UM-DAE Center for Excellence in Basic Sciences

Outline of course structure for the M. Sc. (Integrated) Physics stream

Revised on : 29 Sept. 2010

FIRST YEAR

(P: Physics, M: Mathematics, C: Chemistry, B: Biology, G: General, H: Humanity, E: Electives, Pr : Project)

SEMESTER –I

Subject Code	Subject	Contact hrs/per week Theory + Tutorials	Credits
M 101	Mathematics I (Calculus)	[2 +1]	3
P 101	Physics I (Classical Physics)	[2 +1]	3
C 101	Chemistry I (Structure & Bonding)	[2 +1]	3
B 101	Biology I (Cell Biology etc.)	[2 +1]	3
G 101	Computer Basics	[2 +1]	3
H 101	Communication Skills	[2 +0]	1
		Contact hrs/per week Lab	**Credits**
PL101	Physics Laboratory	[3]	2
CL101	Chemistry Laboratory	[3]	2
BL 101	Biology Laboratory	[3]	2
GL101	Computer Laboratory	[3]	2

24

SEMESTER –II

Subject Code	Subject	Contact hrs/per week Theory + Tutorials	Credits
M 201	Mathematics II (Linear Algebra, Calculus of several variables)	[2 +1]	3
P 201	Physics II (Modern Physics)	[2 +1]	3
C 201	Chemistry II (Thermodynamics & Chemical Equilibrium)	[2 +1]	3
B 201	Biology II (Molecular Biology)	[2 +1]	3
G 201	Electronics & Instrumentation	[2 +1]	3
H 201	History of Science	[2 +0]	1
		Contact hrs/per week Lab	**Credits**
PL201	Physics Laboratory	[3]	2
CL 201	Chemistry Laboratory	[3]	2
BL 201	Biology Laboratory	[3]	2
GL 201	Electronics Laboratory	[3]	2

24

SECOND YEAR

SEMESTER –III

Subject Code	Subject	Contact hrs/per week Theory + Tutorials	Credits
M 301	Mathematical Methods	[3 +1]	4
P 301	Classical Mechanics I (including Special Relativity)	[3 +1]	4
P 302	Electricity & Magnetism	[3 +1]	4
G 301	Statistical Techniques & Applications	[3 +1]	4
H 301	World Literature	[2 +0]	1
		Contact hrs/per week Lab	**Credits**
PL 301	Physics Laboratory	6	6
GL 301	Applied Electronics Laboratory	3	3

26

SEMESTER –IV

Subject Code	Subject	Contact hrs/per week Theory + Tutorials	Credits
P 401	Mathematical Physics I	[3 +1]	4
P 402	Quantum Mechanics I	[3 +1]	4
P 403	Thermal & Statistical Physics	[3 +1]	4
C 401	Chemical Kinetics & Reaction Dynamics	[3 +1]	4
G 401	Energy & Environment	[2 +1]	3
		Contact hrs/per week Lab	**Credits**
PL 401	Physics Laboratory	6	6
GL 401	Computational Laboratory	3	3

28

THIRD YEAR

SEMESTER –V

Subject Code	Subject	Contact hrs/per week Theory + Tutorials	Credits
P 501	Optics	[3 +1]	4
P 502	Advanced Classical Mechanics & Field Theory	[3 +1]	4
P 503	Electromagnetism (including Introductory Magnetohydrodynamics)	[3 +1]	4
G 501	Numerical Methods	[3 +1]	4
G 502	Earth Sciences	[2 +1]	3
		Contact hrs/per week Lab	**Credits**
PL 501	Physics Laboratory	6	6
GL 501	Computational Laboratory	3	3

28

SEMESTER –VI

Subject Code	Subject	Contact hrs/per week Theory + Tutorials	Credits
P 601	Mathematical Physics II	[3 +1]	4
P 602	Quantum Mechanics II	[3 +1]	4
P 603	Statistical Mechanics	[3 +1]	4
P 604	Solid-state Physics	[3 +1]	4
C 601	Atomic & Molecular Spectroscopy	[3 +1]	4
		Contact hrs/per week Lab	**Credits**
PL 601	Physics Laboratory	6	6

26

FOURTH YEAR

SEMESTER –VII

Subject Code	Subject	Contact hrs/per week Theory + Tutorials	Credits
P 701	Classical Electrodynamics	[3 +1]	4
P 702	Fluid Mechanics	[3 +1]	4
P 703	Nuclear & Particle Physics	[3 +1]	4
P 704	Nonlinear Dynamics & Chaos	[3 +1]	4
P 705	Accelerator & Reactor Physics	[3 +1]	4
		Contact hrs/per week Lab	**Credits**
PL 701	Physics Laboratory	3	3
PR 701	Project	-	6
			29

SEMESTER –VIII

Subject Code	Subject	Contact hrs/per week Theory + Tutorials	Credits
P 801	Condensed Matter & Statistical Physics	[3 +1]	4
P 802	Advanced Quantum Mechanics	[3 +1]	4
P 803	Techniques of Modern Physics	[3+1]	4
E 802	Elective I	[3+1]	4
E 803	Elective II	[3+1]	4
		Contact hrs/per week Lab	**Credits**
PL 801	Physics Laboratory	3	3
PR 801	Project	-	6
			29

FIFTH YEAR

SEMESTER –IX

Subject Code	Subject	Contact hrs/per week Theory + Tutorials	Credits
P 901	Advanced Nuclear Physics	[3 +1]	4
P 902	Advanced Condensed Matter Physics	[3 +1]	4
E 901	Elective III	[3 +1]	4
E 902	Elective IV	[3+1]	4
G 901	Radiation Science	[3 +1]	4
		Contact hrs/per week Lab	**Credits**
PL 901	Physics Laboratory	3	3
PR 901	Project	-	6
			29

SEMESTER –X

Subject Code	Subject	Contact hrs/per week Lab	Credits
E 1001	Special Course	[3+1]	4
PR 1001	Project	-	24
			28

Total Credits: 271

ELECTIVES:

E 1 Nano Sciences
E 2 Relativity & Cosmology
E 3 Advanced Semiconductor Physics & Photonics
E 4 Ultrafast Phenomena in Natural Sciences
E 5 Advanced Nuclear Physics
E 6 Differential Geometry & Applications to Physics
E 7 Phase transitions & Critical Phenomena
E 8 Advanced Electronics
E11 Strong Field Science
E12 Advanced Particle Physics
E13 Classical & Quantum Information Theory
E14 High Pressure Physics
E 15Advanced Quantum Field Theory
E 16 Advanced Reactor Physics
E 17 Plasma Physics
E 18 Biological Physics
E 19 Lasers & Quantum Optics
E 20 Advanced Accelerator Physics
E 21 Astronomy & Astrophysics
E 22 Nuclear Magnetic resonance
E 23 Biostatistics
E 24 Mathematical Biology

UM-DAE Centre for Excellence in Basic Sciences

Detailed Syllabus of Integrated MSc (Physics)

Last Revision: 27th September 2011

Physics I (Classical Physics) P101

Concepts of energy and mass, Linear kinematics and dynamics. Concept of force: Conservative and non-conservative forces, Friction. Conservation of momentum, energy, and angular momentum. Work-energy theorem, Centre of mass, moment of inertia. Rotational kinematics and dynamics, Rigid body motion. Impulse and collisions, Central forces, Kinetic theory of gases, Equipartition of energy.

Free oscillations in one, two, and many degrees of freedom. Linearity and superposition principle. Normal modes; Transverse and longitudinal modes. General notion of a continuous string; Resonance; Coupled pendula and oscillators, Normal coordinates.

Probability (chance, fluctuations, random walk, probability distribution, uncertainty principle); Curvilinear Coordinates, Vector calculus (differentiation and integration, gradient, divergence, curl, Green's theorem, Gauss' theorem, Stokes' theorem); Fourier series (an introduction).

1. "The Feynman lectures in Physics" volume 1, by R. P. Feynman, R. B. Leighton, M. Sands.
2. "An introduction to mechanics", by D. Kleppner and R. Kolenkow.
3. “Mechanics”, by Charles Kittel, Walter D. Knight and Malvin A. Ruderman, Berkeley Physics Course Volume 1.
4. "Waves", by F. S. Crawford, Berkeley Physics Course Volume 3.

Computer Basics and Computer Laboratory G101 - GL101

History of computers; hardware basics. Concept of operating system; basic Unix/Linux commands; Office suite, including spreadsheets. Flowcharts; computer arithmetic. Simple FORTRAN programming - mathematical operators, input, output from keyboard, library functions. Conditional statements - If-then-else, Case, Go-to. Loops- Do loops, cycle, exit, nested loops. Arrays- 1 dimensional and multi-dimensional. Formatting - input and output. Input and output from file. Functions and Subroutines. Creating HTML pages. Plotting utilities like GNU Plot.

1.Computer Oriented Numerical Methods - V. Rajaraman

Physics Laboratory I PL101

Introduction to experimental physics – conceptual and procedural understanding, planning of experiments; Plots (normal, semi-log, log-log); uncertainty / error in measurements and uncertainty / error analysis. Introduction to measuring instruments – concepts of standards and calibration; determination of time periods in simple pendulum and coupled strip oscillator system with emphasis on uncertainty in the measurements and accuracy requirements; study of projectile motion – understand the timing requirements; determination of surface tension of a liquid from the study of liquid drops formed under the surface of a glass surface; determination of Young’s modulus of a strip of metal by double cantilever method (use of traveling microscope); study of combination of lenses and nodal points and correspondence to a thick lens; study of thermal expansion of metal – use of thermistor as a thermometer; measurement of small resistance of a wire using Carey-Fosterbridge and determine electrical resistivity of the wire; study of time dependence of charging and discharging of capacitor using digital multimeter – use of semi-log plot.

1. Advanced Practical Physics for Students – Worsnop and Flint

Mathematics I (Calculus) M101

Review of real numbers, their completeness with respect to order, the Archimedean property. Sequences and series, tests for their convergence and basic properties of their limits and sums, radius of convergence. Functions of one real variable and their graphs, limits, continuity and their basic properties, continuity of standard functions. Differentiation, interpretation of the derivative as slope, velocity and rate of change, derivatives of sums and products, the chain rule, derivative of the inverse of a function, derivatives of standard functions. Rolle’s and Mean value theorems, their geometric interpretations. Higher order derivatives, application of derivatives to finding maxima and minima and to curve sketching. The integral as the limit of the lower and upper Riemann sums and as an area, connection with an anti-derivative and the Fundamental Theorem of Calculus. Applications of integration. Brief description of limits and continuity of functions of several variables, partial derivatives and directional derivatives, extreme values and saddle points, iterated integration. Vector fields, gradient, divergence and curl: definitions, properties and physical interpretations.

1. Inder K. Rana, Calculus@iitb, Concepts and Examples, Version 1.2, math4all 2009.
2. G. B. Thomas and R.L. Finney, Calculus and Analytic Geometry, 9th ed., Addison-Wesley/Narosa, 1998.
3. James Steward, Calculus, Thomson Press, 2006.

Communication Skills H101

An interactive session (with examples) on what is communication, communication in the natural and civilized worlds, types of human communication: visual/non-verbal/verbal, written/spoken, etc. An overview of mass media; a brief discussion of their types (with examples). The concepts of facilitating factors, barriers, and filters in communication; the seven C's of effective communication. Verbal communication: How to speak/listen effectively (in interpersonal communication), types of public speaking, tips for effective public speaking, how to make effective presentations. The role of written text in communication, types of writing (academic/creative/general; formal/informal etc.) with examples of good/bad writing and their analysis. Introduction to letter writing, with stress on formal correspondence; email do's and don'ts. Academic writing - an overview; explanation of various terms used in academic writing; parts of a paper/thesis; aspects such as formal language, grammatical accuracy, etc. Common grammatical/punctuation errors and how to avoid them (example-based instruction).

Physics II (Modern Physics) P201

Special theory of relativity: Michelson-Morley experiment, Galilean and Lorentz transformations, time dilation, Lorentz contraction, Doppler effect and applications. Momentum and energy relation in relativity, mass-energy conservation. Electron charge and e/m experiments, Emission and absorption spectra, Balmer and Rydberg formulae, Bohr model of H-atom, H-like ions, X-rays, Moseley’s law, X-ray diffraction, photoelectric effect, Compton effect, de Broglie’s principle, electron diffraction experiments, electron microscope, wave groups - group, phase and particle velocities. Wave mechanics: Heisenberg’s uncertainty principle, double slit experiment, classical wave equation. Schrodinger’s time dependent wave equation, well-behaved wave functions: continuity condition, single-valuedness, finiteness, orthonormality. Born’s statistical interpretation, expectation values, time independent wave function. Applications: 1-D rigid box, finite 1-D potential well, 1-D harmonic oscillator, 1-D rectangular potential barrier. Tunnel diode and alpha-decay, Scanning Electron Microscopy (SEM), 2- and 3-D rigid boxes - degeneracy. H-atom, vector model, removal of degeneracy: normal Zeeman effect, periodic table of elements, spin, Pauli’s exclusion principle. Basics of radioactivity, radioactive series, carbon dating, age of the earth. Nuclear constituents and properties, liquid drop model, stability against beta decay and spontaneous fission. Induced fission and elements of a nuclear reactor, thermonuclear fusion, nucleosynthesis, stellar energy production, elements of alpha and beta decay and nuclear reactions, single-particle shell model of a nucleus. Semiconductors, doping, reversed bias p-n junction, diode-rectification, transistor-amplification. Molecular spectra, phosphorescence, fluorescence. Superconductivity and applications. LASERS: properties and applications.

1. Concepts of Modern Physics – Arthur Beiser

2. Modern Physics – Kenneth S. Krane
3. Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles – Eisberg and Resnick
4. Perspectives of Modern Physics – Arthur Beiser

Physics Laboratory II PL201

Review of uncertainty / error analysis; least squares fit method; introduction to sensors / transducers; determination of 'g' (acceleration due to gravity) by free fall method; study of physical pendulum using a PC interfaced apparatus – study variation of effective 'g ' with change of angle of plane of oscillation - investigation of effect of large angle of oscillation on the motion; study of Newton's laws of motion using a PC interfaced apparatus; study of conservation of linear and angular momentum using 'Maxwell's Wheel' apparatus; study of vibrations of soft massive spring; study of torsional oscillatory system; study of refraction in a prism - double refraction in calcite and quartz; study of equipotential surface using different electrode shapes in a minimal conducting liquid medium; determination of electrical inductance by vector method and study effect of ferromagnetic core and study the effect of non-linearity of inductance with current.

1. Advanced Practical Physics for Students – Worsnop and Flint

Electronics & Instrumentation G201 and Electronics Lab GL201

Analog electronics: Introduction to passive electronic components -resistance, capacitance, inductance; Circuit theorems: Thevenin's theorem, Norton's theorem and Maximum power transfer theorem; basic concepts of semiconductor diode and transistor; Principle of DC power supply; half and full wave bridge rectifier, capacitor filter – ripple factor, concept of load and line regulation, concept of constant voltage source and constant current source; concept of short circuit protection and current limit protection; Zener regulator; concept of Switch Mode Power Supply (SMPS), power supply ICs, charge pump ICs for stepping up voltage and for bipolar supply; application of Bipolar Junction Transistor (BJT) - biasing circuits: The CE configuration, fixed base bias, emitter bias, and potential-divider or voltage divider bias; CE amplifier, amplifier as a switch, concept of negative feedback, differential amplifier; Operational Amplifier (OPAMP): principle, basic characteristics and parameters relevant for general use; non-inverting and inverting amplifier, voltage follower, difference amplifier, summing amplifier, voltage controlled current source; OPAMP comparator, Schmidt trigger; Digital to Analog Converter (DAC) with weighted resistance and R-2R ladder network; Anlog to Digital Converter (ADC); filters: low pass, high pass; band pass; Butterworth filter. Digital electronics: Review of basic logic gates; DeMorgan's theorem, Use of NAND / NOR as universal building blocks; arithmetic circuits; binary addition, half adder, full adder, binary subtraction - 1s and 2s complement, controlled inverter, adder / subtracter, parity checker; Flip-Flops (FF): RS-FF, D-FF, JK-FF; counters and shift registers: binary counter, ripple counter.

1. Electronic Principles - Malvino and Bates
2. Electronic Devices and Circuits – David A. Bell
3. Digital Principles and Applications – Leach, Malvino and Saha

Mathematics II (Linear Algebra and Calculus of Several Variables) M201
Prerequisite: Mathematics I M101

Algebra of matrices (real numbers and other fields), special matrices (scalar, diagonal, upper and lower triangular, etc). Linear equations and their matrix representations, row-echelon form, Gauss-Jordan elimination, general and particular solutions, homogeneous equations. Invertible matrices and elementary matrices, computation of inverse using elementary row operations. Determinants and their properties, minors and cofactors, determinant of a product of matrices, adjoint of a matrix, invertible matrices and determinants. Cramer's rule. Rank of a matrix, rank and invertibility. Vector spaces (real numbers and other fields). Examples including the space of polynomials, the space of functions, the solution space of a system of homogeneous linear equations, and row and column spaces of a matrix. Span, linear independence, basis, dimension and its uniqueness. Linear transformations, isomorphisms, kernel and image, the dimension formula. Eigenvalues and eigenvectors of a square matrix or a linear operator, computation of eigenvalues and eigenvectors, characteristic polynomial, sums and products of eigenvalues, similar matrices, diagonalization. Review of geometric properties of vectors in R^2 and R^3, dot, cross and scalar triple products, their properties and their geometric interpretation. Vector fields, review of definitions and basic properties of gradient, divergence, directional derivatives, divergence, curl and the Laplace operator. Paths and curves in R^2 and R^3, tangent, velocity, acceleration and force vectors, arc length. A brief overview of differentials. Double integrals as limits of Riemann sums and as volumes, their computation as iterated integrals, elementary regions. Triple integrals as limits of Riemann sums, their computation as iterated integrals, elementary regions. Change of variables, the Jacobian determinant, spherical and cylindrical coordinates. Application of double and triple integrals to finding volume, centre of mass, etc. Line integrals, their dependence on parametrization, their computation, work done. Parametrized surfaces, normal to a surface, surface area, surface integrals and their dependence on parametrization, their computation. Oriented surfaces, statement of Green's theorem and its application to computing the area of a region, statements of Stokes' theorem, and Gauss' divergence theorem. Conservative vector fields.

1. D.J.S. Robinson, A Course in Linear Algebra with Applications, World Scientific.
2. G. B. Thomas and R.L. Finney, Calculus and Analytic Geometry, 9th ed., Addison-Wesley/Narosa, 1998.
3. J. Marsden, A. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer.
4. Inder K. Rana, Calculus@iitb, Concepts and Examples, Version 1.2, math4all 2009.

History and Philosophy of Science H201

Module 1: History of Science
Genesis of systematic ideas: Science in ancient Greece; against mythological explanations to natural phenomena; Early atomism, mathematical atomism, against atomism; Method of analysis and synthesis; Beginning of mathematical sciences; multicultural origins of science. Renaissance and scientific revolution: Galilean ideas; mechanisation of world picture; From alchemy to chemistry, from natural history to evolutionary history, from natural numbers to complex numbers, from physiology to cell biology. Rise of experimental science: Discussion of some of the crucial experiments with an emphasis on the analysis of conceptual changes rather than the technical details.
1. Cambridge Illustrated History of Science by Colin Ronan
2. Great Scientific Experiments: 20 Experiments that Changed our View of the World by Rom Harre

Module 2: History of Indian Science
Comprehensive idea about Sanskrit literature in relation to scientific writing: Vedic and Classical literature – aim and perspective; Brief overview of the contemporary cultural development elsewhere in the world; Indus Civilisation: progress of art, architecture, science and technology, role of geometry in art and architecture; Study of ancient Indian linguistic techniques and their relation with modern programming languages; Overview of Paninian style and techniques; Precision of Sanskrit in expressing technical terms; History of number naming and writing in India; *Sulbasutra* and *Vedanga Jyotisha* – geometrical constructions and astronomical calculations; Jain literature on mathematics and astronomy; Linguistic techniques used in *Aryabhatiya;* Works of *Brahmagupta* in opposition of *Aryabhata;* Contribution of Kerala school of mathematics to development of mathematical ideas.
1. Geometry in Ancient and Medieval India by Dr. T. A. Saraswati Amma, MLBD
2. Mathematics in India by Kim Plofker (Princeton Univ. Press)

Module 3: Philosophy of Science
Introduction to epistemology; Possible criteria of demarcation between science and folklore; Non–science and metaphysics; Introduction to logical positivism and the "standard view"; Criticism of "standard view".
1. Philosophy of Science – A Very Short Introduction by Samir Okasha (Oxford Univ. Press, 2002)
2. The Golem – What Everyone should Know about Science by Henry Collins and Trevor Pinch (Cambridge Uni. Press, 1996)
3. What is this thing called Science? By Alan Chalmers

Classical Mechanics and Special Relativity P301
Prerequisite: Classical Physics P101

Review of Newtonian mechanics. One-dimensional motion of a particle: momentum and energy theorems, damping force, conservative forces, simple and damped harmonic oscillators. Motion in two and three dimensions: kinematics in a plane and three dimensions, elements of vector algebra and analysis, harmonic oscillator in two and three dimensions, potential energy, projectiles and central forces. Motion of a system of particles: conservation of linear and angular momentum and energy, various illustrative examples: collisions, two and N-body problem, center of mass coordinates, coupled harmonic oscillators. Rigid bodies: rotation about an axis, simple and compound pendulum, moments of inertia, statics of rigid bodies and structures, stress and strain. Mechanics of continuous media: Vibrating string: equation of motion and normal modes of vibration, wave propagation. Kinematics of fluids, equations of motion and conservation laws, sound waves. Lagrange's equations, generalized coordinates, systems subject to constraints, constants of motion, Hamilton's equations and Liouville's theorem. Introduction to Tensor Algebra, Rotation of a rigid body, Euler's equations, Euler's angles, symmetrical top. Michelson-Morley experiment, Galilean transformations, Postulates of special relativity. Relativistic kinematics: Lorentz transformations, relativistic addition of velocities, Doppler effect. Relativistic dynamics: mass, energy, momentum and their transformation properties, equivalence of mass and energy. Transformations of electric and magnetic fields, forces between moving charges, invariance of Maxwell's equations. Space-time diagrams, simultaneity, length contraction and time dilation, twin paradox. Principle of equivalence, gravitational red shift, elements of general relativity.

1. Mechanics – Keith R. Symon
2. An Introduction to Mechanics - Kleppner and Kolenkow
3. Introduction to Special Relativity - Robert Resnick
4. Classical Mechanics – Goldstein, Poole and Safko

Electromagnetism P302
Prerequisite: Classical Physics P101

Elements of vector calculus and curvilinear coordinates; Electrostatics: Gauss's law, electrostatic potential; work and energy in electrostatics. Laplace's equation, uniqueness theorems. Special techniques for calculating potentials: multipole expansion (introductory level); Electric fields in matter: polarisation, displacement, linear dielectrics; Magnetostatics: Ampere's law, Biot-Savart law, magnetic vector potential; Magnetostatic fields in matter: magnetic dipole, magnetisation, bound currents, auxiliary field H; Electromagnetic induction, Faraday's law; Maxwell's equations; Gauge transformations; Some applications of Maxwell's equations: wave equation, electromagnetic waves in loss-less media, dipole radiation.

1. 'Introduction to Electrodynamics', D. J. Griffiths (3/e)
2. 'Electricity and Magnetism' (Berkeley Physics Course, Vol. 2), E. M. Purcell
3. 'Introduction to Electrodynamics', A. Z. Capri and P. V. Panat
4. 'Foundations of Electromagnetic Theory', J. R. Reitz, F. J. Milford and R. W. Christy (4/e)

Physics Laboratory III PL301 - PL302

Frequency response of R-C circuit (concept of cut-off freq and filter) and frequency response of L-C circuit; concepts of phase difference between voltage and current in these circuits, phase factor for appliances using AC mains supply; R-L-C (series / parallel) resonance; transient response in R-L-C series circuit; study of Newton's rings and interference in wedge shaped films; study of double refraction in calcite / quartz prisms, polarisation of the refracted light rays, optical activity in dextrose and fructose; soldering experience - make a gated timer with indicator; measurement of heat capacity of air; Use of thermocouple / platinum resistance thermometer, use of instrumentation amplifier in amplifying signal from thermocouple; study of the laws of a gyroscope; determination of the charge of an electron by Millikan's oil drop experiment.

1. Advanced Practical Physics for Students – Worsnop and Flint

Applied Electronics Laboratory GL301

Concepts of microprocessor: Handling of binary numbers: ‘Bit’, ‘Byte’, ‘Word’, hexa-decimal; CPU, registers, memory (RAM, ROM, different kinds of ROM), data and address bus, decoder, encoder, instruction set, etc., concept of interrupt; review of concepts of Digital to Analogue Conversion (DAC) and Analogue to Digital Conversion (ADC), Introduction to microprocessor 8085. concepts of programming, flow chart, assembly language, and simulator. Use of 8085 microprocessor kit; Compose simple programs in HEX code enter into kit and execute; use of Programmable Peripheral Interface (PPI) – 8255; use of ADC (ADC 0804) and DAC (DAC0808) in stand-alone mode; program in assembly language, assemble it in an assembler in a PC and download the hex code into microprocessor kit through RS-232C serial cable; use of ADC and DAC along with microprocessor; use of interrupt in data acquisition. Introduction to microcontrollers: Atmel-Atmega-AVR-16 (used in PHOENIX kit of Inter University Acceleration Center, New Delhi - operating under LINUX). Introudction to elements of PYTHON language. Introduction to PHOENIX system used under PC command in Python language; Automation of simple physics experiments under PHOENIX (monitoring temperature, monitoring pendulum motion, charge and discharge of capacitor etc). Use of Atmega-16 standalone board for digital input and output using simple assembly commands (compiled in C language in PC and down load the hex code to the microcontroller board via parallel port of PC).

1. Microprocessor architecture, programming, and applications with the 8085 – Ramesh S. Gaonkar
2. Phoenix: Computer Interfaced Science Experiments – http://www.iuac.res.in/~elab/phoenix/

Mathematical Methods: Complex Analysis and Differential Equations M301
Prerequisite: Mathematics II M201

Complex Variables , Analytic functions and the Cauchy-Riemann equations, Power series, Conformal mappings. Line integrals, Cauchy integral theorem and its consequences. The residue formula and computation of definite integrals. Linear differential equations, Methods for solving them in the constant coefficient case and the Variable coefficients, Bernoulli, Euler equations, Wronskian and linear independence, initial and boundary value problems, mixed problems, successive approximations, power series method, Legendre, Hermite, Chebyshev equations, separation of variables, Vibrations of a String, Fourier method. Laplace transforms and its applications to solving differential equations. Fourier transforms and some of its applications.

1. J.D. Fisher : Complex variables, Dover
2. L.V. Ahlfors : Complex Analysis, McGraw Hill
3. Churchill and Brown: Complex Variables, Academic Press
4. J.B. Conway : Functions of one complex variable, Springer Student Edition
5. P.P.G . Dyke, An Introduction to Laplace transforms and Fourier Series, Springer, SUMS
6. G.F. Simmons : Differential equations with Applications and Historical Notes, McGraw Hill
7. W.E. Boyce & R.C. Diprima : Elementary Differential Equations and Boundary Value Problems, John Wiley

Introduction to World Literature H301

What is Literature? - a discussion; Introduction to literary terms, genres, and forms of various periods, countries, languages, etc. The Novel: Class study of 'Brave New World' by Aldous Huxley; Group discussions and student presentations on other genres such as the graphic novel, detective fiction, children's literature, etc. Plays: Introduction to the history of theatre, class study of (mainly) two plays: 'Pygmalion' by G. B. Shaw and 'Fire and Rain' by Girish Karnad, the setting up of play – reading group through which the students can be introduced to several other plays. Poetry: Brief introduction; Study of poetic genres, forms, topics, figures of speech, poetic language etc. by analysing various poems from around the world. Short stories, essays and other types of writing by various authors. Screening of films based on literary works, such as Pygmalion (My Fair Lady), Fire and Rain (Agnivarsha), Persepolis (a graphic novel) and a few others.

Mathematical Physics I P401
Prerequisite: Mathematical Methods

Vector calculus, identities. Gauss, Green, Stokes theorems, Curvilinear coordinates, scale factors, diagonal metric, Jacobian matrix, tensors. Matrices, vector spaces - determinants, simultaneous equations, diagonalisation, symmetric, orthogonal, Hermitian, unitary matrices. Fourier series, transforms; solving differential equations and representing functions, Parseval theorem, convolution. Laplace transforms, identities, applications. Ordinary Differential Equation's & solutions - particular integral, Wronskian, Green's function and series methods. Special functions – Legendre, Bessel functions, series solution, generating functions, Rodrigues formula, identities and applications, normalization, expansion of functions in orthogonal polynomial basis. PDEs in curvilinear coordinates - classification, separation of variables, standard forms, boundary conditions and initial conditions, time dependent and independent. Spherical, cylindrical form of Helmholz equation, general solution using Legendre and Bessel special functions, Laplace, heat, and wave equations, applications to vibrating systems, electrostatics, boundary value problems, Green's function, inhomogeneous equations.

1. Mathematical Methods for Physicists – G.B. Arfken, H.J. Weber and F. Harris.

Quantum Mechanics I P402 / P501
Prerequisite: Modern Physics P201

Historical background: A brief overview of the old quantum theory, particle properties of EM waves and wave properties of particles, de Broglie Hypothesis. Mathematical framework and postulates of quantum mechanics. Schrödinger equation. Properties of wavefunctions, superposition of wavefunctions, wave packets, ideas of phase and group velocities. Probabilistic Interpretation. Stationary solutions of the Schrödinger equation, eigenvalue equations. Significance of eigenvalues of an operator. Piecewise continuous potentials in one dimension: bound states of a particle in a box, square well. Delta function and harmonic oscillator potentials, scattering from step and square barriers, matrix mechanics, Heisenberg equation. Spin, Pauli matrices and their properties.

1. 'Quantum Mechanics', L. I. Schiff
2. 'Quatum Mechanics', Franz Schwabl
3. 'Quantum Mechanics: Non – Relativistic Theory', L. D. Landau and E. M. Lifshitz

Thermal & Statistical Physics P403
Prerequisite: Statistical Techniques and Applications

Review of semi empirical thermodynamics, laws and cycles. Axiomatic thermodynamics, exact differentials, thermodynamic potentials, Euler equation. Boltzman entropy principle, entropy identities. Application to low temperature physics. Kinetic theory and dynamics, collisions, Maxwell distributions. kinetic theory of transport, mean free path, Boltzman kinetic equation. Kinetic theory for interacting gases and ionised gases, Vlasov equation. Applications. Statistical Physics : binomial distribution, random walks.
Probability distribution, equilibrium, partition function. Statistical averages, thermodynamic quantities. Thermal radiation distribution. Foundations of statistical physics, dynamics, Gibbs distribution. Equilibrium probability distributions, Maxwell- Boltzman, Fermi-Dirac, Bose – Einstein. Statistical thermodynamics of ideal and interacting gases. Statistical thermodynamics of solids, specific heats. Statistical thermodynamics of magnetism.

1. Thermodynamics, kinetic theory and statistical physics--- Sears and Salinger
2. Thermodynamics – Zemansky and Dittman
3. Statistical physics – Berkeley physics course vol 5 F.Reif
4. Thermodynamics – H.B.Callen
5. Statistical physics – K. Huang

Energy and Environment G401

Introduction to Environmental Science. Natural Environments: Ecosystems and ecology, biodiversity. Socio-cultural environments: demography, population density, human organizations. Land use and its planning. Global climate change and effects on environment. Carbon cycle from human activity, calculation of carbon budgets. Water harvesting, storage and treatment. Natural calamities, hazards, and effects of human activity: Chemical and other technological hazards. Various case studies of natural calamities and human-induced disasters. Causes, effects, forecasting, preparedness, planning measures, technological solutions, social interventions. Concept of sustainability, individual and social, and local and global actions for a sustainable future. Introduction to energy Sources - evolution of energy sources with time. Power production, per capita consumption in the world, and relation to development index. Energy scenario in India: Various issues related to consumption and demands -energy crisis issues in India. Renewable and non-renewable energy sources - technology and commercialization of energy sources, local (decentralized) versus centralized energy production, constraints and opportunities of renewable energy (hydrocarbon and coal based energy sources). Energy conservation – calculation of energy requirements for typical and home and industrial applications. Alternative to fossil fuels - solar, wind, tidal, geothermal. Bio-based fuels. Hydrogen as a fuel. Energy transport and storages, comparison of energy sources - passage from source to delivery (source, production, transport, delivery) - efficiencies, losses and wastes. Nuclear energy: Power production: Components of a reactor and its working, types of reactors and comparison. India's three stage nuclear program. Nuclear fuel cycle. Thorium based reactors. Regulations on nuclear energy.

1. Energy in Perspective, J.B.Marion, University of Maryland, Academic Press, (1974)
2. Energy and Environment, Robert A.Ristinen and Jack J. Kraushaar, 2nd Edn., John Wiley and Sons, Inc. (2006) .
3. Renewable Energy, Boyle Godfrey, Oxford University Press (2004)
4. Environment, Problems and Solutions, D.K.Asthana and Meera Asthana, S.Chand and Co.(2006)
5. Text Book on Environmental Chemistry, Balaram Pani, I.K.International Publishing House(2007).

Physics Laboratory IV PL401-402

Application of PHOENIX (IUAC, New Delhi) microcontroller system for automation in experiments (six sessions); study of acoustic resonance in Helmholtz resonator using PHOENIX system; Resolving power of optical grating; study of atomic spectra in hydrogen, helium, mercury; Application of gamma counts from detected by G.M. counter for study of Poisson and Gaussian distributions; study of black body radiation by optical and thermal thermal radiations; study of electrically coupled oscillators – normal and transient response. Assembling components for an experiment on thermal and electrical conductivity of metals and making of measurements.

1. Phoenix: Computer Interfaced Science Experiments – http://www.iuac.res.in/~elab/phoenix/
2. The Art of Experimental Physics – Preston and Dietz
3. Manual of Experimental Physics with Indian Academy of Sciences, Bangalore kit – R. Srinivasan and K.R.S. Priolkar

Computational Laboratory GL401
Prerequisites: Computer Basics G101, Computer Laboratory GL101

Pointers and Object Oriented Programming (OOP). The nature of computational physics - machine representation, algorithmic and roundoff errors; single/double precision. Solution of algebraic functions - Fixed point method, Newton-Raphson method, Secant method. Numerical Integration - rectangular method, trapezoidal method. Lagrange's interpolation. Matrix algebra - approximate solution of a set of linear simultaneous equations by Gauss Sidel iteration method; exact solution by Gauss-Jordan elimination, determining all the eigenvalues of a real symmetric matrix by Householder's method of tri-diagonalization followed by QR factorization of the tridiagonalized matrix. Differential equations (ODE and PDE) - solution of an ODE by Euler's method and Runge-Kutta(4) method, solution of partial differential equation (Laplace's equation and Poisson's equation), using Gauss-Sidel elimination. Nonlinear systems, dynamics – fractals,, solution of nonlinear set of ODEs, strange attractors and sensitive depencence upon initial conditions, study of the logistic map.

1. Computer Oriented Numerical Methods - V. Rajaraman
2. Advanced Engineering Mathematics - E. Kreyszig

Optics P502
Prerequisites: Classical Physics P101, Electricity & Magnetism

Geometrical optics: lens maker's formula, combination of lenses, thick lens, cardinal points. Defects of images: chromatic and spherical aberrations, coma and astigmatism, and their corrections; Optical instruments: telescope and microscope, their magnification power and resolving power. Physical optics: interference by division of wavefront and amplitude, thin films, Newton's rings, fringes of equal inclination and thickness, Michelson's and Fabry Perot interferometers, Lummer plate, resolving power of interferometers, Fresnel and Fraunhofer diffraction, single slit and double slit diffraction, zone plate, Fresnel integrals and Cornu's spiral, plane and concave diffraction grating and their resolving and dispersive powers, lasers in interferometers; polarization: Malus's and Brewster's law, double refraction; plane, elliptically and circularly polarized light, quarter, half and full-wave plates, Babinet's compensator, polarization by scattering, Rayleigh scattering, Tyndal effect, Nicol prism, biaxial crystals, Kerr effect, optical activity, saccharimeter. Introduction to quantum optics, nonlinear phenomena, optical fibers and communications, elements of photonics, quantum entanglement and disentanglememnt, quantum computing.

1. Introduction to Modern Optics, G. R. Fowles, 2nd ed., Dover Publications, New York, 1975

Electrodynamics I P503
Prerequisites: Classical Physics P101, Electricity & Magnetism

Review of Maxwell's equations; Potential formulation of electrodynamics, Gauge transformations, notion of generalised potentials; Boundary value problems in electrostatics: method of images, Green's function technique, Green's functions in spherical and cylindrical coordinates, applications; Magnetostatics: boundary value problems, applications; Electromagnetic waves in media: Poynting's theorem, dispersive media, Kramers–Kronig relations, conducting media, etc.; Waveguides and cavities: rectangular and cylindrical waveguides, modes in a waveguide, energy flow and attenuation, power losses in cavities and Q value; Antennas: dipole antennas and arrays.

1. 'Classical Electrodynamics', W. Greiner
2. 'Classical Electrodynamics', J. D. Jackson (3/e)
3. 'Classical Electrodynamics', H. C. Ohanian (2/e)

Numerical Methods G501 and Numerical Methods Laboratory GL501
Prerequisites: Mathematical Physics I P401, Computational Laboratory

Representation of numbers in computers and round-off errors. Liner algebraic equations: Gaussian elimination, triangular decomposition, error analysis, singular value decomposition. Interpolation: polynomial interpolation, splines, B-splines, differentiation. Integration: Newton-Cotes formulas, extrapolation methods, Gaussian quadrature, improper integrals, summation, multiple integration, Monte-Carlo method. Non-linear algebraic equations: Bisection, fixed-point iteration, secant method, Newton-Raphson method, Brent's method, Muller method, round-off errors, solution of system of non-linear equations. Optimisation: Golden section search, Brent's method, minimisation in several dimensions, introduction to linear programming. Approximations: Least-squares approximation, Discrete Fourier Transform, L1-approximations. Algebraic eigenvalue problem: Power method, inverse iteration, brief outline of QR/QL algorithm. Ordinary differential equations: Stability of numerical integration methods, Predictor-corrector methods, Runge-Kutta methods, stiff differential equations, introduction to boundary value problems.

1. H. M. Antia, Numerical Methods for Scientists and Engineers

Earth Sciences G502

Origin of the earth, type of rocks in different layers, their physical and chemical properties, mechanism of their formation and destruction. Radioactivity and its role in geochronology, Plate tectonics and geodynamics and the role of mantle plumes in sustaining these processes. Gravity, electrical and magnetic properties of the different layers in the earth. Their variations in different geological terrains. Instrumentation, field procedures used in these studies. Response of the earth to the elastic (Seismic) and electromagnetic waves, use of this phenomena to study the earth's interior. Geodynamo and the internal magnetic field of the earth. Paleomagnetic studies, Polar wandering and reversal, possible theoretical arguments for understanding the phenomena. Seismology and its use in understanding of the different layers in the earth's interior. Utility of the different geophysical techniques (discussed above) in exploration for academic as well as for harnessing resources.

1. The magnetic field of the Earth, Merill, R.T. McElhinny, M.W. and McFadden, P.L. International Geophysical Series.
2. Earth Science by Edward J. Tarbuck, E.J. and Lutgens, F.K.
3. Introduction to Applied Geophysics: Exploring the Shallow Subsurface Burger, H.R., Sheehan, A.F., C.H.
4. Mantle Plumes and Their Record in Earth History, Condie, K.C., 2001, Cambridge University Press, Cambridge, UK
5. Applied Geophysics (Paperback) W M Telford, Robert E Sheriff and L P Geldart.

Physics Laboratory V PL501-502

Study of diffraction by single slit, double slit and multiple slits leading to grating, quantitative determination and compare with simulation; Study of Michelson interferometer and determination of refractive index of air; study of Fabry-Perot interferometer; Study of Zeeman effect using Fabry-Perot Interferometer; study of characteristics of scintillation counter used in nuclear radiation detection; study of Hall effect in semiconductors; Introduction to Labview software for automation and use of NI data acquisition card in PC (six sessions).

1. The Art of Experimental Physics – Preston and Dietz

Mathematical Physics II P601
Prerequisite: Mathematical Physics I P401

Linear vector spaces: inequalities (Cauchy-Schwarz, triangle, Bessel), Gram-Schmidt orthogonalization, metric spaces, Hilbert space. Tensors: contravariant and covariant notation, Levi-Civita symbol, pseudotensors, quotient rule, dual tensors, integral theorems, tensors in 4D space-time, covariant differentiation. Group Theory: cyclic, permutation groups; isomorphism, homomorphism, subgroups, Lagrange's theorem, normal subgroup, classes and cosets; orthogonal, rotation group, Lie group; equivalent, reducible, irreducible, Schur's lemma. Probability and Statistics: Conditional probability, Bayes' theorem, Maxwell-Boltzmann, Fermi-Dirac, Bose-Einstein. Green functions: motivation, solutions of inhomogeneous boundary-value problems, symmetry of Green's functions, eigenfunction expansion, Sturm-Liouville operator.

1. Mathematics for Physicists, P. Dennery and A. Krzywicki
2. Mathematical Methods for Physicists, G.B. Arfken and H.J. Weber
3. Mathematical Physics: The Basics, S.D. Jogalekar (2 volumes)
4. Mathematical Methods for Physics and Engineering: A Comprehensive Guide, K.F. Riley, M.P. Hobson, and S.J. Bence
5. Mathematical methods in Classical and Quantum Physics, T. Dass and S.K. Sharma

Quantum Mechanics II P602
Prerequisite: Quantum Mechanics I, Mathematical Physics I P401

Angular momentum. Bound states in three dimensions: three-dimensional box, central potential, radial equation and effective potential, solutions for free particle, spherical oscillator and hydrogen atom. Time independent perturbation theory: degenerate, non – degenerate. Zeeman and Stark effects. Time dependent perturbation theory. Radiative transitions. WKB approximation. Connection formulae. Application to alpha decay problem. Many particle systems: Thomas Fermi approximation, Hartree and Hartree–Fock approximations, atomic structure. Molecules: Born – Oppenheimer approximation, hydrogen molecule – molecular orbital and Heitler–London method, energy levels of two atom molecules – vibrational and rotational levels. Scattering Theory: scattering amplitude and scattering cross-section, reciprocity theorem, generalized optical theorem, Green's functions, Born approximation and application to simple systems, partial wave technique, phase shifts, optical theorem, resonances and Breit–Wigner approximation, time delay, scattering length.

1. 'Intermediate Quantum Mechanics', Hans Bethe
2. 'Quantum Physics: A Text for Graduate Students', R. G. Newton
3. 'Quantum Mechanics', Cohen – Tannoudji (vol. 1 and 2)
4. 'Quantum Mechanics', Walter Greiner

Advanced Classical Mechanics P60x
Prerequisite: Classical Mechanics & Special Relativity P301

Classification of constraints, virtual work, D'Alembert's principle, applications. Elements of variational calculus, geodesics, the principle of least action, Euler-Lagrange equations, generalized coordinates and momenta, energy, invariance and symmetry, integrals of the motion, Noether's theorem, illustrations. Legendre transformation (geometry and examples), Hamiltonian, covariance of Euler-Lagrange equations and action, active and passive viewpoints, extended point transformations. Huygens principle and the geometry of classical mechanics, Hamilton's equations, canonical transformations, contact transformations, generating functions, conditions of canonicality, properties of canonical transformations, canonical group, examples, symplectic geometry, phase-space portraits, Liouville theorem, Poincare-Cartan integral invariant. Poisson brackets, identities, Poisson theorem, Jacobi-Poisson theorem, examples, invariance of Poisson bracket under canonical transformations, Poisson brackets involving angular momenta, Lagrange bracket. Hamilton-Jacobi theory, time-independent Hamilton-Jacobi equation, Jacobi theorem, examples, action-angle variables, examples, integrable systems, Liouville-Arnold theorem (statement), topology of invariant integral surfaces in phase space. Adiabatic invariance, examples. Introduction to chaos: one-dimensional maps, tent maps, circle map, fixed points, logistic map, period-doubling bifurcation, Feigenbaum constants, Generalized baker transformation, Smale horseshoe, invariant sets, unstable and stable manifolds.Chaos in Hamiltonian systems: symplectic geometry, Kolmogorov-Arnold–Moser theorem, resonant tori, canonical perturbation theory, secular perturbation theory.

1. Classical mechanics, N. C. Rana, P. S. Joag.
2. Chaos in dynamical systems, E. Ott
3. Classical dynamics: a modern perspective, J. V. Jose, E. Saletan
4. Classical mechanics, H. Goldstein
5. Mathematical methods in classical mechanics, V. I. Arnold
6. Regular and stochastic motion, A. J. Lichtenberg, M. A. Lieberman

Nuclear and Particle Physics P60x
Prerequisite/Co-requisite: Modern Physics P201, Quantum Mechanics II

Discovery of radioactivity, the atomic nucleus and the neutron, properties of nucleons. nature of nuclear forces. Overview of basic nuclear properties: size, angular momentum, binding energy and electromagnetic moments. Properties of deuteron: spin and binding energy, tensor forces. Liquid drop model, shell model and predictions, residual interactions, deformed shell model. Collective excitations in nuclei: rotation and vibration. Alpha decay: tunneling for a generalized potential, fine structure. Fermi's theory of beta-decay, selection rules, Fermi-Kurie plot, Parity violation on beta decay, neutrinos, Cowan-Reines experiment. Gamma rays: selection rules and multipolarities, lifetimes for gamma emission, internal conversion. Nuclear reactions: Scattering: low energy n-p scattering, elements of s-wave scattering. Centre-of-mass frame and some simple transformations. Q-value, mean free path, Cross-section, Concept of phase shift (δ). Scattering/reaction channel: elastic, inelastic and reactive channels. Concept of partial waves. Introduction to Optical Potential. Classification of nuclear reaction mechanisms: Compound Nucleus and Direct Reactions. Compound Nucleus: Basic elements, observables, decay of CN. Concept of temperature (T) and entropy (S). Direct reactions: Basic characteristics. Stripping, pick-up, break-up, knock-out reactions. Basic elements of heavy-ion reactions. A primer on particle physics, fundamental particles and interactions, Intermediate energy reactions: Absorption and production of bosons, pion-nucleon resonances.

1. Introductory Nuclear Physics - Kenneth S. Krane
2. Concepts of Nuclear Physics - Bernard L. Cohen
3. Subatomic Physics - Frauenfelder and Henley
4. Nuclei and Particles - Emilio Segre
5. Nuclear Physics: An Introduction - S.B. Patel
6. Introduction to Nuclear Reactions: G.R. Satchler
7. Introduction to Elementary Particles: David Griffiths

Statistical Mechanics P603

Prerequisite: Statistical and Thermal Physics

Basic methods of statistical mechanics. The microcanonical, canonical and grand canonical ensembles. Illustrations with simple models. Simple applications of the canonical ensemble. ideal gas, Gibbs paradox. Equipartition theorem and paramagnetism. Applications to chemical systems. The Clausius-Clapeyron equations. The three statistics: Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein. The free electron gas: specific heat and Pauli paramagnetism. The ideal Bose gas and Bose-Einstein condensation. Interacting systems. The Debye theory of specific heat. The non-ideal gas (Van der Waal gas). The Weiss molecular field approximation. The Ising model in one and three dimensions. Mean field and related approximations. The Landau theory of second order phase transitions. Elementary introduction to critical phenomena. Transport theory using the relaxation time approximation. Boltzmann formulation. Kinetic theory of gases.

1. F. Reif, Fundamentals of Statistical and Thermal Physics, McGraw-Hill Book Company.
2. L.D. Landau and E.M. Lifshitz, Statistical Physics, Addison-Wesley Publishing Company Inc.
3. R. P. Feynman, Statistical Mechanics - A Set of Lectures, W.A. Benjamin, Inc.
4. S. K. Ma, Statistical Mechanics, World Scientific.
5. L. E. Reichl, A Modern Course in Statistical Physics, University of Texas Press, Austin.
6. Kerson Huang, Statistical Mechanics, John Wiley & Sons.
7. M. N. Saha and B. N. Srivastava, "A Treatise on Heat", The Indian Press Pvt. Ltd. (1st ed. 1931).

Physics Laboratory VI PL601-602

Study of quantum mechanics through acoustic analog (four sessions); Fourier analysis / synthesis – use of simulation; Study of characteristics of a coaxial cable and determination of speed of electromagnetic waves in the coaxial cable; determination of specific charge (e/m) of electron; Study of Faraday rotation and determination of Verdit’s constant in a glass material; investigation of chaos in a spring based coupled oscillator system; Introduction to workshop practice (two sessions); Introduction to vacuum practice (two sessions).

1. The Art of Experimental Physics – Preston and Dietz

Electrodynamics II P701
Prerequisites: Electromagnetism, Mathematical Physics II

Relativistic Electrodynamics: dynamics of relativistic particles and electromagnetic fields; Radiation from moving charges: Lienard–Wiechert potentials, Larmor's formula and its relativistic generalisation etc.; Scattering: scattering at long wavelengths, perturbation theory, applications; scattering of charged particles, method of virtual quanta, applications; Diffraction: scalar and vectorial diffraction theory, applications; Topics in applied electrodynamics; Introductory computational electrodynamics.

1. 'Classical Electrodynamics', J. D. Jackson (3/e)
2. 'Classical Electricity and Magnetism', W. K. H. Panofsky and M. Phillips (2/e)
3. 'Classical Electrodynamics', W. Greiner

Fluid Mechanics P702
Prerequisites: Classical Mechanics & Special Relativity P301, Mathematical Physics II

Validity of hydrodynamical description. Kinematics of the flow field. Stress-strain relationship. Basic equations governing conservation of mass, momentum & energy. Navier-Stokes equation for viscous flows. Shear and bulk viscosity and radiative diffusivity in fluids. Viscous and thermal boundary layers. Potential flows. Water waves. Kelvin's circulation theorem. Stokes's flow Lubrication theory. Virial theorem in the tensor form. Magnetohydrodynamic flows. Generalized Ohm's law in the presence of Hall current & Ambipolar diffusion. Magneto-gravity-acoustic modes. Classical hydrodynamic and hydromagnetic linear stability problems:Rayleigh-Taylor and Kelvin-Helmholtz instabilities. Jeans' gravitational instability; Benard convection. Parker instability and magnetic buoyancy. Thermal instability. Non-linear Benard problem. Spherical accretion flows onto compact objects and accretion disks. High Speed flow of gases. Shock waves and blast waves. Supernova hydrodynamics. Superfluid hydrodynamics. Physiological hydrodynamics. Biofluids. Relativistic hydrodynamics.

1. H. Lamb, Hydrodynamics
2. G.K, Batchelor, Fluid Mechanics
3. L.D. Landau and E.M. Lifshitz, Fluid Mechanics
4. T.G. Cowling, Magnetohydrodynamics

Solid State Physics P703
Prerequisites: Quantum Mechanics II, Statistical Mechanics

Crystal lattices, symmetries, Quasi-crystals, The reciprocal lattice, X-ray scattering. Types of solids - van der Waals, covalent, ionic and metallic bonding. Lattice vibrations, phonons, dispersion relations for mono and diatomic linear chain, heat capacity- Einstein and Debye models. Free electron model, electronic heat capacity and transport, Hall effect. Electrons in periodic potential, bands, Bloch theorem. Transport properties in electric and magnetic fields, effective mass, holes. Semiconductors - basics. Superconductivity- Meissner effect, London's equations, types of superconductors, vortex lattice, BCS model, Ginzburg-Landau model, flux quantization. Magnetism- diamagnetism, paramagnetism of d and f electrons, exchange interaction, ferro and anti-ferromagnetism, spin glass, Heisenberg model, mean field theory, spin waves, Pauli paramagnetism, Kondo effect. Special topics- CMR/GMR, Quantum Hall effect, soft condensed matter, Novel materials.

1. Introduction to solid state physics by Kittel
2. Solid state physics by Ali Omar
3. Solid state physics by Dekker
4. Introduction to superconductivity by Rose and Innes
5. Magnetism by Martin
6. Solid state physics by Ashcroft and Mermin

Nonlinear Dynamics and Chaos P704
Prerequisites: Mathematical Physics II, Classical Mechanics & Special Relativity P301

Dynamical Systems, phase portraits, vector fields, nullclines, flows, discrete dynamical systems, 1-d maps. Fixed points, linearization of vector fields, canonical forms, generalized eigenvectors, semisimple - nilpotent decomposition, Jordan canonical form, classification of fixed points. Hartman-Grobman theorem, homeomorphism, Stable Manifold Theorem, Center Manifold Theorem, examples of manifolds. Index theory, Lyapunov functions and stability analysis, Limit cycles, Poincare-Benedixon Theorem. Gronwall's inequality, the Variational Equation, exploring neighbourhoods, Lyapunov exponents, Monodromy matrix, Floquet exponents. Bifurcations: Saddle-Node, Transcritical, Pitchfork and Hopf Bifurcation. 1-d maps, linear stability of fixed points and higher order fixed points, chain rule, lyapunov exponent, bifurcation diagram, finding period-n orbits in 1-d maps. 2-d maps, Linearization, the Henon map, Poincare surface of section. Symbolic dynamics, Sensitivity to initial conditions, Chaos, Partitions, Transition matrix, Entropies, Smale Horseshoe. Invariant density, the Perron-Frobenius operator. Fractals. Hamiltonian Dynamics.

1. S. Strogatz "Nonlinear Dynamics And Chaos", Addison-Wesley
2. K.T. Aligood, T.D. Sauer, J.A. Yorke “Chaos: An Introduction to Dynamical Systems”, Springer-Verlag
3. M. Hirsh,S. Smale and R. Devaney "Differential Equations, Dynamical Systems and an Introduction to Chaos" (Elsevier Academic Press)
4. M. Tabor "Chaos and Integrability in Nonlinear Dynamics : An Introduction", John Wiley & Sons
5. P. Cvitanovic et. al. "Chaos: Classical and Quantum"

Reactor Physics P705
Prerequisites: Modern Physics P201, Nuclear Physics

Properties of Nuclei: Structure, nuclear forces, Binding energy, Liquid drop model, fission rate, reactor power, prompt and delayed neutrons, fission products, energy balance, photo neutrons. fissile, fertile and fissionable materials. Fission product activity and decay heat. Interaction of Neutrons with Matter: Production of neutrons, nuclear reactions with thermal and fast neutrons, transmutation. Microscopic cross section: scattering, Maxwell-Boltzmann distribution and deviations. Variation of cross-section with energy, fast, resonance and thermal ranges. 1/v law of neutron cross-section, resonance absorption, Doppler effect. Eta vs E curve, conversion & breeding concepts-Thorium utilization. Diffusion of neutrons: Fick’s law, steady state neutron diffusion equation, neutron flux and current, interface conditions, diffusion coefficient, diffusion length and extrapolation distance. Chain Reaction: Four Factor formula, diffusion of one group of neutrons in non-multiplying and multiplying media, infinite and effective multiplication factors, bare homogeneous reactor - material and geometric buckling, sub criticality and super criticality, non leakage probabilities in bare homogeneous cores, neutron cycle and lifetime in finite and infinite reactor system. Neutron slowing down, slowing down power and moderating ratio. Slowing down with spatial migration, Fermi age concepts, migration length, use of reflectors/blankets, reflector savings. Heterogeneous reactors: Multigroup neutron diffusion: two group approach, unit-cell concept. Reactor kinetics: Time dependent neutron diffusion equation, one group kinetic equation, prompt neutron life time, Point kinetic model - importance of delayed neutrons, reactor period, reactivity and its units. Fuel burn-up units. Neutron Poisons: Xenon and Samarium. Xenon loads (operating and post shutdown) - variation with power and enrichment. Xenon oscillations and their control. Reactivity coefficients: Temperature and void coefficient of reactivity, relevance to reactor safety. techniques to control reactors, typical reactivity balance, long-term burnup, fuel management. Reactor control system – physical requirements. Reactor shutdown mechanisms and neutron monitoring during operation and shut down. Approach to criticality; measurements, calibrations/validations. Reactivity worth measurements of control rods. Research Reactors at Trombay, Indian PHWRs.

1. S Glasstone and A Sesonske, "Nuclear Reactor Engineering", 4th Edition, 2004.
2. K S Ram, "Basic Nuclear Engineering", Wiley Eastern, 1977.
3. J R Lamarsh, "Introduction to Nuclear Reactor Theory", Addison Wesley, 1960.
4. Suresh Garg, Feroz Ahmed & L. S. Kothari, “Physics of Nuclear Reactors”,Tata McGraw-Hill,1986.
5. A M Weinberg and E P Wigner, "Physical Theory of Neutron Chain Reactors", Chicago University Press, 1958.
6. P P Zweifel, "Reactor Physics", McGraw Hill, NY, 1973.

7. Weston M. Stacy, “Nuclear Reactor Physics”, John Wiley & Sons, Inc.

Physics Laboratory VII PL701

Study of principle and characteristics of a lock-in-Amplifier (LIA); use of LIA in detecting small signals in the presence of background noise- e.g., signal from a mutual inductance of a coil and / or measurement of intensity of a light source in the presence of ambient light; Study of temperature dependence of resistivity in metals and semiconductors. Study of band gap in semiconductors. Study of paramagnetic and diamagnetic susceptibility; Study of temperature dependence of dielectric constant of a para-electric material; study of Electron Spin Resonance (ESR) in DPPH sample at RF frequency range. (Note: the list of experiments is subject to change).

Advanced Quantum Mechanics P80x
Prerequisites: Quantum Mechanics II, Mathematical Physics II

Relativistic quantum mechanics: infinitesimal Lorentz transformations, Klein-Gordan and Dirac equations, plane wave solutions, Dirac matrices and their properties, trace relations, Lorentz invariance of Dirac equation, bilinear covariants, projection operators. Dirac theory of Hydrogen and Hydrogen – like atoms. Free relativistic field quantization: scalar field quantization, field operators, expectation values, Hamiltonian quantization of electromagnetic field, photon polarization, Dirac field quantization, spin-statistics theorem. Feynman diagrams, Yukawa theory, elements of QED: basic processes, calculation of cross-sections and decay widths. Applications of QED: Moeller and Bhabha scattering. Self-interactions - $\lambda\varphi^4$ theory.

1. 'Relativistic Quantum Mechanics', Bjorken and Drell
2. 'Advanced Quantum Mechanics', J. J. Sakurai
3. 'Quantum Field Theory', L. H. Ryder
4. 'Quantum Field Theory', C. Itzykson and J.B. Zuber
5. 'Introduction to Quantum Field Theory', M.E. Peskin and D.V. Schroeder

LASERs and Quantum Optics P80x
Prerequisites: Optics, Electrodynamics, Quantum Mechanics II

Elementary aspects of light-matter interaction - classical and quantum approaches; principles of laser action and properties of laser light; generation and propagation of ultrashort laser pulses and their interactions with matter; laser applications in science and technology; simple considerations for obtaining laser action;properties of laser light; lasers - types, materials and designs; resonators, amplification and different lasing regimes; practical aspects of lasers; principles of generation of short laser pulses; methods of ultrashort pulse generation; recent advances in femtosecond laser pulses; propagation of Ultrashort laser pulses; lasers in science and technology.

1. Laser Fundamentals - Silvfast
2. Principles of Lasers - Svelto
3. Lasers - Siegman

Charged-Particle Accelerators and Beams
Prerequisite: Electrodynamics

Transverse beam dynamics: Accelerator coordinates; Canonical transformation to accelerators coordinates; Guide field; Dipole and Quadrupole Magnets; Hills equation and solution; Twiss parameters; Matrix formulation; Dispersion; Design of lattices; Field and gradient errors; Chromaticity; sextupole magnets and dynamics aperture. Longitudinal beam dynamics: Fields and forces; acceleration by time varying fields; relativistic equations; Overview of acceleration; transit time factor; main RF parameters; momentum compaction factor; transition energy; Equations related to synchrotron; synchronous particle; synchrotron oscillations; principle of phase stability; RF acceleration for synchronous and for non-synchronous particle; small amplitude oscillations; Oscillations with Hamiltonian formalism; limits of stable region; adiabatic damping. Linear accelerators: Basic methods of linear acceleration; Fundamental parameters of accelerating structures; Energy gain in linear accelerating structures; Q, Shunt-impedance, transit-time factor; periodic accelerating structures; RFQs; Microwave topics for linacs; Single particle dynamics in linear accelerators; Multi-particle dynamics in linear accelerators. Synchrotron radiation: Introduction to electromagnetic radiation; Radiation of accelerated charged particles; radiation from wigglers and undulators; Electron dynamics with radiation; Low emittance lattices; synchrotron-radiation sources. Free-electron lasers: Introduction; electron dynamics in the undulator; spontaneous emission; electron dynamics in the laser field; dynamics of the laser field; dimensionless equations of motion; solution in the small-signal, small-gain regime; Madey theorem; three-dimensional effects; undulators; X-ray laser. Advanced accelerator concepts: Photoinjectors; laser-wakefield acceleration; plasma-wakefield acceleration; linear colliders; muon colliders.

1. An Introduction to the Physics of High-Energy Accelerators, D. A. Edwards & M. J. Syphers
2. An Introduction to Particle Accelerators, Edmund Wilson
3. Introduction to Accelerator Physics, Arvind Jain
4. R. F. Linear Accelerators, T. P. Wangler
5. Classical Electrodynamics (3rd Ed.), J. D. Jackson

Electives

Some electives from the list below will be offered every semester. The course instructor will determine the prerequisites.

1. General Relativity
2. Topics in Mathematical Physics
3. Astronomy & Astrophysics
4. Physics of Particle Accelerators
5. Chaos in Non-Equilibrium Statistical Mechanics
6. Experimental Electromagnetism
7. Quantum Field Theory
8. Particle Physics
9. Galactic and Extra-Galactic Astronomy
10. Advanced Nuclear Physics
11. Advanced Statistical Mechanics
12. Advanced Atomic Physics
13. Protein Crystallography
14. Advanced Condensed Matter Physics
15. Experimental Techniques of Nuclear and Particle Physics
16. Nano Sciences
17. Advanced Semiconductor Physics & Photonics
18. Ultrafast Phenomena in Natural Sciences
19. Advanced Nonlinear Dynamics
20. Differential Geometry & Applications to Physics
21. Phase transitions & Critical Phenomena
22. Advanced Electronics
23. Strong Field Science
24. Advanced Particle Physics
25. Classical & Quantum Information Theory
26. High Pressure Physics
27. Advanced Reactor Physics
28. Plasma Physics
29. Biological Physics
30. Advanced Accelerator Physics
31. Nuclear Magnetic resonance
32. Biostatistics