'Reilly Publications
2. The C++ Programming Language 4th Edition by Bjarne Stroustrup, Addison-Wesley Professional
3. An Introduction to Computational Physics by Tao Pang, Cambridge University Press
4. A Guide to Monte Carlo Simulations in Statistical Physics, by David P. Landau and Kurt Binder, Cambridge University Press.
5. Numerical Recipes in C++: The Art of Scientific Computing by William H. Press, Saul A. Teukolsky, Cambridge University Press

P345 Optics Laboratory

Outcome of the Course:
This course provides additional experience to the students in experiments in optics.

1. Diffraction of laser light using single and double slits
2. Splitting of Sodium D-line
3. Diffraction by ultrasonic waves in liquids
4. Spatial Filtering
5. Fourier imaging
6. Conversion of polarization of light using wave plates
7. Study of Birefringence
8. Study of Zone plates
9. Michelson Interferometer
10. Fabry-Perot Interferometer

P343: Modern Physics Laboratory

Outcome of the Course:

This course provides further experience to the students in experiments in modern quantum mechanics including highly specialized experiments on electron spin resonance.

1. Franck-Hertz Experiment
2. Emission spectra of metals and hydrogen
3. Planck's constant by Photoelectric Effect
4. Electron spin resonance and estimation of Lande 'g' factor in DPPH
5. Circular and linear polarised light, Normal and Anomalous Zeeman effect and determination of Bohr magnetic moment
6. Electromagnetic induction, measurement of magnetic moment of a magnet, physical property sensors and interfacing with EXPEYES board
7. Instrumentation and Measurement of light with photo diode and photo transistor

P341: Nuclear Physics and Instrumentation Laboratory

Outcome of the Course:

This course teaches the students about basic experimentation in nuclear physics. It in conjunction with theory course on Nuclear physics P307 builds a background to carry our basic research in the field of experimental particle physics.

1. Basics of GM: Characteristics and counting statistics
2. Application of GM counter (range of beta particles, attenuation of Bremsstrahlung, half-life measurement)
3. Rutherford scattering
4. Gamma Ray spectroscopy
5. Compton Scattering
6. Gamma-Gamma correlation spectroscopy and absorption of gamma radiation
7. Alpha spectroscopy and energy loss of alpha radiation
8. Ratio of Photonuclear cross section and Compton scattering cross section
9. Analog to digital conversion and digital to analog conversion
10. Application of Monte-Carlo techniques to Nuclear physics: estimation of solid angle, expected count rate etc.

P347: Solid State Physics Laboratory

Outcome of the Course:

In this course the student is introduced to a variety of basic experiments in solid state physics. This prepares them for taking up more challenging experiments in this are in future courses.

1. Estimation of resistance in metals and semiconductors, two probe and four probe methods, Resistivity as a function of temperature, PID controller and estimation of band gap
2. Phonon vibrations, realisation of monoatomic and diatomic lattices with inductors and capacitors, estimation of phonon gap in diatomic electronic analogue lattice
3. Measurement of Hall voltage in p-type and n-type Ge, Hall voltage as a function of temperature in p type Ge, Types of charge carriers, mobility and concentration of charge carriers

4. Estimation of Resistance in presence of magnetic field strength (Magneto-resistance) in semi metals and semiconductors, Ohmic contact and Shottky barrier
5. Temperature measurement with thermocouple, PT100 sensor and diode, Seebeck effect; Photovoltaic effect
6. Characteristics and estimation of maximum power of a solar cell.
7. Thick ness and refractive index of thin films using Ellipsometry
8. Measurement of indirect and direct band gap of semiconductors
9. Dielectric constant of ferroelectric material, study of Paraelectric-Ferroelectric transition
10. Mosley's law and X-ray diffraction

P445: Integrated Physics Laboratory I

Outcome of the Course:
In this course the student is introduced to a variety of advanced experiments in solid state physics and laser optics.

1. Superconductivity using LC Circuit
2. Dielectric constant at microwave frequency
3. Study of Magnetostriction using Michelson interferometry and interfacing with LABVIEW
4. Experiments using Educational SQUID
5. Study of Raman spectroscopy
6. Alignment of He-Ne Laser and study of spectral and spatial properties of the beam
7. Study of Nd-Yag laser
8. Study of Z-scan
9. Experiments with Optical fiber
10. Thin film deposition and characterization
11. Muon life time measurement

P446: Integrated Physics Laboratory II

Outcome of the Course:
In this course the student is introduced to a further variety of advanced experiments in solid state physics and laser optics.

1. Study of Negative group delay in electronics circuit
2. Faraday effect using Lock-in-amplifier
3. Study of Coupled Oscillators
4. Study of Holography
5. Study of Laser Gyroscope
6. Study of Earth Field Nuclear Magnetic Resonance
7. Study of various optical experiments using Microwaves
8. Study of Laser Doppler Anemometry
9. Noise Fundamentals: Study of Johnson noise and Schottky noise
10. Study of Nonlinear circuits: Feigenbaum, Chua and Lorentz oscillator
11. Programming and instrumentation with FPGA board