Center for Basic Sciences (CBS)

SCHEME OF EXAMINATION

&

COURSE STRUCTURE

of

M.Sc. Integrated (Physics Stream)

UNDER

FACULTY OF SCIENCE

Approved by Board of Studies in Physics

EFFECTIVE FROM JULY 2015

Center of Basic Science
Pt. Ravishankar Shukla University
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Course structure for the M. Sc. (Integrated) Physics Stream
July, 2015

(B: **B**iology, C: **C**hemistry, M: **M**athematics, P: **P**hysics, G: **G**eneral, H: **H**umanities, BL: **B**iology **L**aboratory, CL: **C**hemistry **L**aboratory, PL: **P**hysics **L**aboratory, GL: **G**eneral **L**aboratory, PE: **P**hysics **E**lective, PPr: **P**hysics **Pr**oject)

FIRST YEAR

SEMESTER –I

Subject Code	**Subject**	**Contact Hours / Week Theory+Tutorials**	**Credits**
B101	Biology – I	[2 + 1]	3
C101	Chemistry – I	[2 + 1]	3
M100/101	Mathematics – I	[2 + 1]	3
P101	(A) Physics – I (PCM Stream) (B) Physics-I (Biology Stream)	[2 + 1]	3
G101	Computer Basics	[2 + 1]	3
H101	Communication Skills	[2 + 1]	3
		Contact Hours /Week Laboratory	
BL101	Biology Laboratory – I	[4]	1
CL101	Chemistry Laboratory – I	[4]	2
PL101	Physics Laboratory – I	[4]	2
GL101	Computer Laboratory	[4]	2

25
(25 of 240 credits)

SEMESTER –II

Subject Code	**Subject**	**Contact Hours /Week Theory+Tutorials**	**Credits**
B201	Biology – II	[2 + 1]	3
C201	Chemistry – II	[2 + 1]	3
M200/201	Mathematics – II	[2 + 1]	3
P201	Physics – II (PCM & Bio Stream)	[2 + 1]	3
G201	Electronics and Instrumentation	[2 + 1]	3
G202	Glimpses of Contemporary Science	[2 + 1]	3
		Contact Hours /Week Laboratory	
BL201	Biology Laboratory – II	[4]	1
CL201	Chemistry Laboratory – II	[4]	2
PL201	Physics Laboratory – II	[4]	2
GL201	Electronics Laboratory	[4]	2

25
(50 of 240 Credits)

SECOND YEAR

SEMESTER –III

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
P301	Mathematical Physics – I	[3 + 1]	4
P302	Classical Mechanics – I	[3+ 1]	4
P303	Electromagnetism	[3 + 1]	4
P304	Waves and Oscillations	[3 + 1]	4
H301	World Literature	[2 + 0]	2
H302	History and Philosophy of Science	[2 + 0]	2
		Contact Hours / Week Laboratory	
PL301	Physics Laboratory – III	[6]	3
GL301	Applied Electronics Laboratory	[4]	2

25
(75 of 240 Credits)

SEMESTER –IV

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
P401	Mathematical Physics – II	[3 + 1]	4
P402	Quantum Mechanics – I	[3+ 1]	4
P403	Statistical Mechanics – I	[3 + 1]	4
PCB401	Physical and Chemical Kinetics	[3 + 1]	4
G401	Statistical Techniques and Applications	[3+ 1]	4
		Contact Hours / Week Laboratory	
PL401	Physics Laboratory – IV	[6]	3
GL401	Computational Laboratory and Numerical Methods	[4]	2

25
(100 of 240 Credits)

THIRD YEAR
SEMESTER –V

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
P501	Quantum Mechanics – II	[3 + 1]	4
P502	Classical Mechanics – II	[3+ 1]	4
P503	Atomic and Molecular Physics	[3 + 1]	4
PM501	Numerical Analysis	[3 + 1]	4
G502	Earth Science and Energy & Environmental Sciences	[3+ 1]	4
		Contact Hours / Week Laboratory	
PL501	Physics Laboratory – V	[6]	3
PML501	Numerical Methods Laboratory	[4]	2

25
(125 of 240 Credits)

SEMESTER –VI

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
P601	Electrodynamics	[3 + 1]	4
P602	Nuclear Physics – I	[3+ 1]	4
P603	Condensed Matter Physics – I	[3 + 1]	4
P604	Lasers	[3 + 1]	4
P605	Nonlinear Dynamics and Chaos	[3+ 1]	4
H601	Ethics of Science and IPR	[2+ 0]	2
		Contact Hours / Week Laboratory	
PL601	Physics Laboratory – VI	[6]	3

25
(150 of 240 Credits)

FOURTH YEAR
SEMESTER –VII

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
P701	Fluid Mechanics	[3 + 1]	4
P702	Quantum Mechanics – III	[3+ 1]	4
P703	Statistical Mechanics – II	[3 + 1]	4
P704	Reactor Physics and Radiation Science	[3 + 1]	4
		Contact Hours / Week Laboratory	
PL701	Advanced Physics Laboratory – I	[8]	5
PPr701	Reading Project		4

25
(175 0f 240 Credits)

SEMESTER –VIII

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
P801	Astronomy and Astrophysics	[3 + 1]	4
P802	Accelerator Physics and Applications	[3+ 1]	4
P803	Nuclear and Particle Physics	[3 + 1]	4
P804	Condensed Matter Physics – II	[3 + 1]	4
		Contact Hours / Week Laboratory	
PL801	Advanced Physics Laboratory – II	[8]	5
PPr801	Project		4

25
(200 of 240 Credits)

SEMESTER- IX

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
PPr901	Project		20

20
(220 of240 Credits)

SEMESTER- X

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
PE1001	Quantum Field Theory	[3 + 1]	4
PE1002	Non-equilibrium Statistical Mechanics	[3+ 1]	4
PE1003	Advanced Mathematical Physics	[3 + 1]	4
PE1004	General Relativity and Cosmology	[3 + 1]	4
PE1005	Experimental Techniques	[3+1]	4
PE1006	Biophysics	[3+1]]	4
PE1007	Quantum Computing and Information	[3+1]	4
PE1008	Disordered Systems	[3+1]	4
PE1009	Particle Physics	[3+1]	4
PE1010	Computational Electrodynamics	[3+1]	4

Min. 16
(240 of 240 Credits)

***Subject to availability of instructors and minimum number of interested students offering a course. The course structure for the above mentioned elective papers will be provided by the respective instructor.**

SEMESTER- I

P101: (B) Physics-I (Classical Physics): (For Biology Stream)

UNIT- I

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.

UNIT- II

Moment of inertia. Rotational kinematics and dynamics, Rigid body motion. Impulse and collisions, Central forces, Kinetic theory of gases, Equipartition of energy.

UNIT- III

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.

UNIT- IV

Probability (chance, fluctuations, random walk, probability distribution, Matter wave, Wave Packet, De-Brogle's theory, uncertainty principle); Curvilinear Coordinates.

UNIT- V

Vector calculus (differentiation and integration, gradient, divergence, curl, Green's theorem, Gauss' theorem, Stokes' theorem); Fourier series (an introduction).

Suggested texts and References:

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.

P101: (A) Physics – I (For Physics, Chemistry and Mathematics Stream)

UNIT- I

Mechanics: Energy, mass and momentum – evolution of the concepts and definitions. Newton's three laws of mechanics; conservative forces, potential energy functions; Conservation of mechanical energy, linear momentum and angular momentum; Applications to athletics; harmonic oscillator, inverse square law force; Kepler's laws.

UNIT- II

Elementary dynamics of rigid bodies: moment of inertia, angular momentum, rotational kinetic energy, displacement and rotation of rigid bodies. Friction, illustrations of non conservative forces. Impulse, elastic and inelastic collisions, Poisson's hypothesis, deformation energy, Karate punch. Dimensional analysis via examples illustrating Buckingham Pi theorem.

UNIT- III

Thermodynamics and kinetic theory: Thermodynamics: Basic notions of thermodynamics; Macroscopic equilibrium, quasistatic processes, reversible processes; Equation of state; Zeroth law; First law for closed systems; Notion of heat, work and internal energy; Notion of state variable and path.

UNIT- IV

Exact and inexact differentials; Ideal gas and Van der Waal's gas equation, some examples of non – pV systems (qualitative); Second law (Kelvin – Planck and Clausius statements); Carnot cycle; Entropy formulation of Second law; Third law (statement); Thermodynamic potentials.

UNIT- V

Kinetic theory: Kinetic theory of ideal gas; Kinetic interpretation of temperature; Adiabatic reversible compression; Boltzmann factor; Derivation of Maxwell's velocity distribution; Average, *rms* and most probable speed; Elementary theory of transport processes (viscosity, thermal conducting and diffusion coefficient); Failure of classical physics.

Suggested texts and References:

1. Mechanics, Berkeley Physics Course Vol. 1, 2nd Edition, C. Kittel *et al.*, Tata McGraw – Hill Education, 2011.
2. An Introduction to Mechanics, 1st Edition, D. Kleppner and R. J. Kolenkow, Tata McGraw – Hill Education, 2007
3. Thermodynamics, Kinetic theory and Statistical Thermodynamics, 3rd Edition, F. W. Sears and G. L. Salinger, Narosa Publishing House, 1998.
4. Heat and Thermodynamics, 8th Edition, M. W. Zemansky and R. H. Dittman, Tata McGraw – Hill Education, 2011.
5. University Physics, 7th Edition, Francis W. Sears, Mark Zemansky and Hugh D. Young, Massachusetts: Addison Wesley, 1987.
6. Mechanics, D. S. Mathure
7. Thermal Physics, B. K. Agrawal
8. A Treaties on Heat, M. N. Saha and B. N. Shrivastav.
9. Physics: Structure and Meaning L. N. Cooper University press of New England, 1992
10. Fundamentals of Physics, 8th Edition David Halliday, Robert Resnick & Walker New Jersey: John Wiley, 2 2008
11. Mechanics 3rd Edition Keith R. Simon Massachusetts: Addison Wesley Pub. Co., 1987

PL101: Physics Laboratory – I

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 travelling 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.

Suggested Texts and References:

1. Advanced Practical Physics for Students, B. L. Worsnop and H. T. Flint, Methuen and Co. Ltd., London

SEMESTER-II

P201: Physics – II (For Physics, Chemistry and Mathematics Stream) & (For Biology Stream)

UNIT- I

Electricity and Magnetism: Electrostatics: Coulomb's law and Gauss' law; Electrostatic potential, uniqueness theorem, method of images; Electrostatic fields in matter; Conductors and insulators; Capacitors and capacitance; Electric current.

UNIT- II

Magnetostatics: Biot – Savart law, Ampere's law; Electromagnetic induction; Mutual inductance and self inductance; Magnetic fields in matter. Displacement current; Maxwell's equations; Alternating current circuits; Electric and magnetic properties of matter.

UNIT- III

Plane electromagnetic waves in vacuum; Polarisation; Energy and momentum in electromagnetic waves; electromagnetic radiation (qualitative); Dipole radiation formula; Larmor's formula for radiation due to accelerated charge (without proof); Synchrotron radiation (descriptive).

UNIT- IV

Optics: Interference of two beams and involving multiple reflections; Young's experiment, Fresnel's biprism, Lloyd's mirror.

UNIT- V

Optical instruments; Telescope and microscopes; Magnifying power and resolving power. Sources of light and spectra; Dispersion, polarisation, double refraction; Optical activity.

Suggested texts and References:

1. Electricity and Magnetism, Berkeley Physics Course Vol. 2, 2nd Edition, Edward M. Purcell, Tata McGraw Hill, 2011.
2. The Feynman Lectures on Physics Vol. 2, R. P. Feynman, R. B. Leighton and M. Sands, Narosa Publications, 2010.
3. The Feynman Lectures on Physics Vol. 3, R. P. Feynman, R. B. Leighton and M. Sands Narosa 2010.
4. Waves, Berkeley Physics Course Vol. 3, Frank S. Crawford, Tata McGraw – Hill, 2011.
5. Fundamentals of Optics, 4th Edition, F. A. Jenkins and H. E. White, Tata McGraw Hill, 2011.
6. University Physics, 7th Edition, Francis W. Sears, Mark Zemansky and Hugh D. Young, Massachusetts: Addison Wesley, 1987.
7. Optics , 4th Edition Eugene Hecht Massachusetts: Addison Wesley
8. "Foundations of Electromagnetic Theory 4th edition, "John R. Reitz, Fredrick Milford & RobertChrist" Massachusetts: Addison Wesley, 1993

9. Fundamentals of Optics 4th Edition Francis A. Jenkins and Harvey E. White "New York Mc Graw Hill Book Company Inc. 2001"
10. Optical Physics 3rd Edition "Stephen G. Lipson, Henry Lipson & D. S. Tannhauser" New York Cambridge University Press 1995
11. Fundamental of Optics 4th Edition Francis A. Jenkins and Harvey E. White Tata Mc Graw Hill 2011.
12. Introduction to Electrodynamics 3rd Edition David J. Grifiths New Jersey: Prentice hall

PL201: Physics Laboratory – II

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.

Suggested Texts and References:

1. Advanced Practical Physics for Students, B. L. Worsnop and H. T. Flint, Methuen and Co. Ltd., London

SEMESTER-III

P301: Mathematical Physics – 1

UNIT- I

Review of first order differential equations, the notion of Wronskian and its properties, Series solutions of second order differential equations, Frobenius method. Rodrigues formula and classical orthogonal polynomials, recurrence relations, symmetry properties, special values, orthogonality, normalisation.

UNIT- II

Generating functions. Legendre, Hermite, Laguerre, Bessel and Hypergeometric differential equations. Integral representations of special functions. Expansion of functions in orthonormal basis.

UNIT- III

Complex variables: Notion of analyticity, Cauchy – Riemann conditions, Harmonic functions; Contour integrals, Cauchy theorem, simply and multiply connected domains, Cauchy integral formula, derivatives of analytic functions.

UNIT- IV

Laurent series, uniform convergence; Notion of residues, residue theorem, notion of principal values, applications of residues to evaluation of improper integrals, definite integrals, indentation, branch points and branch cuts.

UNIT- V

Fourier series and simple applications. Fourier transforms, Parseval's theorem, convolution, and their simple applications. Laplace transforms, initial value problems, simple applications, transients in circuits, convolution.

Suggested Texts and References:

1. Complex Variables and Applications, R. V. Churchill and J. W. Brown, McGraw-Hill, 2009
2. Complex Variables: Introduction and Applications, 2nd Edition, M. J. Ablowitz and A. S. Fokas, Cambridge 2003
3. Differential Equations, G. F. Simmons, McGraw-Hill, 2006
4. Ordinary Differential Equations, V. I. Arnold, MIT Press 2009
5. Mathematical Methods for Physicists, 7th Edition, G. Arfken and Hans J. Weber, Elsevier 2012

P302: Classical Mechanics – I

UNIT- I

Recap- Newton's laws, vector algebra, gradient; momentum, energy, constraints, conservative forces, potential energy, angular momentum. Inertial and non – inertial frames, fictitious forces.

UNIT- II

Foucault pendulum, effects of Coriolis force. Central forces, conservation of energy and angular momentum, trajectories, orbits, 1/r potential (quadrature), classical scattering, two body problem, centre of mass and relative motions.

UNIT- III

Rigid body motion, moment of inertia tensor, energy and angular momentum, Euler's theorem, motion of tops, gyroscope, motion of the Earth. Introduction to Lagrangian through variational principle, applications of variational principle.

UNIT- IV

Relativity: Historical background, inconsistency of electrodynamics with Galilean relativity. Einstein's hypothesis and Lorentz transformation formula, length contraction, time dilation.

UNIT- V

Doppler shift. Energy, momentum and mass, mass – energy equivalence. Four vector notation, consistency of electrodynamics with relativity.

Suggested texts:

1. An Introduction to Mechanics, 1st Edition, D. Kleppner and R. J. Kolenkow, Tata McGraw – Hill Education, 2007
2. Classical Mechanics, 5th Edition, T. W. B. Kibble, F. Berkshire, World Scientific 2004.
3. Introduction to Special Relativity, R. Resnik, Wiley (India), 2012
4. Spacetime Physics, 2nd Edition, E. F. Taylor, J. A. Wheeler, W. H. Freeman and Co. 1992.
5. Classical mechanics, N. C. Rana, P. S. Joag, Tata McGraw-Hill Education, 2001.

P303: Electromagnetism

UNIT- I

Electrostatics: Coulomb's law, Electric field, Gauss' law in differential and integral forms, Scalar potential, Poisson and Laplace equations, Discontinuities in Electric field and potential: electrostatic boundary conditions, Uniqueness theorem, conductors and second uniqueness theorem, method of images, multipole expansion, work and energy in electrostatics.

UNIT- II

Electric Fields in matter: dielectrics, polarisation, bound charges, notion of electric displacement, Gauss' law in presence of dielectrics, boundary conditions, linear dielectrics: susceptibility, permittivity, dielectric constant, boundary value problems, energy in dielectric systems.

UNIT- III

Magnetostatics: Lorentz force law, steady currents, Biot – Savert law, Ampere's law, vector potential, magnetostatic boundary conditions, multipole expansion for vector potential, magnetic scalar potential. Diamagnets, paramagnets and ferromagnets, magnetisation, bound currents, the H field, boundary conditions, magnetic susceptibility and permeability.

UNIT- IV

Electrodynamics: Electromotive force, electromagnetic induction and Faraday's law, induced electric fields and inductance, energy in magnetic fields. Maxwell's equations: equation of continuity and Modification in Ampere's law, Gauge transformations, Lorentz and Coulomb gauge. Maxwell's equations in matter, integral and differential forms, boundary conditions.

UNIT- V

Poynting's theorem, conservation of momentum, angular momentum. Lossy media, Poynting's theorem for lossy media. Wave equation, electromagnetic waves in vacuum, plane waves, propagation in lossless and lossy linear media, absorption and dispersion, reflection at the interface of two lossy media, guided waves.

Suggested Texts and References:

1. Introduction to Electrodynamics, 4th Edition, D. J. Griffiths, Addison-Wesley 2012
2. Classical Electricity and Magnetism, 2nd Edition, W.K.H. Panofsky and M. Phillips, Dover 2005.
3. Engineering Electromagnetics, 2nd Edition, Nathan Eda, Springer 2007

P304: Waves and Oscillations

UNIT- I

Free oscillations, Simple harmonic motion, damped and forced oscillations; Coupled oscillators, normal modes, beats, infinite coupled oscillators and dispersion relation of sound; vibrating string; travelling and stationary waves; Amplitude, phase and energy. Derivation of wave equation for a string; Longitudinal and transverse waves.

UNIT- II

Waves in two and three dimensions, the wave vector, wave equation, linearity, superposition, Fourier decomposition of a wave, notion of wave packets, phase and group velocity. Example of mechanical waves (sound waves), speed of sound in air, effect of bubbles, natural observations and qualitative explanations.

UNIT- III

String and wind instruments. Chaldni plates. Propagation in changing media, continuity conditions, characteristic impedance. Snell's laws and translation invariant boundary, prism, total internal reflection, evanescent waves. Water waves, ocean waves, Tsunami.

UNIT- IV
Electromagnetic waves, polarisation, interference.

UNIT- V
Fraunhofer diffraction. Shocks waves, boat wakes, linear analysis of the Kelvin wake. Alfven waves (qualitative).

Suggested Texts and References:

1. Waves, Berkeley Physics Course Vol. 3, Frank S. Crawford, Tata McGraw – Hill Education, 2011
2. Introduction to the Physics of Waves, Tim Freegarde, Cambridge Univ. Press 2012
3. The Physics of Waves, Howard Georgi (http://www.people.fas.harvard.edu/~hgeorgi/new.htm)

H301: Introduction to World Literature
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.

H302: History and Philosophy of Science
History of World Science up to the Scientific Revolution: Introduction about stone age, beginning of agriculture, urban civilization and science. Science in Sumeria, Babylonia and Egypt. Natural philosophy of pre-Socratic Greece. Natural philosophy in Athens. Greek science in the Alexandrian period. Rome and decline of Ancient European science. Science and technology in China. Science and technology in the Muslim world. Technology and the craft tradition in medieval Europe. The scholarly tradition during the middle ages. Renaissance, the Copernican system of the world. Gilbert, Bacon and the experimental method. Galileo and the science of mechanics. Descartes – the mathematical method and the mechanical philosophy. The Protestant reformation and the scientific revolution. Newton –the theory of universal gravitation and optics. Alchemy and iatrochemistry. Medicine, theory of circulation of blood. Growth and characteristics of the scientificrevolution.

History of Ancient Indian Science: Indian civilization from pre-historic times to the Indus Valley Civilization. Ancient Indian mathematics and astronomy. Ancient Indian medicine and biology. Chemistry, metallurgy and technology in general in ancient India. Strengths, weaknesses and potentialities of ancient Indian science.

Introduction to Philosophy of Science: What is science? Scientific reasoning; Explanation in science; Realism and instrumentalism; Scientific change and scientific revolutions.

Great Scientific Experiments: Group wise study and presentations by students of historically significant experiments in science.

Suggested Texts and References:

1. A History of the Sciences, Stephen F. Mason, Collier Books, Macmillan Pub. Co. (1962)
2. A Concise History of Science in India, D. M. Bose, S. N. Sen, B. V. Subbarayappa, INSA (1971)
3. Philosophy of Science – A Very Short Introduction, Samir Okasha, Oxford Univ Press (2002)
4. Great Scientific Experiments – Ron Harre, Oxford University Press (1983)
5. The Story of Physics, Lloyd Motz and Jefferson Hane Weaver, Avon Books (1992)
6. The Cambridge Illustrated History of World Science, Colin A. Ronan, Cambridge-Newnes (1982)
7. Encyclopaedia of Classical Indian Sciences, Ed. Helaine Selin and Roddam Narasimha, University Press (2007)

1. Articles from Wikipedia on History and philosophy of science

PL301: Physics Laboratory – III

Frequency response of R-C circuit (concept of cut-off freq and filter) and frequency response of LC 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 RL- 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.

Suggested Texts and References:

1. Advanced Practical Physics for Students, B. L. Worsnop and H. T. Flint, Methuen and Co. Ltd., London

GL301: Applied Electronics Laboratory

The course is based on the micro-controller system expEYES and 'Microhope' based on ATmega32 micro controller, developed at IUAC, under a UGC programme.

Use of expEYES kit for monitoring pendulum motion, charge and discharge of capacitor etc to appreciate the goal of the course; Revision of concepts of binary numbers: ‘Bit’, ‘Byte’, ‘Word’, hexa-decimal numbers; Concepts of microprocessor and microcontrollers - CPU, registers, memory (RAM, ROM, different kinds of ROM), data and address bus, decoder, encoder, instruction set, etc. Review of concepts of Digital to Analogue Conversion (DAC) and Analogue to Digital Conversion (ADC), Introduction to micro-controller ATmega32 (which is used in expEYES). Concepts of programming, flow chart, assembly language, and simulator. Concept of I/O programming for ATmega32 Examples of simple I/O program in assembly language, assemble it in an assembler in a PC and download the hex code into microcontroller kit 'microhope' through USB port and verify the operation. C language for writing larger programmes, such as monitoring temperature, which uses ADC of ATmega32. Concept of interrupt and its use in real time data acquisition. Introduction to elements of PYTHON language. Concepts of how expEYES system program resident in ATmaga32 is interfaced to commands from PC in Python language; Automated measurement of simple experiments under expEYES, such as, applications such as temperature monitor, pH meter, colorimeter, protein measurement experiments, etc., will be done. As a part of these applications, ntroduction will be given to sensors, such as temperature sensors, pressure sensors, humidity, pH sensors, photodetectors etc, The experiments will also include I/O programme for keypad inputs and LCD display.

Suggested Texts and References:

1. Phoenix: Computer Interfaced Science Experiments, B.P. Ajith Kumar at http://www.iuac.res.in/~elab/phoenix/
2. expEYES micro-controller system B.P. Ajith Kumar at http://www.iuac.res.in/~elab/phoenix/
3. The AVR micro-controller and embedded systems using assembly and C, by A.A. Mazidi, S. Naimi and S. Mnaimi, Pearson Publications, Delhi, 2013.

SEMESTER-IV

P401: Mathematical Physics – II

UNIT-I

Review of curvilinear coordinates, scale factors, Jacobian. Partial differential equations in curvilinear coordinates, classification. Laplace equation, separation of variables, boundary conditions and initial conditions, examples.

UNIT-II

Inhomogeneous equations, Green's functions in 1, 2 and 3 dimensions.

UNIT-III

Tensors calculus: contravariant and covariant notation, Levi-Civita symbol, pseudotensors, quotient rule, dual tensors.

UNIT-IV

Integral equations: Fredholm and Volterra equations, separable kernel, applications. Elementary group theory and group representations, cyclic, permutation groups; isomorphism, homomorphism.

UNIT-V

subgroups, normal subgroup, classes and cosets; orthogonal, rotation group, Lie group; equivalent, reducible, irreducible; Schur's lemma.

Suggested Texts and References:

1. Mathematical Methods for Physicists, 7th Edition, G. Arfken and Hans J. Weber, Elsevier 2012
2. Mathematics for Physicists, P. Dennery and A. Krzywicki, Dover 1996
3. Mathematics for Quantum Mechanics, 4th Edition, J. D. Jackson, Dover 2009.
4. Elements of Group Theory for Physicists, A. W. Joshi
5. Lectures on Groups and Vector Spaces for Physicists, C. J. Isham, World Scientific 1989
6. Group Theory and Its Application to Physical Problems, M. Hemmermesh, Dover 1989
6. Elements of Green's Functions and Propagation, G. Barton, Oxford 1989

P402: Quantum Mechanics – 1

UNIT- I

Origins of quantum theory (short version); Wave – particle duality, wave packets, uncertainty relation; Time dependent and time independent Schrödinger equation; Interpretative postulates; Hermitian operators, eigenfunctions and eigenvalues; nodal lines and domains; Orthonormality and completion.

UNIT- II

Energy and momentum eigenfunctions; Illustrative one dimensional phenomena (short revision if done in an earlier semester) rigid box; square well and barrier; Linear harmonic oscillator (detailed treatment).

UNIT- III

Abstract vector space formulation of quantum mechanics; Hilbert space, Dirac notation; Hermitian and unitary operators, momentum space representation; Schrödinger and Heisenberg pictures; Linear Harmonic oscillator (matrix theory).

UNIT- IV

Schrödinger equation for a central potential; Orbital angular momentum eigenfunctions (spherical harmonics) and eigenvalues; Bound state solution of Schrödinger equation for Coulomb potential, Hydrogen atom orbits and energies, degeneracy; Electron spin; Addition of two angular momenta, Clebsch – Gordon coefficients.

UNIT- V

Approximation methods: stationary perturbation theory (non – degenerate and degenerate); Stark effect; Zeeman effect; Time dependent perturbation theory; Harmonic perturbations, transition probability (Fermi's golden rule).

Suggested Texts and References:

1. Introduction to Quantum Mechanics, 2nd Edition, D. J. Griffiths, Pearson Education 2008.
2. Quantum Mechanics, 3rd Edition, L. I. Schiff, Tata McGraw-Hill 2010.
3. Quantum Mechanics I and II, Claud Cohen Tannoudji, B. Diu and F. Laloe, Wiley 2006
4. Lectures on Quantum Mechanics, S. Weinberg, Oxford University Press 2012.

P403: Statistical Mechanics – I

UNIT- I

Elementary probability theory; random walk; binomial, Poisson, log normal distributions; the Gaussian. Kinetic theory of gases.

UNIT- II

Ensembles; micro-canonical ensemble; canonical ensemble; grand canonical ensemble. Partition functions and their properties; calculation of thermodynamic quantities; Gibbs paradox; the equipartition theorem.

UNIT- III

Two level system and paramagnetism. Validity of the classical approximation; identical particles and symmetry; quantum distribution functions; Bose-Einstein statistics; Fermi-Dirac statistics;

UNIT- IV

Quantum Statistics in the classical limit; physical implications of the quantum-mechanical enumeration of states; conduction electrons in metals.

UNIT- V

Special topics: the Chandrasekhar Limit; Saha Ionization formula. Systems of interacting particles; Debye approximation; van der Waals equation; Weiss molecular-field approximation

Suggested Texts and References:

1.Thermodynamics and an Introduction to Thermostatistics, 2nd Edition, H. B. Callen, Wiley 2006
2. Fundamentals of Statistical and Thermal Physics, F. Reif, McGraw-Hill Book Company
3. Statistical Physics part 1, 3rd Edition, L. D. Landau and E. M. Lifshitz, Elsevier 2008
4. Statistical Mechanics: A Set of Lectures, R. P. Feynman, W. A. Benjamin, Inc. 1998
5. A Modern Course in Statistical Physics, L. E. Reichl, Wiley 2009

PCB 401: Physical and Chemical Kinetics

UNIT- I

Basic Concepts: Rate, order and molecularity of a reaction, First, second and third order reactions – effect of concentration on reaction rate, rate expressions and integrated form, pseudo-unimolecular and second order autocatalytic reactions, nth order reaction of a single component, effect of temperature on reaction rate – Arrhenius equation and activation energy.

UNIT- II

Complex Reactions: parallel first order reactions, series first order reactions – determination of rate constants by graphical method and the time ratio method. The stationary state, radioactive decay, general first order series and parallel reactions. Competitive, consecutive second order reactions, reversible reactions, equilibrium from the kinetic view point, complex mechanisms involving equilibria.

UNIT- III

Kinetic Measurements: Experimental determination of reaction rates and order of reactions – correlation of physical properties with concentrations, reactions in the phase, reactions at constant pressure, fractional-life period method, initial rate as a function of initial concentrations.

UNIT- IV

Reactions in Solutions: General Properties, Phenomenological theory of reaction rates, Diffusion limited rate constant, Slow reactions, Effect of ionic strength on reactions between ions, Linear free energy relationships, Relaxation methods for fast reactions.

UNIT- V

Catalysis: Homogeneous catalysis in gas phase, in solution, basis of catalytic action, catalysis and the equilibrium constant, acid base catalysis, The Bronsted catalysis law, linear free energy changes, general and specific catalysis. Heterogeneous catalysis. Negative catalysis and inhibition, Surface reactions – effect of temperature and nature of surface. Industrial catalysis.

Suggested Texts and References:

1. Chemical Kinetics : A Study of Reaction Rates in Solution, K.A. Connors, V.C.H. Publications 1990.
2. Chemical Kinetics and Dynamics, J.I. Steinfeld, J.S. Francisco and W.L. Hase, Prentice Hall 1989.
3. Chemical Kinetics and reaction dynamics, Paul L. Houston.
4. Chemical Kinetics, 3rd ed., K.J.Laidler, Harper and Row, 1987.
5. Kinetics and Mechanisms, J.W. Moore and R.G. Pearson, John Wiley and Sons, 1981.
6. Kinetics and Mechanism, A. A. Forst and R. G. Pearson, Wiley International Edition.

7. Chemical Kinetics and Reaction Dynamics, Sanjay K. Upadhay, Springer, 2006

G401: Statistical Techniques and Applications

UNIT- I

Purpose of Statistics, Events and Probabilities, Assignments of probabilities to events, Random events and variables, Probability Axioms and Theorems. Probability distributions and properties: Discrete, Continuous and Empirical distributions. Expected values: Mean, Variance, Skewness, Kurtosis, Moments and Characteristics Functions.

UNIT-II

Types of probability distributions: Binomial, Poisson, Normal, Gamma, Exponential, Chi-squared, Log-Normal, Student's t, F distributions, Central Limit Theorem.

UNIT- III

Monte Carlo techniques: Methods of generating statistical distributions: Pseudorandom numbers from computers and from probability distributions, Applications. Parameter inference: Given prior discrete hypotheses and continuous parameters, Maximum likelihood method for parameter inference. Error Analysis: Statistical and Systematic Errors, Reporting and using uncertainties.
Propagation of errors, Statistical analysis of random uncertainties, Averaging Correlated/ Uncorrelated Measurements.

UNIT- IV

Deconvolution methods, Deconvolution of histograms, binning-free methods. Least-squares fitting: Linear, Polynomial, arbitrary functions: with descriptions of specific methods; Fitting composite curves. Hypothesis tests: Single and composite hypothesis, Goodness of fit tests.

UNIT- V

P-values, Chi-squared test, Likelihood Ratio, Kolmogorov- Smirnov test, Confidence Interval. Covariance and Correlation, Analysis of Variance and Covariance. Illustration of statistical techniques through hands-on use of computer programs.

Suggested Texts and References:

1.Statistics: A Guide to the Use of Statistical Methods in the Physical Sciences, R.J. Barlow, John Wiley 1989
2. The Statistical Analysis of Experimental Data, John Mandel, Dover Publications 1984
3. Data Reduction and Error Analysis for the Physical Sciences, 3rd Edition, Philip Bevington and Keith Robinson, McGraw Hill 2003

PL401: Physics Laboratory – IV

Application of PHOENIX (IUAC, New Delhi) microcontroller system for automation in 20 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.

Suggested Texts and References:

1. Phoenix: Computer Interfaced Science Experiments – http://www.iuac.res.in/~elab/phoenix/
2. The Art of Experimental Physics, D. W. Preston and D. R. Dietz, Wiley 1991

3. Manual of Experimental Physics with Indian Academy of Sciences, Bangalore kit, R. Srinivasan and K.R.S. Priolkar

GL401: Computational Laboratory and Numerical Methods
GNU Plot, FORTRAN90, Pointers and Object Oriented Programming

I. The nature of computational physics: Machine representation, precision and errors in computation. Errors and uncertainties. E.g. One should understand how to analyze whether a calculation is limited by the algorithm or round-off error. Single/double precision.

II. Basic tools for numerical analysis in science: Solution of algebraic functions – Fixed point method, Newton-Raphson method, Secant method. Numerical Integration – Rectangular method, trapezoidal method. Lagrange's interpolation.

III. Matrix Algebra: Approximate solution of a set of linear simultaneous equations by Gauss-Sidel iteration method. Exact solution by Gaussian elimination. Inversion of a matrix by Gaussian elimination. Determining all the eigenvalues of a real symmetric matrix by Householder's method of tridiagonalization followed by QR factorization of the tridiagonalized matrix.

IV. Differential Equations (ODE and PDE): Solution of an ODE by Euler's method and Runge-Kutta (4) method – comparison of convergence Solution of partial differential equation (Laplace's equation and Poisson's equation) – Boundary Value Problem – solved using Gauss-Sidel iteration followed by plotting using GNUPlot

V. Nonlinear Systems, dynamics: Fractals – generating the Mandelbrot set and Julia sets. Definition of each. Solution of nonlinear set of ODEs – Lorenz equations – Observation and definition of strange attractor and sensitive depencence upon initial conditions (butterfly effect). Study of the logistic map – non linear dynamical system – obtaining a bifurcation diagram and estimating Feigenbaum's constant.

VI. Fourier analysis of nonlinear systems: Getting used to programming using FFT subroutines. Understanding the relationship between time-domain and frequency domain. Transforming a Gaussian, understanding how temporal FWHM and spectral FWHM are related. Solving a nonlinear PDE which is amenable to solution by multiple steps of FFTs.

SEMESTER-V

P501: Quantum Mechanics – II

UNIT- I
Collision theory: Scattering cross section; Scattering by spherically symmetric potential; Differential cross section, phase shift; Scattering by rigid sphere; Born approximation.

UNIT- II
Path integral formulation of quantum mechanics; The WKB approximation, solution near a turning point, the connection formulas; Tunnelling through a barrier; The adiabatic approximation.

UNIT- III
Variational method, expectation value of energy, application to excited states, ground state of He-atom, Zero point energy of one dimensional harmonic oscillator, Vander-waals interaction.

UNIT- IV
Foundations (Introductory ideas): The EPR paradox, quantum entanglement; Bell's theorem, the No-clone theorem, Schrodinger's cat; Decoherence, quantum Zeno paradox.

UNIT- V
Symmetry in quantum mechanics; Translation, rotation and space inversion operators; Identical particles; Symmetrical and anti-symmetrical wave functions; Spin – statistics connection (empirical); Density matrix; Equation of motion of density matrix.

Suggested Texts and References:
1. Introduction to Quantum Mechanics, 2nd Editon, D. J. Griffiths, Pearson Education 2008.
2. Quantum Mechanics, 3rd Edition, L. I. Schiff, Tata McGraw-Hill 2010.
3. Quantum Mechanics I and II, Claud Cohen Tannoudji, B. Diu and F. Laloe, Wiley 2006
4. Lectures on Quantum Mechanics, S. Weinberg, Oxford University Press 2012.

P502: Classical mechanics – II
UNIT-I
Variational principle (revisited), Lagrangian formulation, constraints, generalised coordinates, applications. Hamilton's equations of motion (from Legendre transformation), Hamiltonian and total energy, cyclic coordinates, variational principle.

UNIT-II
Small oscillations, single oscillator, damped and forced oscillations, coupled oscillators, normal modes.

UNIT-III
Canonical transformations, Poisson brackets, conservation theorems.

UNIT-IV
Hamilton – Jacobi theory, action – angle variables. Canonical perturbation theory, time dependent and time independent.

UNIT-V
Lagrangian formulation of continuous media as a limiting case, extensions.

Suggested Texts and References:
1. Classical mechanics, N. C. Rana, P. S. Joag, Tata McGraw-Hill Education, 2001.
2. Mechanics, L. D. Landau, E. M. Lifshitz, Elesevier 2005.
3. Regular and Chaotic Dynamics, 2nd Edition, A. J. Lichtenberg, M. A. Lieberman, Springer 1992.
4. Classical mechanics, 3rd Edition, H. Goldstein, C. P. Poole, J. Safko, Pearson Education 2011.

P503: Atomic and Molecular Physics

UNIT- I
Many – electron atoms: One – electron wavefunctions and energies in Coulomb potential (revision); Atomic orbitals, spin – orbit coupling, Thomas precession, fine structure; Alkali atoms; Helium ground state and excited states, direct and exchange integrals; Many – electron atoms: LS and jj coupling schemes; Hartree – Fock method; Pauli's principle and the Periodic Table; Nuclear spin and hyperfine structure.

UNIT- II

Atoms in External Fields: Quantum theory of normal and anomalous Zeeman effect, Linear and quadratic Start effect; Semi – classical theory of radiation; Absorption and induced emission; Einstein's A and B coefficients, dipole approximation, intensity of radiation, selection rules.

UNIT- III

Two level atom in a coherent radiation field, Rabi frequency, radiative damping, optical Bloch equation, Broadening of spectral lines (Doppler, pressure and power broadening).

UNIT- IV

Lasers: Basic concepts, rate equation and lasing conditions, working of some common lasers. Doppler free laser spectroscopy; Crossed – beam method, saturated absorption spectroscopy, two photon spectroscopy; Laser cooling and trapping (descriptive); Atom interferometry (descriptive).

UNIT- V

Molecules: Ionic and covalent bonding, Hydrogen molecular ion (H2 +), Born – Oppenheimer approximation; Bonding and anti – bonding orbitals, Hydrogen molecule; Heitler – London method, Molecular orbital method, hybridisation, quantum mechanical treatment of rotational and vibrational spectra (diatomic and polyatomic molecules); Electronic spectra, Raman effect (classical and quantum theory); Vibrational and rotational Raman spectra; Electron spin resonance.

Suggested Texts and References:

1. Atomic Physics, Christopher Foot, Oxford University Press, 2005.
2. Intermediate Quantum Mechanics, 3rd Edition, H. A. Bethe and R. W. Jackiew, Persius 1997
3. The Physics of Atoms and Quanta: Introduction to Experiments and Theory, H. Haken, H. C. Wolf and W. D. Brewer, Springer 2005
4. Molecular Physics and Elements of Quantum Chemistry: Introduction to Experiments and Theory, H. Haken, H. C. Wolf and W. D. Brewer, Springer 2010.

PM501: Numerical Analysis

UNIT- I

Error, its sources, propagation and analysis; Errors in summation, stability in numerical analysis. Linear algebraic equations: Gaussian elimination, direct triangular decomposition, matrix inversion.

UNIT- II

Rootfinding: review of bisection method, Newton's method and secant method; real roots of polynomials, Laguerre's method. Matrix eigenvalue problems: Power method, eigenvalues of real symmetric matrices using Jacobi method, applications.

UNIT-III

Interpolation theory: Polynomial interpolation, Newton's divided differences, forward differences, interpolation errors, cubic splines. Approximation of functions: Taylor's theorem, remainder term; Least squares approximation problem, Orthogonal polynomials.

UNIT- IV

Numerical integration: review of trapezoidal and Simpson's rules, Gaussian quadrature; Error estimation. Numerical differentiation. Monte Carlo methods.

UNIT- V

Least squares problems: Linear least squares, examples; Non – linear least squares. Ordinary differential equations: stability, predictor – corrector method, Runge – Kutta methods, boundary value problems, basis expansion methods, applications. Eigenvalue problems for differential equations, applications. Solutions of PDE's using differential quadrature: elementary treatment. Applications to diffusion equation, wave equation, etc.

Suggested Texts and references:

1. An introduction to Numerical Analysis, 2nd Edition, Kendall Atkinson, Wiley 2012
2. Numerical Methods for Scientists and Engineers, H. M. Antia, Hindustan Book Agency 2012.
3. Numerical Receipes in Fortran, 2nd Edition, W. H. Press *et al.*, Cambridge University Press 2000.

G501: Earth Science and Energy & Environmental Sciences

Earth Science

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.

Suggested Texts and references:

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
1. Applied Geophysics (Paperback) W M Telford, Robert E Sheriff and L P Geldart.

Energy and Environmental Sciences

Introduction to Environmental Science. Natural Environments: Ecosystems and ecology, biodiversity. Socio-cultural environments: demography, population density, human rganizations. 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.

Energy and Environmental Sciences

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).

PL501: Physics Laboratory – V

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).

Suggested Texts and references:

1. The Art of Experimental Physics, D. W. Preston and D. R. Dietz, Wiley 1991

PML501: Numerical Methods Laboratory

The methods developed in Numerical Analysis (P501) are to be implemented on a computer. Emphasis to be given on applications to physical problems.

Suggested Texts and references:

1. Numerical Receipes in Fortran, 2nd Edition, W. H. Press *et al.*, Cambridge University Press 2000
2. An Introduction to Computational Physics, 2nd Edition, Tao Pang, Cambridge University Press 2010

SEMESTER-VI

P601: Electrodynamics

<u>UNIT- I</u>

Review of Maxwell's equations, vector and scalar potentials, gauge transformations.
Radiating systems: electric dipole fields and radiation, magnetic dipole and electric quadrupole fields, antenna, spherical wave solutions of the scalar wave equation.

UNIT- II

Multipole expansion of the electromagnetic fields, energy and angular momenta of multipole radiation, angular distribution of multipole radiation, multipole moments, multipole radiation in atoms and nuclei, multipole radiation from linear centre fed antenna.

UNIT- III

Scattering and Diffraction problems: scattering at long wavelength, perturbation theory of scattering, explaination of blue sky (due to Rayleigh), scalar diffraction theory.

UNIT- IV

Covariant formulation of electrodynamics: four vector potential, electromagnetic field tensor, covariant description of sources in material media, field equations in a material medium. Retarded potentials, Jefimenko's generalisations of Coulomb and Biot – Savert laws, Lienard – Wiechert potentials.

UNIT- V

Fields of a moving charge. Cerenkov radiation. Covariant formulation of the conservation laws of electrodynamics.

Suggested Texts and References:

1. Introduction to Electrodynamics, 4th Edition, D. J. Griffiths, Addison-Wesley 2012
2. Classical Electricity and Magnetism, 2nd Edition, W.K.H. Panofsky and M. Phillips, Dover 2005.
3. Classical Electrodynamics, 3rd Edition, J. D. Jackson, Wiley 2012
4. Lectures on Electromagnetism, 2nd Edition, Ashok Das, Hindustan Book Agency 2013.

P602: Nuclear Physics – I

UNIT- I

Nuclear Properties: Size – nuclear radius, charge distribution, matter distribution. Mass- binding energy, liquid drop model/mass formula. Spin, Parity, isospin. Electromagnetic moments- magnetic dipole and electric quadrupole moments/nuclear shapes.

UNIT- II

Nuclear stability, alpha, beta, gamma decays, fission. Experimental methods for size, mass, spin, moments to be included.

UNIT-III

Nuclear Forces: Nuclear interaction, saturation of nuclear density, constancy of binding energy per nucleon. Bound two nucleon system, Deuteron problem, absence of bound pp, nn. N-N scattering – as a function of energy, phase shift, cross section. Salient features of nuclear force. Yukawa's theory of nuclear interaction (basics).

UNIT- IV

Nuclear Structure: Magic numbers, shell model, spin orbit interaction, deformed shell model.
Nuclear excited states vibration, rotation, Collective model. Electromagnetic interactions in nuclei: multipole transitions, selection rules, life times, electron capture, internal conversion, isomers, Coulomb excitation.

UNIT- V

Nuclear Reactions: Kinematics, Q value, excitation energy, conservation laws, cross section, mean free path. Types of nuclear reactions, experimental observables, excitation function, angular distribution, spectra. Compound nuclear reactions, Resonances, level density, temperature, Bohr model. Direct nuclear reactions, optical model, pick up and stripping reactions, spectroscopic factor Nuclear fission and fusion reactions.

Suggested Texts and References:

1. Introductory Nuclear Physics, K.S. Krane, Wiley 2008
2. Concepts of Nuclear Physics, B. L. Cohen, McGraw Hill 1971
3. Introductory Nuclear Physics, S. S. M. Wong, Prentice – Hall 2010
4. Introduction to Nuclear and Particle Physics, 2nd Edition, A. Das and T. Ferbel, World Scientific 2004

P603: Condensed Matter Physics – I

UNIT- I

Crystal Structure and x-ray diffraction: Crystalline and amorphous solids, translational symmetry. Elementary ideas about crystal structure, lattice and bases, unit cell, reciprocal lattice, fundamental types of lattices, Miller indices, lattice planes, simple cubic, f.c.c. and b.c.c. lattices. Simple crystal structures, Closed packed structure, Determination of crystal structure with X-rays, Neutrons and Electron diffraction-Diffraction of waves by crystals, Laue and Bragg equations, Brillouin Zones, Fourier Analysis of the basis. Debye waller factor, X ray broadening -size and temperature effects. X-ray diffraction of liquids and disordered solids- introduction to radial distribution functions.

UNIT- II

Lattice Vibrations: Elastic waves, Thermal properties: Einstein's and Debye's theories of specific heats of solids, Thermal conductivity, Phonons, Lattice waves, Dynamics of a chain of similar atoms and chain of two types of atoms; optical and acoustic modes; Inelastic scattering of x-rays, neutrons and light by phonons, Optical properties of solids: interaction of light with ionic crystals. Raman scattering and Brillouin scattering.

UNIT- III

The Free electron model: Drude Model, Electon conductivity, Heat capacity of conduction electrons, Fermi surface, Sommerfield model, Thermal conductivity of metals, Hall effect, AC conductivity and optical properties, Wiedemann-Franz law, Failure of the Free-electron model, optical properties of metals.

UNIT- IV

Basics of Semiconductors and device: Crystal structure, Band structure, Intrinsic and extrinsic semiconductors, Concept of majority and minority carriers, Energy gap, Mobility, conductivity, Hall effect, Diffusion, Optical properties: Absorption, Luminescence, Photoconductivity, effect of disorder on absorption. Interpretation of energy band diagrams. Devices: p-n diode (derivation of Shockley equation), tunnel diode, photodiode, solar cell, LED, Lasers.

UNIT- V

Superconductivity: Introduction (Kamerlingh Onnes experiment), effect of magnetic field, Type-I and type-II superconductors, Isotope effect. Meissner effect. Heat capacity. Energy gap. Electrodynamics of superconductivity: London's equation, Thermodynamics of the transition, Intermediate state of Type 1, Mixed state of type 2, Flux Quantization, Salient points of BCS theory, Cooper problem, Definition of coherence length, Josephson effect

Suggested Texts and References:

1. Elementary Solid State Physics, M. Ali Omar, Pearson Education 2008.
2. Introduction to Solid State Physics, 8th Edition, C. Kittel, Wiley 2012.
3. Solid State Physics, N. W. Ashcroft and N. D. Mermin, Cengage 2003.
4. Physics of Semiconductor Devices, 3rd Edition, S. M. Sze and K. K. Ng, 2007.
5. Introduction to Superconductivity, A. C. Rose -Innes, E. H. Rhoderik, Pergamon Press
6. Solid State Physics, J. P. McKelvey, Krieger Publishing Co. 1993.
7. Electron theory of solids, J. M. Ziman, Cambridge University Press, 2011.

P604: Lasers

<u>Unit- I</u>

Laser Characteristics –Spontaneous and stimulated emission, Einstein's quantum theory of radiation, theory of some optical processes, coherence and monochromacity, kinetics of optical absorption, line broadening mechanism, Basic principle of lasers, population inversion, laser pumping, two & three level laser systems, resonator, Q-factor, losses in cavity, threshold condition, quantum yield.

<u>Unit – II</u>

Laser Systems- Solid state lasers- the ruby laser, Nd:YAG laser, ND: Glass laser, semiconductor lasers – features of semiconductor lasers, intrinsic semiconductor lasers, Gas laser -neutral atom gas laser, He-Ne laser, molecular gas lasers, CO2 laser, Liquid lasers, dye lasers and chemical laser.

<u>Unit-III</u>

Advances in laser Physics, Production of giant pulse -Q-switching, giant pulse dynamics, laser amplifiers, mode locking and pulling, Non-linear optics, Harmonic generation, second harmonic generation, Phase matching, third harmonic generation, optical mixing, parametric generation and self-focusing of light.

<u>Unit – IV</u>

Multi-photon processes; multi-quantum photoelectric effect, Theory of two-photon process, three- photon process, second harmonic generation, parametric generation of light, Laser spectroscopy : Rayleigh and Raman scattering, Stimulated Raman effect, Hyper-Raman effect, Coherent anti-stokes Raman Scattering, Photo-acoustic Raman spectroscopy.

Unit – V

Laser Applications – ether drift and absolute rotation of the Earth, isotope separation, plasma, thermonuclear fusion, laser applications in chemistry, biology, astronomy, engineering and medicine.

Communication by lasers: ranging, fiber Optics Communication, Optical fiber, numerical aperture, propagation of light in a medium with variable index, pulse dispersion.

TEXT AND REFERENCE BOOKS:

1. Laud, B.B.: Lasers and nonlinear optics, (New Age Int.Pub.1996).
2. Thyagarajan, K and Ghatak, A.K.: Lasers theory and applications (Plenum press, 1981).
3. Ghatak, A.K.and Thyagarajan, K : Optical electronics (Cambridge Univ. Press 1999).
4. Seigman, A.E.: Lasers (Oxford Univ. Press 1986)
5. Maitland, A. and Dunn, M.H. : Laser Physics (N.H.Amsterdam, 1969).
6. Hecht, J.The laser Guide book (McGraw Hill, NY, 1986).

7. Demtroder, W. : Laser Spectroscopy (Springe series in chemical physics vol.5,Springe verlag, Berlin, 1981).
8. Harper, P.G.and Wherrett B.S. (Ed.): Non-linear-optics (Acad.press, 1977).

P605: Nonlinear Dynamics and Chaos

UNIT-I

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.

UNIT-II

Classification of fixed points. Hartman -Grobman theorem, homeomorphism, Stable Manifold Theorem, Centre Manifold Theorem, examples of manifolds. Index theory, Lyapunov functions and stability analysis, Limit cycles, Poincare-Benedixon Dynamical Systems, phase portraits, vector fields, nullclines, flows, discrete dynamical systems, 1-d maps, Fixed points.

UNIT-III

Linearization of vector fields, canonical forms, generalized eigen vectors, semisimple-nilpotent decomposition, Jordan canonical form, classification of fixed points. Hartman-Grobman theorem, homeomorphism, Stable Manifold Theorem, Centre Manifold Theorem, examples of manifolds. Index theory, Lyapunov functions and stability analysis, Limit cycles, Poincare-Benedixon Theorem. Gronwall's inequality.

UNIT-IV

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.

UNIT-V

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.

Suggested Texts and References:

1. Nonlinear Dynamics And Chaos: With Applications To Physics, Biology, Chemistry and Engineering, S. Strogatz, Addison-Wesley 2001
2. Chaos: An Introduction to Dynamical Systems, K.T. Aligood, T.D. Sauer, J.A. Yorke, Springer 2000
3. Differential Equations, Dynamical Systems and an Introduction to Chaos, M. Hirsh, S. Smale and R. Devaney, Elsevier Academic Press, 2012
4. Chaos and Integrability in Nonlinear Dynamics: An Introduction, M. Tabor, John Wiley & Sons,1989
5. Chaos: Classical and Quantum, P. Cvitanovic *et al.*

H601: Ethics of Science and IPR

Introduction to a Collective, Participatory Teaching-learning Program: A Science of Our own. Science Stands the Test of Ethics … Some indicators. Levels of Moral Development - Does it mean anything? Medical Ethics: Different themes pertaining to medical ethics including ethical issues in public health. History, Philosophy and Psychology of Ethics: History of Political Economy and Modern Ethics. Environmental Ethics.

Intellectual Property Rights and Associated Issues: History of Patenting. Digitalizing Culture-I: Free Software and Free Culture. Digitalizing Culture-II: Concentration and appropriation of Power by the few as well as Possibility of Distributive Justice.

Journals and Publishers: Monopolistic practices by Academic Publishers. Quest for Determining what is Virtuous: Ethics in Practice. Collaborative Projects by the Class. Teaching the Teachers and other Virtuous Inquiries.

PL601: Physics Laboratory – VI
Study of quantum mechanics through acoustic analogue (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).

Suggested Texts and References:

1. The Art of Experimental Physics, D. W. Preston and D. R. Dietz, Wiley 1991

Semester-VII

P701: Fluid Mechanics

UNIT-I

Validity of hydrodynamical description. Kinematics of the flow field. Stress-strain relationship. Basic equations governing conservation of mass, momentum & energy.

UNIT-II

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.

UNIT-III

Virial theorem in the tensor form. Magnetohydrodynamic flows. Generalized Ohm's law in the presence of Hall current &Ambipolar diffusion, Magneto-gravity-acoustic modes.

UNIT-IV

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.

UNIT-V

Spherical accretion flows onto compact objects and accretion disks. High Speed flow of gases. Shock waves and blast waves. Supernova hydrodynamics. Physiological hydrodynamics. Blood flow in human heart.

Suggested Texts and References:

1. Hydrodynamics, 6th Edition, H. Lamb, Dover 1945
2. An Introduction to Fluid Dynamics, G.K. Batchelor, Cambridge University Press, 2000
3. Fluid Mechanics, 2nd Edition, L.D. Landau and E.M. Lifshitz, Elsevier 1987

4. Magnetohydrodynamics, 2nd Edition, T.G. Cowling, Hilger 1976
5. Introduction to Physics of Fluids and Solids, J. Trefil, Dover 1975.

P702: Quantum Mechanics – III

UNIT- I
Relativistic Equations: Lorentz transformations, covariant notation, Klein – Gordon equation, difficulties with probability interpretation of one – particle K-G equation; Dirac equation; Properties of γ matrices.

UNIT- II
Dirac equation in external electromagnetic field; Non – relativistic reduction; Gyrofactor for spin; Lorentz covariance of Dirac equation; Bilinear covariants.

UNIT- III
Solutions of Dirac equation: Plane wave solutions; Negative energy solutions; Hole theoretic interpretation; Spin; Dirac momentum space spinors; Orthonormality and completeness relations; Projection operators for energy, helicity and spin; Trace theorems; Exact solution of Dirac equation for Coulomb potential; Energy levels of Hydrogen atom in Dirac theory; Fine structure splitting; Relativistic corrections and Lamb shift.

UNIT- IV
Introduction to quantum field theory: Lagrangian field theory, symmetry and conservation laws, Klein – Gordon field (real and complex); Covariant commutators, the K-G propagator; Dirac field; Anti-commutation relations, the Fermion propagator; Electromagnetic field; Covariant quantisation, the photon propagator.

UNIT- V
Feynman rules for QED: Dyson expansion of S – matrix; Feynman diagrams in momentum space, Feynman rules, QED processes in lowest order.

Suggested Texts and References:
1. Relativistic Quantum Mechanics vol. 1: J. D. Bjorken and S. D. Drell, McGraw-Hill 1998
2. Intermediate Quantum Mechanics, H. A. Bethe and R. W. Jackiew, Perseus Books 1997
3. Quantum Field Theory, 2nd Edition, F. Mandl and G. Shaw, Wiley 2010
4. Advanced Quantum Mechanics, F. Schwabl, Springer 2008

P703: Statistical Mechanics – II

UNIT-I
Transport theory using the relaxation time approximation; Boltzmann differential equation formulation; examples of the Boltzmann equation method. Stochastic Processes; Random Walk; Auto-catalytic processes.

UNIT-II
Diffusion equation; Langevin equation; Fokker- Planck equation.

UNIT-III

Ising Model; mean-field theory; Landau theory of second order phase transition; Peierls argument; the Bethe-Peierls approximation; Kramers-Wannier duality argument; Pade Approximant.

UNIT-IV

Phase transition and Critical Phenomenon: critical exponents; exponent inequalities; static scaling hypothesis; block spins and the Kadanoff construction.

UNIT-V

Renormalization Group: Decimation; Migdal-Kadanoff method; general renormalization group prescription; examples. Monte-Carlo Methods in statistical mechanics; Metropolis algorithm; Gilespie method.

Suggested Texts and References:

1. Fundamentals of Statistical and Thermal Physics, F. Reif, McGraw-Hill Book Company
2. Statistical Physics part 1, 3rd Edition, L. D. Landau and E. M. Lifshitz, Elsevier 2008
3. Statistical Mechanics: A Set of Lectures, R. P. Feynman, W. A. Benjamin, Inc. 1998
4. A Modern Course in Statistical Physics, L. E. Reichl, Wiley 2009

P704: Reactor Physics.

UNIT- I

Fission process: Liquid drop model, fission rate, reactor power, prompt and delayed neutrons, fission gammas, fission products energy balance, photo neutrons. fissile, fertile and fissionable materials. Fission product activity and decay heat after shut down.

Interaction of Neutrons with Matter: Production of neutrons and nuclear reactions with thermal and fast neutrons, transmutation.

UNIT- II

Concept of microscopic cross section: Inelastic and elastic scattering, Maxwell-Boltzmann distribution and its departure Variation of cross-section with energy, **f**ast, resonance and thermal ranges. 1/v law of neuron cross-section, Resonance absorption, Doppler effect. Eta vs E curve, conversion & breeding concepts-Thorium utilization.

Diffusion of neutrons: Fick's law and its validity, steady state neutron diffusion equation, concepts of neutron flux and current, interface conditions, diffusion coefficient, diffusion length and extrapolation distance.

UNIT- III

Chain Reaction: Four Factor formula, conceptual treatment of diffusion of one group neutrons in non multiplying and multiplying media, infinite and effective multiplication factors bare homogeneous reactor-concepts of material and geometric buckling, sub criticality and super criticality, critical mass, non leakage probabilities in bare homogeneous cores, neutron cycle and lifetime in finite and in infinite reactor system.

Slowing down process: Neutron slowing down, slowing down power and moderating ratio for moderators. Slowing down with spatial migration, Fermi age concepts, migration length, use of reflectors/blankets, reflector savings.

Heterogeneous reactors: Multigroup neutron diffusion with special reference to 2 group approach, Heterogeneous reactors, comparison with homogeneous reactors, unit-cell concepts.

UNIT- IV

Reactor kinetics: Time dependent neutron diffusion equation, one group kinetic equation, prompt neutron life time, Point kinetic model to illustrate importance of delayed neutrons, reactor period, reactivity and its units. Fuel burn-up units.

Neutron Poisons: Xenon and Samarium Poisons, Xenon loads (operating and post shutdown), Variation of xenon load with power and enrichment. Xenon oscillations and their control.

UNIT- V

Reactivity coefficients: Temperature coefficients of reactivity and void coefficient of reactivity, their relevance to reactor safety. techniques to control reactors, typical reactivity balance, long-term burnup, fuel management. Reactor control system – requirements of physics aspects. Reactor shutdown mechanisms and neutron monitoring during operation and shut down. Approach to criticality, physics measurements and calibrations/validations. Reactivity worth measurements of control rods.

Research Reactors at Trombay, Indian PHWRs.

Suggested Texts and References

1. Nuclear Reactor Engineering: Reactor Systems Engineering, Samuel Glasstone and Alexander Sesonske, 4th Edition, 2012
2. Introduction to Nuclear Engineering, 3rd Ed., John R. Lamarsh and Anthony J. Baratta, 2001.
3. Nuclear Reactor Analysis, James J. Duderstadt and Louis J. Hamilton, 1976
4. Nuclear Energy: An Introduction to the Concepts, Systems, and Applications of Nuclear Processes, 6th Ed., Raymond Murray and Keith E. Holbert, 2008.
5. Fundamentals of Nuclear Reactor Physics, Elmer E. Lewis, 2008.
6. Nuclear Reactor Physics, 2nd Ed., Weston M. Stacy, 2007
7. Nuclear Energy: Principles, Practices and Prospects, David Bodansky, 2008.

PL701: Advanced Physics Laboratory – I

Nuclear Physics

Spectral features of photoelectric absorption and Compton scattering with scintillation detectors (i) Inorganic: NaI(Tl), BaF2 (ii) Organic: BC501A and plastic. Energy calibration, energy resolution, photopeak and total efficiency, relative intensity, photoelectric and Compton cross-sections, radiation shielding. Alpha spectroscopy with a silicon surface barrier detector. Fine structure of alpha spectrum and determination of age of source. Fast timing and coincidence measurements using BaF2 and BC501A detectors. Angular correlation of gamma rays using NaI(Tl) detectors. High resolution, low-energy photon measurements with a silicon drift detector: Internal conversion studies, elemental composition through X-Ray Fluorescence (XRF) analysis. Geiger-Muller counter: operating characteristics, dead time measurement, determination of mass absorption coefficient, verification of inverse square law. Lifetime measurements: from nanoseconds through minutes using fast coincidence and decay studies. High-resolution gamma ray measurements with high-purity germanium detectors. Classic experiments: Rutherford scattering, cloud chamber, beta spectrometer. Spectrum analysis techniques and fitting routines: data/peak fitting, energy and efficiency calibration, 1D and 2D histograms.

(Selected experiments from the above list are performed based on number of contact hours prescribed)

Condensed Matter

Growth of metallic thin films by physical vapor deposition techniques like thermal evaporation and DC magnetron sputtering. Tuning of growth parameters to change the deposition rate and

hence thickness of the films. Introduction to vacuum techniques: vacuum pumps, rotary pump, diffusion pump and turbo molecular pumps. Measurement of vacuum: thermocouple gauges, hot and cold cathode gauges. Thickness measurement of thin films by quartz crystal monitor.
Structural characterization of materials (some known and some unknown) by X-ray diffraction (XRD) and X-ray fluorescence (XRF) (a) Phase identification (b) Chemical composition (c) difference between powder diffraction pattern of single and polycrystalline systems (d) Reasons for line broadening in XRD: Rachinger correction and estimation of particle size from Debye-Scherer formula. (e) Identifying crystal structure and determination of lattice constant.
Introduction to low temperature measurements: operation of a closed cycle cryostat, low temperature thermometers, controlling temperatures using PID feedback using temperature controllers, making electrical contacts on thin films and measuring DC resistance with sourcemeter using four probe method-advantages and disadvantages of the technique, temperature dependent (300-20K) measurement of electrical resistivity of metallic thin films and comparing the room temperature value with the standard. Determination of superconducting transition temperature of a high temperature superconductor using electrical transport measurements. Determination of band gap of a semiconductor: highly doped Si by fitting the temperature dependent resistance to the standard variation in semiconductors. Concepts of measuring electrical resistance in labs: from metals to dielectrics. Introducing GPIB interfacing of electronic instruments with the computer and writing LABVIEW programs to interface temperature controller and sourcemeter.

Introduction to phase sensitive measurements: using of a dual phase lock-in amplifier. Measurement of the superconducting transition temperature of a superconducting thin film using a mutual inductance technique down to 2.6K (working of a cryogen free system). Measuring AC resistance of a milliohm resistor using phase sensitive detection and studying the frequency and amplitude variation of the resistance: introduction to noise, White noise and 1/f noise.

Suggested Texts and References:
1. Radiation Detection and Measurement, Glenn F. Knoll, John Wiley 2010
2. Techniques for Nuclear and Particle Physics Experiments: William R. Leo, Springer 1995
3. Basic Vacuum technology, 2nd Edition, A. Chambers, R. K. Fitch and B. S. Halliday, IOP 1998
4. Physical Vapor Deposition, R. J. Hill, McGraw-Hill 2005
5. Elements of X-ray Diffraction, 3rd Edition, B. D. Cullity and S. R. Stock, Prentice Hall 2001
6. Introduction to Solid State Physics, 8th Edition, C. Kittel, Wiley 2012.

SEMESTER-VIII

P801: Astronomy and Astrophysics

UNIT-I

Stellar Physics: Equations governing the structure of stars: Mechanical & Thermal equilibrium. Virial theorem. Modes of energy transfer in stars: radiative & convective transport of energy. Auxiliary input: equation of state, opacity and energy generation by thermonulcear processes. Boundary conditions at the stellar surface & at the centre.

UNIT-II

Models with linear & quadratic density profiles. Polytropic models. Mass-luminosity-radius relations for low, intermediate & high mass stars. Sources of opacity and nucleosynthesis in stars. Manufacturing of iron-peak and heavier elements by rapid neutron capture processes. Mixing length theory of convective transport of hear. Completely convective stars. Hertzsprung-Russel diagram. Pre-main sequence contraction and the Hayashi phase. Zero-age main sequence.

UNIT-III

Stellar evolution: main sequence, red giant and asymptotic giant branch. Advanced stages of stellar evolution: white dwarfs, neutron stars & black holes. Physics and astrophysics of collapsed objects: pulsars, X-ray &gamma ray sources. Spherical accretion and Bondi solution. Physics of accretion discs. Stellar rotation and magnetism.

UNIT-IV

Galactic Physics: Units in astronomy, co-ordinate system, multi-wavelength sky (radio, IR, Optical, UV, X-ray, Gamma ray), distance ladder, Milkyway Galaxy, interstellar medium, basics of star formation, spiral and elliptical galaxies (morphology, content and kinematics), evidences for dark matter, . astronomy and society (including citizen science), constraints and prospects of astronomy and astrophysics research in India.

UNIT-V

AGNs, evidences for supermassive black holes, M-sigma and similar correlations, radio galaxies, synchrotron radiation, accretion onto black hole, physical processes behind black holegalaxy co-evolution (merger, infall and feedback), clusters of galaxies (contents and kinematics), high redshift galaxies, cosmic evolution of galaxies and black holes, hierarchical structure formation, cosmic-web, GMRT

Suggested Texts and References:

1. The Internal Constitution of Stars, A. S. Eddington, Cambridge University Press, 1988.
2. An Introduction to the Study of Stellar Structure, S.Chandrasekhar, Dover Publications, 2003.
3. The stucture & Evolution of the Stars, M.Schwarzschild, Dover Publications, 1962.
4. Cox and Giuli's Principles of Stellar Structure, 2nd Ed., A. Weiss et al., Cambridge, 2003.
5. The Physical Universe: An Introducing to Astronomy, F. H.Shu, University Science Books, 1982.
6. Galactic Astronomy, James Binny and Michael Merrifield, Princeton University Press, 1998.
7. An Introduction to Active Galactic Nuclei, B. M. Peterson, Cambridge University Press, 1997.
8. Extragalactic Astronomy and Cosmology: An Introduction, Peter Schneider, Springer, 2006.
9. Physics of the Interstellar & Intergalactic Medium, Bruce T. Draine, Princeton Univ. Press, 2011.

P802: Accelerator Physics and Applications

UNIT-I

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.

UNIT-II

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.

UNIT-III

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.

UNIT-IV

Synchrotron radiation: Introduction to electromagnetic radiation; Radiation of accelerated charged particles; radiation from wigglers and undulators; Electron dynamics with radiation; Low emittance lattices; synchrotronradiation sources.

UNIT-V

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: Photo injectors; laser-wakefield acceleration; plasma-wakefield acceleration; linear colliders; muon colliders.

Suggested Texts and References:

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 Edition, J. D. Jackson, Wiley 2012

P803: Nuclear and Particle Physics

UNIT-I

Nuclear Reactions: Partial wave decomposition, phase shifts and partial wave analysis of the cross sections in terms of phase shifts. Behaviour of phase shifts in different situations. Black sphere scattering. Optical theorem and reciprocity theorem. Unitarity.
Optical potential: Basic definition. Relation between the imaginary part, W of the OP and σabs , and between W and mean free path. Folding model and a high energy estimate of the OP.

UNIT-II

Catagorisation of Nuclear Reaction mechanisms:
Low energies: Discrete region, Continuum Region: (a) Discrete Region: Decaying states. Relation between the width and the mean life time. Energy definition: Lorentzian or Breit-Wigner. Resonance scattering. Derivation of the resonance cross section from phase shift description of cross section. Transmission through a square well and resonances in continuum. Coulomb barrier penetration for charged particles scattering and centrifugal barrier for l non-zero states. Angular distributions of the particles in resonance scattering. Application to hydrogen burning in stars. (b) Continuum Region: Bohr's compound nucleus model.

UNIT-III

Direct Reactions: Cross section in terms of the T-matrix. Phase space, and its evaluation for simple cases. Lippmann Schwinger equation for the scattering wave function, and its formal solution. On-shell and off-shell scattering. Plane wave and distorted wave approximation to the T-matrix(PWBA, DWBA). Application to various direct reactions like, stripping, pick-up, knock-out etc.High energy scattering. Glauber theory. Eikonal approximation to the scattering wave function.Evaluation of scattering cross section in eikonal approximation. Introduction to heavy-ion scatteringand the physics with radioactive ion beams.

UNIT-IV

Nuclear Structure: Generalization of the single-particle shell model, residual interactions, Fermi gas model. Single-particle energies in a deformed potential, shell corrections and the Strutinski method. Pairing: BCS model and the Bogolyubov transformation. Hartree-Fock method: general variational approach, Hartree-Fock equations and applications. Nuclear shape parametrization, quadrupole and higher- order deformations. Collective rotation and vibration; Giant resonances. Cranking model, phenomena at high spin including super-deformation. introduction to Density-Functional Models, including relativistic mean field. Selected contemporary research topics: Superheavy nuclei; Spectroscopy of drip-line nuclei.

UNIT-V

Particle Physics: Symmetries and conservation laws, conserved quantities in reactions of particles. Relativistic kinematics in particle reactions, invariants, resonances, decays of resonances and their decays etc. Particle classification, mesons and baryons, SU(3) multiplets, quark model. Quarks, gluons, QCD interaction, colour neutrality. Detection of quarks and gluons, structure function in deep inelastic reactions. Quark and lepton families, weak interactions as guage theory, W and Z bosons. Symmetry breaking and generation of masses, Higgs bosons. Present boundary (strings, grand unification, matter-anti-matter asymmetry, dark matter and energy - seminar, qualitative)

Suggested Texts and References:

1. Subatomic Physics, E. M. Henley & A. Garcia, World Scientific
2. Concepts of Nuclear Physics, B. C. Cohen, McGraw-Hill.
3. Introduction to Nuclear and Particle Physics, A. Das and T. Ferbel, World Scientific.
4. Structure of the Nucleus: M.A. Preston and R.K. Bhaduri, Levant Books, 2008
5. Nuclear Models: W. Greiner and J.A. Maruhn, Springer, 1996
6. Nuclear Structure from a Simple Perspective: R. F. Casten, Oxford University Press, 1990
7. Theory of Nuclear Structure: M.K. Pal, Affiliated East-West Press, 1982
8. An Introduction to Quarks and Partons, F. E. Close, Academic Press 1980
9. Quarks and Leptons: An Introductory Course in Modern Particle Physics, F. Halzen and A. D. Martin, John Wiley 1984
10. Introduction to High Energy Physics, 4th Edition, D. Perkins, Cambridge 2000

P804: Condensed Matter Physics – II

UNIT-I

Superconductivity: Revision, Introduction to second quantization, BCS theory, Electron tunneling and energy gap, Josephson effect (AC and DC). GL theory and concept of penetration depth, coherence length and surface energy, Flux quantization.

UNIT-II

Modified London Equation of Mixed Phase, Interaction between Flux tubes, Flux flow, Flux pinning, Magnetization of Mixed State: Bogoliubov transformation, Boundary between normal metal and superconductor, Andreev Reflection and Proximity effect.

UNIT-III

Magnetism: Quantum theory of magnetism: Rationalization of the Heisenberg Hamiltonian, Hubbard model and Stoner Model: Derivation of susceptibility, Spin wave using Holstein-Primakov transformation.

UNIT-IV

Introduction to Density Functional Theory

Introduction to Special topics: Integer and Fractional Quantum hall effect, unconventional superconductivity, frustrated magnets, Josephson junction qubits, Graphene physics, Topological insulators.

UNIT-V

Kondo Physics, Metamaterials, Physics of photonic band gap materials, quantum cascade lasers, free electron lasers, organic electronics etc.

Note: Special topics in Fermi Liquid Theory may be covered if time permits.

Suggested Texts and References:

1. Introduction to Superconductivity, 2nd Edition, M. Tinkham, Dover 2004
2. Superconductivity, J. B. Ketterson and S. N. Song, Cambridge 1999
3. Basic Solid State Physics by A. K. Raychaudhuri
4. Magnetism in Solids, D. H. Martin, Butterworth 1967
5. Quantum theory of Magnetism, 3rd Edition, R. M. White, Springer 2006
6. Electronic Structure, Basic Theory & Practical Methods, R. Martin, Cambridge 2008

PL801: Advanced Physics Laboratory – II

Introduction to Observational Astronomy: Transmission of radiation through atmosphere in different bands, need for space platforms for invisible astronomies, Introduction to Optical, Infrared, Ultra-violet, X-ray and Gamma-ray astronomy, what do me measure and learn from different wavebands.

Introductory Astronomy and Different types of Optical Telescopes: Astronomical parameters like Apparent and Absolute magnitude, Flux, Luminosity and its dependence on size and temperature of stars, Atmospheric Extinction, Coordinate System in Astronomy Refracting and Reflecting telescopes, different focal plane configurations, their applications and relative merits and demerits. Reflectivity and its wavelength dependence, "seeing" and factors affecting it, use of active and adaptive optics in modern telescopes to overcome atmospheric and thermal effects, calculation of focal length, focal ratio, magnification, field of view, plate scale, diffraction limit of telescopes.

Introduction to Focal Plane Detectors for Optical, infrared and UV astronomy: Developments and evolution of modern Optical and Infrared imaging detectors: Photographic Plates, Phototubes, Image Intensifiers, Charge Coupled Devices (CCDs), Bolometers and how they work, their characterization and parameters (charge transfer efficiency, quantum efficiency, flat fielding etc.). CCDs uses in Imaging, morphological and Spectroscopic studies, Infrared Detectors and IR Arrays, UV Imaging and Photon Counting Detectors.

Different types of Focal Plane Instruments: Imagers, Photometers, Fast Photometers for photon counting, limitations of PMT and CCD bases photometers, Importance of spectroscopy, Design and description of Low and High Resolution Spectrometers and their applications, Polarimeters and their applications.

Interaction of radiation with matter: (a) Passage of charged and neutral particles through matter, Ionization loss formulae and dependence on different parameters, relativistic rise in ionization loss, detection of neutrons, Bremsstrahlung process, Cerenkov radiation and its application (b) Interaction of photons with matter: Photoelectric interaction, mass absorption formula and dependence on energy, atomic number etc, Thompson scattering, Compton scattering, Pair production process, formula and dependence on energy, atomic number, radiation length, critical energy

Introduction to Different Types of Gas-Filled Radiation Detectors: Role of development of new detection techniques in new discoveries in high energy physics and astrophysics, different kind of detection techniques for charged and neutral radiation Dependence of charge multiplication on high voltage and pressure, Townsend coefficient, need for use of inert gases, quench gas, mobility of electrons and ions (a) Ionization Chamber (IC), description of a typical IC, its characteristics, application of IC in physics (b) Proportional Counters (PC): Single and multi cell PCs, filling gases, Penning effect, charge multiplication process, energy resolution of PC, Fano factor, use of PCs in high energy physics, and astronomy especially in X-ray astronomy (c) Geiger Mueller (GM)Counter: Typical GM counter, its characteristics, applications of GM counter

Scintillation Counters, Cerenkov Detectors and other Solid State Detectors: Scintillation processes, dependence on energy, charge and atomic number, Photomultiplier (PMT) for detection of light, PMT characteristics, charge multiplication and use of PMTs with scintillators (a) Organic Scintillation Counters: Plastic Scintillators and light yield, their use in charged particle detection, a typical PS detector and its characteristics (b) Inorganic Scintillation Counters: Scintillation medium and need for activators, Sodium Iodide (NaI) and Caesium Iodide detectors, their light output, application of these detectors in physics and astrophysics (c) Silicon detectors and their applications in X-ray Astronomy, Germanium Detectors, Cadmium -Telluride devices and their arrays

Observational X-ray Astronomy: Birth and evolution of X-ray Astronomy, different types of X-ray sources, Discovery of X-ray Binaries, their broad properties, optical identification, classification in Low Mass X-ray binaries (LMXBs) and High Mass X-ray Binaries (HMXBs), their unique characteristics, estimation of mass of the compact star in X-ray binaries from the binary parameters (a) Neutron Star Binaries (NSB): X-ray Pulsars in Binaries, Rotation powered pulsars in SNRs, detailed discussion of their timing and spectral properties, New physics and astrophysics learnt from their studies (b) Black Hole Binaries (BHB): Inference about black hole nature, time variability, spectral measurements, mass of black hole

X-ray Radiation Processes: (a) Thermal Emission, Black Body emission, Thermal Bremstrahlung (free-free emission),spectral line formation in thermal plasma, examples of thermal spectra, measurement of temperature and elemental abundances from spectral data (b) Non-thermal Emission: Synchrotron mechanism (magnetic bremstrahlung), spectral shape, polarized emission, Inverse Compton Scattering, spectrum of radiation, examples of non-thermal spectra, Cyclotron process in strongly magnetized stars and formation of cyclotron lines, determination of magnetic field of the stars

Experiments to be performed:

1. Measuring energy resolution (R) of a Cadmium Telluride Detector using X-rays of different energies (E) from radioactive sources and deriving expression for variation of R with E.
2. Solar Constant measurement.
3. Measurement of Solar Limb Darkening.
4. Observing an Optical Binary Star and deriving its light curve.
5. Determine Pulsation period and binary light curve of an accreting Neutron star from X-ray data.
6. Measuring X-ray Energy Spectrum of a Black Hole Binary and fit it with different spectral models.
7. Characteristics of a Proportional Counter and dependence of its energy resolution on different parameters of the PC.