Department of Physics
Course structure and Syllabus for Int. M.Sc. in Physics (2018)

Minimum credit required: 200
Minimum duration: 10 Semesters
Maximum duration: 14 Semesters

Semester	Credit	Semester	Credit
I	21	VI	22
II	22	VII	23
III	21	VIII	21
IV	22	IX	21
V	22	X	19

Semester I

Course Code	Course Name	L-T-P	CH	CR	Remark
PI 101	Physics-I	2-1-0	3	3	CORE
CI 101	Chemistry-I	2-1-0	3	3	GE
MI 101	Mathematics-I	2-1-0	3	3	GE
BI 101	Biology-I	2-1-0	3	3	GE
PI 197	Physics Lab -I	0-0-3	6	3	CORE for Physics Major GE for Non-Major (Chemistry & Biology)
BI 107	Biology Laboratory	0-0-3	6	3	GE
EG 110	Communicative English (Language Proficiency)	3-0-0	3	3	AEC
Total credits			27	**21**	

Semester II

Course Code	Course Name	L-T-P	CH	CR	Remark
PI 102	Physics-II	2-1-0	3	3	CORE
CI 102	Chemistry-II	2-1-0	3	3	GE
BI 102	Biology-II	2-1-0	3	3	GE
MI 102	Mathematics-II	2-1-0	3	3	GE
PI 198	Physics Lab-II	0-0-3	6	3	CORE for Physics Major
CI 105	Chemistry Lab	0-0-3	6	3	GE
ES 103	Environmental Studies	4-0-0	4	4	AEC
Total credits			28	**22**	

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 197	Physics Lab-I	0-0-3	6	3	GE for Non-Major (Mathematics)

Semester III

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 201	Physics III	2-1-0	3	3	Non-Major

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 203	Classical Mechanics	2-1-0	3	3	CORE
PI 217	Mathematical Physics-I	2-1-0	3	3	CORE
CI 201	Chemistry III	3-0-0	3	3	GE
MI 201	Mathematics III	2-1-0	3	3	GE
PI 297	Physics Lab-III	0-0-4	8	4	CORE
NS 106	NSS	0-0-2	4	2	SEC
CS 535	Introduction to Scientific Computing	2-0-1	4	3	AEC
Total credit			28	**21**	

Semester IV

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 205	Electromagnetism	2-1-0	3	3	CORE
PI 214	Electronics	2-1-0	3	3	CORE
PI 325	Thermodynamics and Statistical Physics	2-1-0	3	3	CORE
PI 218	Modern Physics	2-1-0	3	3	CORE
PI 298	Physics Lab-IV	0-0-4	8	4	CORE
	Elective I	2-1-0	3	3	DSE
DM 101	Disaster Management	2-1-0	3	3	SEC
Total credit			26	**22**	

Semester V

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 303	Physical and Geometrical Optics	2-1-0	3	3	CORE
PI 202	Introductory QM	2-1-0	3	3	CORE
PI 315	Mathematical Physics II	2-0-1	3	3	CORE
PI 309	Analog Electronics and communications	2-1-0	3	3	CORE
PI 204	Atomic and Nuclear Physics	2-0-1	3	3	CORE
PI 308	Laser Physics	2-1-0	3	3	DSE
PI 399	Physics Lab-V	0-0-4	8	4	CORE
Total credits			**26**	**22**	

Semester VI

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 307	Basic Material Science	2-1-0	3	3	CORE
PI 317	Basic Computation Techniques	2-1-0	3	3	CORE
PI 314	Measurement Physics	2-1-0	3	3	CORE
	Elective II	2-0-1	3	3	DSE
PI 311	Waves and Accoustics	2-1-0	3	3	CORE
	Open Elective	2-1-0	3	3	
PI 300	Project cum Physics Lab-VI	0-0-4	8	4	
Total credits			**26**	**22**	

List of elective papers

1. **PI 220 Renewable Energy**
2. **PI 221 Nanomaterial Fundamentals and application**
3. **PI 222 Earth Science**

Semester VII

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 403	Electromagnetic Theory I	2-1-0	3	3	
PI 413	Advanced Classical Mechanics	2-1-0	3	3	
PI 414	Quantum Mechanics –I	2-1-0	4	3	
PI 416	Condensed Matter Physics and Material Science	2-1-0	3	3	
PI 499	Physics and Computational Lab	0-1-3	7	4	
PI 405	Semiconductor Devices	2-1-0	3	3	
PI 400	Physics Lab-VII	0-0-4	8	4	
Total credits				**23**	

Semester VIII

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 552	Quantum Mechanics-II	2-1-0	3	3	
PI 310	Statistical Physics	2-1-0	3	3	
PI 551	Electromagnetic Theory II	2-1-0	3	3	
PI 417	Advanced Mathematical Physics	2-0-1	4	3	
PI 302	Analog and Digital Electronics	2-1-1	5	4	
PI 450	Seminar	0-0-1	2	1	
PI 498	Physics Lab-VIII	0-0-4	8	4	
Total credits				**21**	

Semester IX

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 559	Project-1	0-0-6	12	6	To be carried out under the guidance of a faculty member
PI 402	Nuclear and Particle Physics	2-1-0	3	3	
PI 553	Atomic and Molecular Spectroscopy	2-1-0	3	3	
	Elective I	2-1-0	3	3	
	Elective II	2-1-0	3	3	
	Open Elective	2-1-0	3	3	
Total credits				**21**	

Semester X

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 500	Project-1I	0-0-10	20	10	To be carried out under the guidance of a faculty member
	Elective III	2-1-0	3	3	
	Elective IV	2-1-0	3	3	
	Open Elective	2-1-0	3	3	
Total credits				**19**	

Elective Courses are offered by the department in Semester IX and Semester X: Minimum of Four is to be chosen from any specialization.

Course Code	Course Name	L-T-P	CH	CR	Remarks
	Astrophysics				
PI 505	Basic Astronomy & Astrophysics	2-1-0	3	3	
PI 506	Introduction to Cosmology	2-1-0	3	3	
PI 515	High Energy & Extragalactic Astrophysics	2-1-0	3	3	
PI 518	General Theory of Relativity	2-1-0	3	3	
PI 412	Plasma and Astrophysics	2-1-0	3	3	

Condensed Matter Physics					
PI 510	Advanced Material Science	2-1-0	3	3	
PI 511	Superconductivity and Critical Phenomena	2-1-0	3	3	
PI 513	Physics of Thin Films	2-1-0	3	3	
PI 514	Physics of Solid State Devices	2-1-0	3	3	
PI 519	Surface Science	2-1-0	3	3	
PI 520	Nanostructures	2-1-0	3	3	
PI 554	Soft Condensed Matter Physics	2-1-0	3	3	
Electronics					
PI 507	Digital Signal Processing	2-1-0	3	3	
PI 508	Digital Communication System	2-1-0	3	3	
PI 516	Microprocessors and Digital Signal Processing Based Systems	2-1-0	3	3	
PI 517	Microwave Systems and Antenna Propagation	2-1-0	3	3	
PI 509	Fiber Optics and Optoelectronics	2-1-0	3	3	
High Energy Physics					
PI 412	Plasma and Astrophysics	2-1-0	3	3	
PI 501	Quantum Field Theory	2-1-0	3	3	
PI 502	Quantum Electrodynamics	2-1-0	3	3	
PI 555	Particle Physics I	2-1-0	3	3	
PI 556	Particle Physics II	2-1-0	3	3	
Photonics					
PI 509	Fiber Optics and Optoelectronics	2-1-0	3	3	
PI 557	Photonics	2-1-0	3	3	
PI 517	Microwave systems and Antenna Propagation	2-1-0	3	3	
PI 546	Fourier Optics and Holography	2-1-0	3	3	
PI 558	Quantum Electronics	2-1-0	3	3	
PI 559	Nanophotonics	2-1-0	3	3	

Plasma Physics					
PI 521	Fundamentals of Plasma Physics	2-1-0	3	3	
PI 524	Plasma Generation and Application	2-1-0	3	3	
PI 525	Non-linear Plasma Physics	2-1-0	3	3	
PI 510	Advanced Material Science	2-1-0	3	3	
PI 505	Basic Astronomy and Astrophysics	2-1-0	3	3	
PI 515	High Energy and Extragalactic Physics	2-1-0	3	3	
PI 412	Plasma and Astrophysics	2-1-0	3	3	
Nano-Science					
PI 520	Nanostructures	2-1-0	3	3	
PI 543	Surface Science	2-1-0	3	3	
PI 559	Nanophotonics	2-1-0	3	3	
PI 554	Soft Condensed Matter Physics	2-1-0	3	3	
PI 560	Nanobiophysics	2-1-0	3	3	
PI 561	Nanomagnetism	2-1-0	3	3	

Total Credit (UG + PG): 130 + 84 =214

Terminology
Core papers (CORE)
Generic Elective (GE)
Discipline Specific Elective papers (DSE)
Ability Enhancement Compulsory (AEC)
Skill Enhancement Course (SEC)

Detailed Syllabi

Semester-I

PI 101: PHYSICS-I **(L2-T1-P0-CH3-CR3)**

Coordinates, Vectors and Matrices:

Coordinate systems, plane polar, cylindrical and spherical polar; line element, surface element and volume element; gradient, divergent and curl.

Line, surface and volume integrals.

Properties of matrices; complex conjugate matrix, transpose matrix, hermitian matrix, unit matrix, diagonal matrix, adjoint of a matrix, self-adjoint matrix, cofactor matrix, symmetric matrix, anti-symmetric matrix, unitary matrix, orthogonal matrix, trace of a matrix, inverse matrix, eigenvalue, diagonalization of matrices.

Mechanics:

Work-energy theorem, conservative forces and potential energy; energy diagram; non-conservative forces; motion in non-inertial frames; uniformly rotating frame; centrifugal and Coriolis forces.

Motion under a central force.

System of particles; centre of mass, equation of motion of the centre of mass; laboratory and centre of mass frame of references; elastic and inelastic collisions; linear and angular momentum and their conservation laws; fixed axis rotation; moment of inertia; theorem of parallel and perpendicular axes; compound pendulum, Kater's and bar pendulum.

Properties of Matter:

Elasticity; elastic constants; Hooke's law; torsional oscillation; bending of a beam; cantilever; surface tension; viscosity; kinematics of moving fluids.

Text Books:

1. Spiegel M., *Vector Analysis: Schaum's Outlines Series*, 2nd edition (McGraw Hill, 2017).
2. Potter M. C., Goldberg J., *Mathematical methods*, 2nd edition (Phi Learning Pvt. Ltd., 2008).
3. Mathur, D. S., *Mechanics*, (S. Chand & Co. Ltd., 2000).
4. Kleppner, D. and Kolenkow, R., *Introduction to Mechanics*, (McGraw-Hill, 1973).

Reference Books:

1. Harper C., *Introduction to Mathematical Physics*, 1st edition *(*Phi Learning Pvt. Ltd., 2008).
2. Chow, T. L., *Mathematical Methods for Physicists: A concise introduction*, 1st edition (Cambridge Univ. Press, 2000).
3. Takwale R., Puranik P., *Introduction to Classical Mechanics*, (McGraw Hill, 2017).
4. Young, H. D. and Freedman, R. A., *University Physics*, 12th edition (Pearson, 2009).

PI 197: Physics Lab –I **(L0-T0-P3-CH6-CR3)**

1. Laboratory related components:
    a. Laboratory safety measures; handling of chemical; electrical and electronics items and instruments; handling of laser and laser related instruments and experiments; handling of radioactive samples and related instruments; general safety measures etc.
2. Familiarization with equipment and components:
    a. Familiarization of different Electrical and Electronics components and hence identification & determination of values of unknown components
    b. Familiarization of different optical and hence show different optical behavior & pattern by using different optical components and optical sources (white light, laser, sodium light etc.)
    c. Familiarization of Microsoft excel, Origin and other software for data analysis
    d. Soldering and de-soldering of components in a circuit board.

3. Use of equipment:
    a. Multimeter and its uses
    b. Function generator and its uses
    c. CRO and its use to measure the wavelength, frequency, amplitude etc. of a given electrical signal.
4. Study the variation of time period with distance between center of gravity and center of suspension for a bar pendulum and,
    a. determine
        a) radius of gyration of the bar about its axis through its center of gravity and perpendicular to its length and,
        b) value of g
5. Determine the moment of a given magnet and horizontal component of Earth's magnetic field using magnetometers
6. Determine g through Kater's Pendulum
7. Find the refractive index of a given prism with the help of a spectrometer.
8. To determine the surface tension of the given liquid (water/CC14) by capillary tube method.
9. To measure the focal length of a given lens using (a) Bessel's method and (b)Magnification method.
10. To study elastic and inelastic collisions using suspended spherical balls of different materials.
11. Determination of Young's modulus of the given wire by torsional oscillation (Searl's method)

Semester-II

PI 102: PHYSICS-II **(L2-T1-P0-CH3-CR3)**

Special Theory of Relativity:

Frames of reference, relative velocity and accelerations, Concept of ether, Michelson-Morley experiment, elements of special theory of relativity, the postulates, Galilean and Lorentz transformations, equivalence of mass and energy, time dilation, length contraction, simultaneity, Doppler effect, twin paradox.

Electromagnetism:

Coulomb's law (electric), electric field due to a system of charges, Gauss's law in differential and integral forms, electric dipole, its electric field and potential, capacitance of parallel plates.

Coulomb's law (magnetic), Biot-Savart law, force on a current and on moving charges in a B-field.

Electronics:

Kirchhoff's law, network theorem, nodal analysis, mesh analysis, maximum power transfer theorem, series circuits, parallel circuits (DC analysis only), semiconductors, p-type, n-type semiconductors, p-n junction, diode, triode.

Text Books:

1. Beiser A., *Concepts of Modern Physics*, 6th edition (Tata McGraw Hill, 2008).
2. Rakshit, P. C. and Chattopadhaya, D., *Electricity and Magnetism*, (New Central Book Agency, 2012).
3. Robbins, A. H. & Miller, W. C., *Circuit Analysis* (Delmar Cengage Learning, 2003).

Reference Books:

1. Resnick, R., *Introduction to Special Relativity*, 1st edition (Wiley, 2007).
2. Griffith, D. J., *Introduction to Electrodynamics*, 3rd edition (Prentice Hall of India, 1999).
3. Edminister, J. A., *Electrical Circuits- Schaum's Outline series*, 2nd edition (McGraw Hill,1983).

PI 198: Physics Lab -II **(L0-T0-P3-CH6-CR3)**

1. Design LCR series and parallel circuits and to measure resonant frequencies.
2. To prove Thevenin's and Norton's theorem
3. Determine the force between two current carrying conductors.
4. Study the I-V characteristics of a Diode
5. Study of Lissajous Figure of two different waves using CRO and find out the unknown frequency of an electrical signal.
6. To determine the thickness of thin film using interferometric method.
7. Determine the mechanical/ Electrical equivalent of heat by Joule's Calorimeter.
8. Determine the coefficient of linear expansion of the given metal sample by optical lever method.
9. Determine of the co-efficient of viscosity of water by Poiseulle's method
10. Determine the wavelength of the given source of light using Fresnels' Biprism
11. Measurement of frequency of an unknown tuning fork using a sonometer.
12. To determine the coefficient of self-inductance of a coil by Rayleigh's D.C. Bridge method

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Semester-III

PI 201: Physics-III **(L2-T1-P0-CH3-CR3)**

Particle properties of waves: Wave particle duality, Photoelectric effect, Black body radiation, Plank radiation law, Rayleigh-Jeans law, Stefan's law.

Atomic physics: Rutherford model, Bohr model, hydrogen atom (quantum numbers and spectral series; qualitative), X-ray, Moseley's law, Basics of Lasers. Basics particle physics: elementary forces and particles.

Limitations of classical physics: Qualitative discussions of the problem of the stability of the nuclear atom. The photo-electric effect. Franck-Hertz experiment and the existence of energy levels. Experimental evidence for wave-particle duality, X-ray diffraction and Bragg law. Compton scattering. Electron and neutron diffraction. Einstein and de Broglie's relations ($E = h\gamma$, $p = h/\lambda$).

Schrodinger equation: The concept of the wave function as a probability amplitude and its probabilistic interpretation. Plane wave solutions of the one-dimensional time-dependent Schrodinger equation for a particle in free space and elementary derivation of the phase and group velocities (quantitative discussion of wave packets is not required).

Uncertainty relation: The position-momentum uncertainty relation and simple consequences. Solutions of the one-dimensional Schrodinger's equation for an infinite square well potential; qualitative treatment of the finite well (derivation not required). Linear harmonic oscillator.

Text Books:

1. Beiser, A., *Concepts of Modern Physics* (McGraw-Hill, 2002).
2. Krane, K. S., *Modern Physics* (Wiley).

Reference Books:

1. Beiser, A., Perspectives *of Modern Physics* (McGraw-Hill Inc.,US).
2. Thornton, S. T. and Rex, A., Modern Physics for Scientists and Engineers (Cengage Learning; 4 edition).
3. Gautreau, R. Schaum's Outline of Modern Physics, (McGraw-Hill; 2 edition).
4. Young, H.D. and Freedman, R.A., *University Physics*, 12th edition, (Pearson, 2009).

PI 203: Classical Mechanics (L2-T1-P0-CH3-CR3)

Mechanics of a particle: Conservation theorems for a particle, motion of a particle under damping forces, motion of a particle under central force, motion of a body in a resisting medium, Kepler's laws of planetary motion, moving co-ordinate systems, Galilean transformation, Coriolis force, Foucault's pendulum.

Mechanics of a System of Particles: Centre of mass and its motion, conservation theorems for a system of particles, collision problems, constraints, generalised co-ordinates, configuration space, principle of virtual work, D'Alembert's principle.

Lagrangian Formulation: Lagrange's equation, the rules of forming Lagrange's equation, Lagrange's equations for non-conservative forces, spherical and cylindrical co-ordinates, Hamilton's principle and Lagrange's equation, application of Lagrange's equation, motion of charged particle in an electromagnetic field, superiority of Lagrange’s approach over Newtonian approach.

Hamiltonian Formulation: Phase space, Hamiltonian function and Hamiltonian equation, Application of Hamiltonian equation, Harmonic oscillator, compound pendulum, cyclic co-ordinates, Liouville's theorem, Routh's procedure.

Text Books:

1. Upadhyaya, J. C., *Classical Mechanics*, (Himalayan Publishing House).
2. Gupta, S. L., Kumar, V. and Sarma, H. V., *Classical Mechanics*, (Pragati Prakashan).

Reference Books:

1. Goldstein, H., *Classical Mechanics*, (Narosa, 2001).
2. Rana N. C., and Joag, P. S., *Classical Mechanics*, (Tata McGraw-Hill, 1991).
3. Takwale, R. G. and Puranik, P. S., *Introduction to Classical Mechanics*, (Tata McGraw-Hill, 1978).
4. Panat, P. V., *Classical Mechanics*, (Narosa Publishing House).

PI 217: Mathematical Physics-I **(L2-T0-P1-CH4-CR3)**

Scalar and vector fields, differentiations, divergence and curl; integrations, Greens, Gauss's and Stokes theorems and their applications, transformations of coordinate systems and vector components, metric coefficients, curvilinear coordinates, expressions for grad., div., and curl, Helmholtz equation in three-dimensions and separable variables in various coordinate systems, matrices and determinants.

Beta, gamma and error functions, relationship between the beta and gamma functions, reduction of some classes of integrals to gamma functions, Sterling's formula; derivation of values of gamma functions.

Fourier series: Evaluation of coefficients, graphical representations, even and odd functions, properties of Fourier series, Fourier integrals.

Elements of probability: Mathematical probability, compound probability, total probability, sample space, random variables, expectation value, averages, mean, standard deviation, binomial distribution, normal distribution; variance, covariance and correlation; theory of errors, central limit.

Random Process: Random variables to random process, statistical averages, stationary processes.

Text Books:

1. Harper, C., *Introduction to Mathematical Physics, (*Prentice Hall, 2009).
2. Arfken, G. B., and Weber, H. J., *Mathematical Methods for Physicists*, (Elsevier Ltd, Oxford, 2005).
3. Spiegel, M. R., *Vector Analysis*, Schaum's outline series, (Tata McGraw-Hill 1979).

Reference Book:

1. Morganeau, H. and Purphy, C. M., *The Mathematics of Physics and Chemistry*, (Young Press, 2009).

PI 297: Physics Lab-III **(L0-T0-P4-CH8-CR4)**

1. To observe the rotation of the plane of polarization of monochromatic light by a given solution and to determine the specific rotation of sugar solution using a Polarimeter.
2. Determine the wavelength (λ) of the given monochromatic light by using Lloyd's mirror.
3. To measure thermo e.m.f. of a thermocouple as a function of temperature and find inversion temperature.
4. To measure the radius of curvature of a given concave mirror and to measure the refractive index of a liquid by this method.
5. To measure the inductance of a given inductor using Anderson bridge.
6. To measure the capacitance of a capacitor by de-Sauty method and to find permittivity of air.
7. To study Op-Amp. characteristics:
    a. To get data for different input bias current,
    b. To measure and null the output offset voltage.
8. Determine the efficiency of the given solar cell for different intensity and different frequency of light sources.
9. Measure the elasticity of the given sample by Newton's ring method.

Semester-IV

PI 205: Electromagnetism **(L2-T1-P0-CH3-CR3)**

Electrostatics in vacuum: Coulomb's law, Electric field due to a system of charges, Field lines, flux and Gauss's law, Gauss's law in differential form, the electric dipole and its electric field and potential, the couple and force on, and the energy of, a dipole in an external electric field, Gauss's law in integral form, field and potential due to surface and volume distributions of charge, force on a conductor, the capacitance of parallel plate, cylindrical and spherical capacitors, electrostatics in the presence of dielectric media, Modification to Gauss's law, polarisation, the electric displacement, relative permittivity, capacitance and energy in the presence of dielectric media.

Magnetic effects in the absence of magnetic media: the B-field, steady currents: the B-field set up by a current, the Biot-Savart law, the force on a current carrying conductor and on moving charges in a B-field, the magnetic dipole and its B-field, the force and couple on, and the energy of, a dipole in an external B-field, energy stored in a B-field.

Gauss's law in integral form, simple cases of the motion of charged particles in electric and magnetic fields.

Text Books:

1. Griffith, D. J., *Introduction to Electrodynamics*, 3rd edition, (Prentice-Hall of India, 1999).
2. Purcell, E. M., *Electricity and Magnetism*, Berkely Physics Course, Vol. 2 (McGraw-Hill, 1965).
3. Matveev, A.N., *Electricity and Magnetism*, (Mir Publishers, 1986).

PI 214: Electronics **(L2-T1-P0-CH3-CR3)**

Series and Parallel Resonant circuits (Detailed AC analysis)
Introduction to Three Phase Circuits. Two port n/w, Z-parameter, Y-parameter, Transmission.
Semiconductors: p and n Type Semiconductors. Energy Level Diagram, Mobility and conductivity, transport phenomenon due to donor and acceptor impurities, Fermi level, Hall Effect, conductivity measurement Conductivity and Mobility.
Diodes: Barrier Formation in pn Junction Diode (Simple Idea). Current Flow Mechanism in Forward and Reverse Biased Diode (Recombination, Drift and Saturation of Drift Velocity). Derivation of Mathematical Equations for Barrier Potential, Barrier Width and Current for Step Junction. pn junction and its characteristics. Static and Dynamic Resistance. Diode Equivalent Circuit. Ideal Diode. Load Line Analysis of Diodes and Q-point.
Two-terminal Devices and their Applications: (1) Rectifier Diode. Half-wave Rectifiers.
Centre-tapped and Bridge Full-wave Rectifiers Calculation of Ripple Factor and Rectification.
Efficiency. Qualitative idea of C, L and π - Filters. (2) Wave shaping circuits (3) Zener Diode and Voltage Regulation. (4) Photo Diode, (5) Varactor Diode.

Bipolar Junction Transistors, n-p-n and p-n-p transistors. Characteristics of CB, CE and CC Configurations. Current gains α, β and γ and Relations between them. Load Line Analysis of transistors. DC Load line and Q-point. Physical Mechanism of Current Flow. Active, Cutoff, and saturation Regions. Transistor in Active Region and Equivalent Circuit.

Fundamental of Digital Circuits, Combinational Circuits.

Text Books:

1. Robbins, A. H. & Miller, W.C., *Circuit Analysis*, (Delmar Cengage Learning., 2003).
2. Hayt, W. H. & Kemmerly, J. E., *Engineering Circuit Analysis*, (McGraw Hill, New York, 1993).
3. Millman, J., Halkias, C.C. and Jit, S., *Electronic Devices and Circuits*, (McGraw Hill Education,India, 2016).
4. Kumar, A., *Fundamentals of Digital Electronics* (PHI Learning Pvt. Ltd., 2003).

Reference Books:

1. Toro,V. Del, *Electrical Engineering Fundamentals*, (Prentice Hall, 1994).
2. Edminister, J.A., *Electrical Circuits- Schaum's Outline series*, 2nd edition (McGraw Hill,1983).
3. Smith, R.J. and Dorf, R.C., *Circuits, Devices and Systems*, (John Wiley & Sons, 1992).
4. Morris, J. *Analog Electronics*, (Arnold Publishers, 1991).
5. Mottershead, A. *Electronic Circuits and Devices*, (Prentice Hall, 1997).
6. Streetman, B.G. & Banerjee, S., *Solid State Electronic Devices*, (Pearson Prentice Hall, 2006).
7. Bhargava, N. N., Kulshreshtha D.C. & Gupta S.C., *Basic Electronics & Linear Circuits*, (Tata McGraw Hill, 2006).
8. Boylestad, R. & Nashelsky, L. *Electronic Devices and Circuit Theory*, 8th edition, (Pearson Education, India, 2004).
9. Malvino A. P., *Electronic Principals*, (Glencoe, 1993).

PI 325: Thermodynamics and Statistical Physics (L2-T1-P0-CH3-CR3)

Macroscopic description of the state, extensive and intensive variables, temperature, thermodynamic variables (pressure, temperature, etc.), thermal equilibrium, equation of state.

Thermal conductivity, zeroth law of thermodynamics**,** temperature scales; work, heat and internal energy, the Gibbs-Duhem relation.

Thermodynamic processes: reversible, irreversible, quasi-static, adiabatic, isothermal.

First law of thermodynamics**,** specific heat capacity, enthalpy, kinetic theory of gases and Maxwell-Boltzmann statistics; calculation of pressure, kinetic interpretation of temperature, mean free path, Maxwell's distribution, equi-partition of energy; heat engines.

The second law of thermodynamics, Carnot cycle and Kelvin temperature scale, Clausius' theorem, entropy and its physical interpretation, entropy change for simple processes.

Free energies: Helmholtz free energy, Gibbs free energy, Legendre transformations, conditions of equilibrium, Maxwell's relations, phases and phase transitions, equilibrium between two-phases, general equilibrium conditions, the Clausius-Clapeyron equation, phase transformation of substances, Van der Walls gas and the liquid gas transition, thermodynamics of magnetic systems, The third law of thermodynamics.

Microscopic versus macroscopic points of view, kinetic theory of gases, concept of ensembles, micro-canonical, canonical, grand-canonical ensembles, partition function, postulates of classical statistical mechanics, derivation of thermodynamics from statistical mechanics principles, equation of state for ideal and real gases, Gibbs paradox.

Text Books:

1. Callen, H. B., *Thermodynamics and Introduction to Thermostatistics*, 2nd edition, (Wiley Student Edition).
2. Reif, F., *Fundamentals of Statistical and Thermal Physics,* (Tata McGraw-Hill, 1985).
3. Zemansky, M. W. and Dittman, R. H., *Heat and Thermodynamics,* 7th edition, (Tata McGraw-Hill International, 2007).

PI 218: Modern Physics (L2-T0-P1-CH4-CR3)

Particle-like properties of electromagnetic radiation: Electromagnetic spectrum, electromagnetic waves, blackbody radiation, the photoelectric effect, the Compton effect, Bremsstrahlung and X-ray production.

Wave-like properties of particles: deBroglie hypothesis, uncertainty relationships for classical waves, Heisenberg uncertainty relationships, wave packets.

One-dimensional time independent Schroedinger equation, probabilities and normalization, applications to the free particle, particle in a box (1-D and 2-D), the simple harmonic oscillator.

Models of the atom: Thompson model, Rutherford model, line spectra, Bohr model, Franck-Hertz experiment, the correspondence principle, deficiencies of Bohr atomic model, vector model, intrinsic spin, Stern-Gerlach experiment, hydrogen atom energy levels, Zeeman effect, fine structure, electronic states in many-electron atoms, X-rays.

Expansion of universe, background radiation, big bang cosmology, the future of the universe.

Text Books:

1. Krane, K. S., *Modern Physics*, (John Wiley & Sons, 1983).
2. Bernstein, J., Fishbane, P. M. and Gasiorowicz, S. G., *Modern Physics*, 1st edition, (Prentice-Hall, 2000).

PI 298: Physics Lab-IV (L0-T0-P4-CH8-CR4)

1. To determine the resistivity of the given semiconductor sample by Four Probe method.
2. To determine the susceptibility of the given sample by Quince tube method.
3. To determine the Planck constant using different wavelength of light using Planck constant kit.
4. To study interference and diffraction with a laser beam at a single slit, double slit, three slits and four slits, and measure the slit separations.
5. To measure the spot size of a beam from a He-Ne laser and a diode laser and to calculate the M parameter.
6. To study the p-n junction characteristics and obtain output voltage at different frequencies.
7. To study connector losses in optical fibers:
    a. loss due to diameter mis-match,
    b. loss due to lateral off-set,
    c. loss due to angular misalignment
8. To measure the refractive index of a sample with a Michelson interferometer.
9. Determination of the focal length and hence the power of a convex lens by displacement method on an optical bench.
10. To find out the velocity of ultrasonic waves in a medium using ultrasonic interferometer.

Semester-V

PI 303: Physical and Geometrical Optics **(L2-T1-P0-CH3-CR3)**

Basic Geometric Optics: law of reflection, reflection from planar and curved surfaces, Snell's law; refraction at the planar and curved surfaces, thin lens, prisms.

Matrix methods: matrix optics concepts and basic matrices, cascading matrices: thin lens, thick lens, principal planes and imaging, study of a compound lens.

Aberrations: monochromatic and chromatic aberrations, Seidel aberrations: spherical aberration, coma, astigmatism, field curvature and distortion, chromatic aberrations, examples.

Polarization: light as a transverse wave, linear and circular polarizations, methods of producing and analyzing polarized light, linear polarizers and wave plates, Fresnel reflection and transmission coefficients, total internal reflection, Jones vectors and matrices for the ploarizer and wave plate, Stokes vectors and Muller matrices.

Interference: division of wavefront and amplitude, intensity distribution in an interference pattern, visibility of fringes, Young's double-slit interferometer, Michelson interferometer, Rayleigh interferometer, multiple beam interference: Fabry-Perot etalon and interferometer, resolving power.

Diffraction: Fresnel-Huygens theory of diffraction, Fresnel and Fraunhofer regions of diffraction, diffraction at a straight edge, Fraunhofer diffraction at the slit, circular and rectangular apertures, resolving power of a telescope, diffraction at multiple slits, grating, resolving power of a grating.

Holography: recording and reconstruction of a wave, characteristics of the diffracted waves from the hologram, diffraction efficiency, types of the holograms, zone plate analogy of the hologram.

Fourier Optics: simple concepts.

Text Books:

1. Subrahmanyam, N., Lal, B. and Avadhanulu, M. N., *A Textbook of Optics*, (S. Chand & Co. Ltd., 2012).
2. Mathur, B. K. and Pandya, T. P., *Principles of Optics*, (Tata McGraw-Hill International, 1981).
3. Chakraborty, P. K., *Geometrical and Physical Optics*, 3rd edition, (New Central Book Agency(P) Ltd., 2005).

Reference Books:

1. Hecht, E., *Optics*, 4th Edition, (Addison-Wesley Pub. Co., 2001).
2. Born, M. and Wolf, E., *Principles of Optics*, 7th edition, (Pergamon Press Ltd, 2000).
3. Jenkins, F. A. and White, H. E., *Fundamentals of Optics*, 4th edition, (Tata McGraw-Hill International, 1981).
4. Sirohi, R. S., *Wave Optics and Applications*, (Orient Longman, 1993).

PI 202: Introductory Quantum Mechanics (L2-T1-P0-CH4-CR3)

Origin of quantum theory, inadequacy of classical ideas, Planck's quantum hypothesis, photoelectric effect, Compton scattering.

Wave-particle duality, deBroglie's hypothesis, experimental evidence for deBroglie's hypothesis, Davisson-Germer experiment, Thompson experiment.

Simple consequences of uncertainty relation, wave function and its probabilistic interpretation, wave packet and uncertainty relation.

Schrodinger equation, solution of one-dimensional Schrodinger equation for an infinite square well potential, reflection and transmission at potential steps, qualitative treatment of barrier penetration for simple rectangular barriers.

The quantum harmonic oscillator.

Text Books:

1. Schiff, L. I., *Quantum Mechanics,* 3rd edition, (McGraw-Hill, New Delhi, 1968).
2. Ghatak, A. and Lokanathan, S., *Quantum Mechanics*, 5th edition, (Macmillan, 2004).

Reference Books:

1. Merzbacher, E., *Quantum Mechanics*, 2nd edition, (John Wiley, New York, 2005).
2. Richtmyer, F. K., Kennard E. H. and Lauritsen, T., *Introduction to Modern Physics,* 5th edition, (McGraw-Hill, 1976).
3. Waghmare, Y. R., *Fundamentals of Quantum Mechanics*, 1st edition, (Wheeler publishing, 1996).
4. Mathews, P. M. and Venkatesan, K., *A Textbook of Quantum Mechanics*, 2nd edition, (Tata McGraw-Hill, 1976).

PI 315: Mathematical Physics-II (L2-T1-P0-CH3-CR3)

Ordinary differential equations, second-order homogeneous and inhomogeneous equations, Wronskian, general solutions, adjoint of a differential equation, ordinary and singular points, series solution, Legendre, Hermite, Laguerre and the associated polynomials, their differential equations, generating functions, Bessel functions, spherical Bessel equations, integral representation of special functions.

Generating functions, Recurrence relations, Rodrigue's formulae and orthogonality of the special functions, Sturm Liouville problem, elements of hyper-geometric functions, Gauss hyper-geometric and confluent hyper-geometric equations, Dirac delta function, Green function.

Partial differential equations in physical problems: Laplace's equation, Poisson's equation, Heat flow equations, Wave equations, Helmholtz equations, solutions of these equations, eigenvalue problems, boundary value problems, method of separation of variables.

Integral transforms: Laplace transform, Hankel transform, Mellin transform, Fourier transform.

Properties of Laplace and Fourier transforms, application of Laplace and Fourier transforms.

Text Books:

1. Harper, C., *Introduction to Mathematical Physics, (*Prentice Hall, 2009).
2. Arfken, G. B., and Weber, H. J., *Mathematical Methods for Physicists*, (Elsevier Ltd, Oxford, 2005).
3. Spiegel, M. R., *Vector Analysis,* Schaum's outline series, (Tata McGraw-Hill 1979).

Reference Book:

1. Morganeau, H. and Purphy, C. M., *The Mathematics of Physics and Chemistry*, (Young Press, 2009).

PI 309: Analog Electronics & Communications (L2-T1-P0-CH3-CR3)

Op-Amp with and without feedback: Open loop considerations-inverting, non-inverting, differential, feedback-voltage follower, Practical op-amps: Offset considerations-input offset voltage, input bias current, input offset current, thermal drift, effect of power supply voltage, other temperature sensitive parameters, noise, CMRR, maximum common mode input voltages, op-amp instrumentation circuits.

Linear Applications: Op-amp as ac amplifiers, summing and averaging circuits, integrators, differentiators, voltage-current converter, current-to voltage converter, analog computers, voltage regulators.

Introduction to communication systems: Elements of a Communication System, terminologies in Communication systems, basics of signal representation and analysis. Noise: external, internal, noise calculations, noise figure. Amplitude modulation techniques: Theory and generation of AM, DSBSC, SSB, VSB.

Angle modulation techniques: theory, practical issues and generation of Frequency Modulation (FM) and Phase.

Radio transmitters and receivers: Introduction to – AM, SSB, FM Transmitters. Receiver Types: tuned radio-frequency (TRF) and superheterodyne receiver, AM and FM Receivers.

Radiation and propagation of waves -Electromagnetic Radiation, Effects of the Environment, Propagation of Waves - Ground (Surface) Waves, Sky Waves and Space Waves.

Text Books:

1. Gayakward, R.A., *Op-Amps and Linear Integrated Circuits*, 3rd Edition, (PHI, 2001).
2. Kennedy, G., Bernard D. and Prasanna, S. R. M., *Electronic Communication Systems,* (McGraw-Hill Global Education India, 5th edition, 2011).

Reference Books:

1. Hambley, A. R., *Electronics*, 2nd Edition, (Prentice Hall, 2000).
2. Horowitz, P. and Hill, W. *The Art of Electronics*, 2nd Edition, (Cambridge University Press, 1995).

PI 204: Atomic and Nuclear Physics (L2-T1-P0-CH3-CR3)

Atomic Physics: The Bohr model of the hydrogen-like atom, brief account of the Sommerfeld model, electron spin; Stern-Gerlach experiment, space and spin quantization, the vector model of the atom, spin-orbit interaction, fine structure of spectral lines, LS and jj coupling, the Zeeman effect, Paschen-Back effect, Stark effect, scattering of light: Rayleigh scattering formula, colour of the sky, polarisation of the scattered light.

Nuclear Physics: General properties of nuclei, concept of nuclear size, spin, parity, magnetic dipole moment and electric quadropole moment of nuclei, nuclear forces and stability of nuclei, concept of packing fraction and binding energy, binding energy curve and its significance.

Natural radioactivity and radioactive decay: Type of radioactive decays, theory of radioactive disintegration, radioactive constants, mean-life of a radio element, radioactive equilibrium, half-life of a radio element, determination of decay constant and half-life.

Nuclear reactions: Types of nuclear reactions, conserved quantities of nuclear reaction, energies of nuclear reaction, Q-value, exoergic & endoergic reactions, nuclear fusion and fission reactions.

Detectors: Principles of detection of charge particles, construction and working principle of gas-filled detectors, ionization chamber, its construction and working principle, interaction of γ-particle with matter, construction and working principles of a scintillating detector.

Text Books:

1. Krane, K. S., *Introductory Nuclear Physics,* (John Wiley, New York, 1987).
2. White, W. H., *Introduction to Atomic Spectra,* (McGraw-Hill, 1934).

Reference Books:

1. Green, A. E. S., *Nuclear Physics,* (McGraw-Hill Book Company, Inc., New York, 1955).
2. Srivastava, B.N., *Basic Nuclear Physics and Cosmic Rays,* (Pragati Prakashan, Meerut, 2011).

PI 308: Laser Physics (L2-T1-P0-CH3-CR3)

Planck's Law, Absorption, spontaneous emission and stimulated emission, Einstein's A & B coefficients, two-level atomic systems, light amplification, threshold condition.

Line broadening mechanism, pumping methods and laser rate equations, variation of laser power around threshold, optimum output coupling.

Modes of a rectangular cavity and open planar resonator, the quality factor (Q-factor), the ultimate bandwidth of laser, mode selection, Q-switching, mode locking, modes of a confocal resonator, general spherical resonator.

Properties of laser beam; propagation of Gaussian beam and ABCD matrix.

Some laser systems like He-Ne laser, ruby laser, neodymium-based lasers, CO_2 laser, dye laser, fiber laser, semiconductor laser, DFB lasers, DH lasers.

Generation of ultra-fast optical pulses, pulse compression, femto-second laser and its characteristics.

Some applications of lasers like laser cooling, laser tweezers, material processing.

Text Books:

1. Ghatak, A. K. and Thyagarajan, K., *Optical Electronics*, (Cambridge University Press, 2009).
2. Svelto, O., *Principles of Lasers*, 3rd edition, (Springer, 2007).
3. Milonni, P. W. and Eberly, J. H., *Laser Physics*, (John Wiley & Sons, 2010).

Reference Books:

1. Yariv, A., *Quantum Electronics*, 3rd edition, (Wiley Eastern Ltd.).
2. Davis, J. H., *Introduction to Low Dimension Physics*, (Cambridge University Press, 1997).
3. Siegman, A. E., *Lasers*, (University Science Books, 1986).

PI 399: Physics Lab-V **(L0-T0-P4-CH8-CR4)**

1. To find out the magneto-resistance of the semiconductor sample as a function of magnetic field and to plot the graph between magnetic field vs. potential developed using magneto-resistance set-up.
2. To plot the gain – bandwidth relation for a negative feedback amplifier using IC 741.
3. To find out the Curie temperature of the given ferromagnetic material ($BaTiO_3$) using Curie temperature kit.
4. To study Malus' law of polarization.
5. To measure optical nonlinearity using z-scan method.
6. To find out the value of Boltzmann constant using Boltzmann Constant kit.
7. To find out the Rydberg constant by observing the Balmer series of Hydrogen using spectrophotometer.
8. To study diffraction at a circular aperture and find the resolving power of a given lens used as an objective of a telescope.
9. a. Develop a clipping and a clamping circuit and determine the output voltage with different DC bias voltage applied.
   b. Design and develop a full wave and a half wave rectifier circuits and find out the ripple factor of the circuits.
10. To study the temperature dependence of Hall coefficient of a semiconductor sample using Hall effect set-up.

Semester-VI

PI 307: Basic Material Science **(L2-T1-P0-CH3-CR3)**

Fundamentals of crystallography: Bravais lattice, unit cell, crystal systems, Miller indices of crystal planes and directions, point groups.

Typical crystal structures: Simple (sc) cubic, body centered (bcc) cubic and face centered (fcc), cubic and structures, Hexagonal closed packed (hcp), Diamond and Zinc blende (ZnS) closed packed structures, packing factors, NaCl, CsCl and cubic perovskite and wurtzite structures.

Structure of solids: linear and planar density, ligancy, packing efficiency, closed pack planes and directions, voids.

Crystal imperfections*:* point imperfections (vacancies and interstitials), Frenkel and Schottky defects, dislocations, grain boundary, grain growth and surface energy calculation.

Crystal binding: Primary and secondary bondings, bond length and bond energy, van der Waals bonding, inert gas crystals, ionic, covalent and metallic bondings, Madelung constant, Madelung energy.

Phase and phase transformation: Melting point of crystalline and amorphous solids, degrees of freedom, phase rule, binary alloys, nucleation and phase transformation.

Elastic properties, Young, bulk and rigidity moduli, yield stress, Poisson’s ratio, compressibility, creep and fatigue, plasticity.

Diffusion*:* Fick’s first and second laws, thermal diffusion.

Text Books:

1. Callister, W. D., *Materials Science and Engineering*, 5th edition (John Wiley, 2000).
2. Raghavan, V., *Materials Science and Engineering*, 4th edition (Prentice Hall India, 1991).
3. Kittel, C., *Introduction to Solid State physics*, 7th edition, (Wiley Eastern Ltd.,1996).
4. Burns, G., *Solid State Physics*, (Academic press, 1995).
5. Dekker, A. J., *Solid State Physics*, (Macmillan India Ltd., 2003).
6. Ashcroft, N. W. and Mermin, N. D., Solid State Physics, (Saunders, 1976).

Reference Books:

1. Smith, W. F., *Principles and Materials Science and Engineering*, 2nd edition (Tata McGraw-Hill Inc., 1990).
2. Patterson, J. D. and Bernard, B., *Introduction to the Theory of Solid State Physics*, 2nd edition, (Springer, 2007).
3. Ghatak, A. K. and Kothari, L.S., *Introduction to Lattice Dynamics*, (Addison-Wesley, 1972).
4. Hall, H. E. and Hook J. R., *Solid State Physics*, 2nd edition, (Wiley, 1991).
5. Azaroff, L. V., *Introduction to Solids*, (Tata McGraw-Hill, 1977).
6. Mathur, D. S., Properties of Matter, (S. Chand & Co., 2010).

PI 317: Basic Computation Techniques **(L2-T1-P0-CH3-CR3)**

Introduction to computers.

Programming using FORTRAN; programming using C and C^{++}

Simple programming examples from calculus; solution of simple algebraic equations, solution of simple differential equations.

Examples of least squares curve fitting, matrix eigenvalue problems.

Text Books:

1. Gottfried**,** B. S**.,** *Schaum's outline of theory and problems of programming with C***,** (McGraw-Hill Professional, 1996).
2. Kanetkar, Y., *Let us C*, (BPB *Publications*, 2012).
3. Mayo, W. E. and Cwiakala, M., *Schaum's Outline of Programming With Fortran 77*, Schaum's Outline series, (McGraw-Hill, 1995).
4. Scheid, F., *Schaum's outline of theory and problems of numerical analysis*, 2^{nd} edition, Schaum's outline series, (McGraw-Hill, 1989).

Reference Books:

1. Mathews, J. H., *Numerical Methods for Mathematics, Science and Engineering*, (Prentice Hall).
2. Narsingh Deo, *System Simulation with Digital Computers*, (Prentice Hall, 1979).

PI 314: Measurement Physics **(L2-T1-P0-CH3-CR3)**

Data interpretation and analysis, precision and accuracy, error analysis, propagation of errors, least squares fitting, linear and nonlinear curve fitting, chi-square test, Measurement of energy and time using electronic signals from the detectors and associated instrumentation, signal processing; multi-channel analyser, Time of flight technique, coincidence measurements, true-to-chance ratio.

Transducers (temperature, pressure/vacuum, magnetic field, vibration, optical), measurement and control, ionization chamber, proportional counter, GM counters, spark chambers, cloud chamber, semiconductor detectors for charged particles and γ-ray detectors, scintillation counters, photodiodes and charge coupled device (CCD) and CMoS cameras for detection of electromagnetic radiation.

Production of low temperature below 1K, adiabatic demagnetisation and magnetic refrigerator, special properties of liquid helium, temperature below 10^{-6}K, nuclear demagnetisation, measurement of low temperatures.

Op-amp based, instrumentation amp, feedback, filtering and noise reduction, shielding and grounding, Fourier transforms, lock-in detector, box-car integrator, modulation techniques.

Text Books:

1. Sayer, M. and Mansingh, A., *Measurement, Instrumentation and Experiment Design in Physics and Engineering*, (Prentice-Hall India, 2000).
2. Nakra, B. C. and Chaudhry, K. K., *Instrumentation Measurement and Analysis* (Tata McGraw-Hill, 1985).

Reference Books:

1. Knoll, G. F., *Radiation, Detection and Measurement*, 3^{rd} edition, (John Wiley & Sons, 2000).
2. Jones, B. E., *Instrumentation measurement and feedback* (Tata McGraw-Hill, 1978).

PI 311: Waves and Acoustics **(L2-T1-P0-CH3-CR3)**

Vibrations: Potential energy vs. displacement relation, concept of equilibrium, development of simple harmonic oscillation (SHO) and other anharmonic terms from force equations, damped oscillation, critical damping, Q-factor of an oscillator, forced vibration, resonance, low and high frequency responses, eigen frequency and normal modes, energy transfers between modes, coupled pendulum, Lissajous figures, anharmonic oscillator, Fourier series and Fourier coefficients, Fourier analysis in some simple cases.

Waves: Progressive wave in one-dimension and in three-dimensions, wave equation, plane wave and spherical wave, intensity, dispersion, group velocity, phase velocity, speed of transverse waves in a uniform string, eigen frequencies and eigen modes for plucked and struck strings, speed of longitudinal waves in a field, energy density and intensity of waves.

Superposition of waves: Superposition principle, interference in space and energy distribution, beats, combinational tones, production, detection and applications of ultrasonic waves, Doppler effect, shock waves.

Acoustics: Vibrations in bounded system, normal modes of a bounded system, harmonics, quality of sound, noise and music, intensity and loudness, bel and phon, principle of sonar system, acoustic transducers and their characteristics, recording and reproduction of sound, measurement of velocity, frequency and intensity, acoustics of halls, reverberation and Sabines formula.

Text Books:

1. Chattopadhyay, D., *Vibration, Waves and Acoustics*, (New Central Book Agency, 2010).
2. Main, I. G., *Vibrations and Waves in Physics*, 2nd edition (Cambridge University Press, 1984).

Reference Books:

1. Randall, R. H., *An Introduction to Acoustics*, Sect. 7-21, 7-22, (Addison-Wesley, 1951).
2. Wood, A. B., *A Textbook of Sound*, 3rd Edition, (Bell & Sons, 1955).
3. Crawford, F. S., *Waves*, *Berkeley Physics Course*, Vol. 3, (Tata McGraw-Hill, 1968).
4. Pain, H. I., *The Physics of Vibrations and Waves*, 6th edition (John Wiley & Sons Ltd., 2005).

PI 300: Project cum Physics Lab-VI **(L0-T0-P4-CH8-CR4)**

List of elective papers:

1. PI 220: Renewable Energy
2. PI 221: Nanomaterial Fundamentals and application
3. PI 222: Earth Science

PI 220: Renewable Energy (L2-T1-P0-CH3-CR3)

Fossil fuels and Alternate Sources of energy: Fossil fuels and nuclear energy, their limitation, need of renewable energy, non-conventional energy sources. An overview of developments in Offshore Wind Energy, Tidal Energy, Wave energy systems, Ocean Thermal Energy Conversion, solar energy, biomass, biochemical conversion, biogas generation, geothermal energy tidal energy, Hydroelectricity.
Solar energy: Solar energy, its importance, storage of solar energy, solar pond, non-convective solar pond, applications of solar pond and solar energy, solar water heater, flat plate collector, solar distillation, solar cooker, solar green houses, solar cell, absorption air conditioning. Need and characteristics of photovoltaic (PV) systems, PV models and equivalent circuits, and sun tracking systems.
Wind Energy harvesting: Fundamentals of Wind energy, Wind Turbines and different electrical machines in wind turbines, Power electronic interfaces, and grid interconnection topologies. Ocean Energy: Ocean Energy Potential against Wind and Solar, Wave Characteristics and Statistics, Wave Energy Devices.
Electromagnetic and Piezoelectric Energy Harvesting, Energy storage and conversion devices: fuel cells, batteries, supercapacitors.
Environmental issues and Renewable sources of energy, sustainability.

Text Books:

1. H. P. Garg and Jai Praksh, *Solar Energy Fundamentals and Applications*, TMH, 2000.
2. J. Twidell and T. Weir, *Renewable Energy Resources*, E & F N Spon, 1986.
3. G. Boyle, (Ed.), *Renewable Energy, Power for a Sustainable Future*, The Open University/Oxford University Press, 1996.
4. R. O. Hayre, S. W. Cha, W. Colella and F. B. Prinz, *Fuel Cell Fundamentals*, Wiley, 2008.
5. B. E. Logan, *Microbial Fuel Cells*, Wiley, 2007.
6. G.D Rai, *Non-conventional energy sources*, Khanna Publishers, New Delhi, 2011.
7. M P Agarwal, *Solar energy*, S Chand and Co. Ltd., 1983.
8. Suhas P Sukhative, *Solar energy: principles of thermal collection and storage*, Tata McGraw - Hill Publishing Company Ltd, 3rd Ed. 2008.

Reference Books:

1. A. Luque and S. Hegedus (Eds.), *Hand book of Photovoltaic Science and Engineering*, 2nd Edn., John Wiley, 2011.
2. P Jayakumar, *Solar Energy: Resource Assessment Handbook, 2009.*
3. P. Takahashi and A. Trenka, *Ocean Thermal Energy Conversion*, John Wiley, 1994.
4. C. Y. Wereko-Brobby and E. B. Hagan, *Biomass Conversion and Technology*, John Wiley, 1997.
5. J. F. Walker and N. Jenkins, *Wind Energy Technology*, John Wiley and Sons, 1997.
6. D. D. Hall and R. P. Grover, *Biomass Regenerable Energy*, John Wiley, 1987.
7. T. Jiandong, Z. Naibo, W. Xianhaun, H. Jing, and D. Huishen, *Mini Hydropower*, John Wiley, 1996.

PI 221: Nanomaterial Fundamentals and Applications **(L2-T1-P0-CH3-CR3)**

Nanoscale systems: Length scales, 1D, 2D and 3D nanostructures (nanodots, nanowires, nanorods, thin films,), Band structure and density of states of materials at nanoscale, Size effects in nano systems, Quantum confinement: Applications of Schrodinger equation- Infinite potential well, potential step, potential box, quantum confinement of carriers in 3D, 2D, 1D nanostructures and its consequences.
Synthesis of nanostructured materials: Top down and Bottom up approach, Photolithography. Ball milling. Gas phase condensation. Vacuum deposition. Physical vapor deposition (PVD): Thermal evaporation, E-beam evaporation, Pulsed Laser deposition. Chemical vapor deposition (CVD). Sol-Gel. Electro deposition. Spray pyrolysis. Hydrothermal synthesis. Preparation through colloidal methods. MBE growth of quantum dots.

Characterization: X-Ray Diffraction, Optical Microscopy, Scanning Electron Microscopy, Transmission Electron Microscopy, Atomic Force Microscopy, Scanning Tunnelling Microscopy.
Properties of nanomaterials: Dielectric constant for nanostructures. Excitons in direct and indirect band gap semiconductor nanocrystals, absorption, emission and luminescence. Optical properties of heterostrctures and nanostructures. Electron transport in nanostrcutures, thermionic emission, tunneling and hoping conductivity. Defects and impurities: Deep level and surface defects. Mechanical and thermal properties of nanomaterials.

Applications: Applications of nanoparticles, quantum dots, nanowires and thin films for photonic devices (LED, solar cells). Single electron devices. CNT based transistors. Micro Electromechanical Systems (MEMS), Nano Electromechanical Systems (NEMS).

Text Books:

1. C.P. Poole, Jr. Frank J. Owens, *Introduction to Nanotechnology* (Wiley-Interscience, May 2003).
2. S.K. Kulkarni, *Nanotechnology: Principles & Practices* (Capital Publishing Company, 2007).
3. K.K. Chattopadhyay and A. N. Banerjee, *Introduction to Nanoscience and Technology* (PHI Learning Private Limited, 2009).
4. Richard D. Booker, Earl Boysen, *Nanotechnology* (John Wiley and Sons, 2005).

Reference Books:

1. M. Hosokawa, K. Nogi, M. Naita, T. Yokoyama, *Nanoparticle Technology Handbook* (Elsevier, 2007).
2. Bharat Bhushan, *Handbook of Nanotechnology* (Springer-Verlag, Berlin, 2004).
3. Cao Guozhong and Wang Ying, *Nanostructures and Nanomaterials –Sysnthesis, Properties and Applications*, World Scientific Publishing, 2nd edition, 2011.
4. Dieter Vollath, *Nanomaterials: An Introduction to Synthesis, Properties and Applications*, Wiley, 2008.
5. *Nanoscale Materials in Chemistry*, edited by Kenneth J. Klabunde & Ryan Richards, John Wiley & Sons, 2nd edition, 2009.
6. *Nanomaterials: Synthesis, properties and Applications*, Ed. A. S. Edelstein and R.C.Cammarata, IOP (UK, 1996). Characterization of nanophase materials: Ed. Z.L.Wang, Willey-VCH (New York, 2002).
7. *Naostructured Materials*, Ed. Jackie Yi-Ru Ying (Academic Press, Dec 2001).
8. *Nanotechnology: Basic Science and emerging technologies*, Ed. Michael Wilson, K.Kannangara, G. Smith, M. Simmons, and C. Crane (CRC Press, June 2002).

PI 222: Earth Science **(L2-T1-P0-CH3-CR3)**

Structure: The Solid Earth: Mass, dimensions, shape and topography, internal structure, Magnetic field, Gravity field, Thermal structure and Heat Flow. Earth's Interior.
The Hydrosphere: The oceans, their extent, depth, volume, chemical composition. River systems.
The Atmosphere: variation of temperature, density and composition with altitude, clouds.
The Cryosphere: Polar caps and ice sheets. Mountain glaciers.

Dynamical Processes: Concept of plate tectonics, sea-floor spreading and continental drift. Earthquake and earthquake belts, Seismic waves, Volcanoes and Tsunamis.
The Atmosphere: Atmospheric circulation. Weather and climatic changes and. Cyclones.
I Climate: Earth's temperature and greenhouse effect, The Indian monsoon system.

Geophysical Exploration: Basic principles of Gravity, Magnetic, Electrical and Seismic Explorations.

Reference Books:

1. *Planetary Surface Processes*, H. Jay Melosh, Cambridge University Press, 2011.
2. *Consider a Spherical Cow: A course in environmental problem solving*, John Harte.University Science Books.
3. *Holme's Principles of Physical Geology*. 1992. Chapman & Hall.
4. Emiliani, C, 1992. Planet Earth, Cosmology, *Geology and the Evolution of Life and Environment*. Cambridge University Press.

Semester-VII

PI 403: Electromagnetic Theory-I **(L2-T1-P0-CH3-CR3)**

Review of Electrostatics and magneto-statics: Electrostatic and magnetostatic fields in matter, Method of images, boundary value problems, Laplace equation in rectangular, cylindrical and spherical coordinates, multipole expansion, Gauge transformation, Coulomb and Lorentz gauges, Maxwell's equations, conservation of energy and momentum in electrodynamics, Poynting Theorem, Maxwell's stress tensor.

Wave equation, reflection, refraction and propagation of electromagnetic waves in dispersive media, wave equation in a conducting medium.

Wave-guides and cavity resonance, EM wave propagation of various types of EM modes in different types of wave guides.

Text Books:

1. Griffiths, D. J., *Introduction to Electrodynamics*, (Prentice Hall India, 2009).
2. Jackson, J. D., *Classical Electrodynamics*, 3rd edition, (Wiley, Eastern Ltd, 1998).

Reference Books:

1. Ritz, J. R. and Millford, F. J., *Foundations of Electromagnetic Theory*, (Prentice Hall India).
2. Slater, J. C., and Frank, N. H., *Electromagnetism*, (Dover Publications, 2011).
3. Miah, W., *Fundamentals of Electromagnetism*, (Tata McGraw-Hill, 1982).
4. Feynman, R. P., *Feynman Lecture Series Volume II*, (Addison Wesley Longman, 1970).

PI 413: Advanced Classical Mechanics **(L2-T1-P0-CH3-CR3)**

Variational Principles: Derivation of Euler-Lagrange differential equation, Hamilton's principle and its deduction, derivation of Lagrange's equation from Hamilton's principle, modified Hamilton's equation (vibrational principle) and derivation of Hamilton's principle from it, principle of least action, method of Lagrange's undetermined multipliers.

Two-body Central Force Problems: Reduction of two-body problems to equivalent one body problem, equation of motion under central force, equation for an orbit, inverse square law of force, Kepler's laws of planetary motion and their deduction, Virial theorem, scattering in a central force field and Rutherford scattering.

Canonical Transformations and Brackets: Canonical and Legendre transformations, generating function, procedure for application of canonical transformation, condition for canonical transformation, bilinear invariant condition, integral invariant of Poincaré, Poisson brackets and Lagrange's brackets and their properties, relation between Poisson and Lagrange's brackets, application of Poisson bracket to mechanics, Liouville's theorem.

Hamilton-Jacobi Theory: Hamilton-Jacobi (HJ) equation, Hamilton's characteristic and principal function, HJ equation for Hamilton's characteristic function, solution of Kepler's problem by HJ method, action-angle variable and harmonic oscillator problem, separation of variables in HJ equation, transition from classical to quantum mechanics.

Mechanics of a Rigid Body: Generalised co-ordinates of a rigid body, body and space reference system, Eulerian angles, orthogonal transformations, infinitesimal rotations, kinematics of a rigid body, moving frame of reference, Euler equation, spinning top, gyroscope.

Small Oscillations: One dimensional oscillator; stable, unstable and neutral equilibriums, Normal co-ordinates and normal modes, Two coupled pendulum, double pendulum, vibration of a linear triatomic molecule, general case- system with 'n' degrees of freedom.

Text Books:

1. Upadhyaya, J. C., *Classical Mechanics*, (Himalayan Publishing House).
2. Goldstein, H., *Classical Mechanics*, (Narosa Publishing House).

Reference Books:

1. Takawale, R. G. and Puranik, P. S., *Introduction to Classical Mechanics*, (Tata McGraw Hill).
2. Rana, N. C. and Joag, P. S., *Classical Mechanics*, (Tata McGraw Hill).
3. Panat, P. V., *Classical Mechanics*, (Narosa Publishing House).
4. Gupta, S. L., Kumar, V. and Sarma, H. V., *Classical Mechanics*, (Pragati Prakashan).

PI 414: Quantum Mechanics -I **(L2-T1-P0-CH3-CR3)**

Review of wave-particle duality, uncertainty principle, Schrodinger equation, the basic postulates of quantum mechanics, superposition principle, expectation value, Heisenberg equation of motion.

Application of Schrodinger equation to one-dimensional problem- square well potential; Quantum mechanics of simple harmonic oscillator-energy levels and energy eigenfunctions using Frobenius method.

Quantum theory of hydrogen-like atoms, time independent Schrodinger equation in spherical polar coordinates, separation of variables for the second order partial differential equation, Orbital Angular momentum in spherical polar co-ordinates and quantum numbers, Radial wavefunctions, Eigen values and eigenfunctions of orbital angular momentum.
Spin Angular Momentum and Pauli's Spin matrices.
Hilbert space formalism for quantum mechanics, Dirac notation, linear operators, Hermitian operator, projection operators, unitary operators, eigenvalues and eigen vectors of an operator.
Matrix representation of Kets, Bras and Operators, harmonic oscillator and its solution by matrix method.

Text Books:

1. Schiff, L. S., *Quantum Mechanics*, (Tata McGraw-Hill Education).
2. Ghatak, A. K. and Lokanathan, S., *Quantum Mechanics: Theory and Applications*, (Springer, 2002).

Reference Books:

1. Waghmare, Y. R., *Fundamentals of Quantum Mechanics*, (Wheeler publishing).
2. Mathews, P. M. and Venkatesan, K., *Quantum Mechanics*, (Tata McGraw-Hill Education, 2007).
3. Pauling, L., *Introduction of Quantum Mechanics*, (McGraw-Hill).
4. Dirac, P. A. M., *Principles of Quantum Mechanics*, (Oxford University Press).
5. Kemble, E. C., *The Fundamental principles of Quantum Mechanics*, (McGraw-Hill).

PH 416: Condensed Matter Physics and Materials Science (L2-T1-P0-CH3-CR3)

Review of elements of crystallography and typical crystal structures, Crystal diffraction, reciprocal lattice, atomic form factor, structure factor and Debye-Waller factor, x-ray, electron and neutron diffractions.

Lattice vibration in solids: Enumeration of modes, monoatomic linear chain, infinite and finite boundary conditions, dispersion relation, diatomic chain, acoustical and optical modes, quantization of lattice vibrations (phonons).

Einstein and Debye theory of specific heat of solids, free electron theory of metals, electronic specific heat, electrical conductivity, thermal conductivity, Wiedemann-Franz law.

Motion of electrons in periodic potential, Bloch theorem, Kronig Penney model, band theory of solids, Brillouin zones, insulators, semiconductors and metals, Fermi surface, holes, intrinsic and extrinsic semiconductors, concept of effective mass and law of mass action, Hall effect and magnetoresistance.

Inelastic neutron scattering, analysis of data by generalized Ewald construction, dispersion relations, frequency distribution function, thermal conductivity of insulators, Normal and umklapp processes, crystal imperfections, colour centres, linear and edge dislocations, Bergers' vector, thermo-luminescence.

Text Books:

1. Kittel, C., *Introduction to Solid State physics* 7^{th} Edition (Wiley, Eastern Ltd., 1996).
2. Burns, G., *Solid State Physics* (Academic press, 1995).
3. Dekker, A. J., *Solid State Physics* (Macmillan India Ltd., 2003).
4. Ashcroft, N. W. & Mermin, N. D., *Solid State Physics* (Saunders, 1976).

Reference Books:

1. Ibach, H. & Luth, H., *Solid State Physics*, (Springer-Verlag).
2. Patterson, J. D., *Introduction to the Theory of Solid State Physics*, (Addison-Wesley, 1971).
3. Ghatak, A. K. and Kothari, L. S., *Introduction to Lattice Dynamics*, (Addison-Wesley, 1972).
4. Hall, H. E. and Hook J. R., *Solid State Physics*, 2^{nd} Edition, (Wiley, 1991).
5. Azaroff, L.V., *Introduction to Solids,* (Tata McGraw Hill, 1977).

PI 499: Physics and Computational Lab. **(L0-T1-P3-CH7-CR4)**

Numerical Analysis: Solution of non-linear equations - Newton's method, method of false position (regular falsi), solution of a system of linear equations - Gaussian elimination, iterative methods (Jacobi and Gauss-Seidel methods), Interpolation - Newton's interpolation formula, numerical differentiation and integration - Simpson's rule, trapezoidal rule, quadrature formula, numerical solution of ordinary differential equations - Euler's method, Runge-Kutta method, fitting of curves - principle of least squares.

Simulation: A system and its model, he basic nature of simulation, the simulation of continuous and discrete systems - suitable examples, stochastic simulation - generation of random numbers with different probability distributions, examples of simulation in physics.

Text Books:

1. Mathews, J. H., *Numerical Methods for Mathematics, Science and Engineering*, (Prentice Hall, 1997).
2. Narsingh Deo, *System Simulation with Digital Computers*, (Prentice Hall, 1979).

Reference Books:

1. Yashwant Kanetkar, *Let us C*, (BPB *Publications*, 2012).
2. Gottfried, B .S., *Schaum's outline of theory and problems of programming with C,* (McGraw-Hill Professional, 1996).

PI 499: Computational Laboratory

a. To find mean, variance, standard deviation, moments etc. for a given set of data (about 50 entries).
b. To fit a linear curve for a given set of data
c. To perform a polynomial fit for a given set of data
d. To find the roots of a quadratic equation
e. Fourier Analysis of a square.
f. To generate random numbers between 1 and 100.
g. To perform numerical integration of 1-D function using Simpson and Weddle rules
h. To find determinant of a matrix, its eigenvalues and eigen vectors
i. To simulate phenomenon of nuclear radioactivity using Monte Carlo technique.

PH 405: Semiconductor Devices **(L2-T1-P0-CH3-CR3)**

Review: Schottky diodes, Hall effect and Four Probe measurements semiconductors, Transistors as amplifiers and oscillators.

Field Effect Transistors: JFET, MESFET, MOSFET, HEMT, HBT.
Optical Devices: Solar Cells, LED, Photovoltaic Cells, Semiconductor Laser, VCSEL, SET etc.

Power semiconductor devices: SCR, UJT, thyristors, diacs, and triacs.
Display devices: Active and passive, construction of display devices, applications of LCD, ECD, PDP, ELD, Flat panel types CRT.

Semiconductor Fabrication Technique: Diffusion, Epitaxy growth, Ion Implantation, Optical and Electron lithographical Technique, etching process, dielectric and polysilicon film depositions, metallization.

Text Books:

1. Neaman D.A. and Biswas,D., *Semiconductor Devices* (Tata McGraw Hill, 2012).
2. Kano, K., Semiconductor Devices,(Prentice Hall of India, 1998).

Reference Books:

1. Milliman J. & Halkias C.C., *Integrated Electronics* (Tata McGraw Hill, 2003).
2. Milliman J. & Halkias C.C, *Electronic Devices and Circuits* (Tata McGraw Hill, 2003).
3. Malvino, A.P., *Electronic Principles,* (McGraw-Hill Education (India) Pvt Limited, 2007).
4. Allison J., *Electronic Engineering Semiconductors and Devices*, Edition 2, (McGraw-Hill,1990).

PI 400: Physics Laboratory-VII **(L0-T0-P4-CH8-CR4)**

1. To design and fabricate a phase shift oscillator for the given frequency and to study the output using Op-Amp. 741/ 324 / 325.
2. Determination of thermal conductivity of a substance by Lee's method.
3. Scintillation counter:
    a. Find out the resolution and the FWHM of the given Scintillation counter
    b. Find out the gamma ray energy of the given radioactive sources
4. Determination of the Young's modulus of a beam by four-point bending.
5. To determine the velocity of sound in (a) dry air, and (b) rods by Kundt's tube method
6. Calculate the difference in wavelength between atomic transition lines and Zeeman lines using Zeeman effect set-up. (SES instruments Pvt. Ltd).
7. To study Talbot imaging and to obtain Talbot distances with moiré interferometry and to measure the focal length of a lens.
8. Determination of the boiling point of a liquid by platinum resistance thermometer and metre-bridge.
9. To measure the diameter of a thin wire using (a) interference, and (b) diffraction and compare the results.
10. To measure the dielectric constant and loss using microwave bench.

Semester-VIII

PI 552: Quantum Mechanics-II **(L2-T1-P0-CH3-CR3)**

Review of angular momentum, general formalism of angular momentum, addition of angular momenta, Clebsch-Gordon coefficients.

Time-independent perturbation theory; non-degenerate case, first-order and second-order perturbations, degenerate cases, first-order Stark effect in hydrogen atom.

Time-dependent perturbation theory, Fermi's golden rule, transition probability,WKB approximation, Ritz-variational method, Scattering theory, partial wave analysis and phase shift.

Relativistic quantum mechanics: Relativistic wave equation (Klein-Gordon and Dirac equations), elementary idea about field quantization.

Text Books:

1. Schiff, L.S., *Quantum Mechanics,* (Tata McGraw-Hill, 2004).
2. Zettili, N., *Quantum Mechanics*, (John Wiley & Sons, 2001).

Reference Books:

1. Ghatak, A. K. and Lokanathan, S., *Quantum Mechanics: Theory and Applications*, (Springer, 2002).
2. Mathews, P. M. and Venkatesan, K., *Quantum Mechanics*, (Tata McGraw-Hill Education, 2007).
3. Pauling, L., *Introduction of Quantum Mechanics*, (McGraw-Hill).
4. Dirac, P. A. M., *Principles of Quantum Mechanics*, (Oxford University Press).

PI 310: Statistical Physics **(L2-T1-P0-CH3-CR3)**

Review of Thermodynamics, Introduction to probability theory, Random walk, Central limit theorem and law of large numbers.

Dynamics in phase space, ergodicity and Liouville theorem, Macrostates, microstates and fundamental postulate of equilibrium statistical mechanics. Microcanonical ensemble, Boltzman definition of entropy, Canonical ensemble, partition function, calculation of thermodynamic quantities, Partition functions and few examples: Classical ideal gas, two level system, Harmonic oscillator, Paramagnetism, Curie's law, generalized expression for entropy, Gibbs entropy and mixing of entropy. Grand canonical ensemble, the grand partition function, grand potential and thermodynamic variables.

Introduction to Quantum Statistics, Density Matrix, Ideal Quantum Gases and their properties, Bose-Einstein Condensation, Black body radiation spectrum, non-interacting free Electron gas, Einstein and Debye model of specific heat, Pauli paramagnetism and negative temperature, diamagnetism, photons, phonons and White Dwarft.

Phase transitions, symmetry, order of phase transitions and order parameter, Landau's mean-field theory, Symmetry breaking. Elementary ideas on Ising, Heisenberg models of ferromagnetism, Critical point, critical exponents and their scaling.

Text Books:

1. Karder M. *Statistical Physics of Particles,* Cambridge University Press, 2007.
2. Pathria, R.K., *Statistical Mechanics*, Butterworth Heinemann, Second Edn, 1996.
3. Huang, K., *Statistical Mechanics*, 2nd Edition (Wiley,1987).
4. Reif, F., *Statistical Physics*, (Tata McGraw Hill, 2008).

Reference Books:

1. Landau and Lifshitz, *Statistical Physics*, 3rd edition (Butterworth-Heinemann;1980).
2. *Statistical Mechanics of Phase Transitions*: J. Yeomans (1992) Oxford University Press.
3. *Introduction to Modern Statistical Mechanics*: D. Chandler (1979) Oxford University Press.

PI 551: Electromagnetic Theory-II **(L2-T1-P0-CH3-CR3)**

Radiation: Retarded potentials, Hertzian dipole, antennas and arrays, half-wave dipole, Loop current element, Lenard-Wiechert potentials and electromagnetic fields of a moving point charge, electric and magnetic dipole radiations, power radiated by a moving point charge, motion of charged particles in electromagnetic fields, Cherenkov radiation, transmission lines, impedance of line, scattering and diffraction.

Four vectors, relativistic electrodynamics, field tensor, energy-momentum tensor, interdependence of electric and magnetic fields, transformation of electromagnetic fields under Lorentz transformation, invariance of Maxwell's equations, Lagrangian for electromagnetic fields, Maxwell's equations from least action principle.

Text Books:

1. Jordan, E. K. and Balmain, K. G., *Electromagnetic waves and Radiating systems*, (Prentice Hall, 1971).
2. Nasar, S. A., *2000 Solved Problems in Electromagnetics*, Schaum's series, (McGraw- Hill, 1992).
3. Puri, S. P., *Classical Electrodynamics*, 2nd edition, (Tata McGraw-Hill Pub., 1997).
4. Ritz, J. R. and Millford, F. J., *Foundations of Electromagnetic Theory*, (Prentice Hall India).
5. Jackson, J. D., *Classical Electrodynamics,* 3rd edition, (Wiley Eastern Ltd, 1998).
6. Panofsky, W. K. H. and Phillips, M., *Classical Electricity and Magnetism,* 2nd edition, (Addison-Wesley, 1962).
7. Griffiths, D. J., *Introduction to Electrodynamics,* (Prentice Hall of India, 2009).

PI 417: Advanced Mathematical Physics **(L2-T0-P1-CH4-CR3)**

Linear equations of homogeneous and inhomogeneous types, linear vector spaces, scalar product, linear independence, change of basis, Schmidt orthogonalisation, special matrices, diagonalization, orthogonal and unitary transformations, functions of complex variables, limit, continuity, analytic function, Cauchy formula, Laurent series, isolated and essential singularities, Contour integrations, conformal transformations.

Complex variables: Complex algebra, graphical representation, analytical functions, Cauchy-Riemann conditions, complex integrations, Cauchy's theorem, Cauchy's integral formula, residue, Cauchy's residue theorem.

Tensor analysis: Tensor in three and/or four dimensions, rank of tensors, covariant and contravariant tensors, symmetric and antisymmetric tensors, metric tensors, mathematical operations involving tensors.

Group theory: Group representation, reducible and irreducible representation, unitary group, special unitary group, Lorentz group, rotation group, direct product, Young Tableau, Dynkin diagrams.

Text Books:

1. Joshi, A. W., *Group Theory for Physicists,* (Wiley Eastern, 2008).
2. Brown, J. W. and Churchill, R. V., *Complex Variables and Applications*, 6th edition, (McGraw-Hill International, 1996).
3. M R Spiegel, S Lipschutz, J J Schiller and D Spellman, *Schaum's Outline of Complex Variables*.
4. Ablowitz, M. J. and Fokas, A. S., *Complex Variables, 1st South Asian paperback edition, (Cambridge University Press, 1998).*
5. Joshi, A. W., *Matrices and Tensors in Physics*.
6. Hoffman, K. and Kunze, R., *Linear Algebra*, (Prentice Hall India).

PI 302: Analog and Digital Electronics **(L2-T1-P1-CH5-CR4)**

Op Amp non-linear applications: Voltage limiters, comparators, zero detector, Schmitt trigger, voltage to frequency and frequency to voltage converter, small-signal diodes, sample-and-hold circuits and signal generators: oscillators-square-wave, Wien bridge, phase shift.
Frequency response of an op-amp and active filter: Gain and phase shift vs. frequency, Bode plots, compensated frequency response, slew rate, active filter, first and second order low pass and high pass, Butterworth filter, band reject filter.
555 timer: monostable, astable.

Digital Electronics: Review of Boolean algebra, gates, transistor switching times, INHIBIT (ENABLE) operation, De Morgan's laws, gate assemblies, binary adders.
Combinatorial digital systems: arithmetic functions, decoder/demultiplexer, data selector/multiplexer, encoder, ROM and applications.
Sequential digital systems: flip-flops, shift registers and counters, random access memory (RAM), dynamic MOS circuits, MOS shift registers, MOS Read Only Memory, D/A and A/D systems, digital-to-analog converters, analog-to-digital converters, character generators.

Microprocessor: Architecture and Laboratory.

Text Books:

1. Kumar, A., *Fundamentals of Digital Electronics* (PHI Learning Pvt. Ltd., 2003).
2. Gayakward, R.A., *Op-Amps and Linear Integrated Circuits*, 3rd Edition, (PHI, 2001).
3. Gaonkar R.S., *Microprocessor Architecture, Programming, and Applications with the 8085*, 5th Edition, (Prentice Hall, 2002).

Reference Books:

1. Malvino A.P.and Leach D.J., *Digital Principles and Applications,* (Tata McGraw Hill 1994).
2. Milliman, J. & Halkias, C.C., *Integrated Electronics,* (Tata McGraw Hill, 2003).
3. Tocci R.J., *Digital Systems,* (Pearson/Prentice Hall, 2004).
4. Bartee T.C., *Digital Computer Fundamentals,* (Tata McGraw Hill Publishing Company, 1985).

PI 450: Seminar **(L0-T0-P1-CH2-CR1)**

PI 498: Physics Laboratory-VIII **(L0-T0-P4-CH8-CR4)**

1. Electron spin resonance spectrometer:
   a. To find out the Lande' g – factor of 2,2-Diphenyl-1-picrylhydrazyl sample using ESR spectrometer.
   b. To observe the E.S.R. signal of given sample (DPPH) and to measure its full width at half maximum (FWHM).
2. GM counter:
   a. Determine the resolving time of the GM counting system.
   b. Study and determine the statistical distribution low that governs nuclear decay.
   c. Determine the characteristics of a GM tube to study the variations of count rate with applied voltage and thereby determine the plateau, the operating voltage and the slope of the plateau.
   d. Determine the dead time of the GM tube using a single source.
3. To determine the coercivity, saturation magnetization and retentivity of different given samples using hysteresis loop tracer set-up.
4. To measure the impedance of a coaxial cable and a rectangular waveguide using microwave bench.
5. Determine the dielectric constant of the ferroelectric ceramic sample using the given experimental set-up.
6. Determine the electrical charge of an electron by Millikan oil drop experiment and determine the value of e/m.
7. To study response of a non-linear crystal as a function of intensity of Nd:YAG laser (532nm)
8. a. To plot intensity of Luminescence vs. Temperature glow curve using thermo-luminescence set-up.
   b. To draw the glow curve and find out the activation energy (E) of different Alkali Halide Crystals using thermo-luminescence set-up (Demonstration only)
9. To study, take a measurement and prepare a report on
   a. PL/UV-VIS Spectrophotometer
   b. Scanning Electron Microscope (SEM)
   c. X-Ray Difractometer (XRD)

Semester-IX

PI 559: Project-I **(L0-T0-P6-CH12-CR6)**

PI 402: Nuclear and Particle Physics **(L2-T0-P1-CH3-CR3)**

Basic nuclear properties: Nuclear size determination from electron scattering, nuclear form factors, nuclear radius and charge distribution, mass and binding energy, angular momentum, parity and symmetry, magnetic dipole moment and electric quadrupole moment.

Bound state problem: properties of deuteron, Schrodinger equation and its solution for ground state of deuteron, rms radius and tensor forces, magnetic and quadrupole moments of deuteron.

Scattering problem: low energy n-p scattering and its spin dependence, effective range theory, scattering length, spin dependence (ortho & para-hydrogen), low energy p-p scattering, nature of nuclear forces, charge independence, charge symmetry and isospin formalism, evidence for saturation property, exchange character.

Fermi's theory of beta decay, Curie' Plot, electron capture, selection rules for Fermi and Gamow-Teller transitions, parity violation in -decay and Wu's experiment, two-component theory of neutrinos, neutrino helicity, concepts of neutrino mass and oscillation (solar and atmospheric neutrino puzzles), Reins and Cowen experiment, concept of double beta decay and Majorana neutrino, radioactive dating.

Evidence of shell structure, magic numbers, effective single particle potentials – square well, harmonic oscillator, Wood-Saxon with spin orbit interaction, extreme single particle model and its successes and failures in predicting ground state spin, parity, Nordheim rule.

Different types of nuclear reactions: fission, fusion, Breit-Wigner dispersion formula.

Nuclear radiation detectors: GM counter, proportional, scintillation, solid state detectors, electrostatic accelerators, cyclotron, synchrotron, linear accelerators, colliding beam accelerators.

Particle Physics: Symmetries and conservation laws, quantum numbers, strange mesons and baryons, hadron classification by isospin and hypercharge, SU(2) and SU(3), CPT theorem, CP violation in K decay, Gell-Mann Nishijima relation, quark model, coloured quarks and gluons, quark dynamics.

Text Books:

1. Krane, K. S., *Introductory Nuclear Physics*, (Wiley India Pvt. Ltd, 1998).
2. Roy R. R. and Nigam, B. P., *Nuclear Physics: Theory and Experiment*, (New Age International, 1967).
3. Wong, S. S. M., *Introductory Nuclear Physics*, 2nd edition, (Wiley-VCH, 1999).

Reference Books:

1. Martin, B., *Nuclear and Particle Physics: An Introductory*, (Wiley, 2006).
2. Tayal, D. C., *Nuclear Physics*, (Pragati Prakashan, 2008).
3. Bernard L. Cohen, *Concept of Nuclear Physics*, (Tata McGraw-Hill Education Private Ltd,2011).
4. Beiser, A. and Mahajan, S., *Concept of Modern Physics*, (Tata McGraw-Hill Pvt Ltd, 2009).

2. Mohapatra, R. N. and Pal, P. B., *Massive Neutrinos in Physics and Astrophysics*, (World Scientific).
3. Giunti, C. and Kim, C., *Fundamental of Neutrino Physics and Astrophysics*, (Oxford University Press, 2007).
4. Halzen, F. and Martin, A. D., *Quarks and Leptons*, (John Wiley, 1984).
5. Griffiths, D., *Introductory to Elementary Particles*, 2nd edition, (Academic Press, 2008).
6. Leo, W. R., *Techniques for Nuclear & Particle Physics Experiments*, (Springer-Verlag, 1994).
7. Knoll, G. F., *Radiation Detection and Measurement*, (John Wiley & Sons, 2010).

PI 553: Atomic and Molecular Spectroscopy (L2-T1-P0-CH3-CR3)

Atomic emission and absorption spectra (AES and ASS), series spectra in alkali and alkaline earths, LS and jj coupling in central field approximation.

Spectra of diatomic molecules, pure rotation, pure vibration; vibration-rotation and electronic spectra, Born-Oppenheimer approximation and its application to molecular spectroscopy, formation of bands, structure of bands, dissociation and pre-dissociation, valence-bond theory, molecular orbital theory, bonding and anti-bonding of electrons for equal nuclear charges, energy level of symmetric top molecules, potential energy function.

Morse potential function, Raman spectroscopy, electron spin resonance (ESR) spectroscopy, nuclear magnetic resonance (NMR) spectroscopy, Mossbauer spectroscopy.

Text Books:

1. White, H. E., *Introduction to Atomic Spectra,* (McGraw-Hill, New York, 1934).
2. Herzberg, G., *Atomic Spectra and Atomic Structure,* 2nd edition, (Dover Publications, 2010).
3. Banwell, C. N. and McCash E. M., *Fundamentals of Molecular Spectroscopy,* (McGraw-Hill, 1994).

Reference Books:

1. Kuhn, H. G., *Atomic Spectra,* (Longmans, 1969).
2. Ruark, A. E., and Urey, H. C., *Atoms, Molecules and Quanta* (McGraw-Hill, 1930).
3. Siegman A. E., *Lasers*, (University Science Books, 1986).

Elective I

Elective II

Open Elective

Semester-X

PI 500: Project-II **(L0-T0-P10-CH20-CR10)**

Elective III

Elective IV

Open Elective

Elective Papers:

Course Code	Course Name	L-T-P	CH	CR	Remarks
Astrophysics					
PI 518	General Theory of Relativity	2-1-0	3	3	
PI 505	Basic Astronomy & Astrophysics	2-1-0	3	3	
PI 515	High Energy & Extragalactic Astrophysics	2-1-0	3	3	
PI 506	Introduction to Cosmology	2-1-0	3	3	
PI 412	Plasma and Astrophysics	2-1-0	3	3	

PI 518: General Theory of Relativity **(L2-T1-P0-CH3-CR3)**

Tensor analysis: Covariant and contravariant tensors, quotient rule, metric tensor, Christoffel symbol, covariant derivative of contravariant and covariant tensors, equations of geodesics, Rhemmann-christeffel tensor, Ricci tensor, scalar curvature, Biranchi identity, Einstein tensor.

Elements of general theory of relativity: Brief review of special theory of real Mincowskhi dgn, equivalence ppl & ppl of general congruence, Einstein equation, low velocity and weak field approximation of Einstein field equation, gravitational waves, Solution of EFE, static and Schwarzschild solution of Einstein equation, exterior and interior solutions, Schwarzschild singularity & concept of black hole, planetary orbits, bending of light, advance of perihelion of mercury and gravitational red shift, Shapiro delay, early Universe, the big bang theory vs. steady state theory, primordial Helium abundance, CMBR, decoupling of matter and radiation, formation of galaxies, gravitational lensing and microlens, elements of quantum gravity and quantum cosmology, Hawking radiation.

Text Books:

1. Chandrasekhar, S., *Introduction to the Study of Stellar Structure,* (Dover Publications, 1958).
2. Kippenhahn, R. A. and Weigert, A., *Stellar Structure and Evolution*, (Springer- Verlag, 1994).
3. Frank, S., *The Physical Universe*, (Universal Science Books, 1982).

Reference Books:

1. Stewart, J., *Advanced General Relativity*, (Cambridge University Press, 2008).
2. Landau, L. D. and Lifshitz, E. M., *The Classical Theory of Fields*, 4th edition, (Butterworth-Heinemann, 2000).
3. Erika, B., *Stellar Physics, Vol. I, II, III*, (Cambridge University Press, 1997).
4. Weinberg, S., *Gravitation and Cosmology*, (John Willey & Sons, 2005).
5. Shutz, B., *A First Course in General Relativity*, (Cambridge University Press, 2009).
6. Padmanabhan, T., *Theoretical Astrophysics, Vol. I, II, III*, (Cambridge University Press, 2003).
7. Giunti, C. and Kim C., *Fundamentals of Neutrino Physics and Astrophysics*, (Oxford University Press, 2007).
8. Abhyankar, K. D., *Astrophysics: Stars and Galaxies*, (Tata McGraw Hill, 2002).
9. Bisnovatyi- Kogan, G. S., *Stellar Physics, Vol. I, II*, (Springer-Verlag, 2002).

PI 505: Basic Astronomy & Astrophysics (L2-T1-P0-CH3-CR3)

Basic Astronomy: Celestial co-ordinate systems, telescope and its operational principles and mounting, atmospheric extinctions, magnitude systems, constellations and zodiac.

Stellar structure and evolution: Mass, luminosity, chemical composition, temperature and equation of a star and their measurements, stellar spectra and classifications, main sequence stars, Colour-magnitude plot, Herzsprung-Russel (H-R) diagram, equation of hydrostatic equilibrium, polytropic stars and related integral theorems, stellar atmosphere, blackbody radiation, Saha equation, post-main sequence stars, red giants, nuclear reactions, reaction rates, p-p chain and carbon-nitrogen-oxygen (CNO) cycle.

Solar System: Sun and its properties, planets and satellites, asteroids, comets and Oort's cloud, dust in the solar system, origin of the solar system-different hypotheses.

Text Books:

1. Chandrasekhar, S., *Introduction to the Study of Stellar Structure*, (Dover Publications, 1958).
2. Kippenhahn R. A., and Weigert, A., *Stellar Structure and Evolution*, (Springer- Verlag, 1994).
3. Abhyankar K. D., *Astrophysics: Stars and Galaxies*, (Universities Press, 2009).

Reference Books:

1. Stewart, J., *Advanced General Relativity*, (Cambridge University Press, 2008).
2. Landau, L. D. and Lifshitz, E. M., *The Classical Theory of Fields*, (Butterworth-Heinemann, Elsevier, 1987).
3. Vitense, E. B., *Stellar Physics, Vol. I, II, III*, (Cambridge University Press, 1992).
4. Weinberg, S., *Gravitation and Cosmology*, (Wiley, New York, 1972).
5. Shutz, B., *A First Course in General Relativity*, (Cambridge University Press, 2009).
6. Padmanabhan, T., *Theoretical Astrophysics, Vol. I, II, III*, (Cambridge University Press,2003).
7. Giunti, C. and Kim, C., *Fundamentals of Neutrino Physics and Astrophysics*, (Oxford University Press, 2007).
8. Bisnovatyi-Kogan, G. S., *Stellar Physics, Vol. I, II*, (Springer-Verlag, 2002).
9. Shu, F., *The Physical Universe*, (Universal Science Books, 1982).

PI 515: High Energy & Extragalactic Astrophysics **(L2-T1-P0-CH3-CR3)**

Advanced stages of evolution of stars, gravitational collapse, degeneracy pressure in stars, supernova.

Compact objects: White dwarfs (WD), onset of degeneracy, Chandrasekhar limit, masses, radii and cooling of WD, magnetic WD, neutron stars (NS), equation of state in nuclear domain, realistic theoretical models, Tolman-Oppenheimer-Volkoff (TOV) equation, observation of NS masses, maximum masses and effects of rotation, pulsars (PLSR): history and discovery, connections with fast rotating NS, magnetic dipole model for PLSR, braking index, PLSR emission mechanisms, PLSR glitches, X-ray PLSR, black holes (BH), Schwarzchild BH, Kruskal diagram, test particle motion, Kerr BH, area theorem, BH evaporation.

Galaxies: Hubble's classification of galaxies, rotation law, evolution of galaxies, cluster of galaxies – Virgo and Coma clusters, galaxy mergers, radio galaxies, quasars, active galactic nuclei (AGN).

Text Books:

1. Kippenhahn, R. A. and Weigert, A., *Stellar Structure and Evolution*, (Springer- Verlag, 1994).
2. Misner, C., Thorne, K. S. and Wheelar, J. A., *Gravitation*, (Freeman, 2003).
3. Kenyon, I.R., *General Relativity,* (Oxford University Press, 1990).

Reference Books:

1. Landau, L. D. and Lifshitz, E. M., The *Classical Theory of Fields*, (Butterworth-Heinemann, Elsevier, 1987).
2. Weingberg, S., *Gravitation and Cosmology,* (Wiley, New York, 1972).
3. Vitense, E. B., *Stellar Physics – Vol. I, II, III,* (Cambridge University Press, 1992).
4. Robert, J. and Mark, H., *An Introduction to Galaxies and Cosmology*, (Cambridge University Press, 2004).
5. Lindu, S. and John, S., *Galaxies in the Universe*, (Cambridge University Press, 2007).
6. Rosswog, S. and Bruggen, M., *Introduction to High Energy Astrophysics*, (Cambridge University Press, 2007).
7. Bradt, H., *Astrophysics Processes*, (Cambridge University Press, 2008).
8. Shu, F., *The Physical Universe*, (Universal Science Books, 1982).
9. Abhyankar, K. D., *Astrophysics Stars and Galaxies,* (Universities Press, 2009).
10. Shapiro, S. L. and Teukolsky, S. A., *Black Holes, White Dwarfs and Neutron Stars: The Physics of Compact Objects, (*Wiley-VCH, 1983).
11. Zel'dovich, Y. B. and Novikov, I. D., *Realistic Astrophysics Vol. I & II,* (University of Chicago Press, Chicago, 1983).

PI 506: Introduction to Cosmology (L2-T1-P0-CH3-CR3)

Introduction: Large-scale structure of universe, Olber's paradox, cosmological principle, elements of Newtonian cosmology.

Cosmological Models: Friedman-Robertson-Walker (FRW) metric, Commoving time, Hubble's law, Einstein universe, De-Sitter universe, big bang theory, steady state theory.

Early Universe: Inflationary universe, primordial helium abundance, cosmic microwave background radiation (CMBR), decoupling of matter and radiation, formation of galaxies, gravitational lensing and microlensing, elements of quantum gravity and quantum cosmology, Hawking radiation.

Text Books:

1. Narliker, J. V., *Introduction to Cosmology*, (Cambridge University Press, 2002).
2. Adler, R., Bazin, M. and Schriffer, M., *Introduction to General Relativity*, (McGraw-Hill, 1975).
3. Misner, C., Thorne, K. S. and Wheelar, J. A., *Gravitation*, (Freeman, 2003).

Reference Books:

1. Weinberg S., *Gravitation & Cosmology*, (Willey, New York, 1972).
2. Erika, Bohm, *Stellar Physics- Vol. I, II, III*, (Vitense, 1992).
3. Weinberg S., *Cosmology*, (Oxford University Press, 2008).
5. Liddle, A. and Loverday, J., *The Oxford Companion to Cosmology*, (Oxford University Press, 2008).
6. Kenyon, I. R., *General Relativity*, (Oxford University Press, 1990).
7. Shu, F., *The Physical Universe*, (Universal Science Books, 1982).
8. Abhyankar, K. D., *Astrophysics: Stars and Galaxies*, (Tata McGraw-Hill, 2002).
9. Shapiro S. L. and Teukolski S. A., *Black Hole, White Dwarf and Neutron Star*, (Addition-Wesley, 1983).
10. Zel'dovich Ya. B. and Novikov, I. D., *Relativistic Astrophysics, Vol. I & II*, (University Chicago Press, Chicago, 1983).

PI 412: Plasma and Astrophysics (L2-T1-P0-CH3-CR3)

Basic plasma concepts: Debye shielding, plasma frequency, plasma parameter; motion of charged particle in electromagnetic field, uniform E and B fields, gradient B drift, parallel acceleration and magnetic mirror effect.

Waves in plasma, electron and ion plasma waves, their dispersion relations and properties, fundamental equations of magneto-hydrodynamics (MHD), the MHD approximation, hydromagnetic waves, plasma confinement schemes, plasma in space.

Introduction to the interstellar medium: Neutral and ionized gas, gaseous nebulae, HII regions, supernova remnants, photo-dissociation regions, different phases of the interstellar medium: cold neutral medium, warm neutral and ionized medium, hot medium, diffuse clouds, dense clouds.

Radiative processes: Radiative transfer, emission and absorption coefficients, emission and absorption lines, the role of thermal and free electrons.

Text Books:

1. Bellan, P. M., *Fundamentals of Plasma Physics*, 1st edition (Cambridge University Press, 2008).
2. Chen, F. F., *Introduction to Plasma Physics and Controlled Fusion*, 2nd edition, Vol. 1, (Springer, 1984).

Reference Books:

1. Tielens, A. G. G. M., *Physics and chemistry of the interstellar medium*, (Cambridge University Press, 2010).
2. Dyson, J. E. and Williams, D. A., *The Physics of the interstellar medium*, 2nd edition (Taylor and Francis, 1997).
3. van der Hulst, J. M., *The interstellar medium in galaxies*, 1st edition (Astrophysics and Space Science Library, Springer; 2001).
4. Krishan, V., *Astrophysical Plasmas and Fluids*, 1st edition (Springer, 1999).
5. Spitzer, L., *Physical Processes in the interstellar medium*, (Wiley-VCH, 1998).
6. Draine, B. T., *Physics of the Interstellar and Intergalactic Medium*, (Princeton University Press, 2010).
7. Shu, F., *The Physical Universe*, (University Science Books, 1982).
8. Abhyankar, K. D., *Astrophysics: Stars and Galaxies*, (Sangam Books Ltd, 2002).

Course Code	Course Name	L-T-P	CH	CR	Remarks
		Condensed Matter Physics			
PI 513	Physics of Thin Films	2-1-0	3	3	
PI 511	Superconductivity and Critical Phenomena	2-1-0	3	3	
PI 514	Physics of Solid State Devices	2-1-0	3	3	
PI 510	Advanced Material Science	2-1-0	3	3	
PI 519	Surface Science	2-1-0	3	3	
PI 520	Nanostructures	2-1-0	3	3	
PI 554	Soft Condensed Matter Physics	2-1-0	3	3	

PI 513: Physics of Thin Films **(L2-T1-P0-CH3-CR3)**

Thin films and thick films, their differences, deposition techniques of thin films and thick films, physical vapour deposition (PVD), chemical vapour deposition, electroless or solution growth deposition, electrochemical deposition (ECD), screen printing of thin films.

Nucleation and growth processes, structure of thin films, epitaxial growth (VPE, MBE, MOCVD, etc.), thin film thickness measurement.

Analytical and characterization techniques, mechanical, electrical, electronic and dielectric properties of thin films, transport phenomena in semiconducting and insulator films, superconductivity of thin films and HTSCs (high temperature superconductor films).

Applications of thin films in electronics, thin films resistors, capacitors and active devices, thin film transducers, thin film, solar cells.

Text Book:

1. Goswami, A., *Thin Film Fundamentals*, (New Age International (P) Ltd., New Delhi, 2008).

References Books:

1. George, J., *Preparation of Thin Films*, (Marcel Dekker Inc., New York, 1992).
2. Wagendristel, A. and Wang Y., *An Introduction to Physics and Technology of Thin Films*, (World Scientific Singapore, 1994).
3. Maissel, L. I. and Glang, R., *Handbook of Thin Film Technology*, (McGraw-Hill, 1970).

PI 511: Superconductivity and Critical Phenomena **(L2-T1-P0-CH3-CR3)**

Review of superconductivity, Type I and Type II superconductors, Thermodynamics of superconductivity, Rutger's formula, London equations, Frohlich model, e-p-e interaction, Cooper pairs, Concept of penetration depth & coherence length, Pippard's equation, G-L parameters, BCS theory, fictitious magnetic field and anti-ferromagnetic ordering, spin analogue treatment of Anderson.

Vortex state and flux pinning, Quantized vorticity, Energy between vortex states, Flux quantisation, A.C. and D.C. Josephson effects, SQUID, Cuprate and non-cuprate superconductors (YBCO, BSSCO etc. and MgB_2), In plane and out of plane structural ordering, role of CuO chains and planes in cuprate SC. *d*-wave structure of the superconducting energy gap, iron based SC.

Applications and limitations of HTSC in high voltage cables, magnetic levitation, ship propulsion and magneto-encephalography etc.

Critical Phenomena: First order and second order phase transitions, Phase diagrams, Examples of critical phenomena: liquid-gas, paramagnetic-ferromagnetic, normal to superconductor, and superfluid transitions. Mean field theory and Spin-1/2 and Spin-l Ising Models, X-Y and Heisenberg models. Universality class, scaling laws, critical exponents and inequalities.

Text Books:

1. Tinkham, M., *Introduction to Superconductivity*, 2nd edition, (Dover Publications, 2004).
2. Ketterson, J.B. and Song, S.N., *Superconductivity*, (Cambridge University Press, 1999).
3. Kittel, C., *Introduction to Solid State Physics*, 8th edition (Wiley, 2004).

Reference Books:

1. Anderson, P. W., *Theory of Superconductivitty in high T_c Cuprates*, 1st edition, (Princeton University Press, 1997).
2. Stanley, H. E. *Introduction to Phase transitions and Critical Phenomena*, (Oxford, 1971).
3. Huang, K. *Statistical Mechanics*, (John Wiley, 2000).
4. Pathria, R. K. *Statistical Mechanics*, (Oxford, 1999).
5. Chaikin, P. M. and Lubensky, T. C., *Principles of condensed matter Physics*, (Cambridge, 2000).

PI 514: Physics of Solid State Devices **(L2-T1-P0-CH3-CR3)**

Review of carrier transport phenomena in semiconductors, abrupt and graded junctions, homo and heterojunctions, Ohmic and Schottky contacts, high field transport, heterostructures, quantum wells, super-lattices, resonant tunneling, energy band scheme, field effect transistors using homo and hetero structures, JFET and HEMT. Tunnel diodes and amorphous semiconductor devices.

Magneto resistance (GMR) and colossal magneto resistance (CMR) effects, Magnetocaloric effect. Magnetic memory, shape memory, resistive switching, DRAM and FRAM, piezoelectric transducers and actuators. Spin injection, transport and spin valve devices.

Quantum confinement, energy states of spatially confined electrons, coulomb blockade, single electron transistors, ballistic scattering, quantum point contacts, Landauer formula, mesoscopic transport.

Applications of heterojunctions, white light LED, OLED, quantum well, quantum dot and quantum cascade lasers, photodetectors and photovoltaics. Space charge limited current, Fowler-Nordheim equations, field emission devices.

Text Books:

1. Neamen, D. A., *Semiconductor Physics and Devices*, 3rd edition, (Tata McGraw-Hill, 2002).
2. Streetmann, B., *Semiconductor Devices*, 6th edition, (PHI, 2006).
3. Shur, M., *Physics of Semiconductor Devices*, (PHI, 1995).

Reference Books:

1. Davis, J., *Low dimensional structures*, 1st edition (Cambridge, 1998).
2. Colinge, J. P., and Colinge, C.A., *Physics of Semiconductor Devices*, Springer (2007).
3. Sze, S. M., *Semiconductor Devices*, 3rd edition, (Wiley, 2012).
4. van der Vaart, N., *Single electron transport in semiconductor nanostructures*, (Ph.D. Thesis 1995)

PI 510: Advanced Materials Science (L2-T1-P0-CH3-CR3)

Fermi surface, cyclotron resonance, de Hass-Van Alphen effect, electron motion in 2-dimension, Quantum Hall effect.

Dia, para and ferro magnetism, Langevin theory of dia and para magnetism, Curie-Weiss law, Pauli paramagnetism, exchange interaction, spin waves and magnons, dispersion relation, neutron scattering from magnetic materials-structure studies, elements of ferrimagnetism and antiferromagnetism. Neel temperature.

Dielectric constant, polarizability, ferroelectricity, displacive- nondisplacive and order-disorder types, Kronig-Kramer relations, Clausius-Mossoti relation, ferroelasticity.

Perfect conductors, superconductors, Meissner effect, critical magnetic field, transition temperature, energy gap parameter, isotopic effect, Type I & Type II superconductors, vortex state and flux pinning, thermodynamics of superconductivity, condensation energy, London equations and concept of penetration depth (λ).

Frohlich model, e-p-e interaction, formation of Cooper pairs, coherence length (ξ), Pippard's equation, G-L parameters, elements of BCS theory.

Flux quantization, single particle tunneling and Josephson effect, superconducting quantum interference device (SQUID).

Giant magneto resistance (GMR) and colossal magneto-resistance (CMR).

Books:

All books prescribed under *Condensed Matter Physics & Materials Science (PI-416)*

References:

All books prescribed under *Condensed Matter Physics & Materials Science (PI-416)*

PI 519: Surface Science **(L2-T1-P0-CH3-CR3)**

Surface and its specificity, surface structure, Terrace-Ledge-Kink model, binding sites and diffusion, surface diffusion model, bulk electronic state, surface electronic state, Energy levels at metal interfaces, structural defects at surfaces - point defects, steps, faceting, adatoms, dislocations.

Growth and epitaxy, growth modes, interfaces, surface energy and surface tension, surface plasmonics.

Non-equilibrium growth, Langmuir-Blodgett films, self-assembled monolayers, thermodynamics and kinetics of adsorption and desorption, binding energies and activation barriers, adsorption isotherms, rate of desorption, lateral interaction.

Chemisorption, physisorption and dynamics, heterogenous catalysis process.

Atomistic mechanisms of surface diffusion – hopping mechanism, atomic exchange mechanism, tunneling mechanism.

Surface analysis: scanning probe microscopy, photoelectron spectroscopy, Auger electron spectroscopy, electron energy loss spectroscopy, low energy electron diffraction.

Text Books:

1. Deb, P., *Kinetics of Heterogeneous Solid State Processes*, (Springer, 2013).
2. Oura, K. Lifshits, V. G. Saranin, A. A. Zotov, A. V. and Katayama M., *Surface Science: An Introduction*, 2nd edition, (Springer, 2010).
3. O'Connor, D. J. Sexton, B. A. and Smart R. S. C., *Surface Analysis Methods in Materials Science*, 2nd edition, (Springer, 2010).
4. Desjonqueres, M.-C. and Spanjaard, D., *Concepts in Surface Physics*, 2nd edition, (Springer, 2002).
5. Kolasinski, K. W., *Surface Science, Foundations of Catalysis and Nanoscience*, (Wiley, 2002).

Reference Book:

1. Richardson, N.V. and Holloway, S., *Handbook of Surface Science,* Vol. 4, (Elsevier, 2014).

PI 520: Nanostructures **(L2-T1-P0-CH3-CR3)**

Introduction to nanoscale materials: Quantum mechanical treatment, parabolic well, rectangular well, triangular well, cylindrical well and spherical well, quantum well, quantum wire and quantum dots, quantum size effect, size and dimensionality effects of density of states, Bohr excitons, strong and weak confinements, oscillator strength, blue-shift energy and effective mass approximation model, semiconductor nanoparticles, nanorods and nanotubes; metallic nanostructures, carbon nanotubes, graphene and layered systems.

Surface properties: Phonons in nanostructured systems, surface optic phonons, surface plasmons, interfacial charge transfer, grain growth, surface defects, Langmuir relation, Ostwald ripening, Hall-Petch relation, grain correlated properties.

Synthesis techniques: Top-down vs. bottom-up techniques, sol-gel method, solution growth and hydrothermal routes, mechanical milling and solid state reaction techniques, chemical and photochemical reduction routes, thermal evaporation and e-beam evaporation methods, molecular beam epitaxy.

Analytical tools: X-ray diffraction, optical absorption and emission spectroscopy, Raman spectroscopy, scanning and transmission electron microscopy.

Green nanotechnology, challenges in nanotechnology.

Text Books:

1. Cao, G. and Wang, Y., *Nanostructures and Nanomaterials: Synthesis, Properties and Applications*, 2nd edition, (World Scientific, 2011).
2. Rao, C. N. R., Thomas, P. J. and Kulkarni, G. U., *Nanocrystals: Synthesis, Properties and Applications*, (Springer-Verlag, 2007).
3. Poole, Jr. C. P. and Owens, F. J., *Introduction to Nanotechnology*, (Wiley, 2003).
4. Deb, P., *Kinetics of Heterogeneous Solid State Processes*, (Springer, 2013).
5. Nouailhat, A., *An Introduction to Nanosciences and Nanotechnology*, (Wiley 2007).

Reference Book:

1. Ariga, K., *Manipulation of Nanoscale Materials: An Introduction to Nanoarchitectonics*, (Royal Society of Chemistry, 2012).

PI 554: Soft Condensed Matter Physics (L2-T1-P0-CH3-CR3)

Phases of soft condensed matter: Colloidal fluids and crystals, Poisson-Boltzmann theory, DLVO theory, sheared colloids, polymer solutions, gels and melts, emulsions and foams, micelles, vesicles, surfactants, nature of amphiphilic molecules, lyophobic and lyophilic molecules, self-assembly, Langmuir-Blodgett technique, forces, energy and bonding, microgels, wetting-dewetting phenomena, super-hydropbobic surfaces, phospholipids and glycolipids, polyelectrolyte, polysachharides, biopolymers and biodegradable polymers.

Liquid crystals: Frank free energy, Landau-de Gennes model of isotropic-nematic transition. Thermotropic and lyotropic LCs, orientational order, order parameters, Onsager equation, Landau description of the isotropic to nematic phase transition, optical retardation, Freederiksz transition.

Flow behaviour: Ferrofluids, shear thickening and shear thinning, diffusion and fluid flow, shear flow, linear and non-linear rheology, microfluidic devices, life at low Reynold number, electrostatics in soft matter, dynamics at equilibrium, glass formation and jamming, percolation model, random walks and dynamics, sandpile model, soft glassy rheology, Energy-elasticity, entropic spring, visco-elastic models, de Gennes-Taupin length, introduction to shape transitions.

Membrane physics: Membrane structure and membrane proteins, Bioenergetics, excitable membranes, resting potential, Hodgkin-Huxley model, ion channels, action potentials, patch clamp method.

Experimental techniques: Contact angle measurements, polarized light optical microscopy, small angle scattering and diffraction, dynamic light scattering and diffusive wave spectroscopy, methods for studying dynamics of soft matter using synchrotron x-ray and neutron scattering, rheometry, scanning probe and traction force microscopy, confocal microscopy.

Text Books:

1. Hamley, I. W., *Introduction to Soft Matter*, (Wiley, Chichester, 2000).
2. Jones, R. A. L., *Soft Condensed Matter,* (OUP, Oxford, 2002).
3. Collings, P. J. and Hird, M., *Introduction to Liquid Crystals*, (CRC Press, 1997).
4. Phillips, R., Kondev, J. and Theriot, J., *Physical Biology of the Cell*, (Garland Science, 2008).

Reference Books:

1. Kleman, M. and Lavrentovich, O. D., *Soft Matter Physics*, (Springer-Verlag, 2003).
2. Safran, S. A., *Statistical Mechanics of Surfaces, Interfaces and Membranes*, (Addison-Wesley, Reading, MA 1994).
3. Russel, W. B., Saville D. A. and Showalter, W. R., *Colloidal Dispersions*, (Cambridge University Press, New York, 1989).
4. Philip Nelson, *Biological Physics: Energy, Information and Life*, (Freeman, 2003).
5. Tabor, D., *Gases, Liquids and Solids*, (CUP, 1991).
6. Cotteril, R., *Biophysics: An Introduction*, (John Wiley, Singapore 2002).

Course Code	Course Name	L-T-P	CH	CR	Remarks
		Electronics			
PI 508	Digital Communication System	2-1-0	3	3	
PI 517	Microwave Systems and Antenna Propagation	2-1-0	3	3	
PI 507	Digital Signal Processing	2-1-0	3	3	
PI 516	Microprocessors and Digital Signal Processing Based Systems	2-1-0	3	3	
PI 509	Fiber Optics and Optoelectronics	2-1-0	3	3	

PI 508: Digital Communication Systems (L2-T1-P0-CH3-CR3)

Introduction to digital communications, sampling techniques, ESD, PSD, autocorrelation function, orthogonality.

Pulse modulation: PAM, PCM, DPCM, delta modulation, ADM.

Data transmission: FSK. PSK, DPSK, Mary modulation systems, error probability calculations.

Random process: PSD of random process, transmission of random process through linear systems, optimum filtering.

Behaviour of digital communication system in presence of noise: optimum threshold detection, OBR, carrier systems ASK, FSK, PSK and DPSK, spread spectrum systems, Optimum signal detection: Gaussian random process, optimum receiver, nonwhite channel noise.

Error control coding: block and convolution codes, combined modulation and coding, examples of typical communication systems: Modems, local area networks, computer communication, microwave, satellite, optical, cellular mobile etc.

Text Book:

1. Lathi, B. P., *Modern Analog and Digital Communication Systems*, (Oxford University Press, 2009).

Reference Books:

1. Haykins, S., *Communication systems*, 3rd edition, (Wiley India Pvt Ltd., 2006).
2. Gallager, R. G., *Principles of Digital Communication*, (Cambridge University Press, 2008).
3. Rao, P. R., *Digital Communication*, (Tata McGraw-Hill *Publishing* Co., 2007).
4. Sklar, B., *Digital Communications: Fundamentals & Applications*, 2nd edition, (Pearson Education, 2009).
5. Proakis, J. G. and Salehi, M., *Communication Systems Engineering*, (McGraw-Hill Higher Education, 2007).

PI 517: Microwave Systems and Antenna Propagation (L2-T1-P0-CH3-CR3)

Review of Maxwell's equations: Electromagnetic radiation, plane waves in dielectric and conducting media, reflection and refraction of waves.

Transmission lines, smith chart and its applications, rectangular wave guide, rectangular cavity, modes in waveguides and cavities, dielectric filled wave guides, dielectric slab guide, surface guided waves, non-resonant dielectric guide, modal expansion of fields and its applications.

Microwave semiconductor devices: Microwave transistor, microwave tunnel diode, varactor diode, Schottky diode.

MESFET: Principle of operation, MOS structure, MOSFET microwave applications, transferred electron devices: Gunn diode, LSA diode, modes of operation.

Microwave generation and amplification, avalanche effect devices: Read diode, IMPATT diode, klystron: velocity modulation process, bunching process, output power and beam loading, reflex klystron: power output and efficiency, traveling wave tubes, magnetron.

Microwave waveguide components: attenuators, phase shifters, matched loads, detectors and mounts, slotted-sections, E-plane tee, H-plane tee, hybrid tees, directional couplers, tuners, circulators and isolators, quarter wavelength transformer, multi section transformer matching section.

Lumped planar components: capacitor, inductor and balun, power dividers, directional couplers, analysis of these components using the S-parameters, microwave planar filters, planar non reciprocal devices, signal generators: fixed frequency, sweep frequency and synthesized frequency oscillators, frequency meters, VSWR meters, measurements of frequency, attenuation, VSWR and impedance.

Antenna characteristics: radiation patterns, directive gain, side lobe, back lobe, polarization, co-polarization and cross polarization level, frequency reuse, beam width, input impedance, bandwidth, efficiency, antenna types: wire, loop and helix antennas, aperture antenna-slot, waveguide and horn antenna; parabolic reflector antenna.

Microwave integrated circuits: different planar transmission lines, characteristics of microwave integrated circuits, microstrip antenna: rectangular and circular patch, feed for microstrip antennas: probe feed, microstrip line feed, aperture feed, electromagnetically fed microstrip patch.

Text Book:

1. Rizzi, P. A., *Microwave Engineering*, (Prentice-Hall, 1999).

Reference Books:

1. Pozar, D. M., *Microwave Engineering*, 3rd edition, (Wiley India Pvt. Limited, 2009).
2. Liao, S. Y., *Microwave Devices and Circuits*, 3rd edition, (Prentice-Hall of India, 2000).
3. Collin, R. E, *Foundations for Microwave Engineering*, (McGraw-Hill, 1992).
4. Griffiths, D. J., *Introduction to Electrodynamics*, (Prentice-Hall, 2009).
5. Jackson, J. D., *Classical Electrodynamics*, 3rd edition, (John Wiley & Sons, 1998).

PI 507: Digital Signal Processing **(L2-T1-P0-CH3-CR3)**

Introduction: digital signal processor, signals and systems, sampling and quantization.

Specialized transforms: z-transform, discrete cosine transform, Hilbert transform, Fourier transform, DFT, FFTs, convolution.

Digital filters:

FIR filters-Linear phase filter, windowing method, standard and multi band, constrained least square filtering, arbitrary response filter design IIR filter- design, Butterworth, Chebyshev type I and type II, elliptical, Bessel.

Spectral analysis: Welch's method, multilayer method, Yule-Walker method, covariance methods, MUSIC and eigenvector analysis method.

Applications in real time problems like extraction of voice from noisy environment, filtering the signal using digital filters etc.

Text Books:

1. Proakis, J. G. and Manolakis, D. G., *Digital Signal Processing: Principles, Algorithms, and Applications*, 3rd edition, (Prentice Hall, 1996).
2. Mitra, S. K., *Digital Signal Processing: A Computer Based Approach*, (McGraw-Hill, 2001).
3. Lyons, R. G., *Understanding DSP*, 3rd edition, (Pearson Education, International, 2010).

Reference Books:

1. Hayes, M. H., *Digital Signal Processing*, Schaum's Outline Series, (McGraw-Hill, 1999).
2. Oppenheim, A. V. and Schafer, R. W., *Digital Signal Processing*, (Macmillan Publishing Company, New York, 1993).
3. Porat, B., *A course in Digital Signal Processing*, (John Wiley & Sons, 1996).
4. Soliman, S. S. and Srinath, M. D., *Continuous and Discrete Signals and Systems*, (Prentice Hall, 1998).
5. Sharma, S., *Signals and Systems*, (Katson Books, 2010).

PI 516: Microprocessor and Digital Signal Processing Based Systems **(L1-T0-P2-CH5-CR3)**

Introduction to microprocessors programming and interfacing, Transducers and sensors: Load cells, strain gauges, weighing transducers, temperature sensors (e.g. RTDs, thermocouples, semiconductor sensors, etc.), displacement sensors (e.g. LVDTs, RVDTs, encoders, linear scale etc.), proximity sensors, magnetic sensors, opto-electronic sensors, fiber optic sensors, motion transducers (velocity, vibration and acceleration), fluid transducers, pressure transducers, level transducers, etc.

The signal conditioning circuits like current booster, current to voltage converter, instrumentation amplifier, level shifter, 4-20mA current loop, etc. with their design.

The open loop, feedback loop and feed forward loop and servo controllers with details of PI, PD, PID controllers, tuning methods of the same and also auto tuning methods.

Interfacing of sensors, stepper motor designing of the signal conditioning circuits along with microcontrollers.

Text Book:

1. Hall, D., *Microprocessors and Interfacing*, 2nd edition, (Tata McGraw-Hill, 1999).

Reference Book:

1. Gaonkar R. S., *Microprocessor Architecture, Programming, and Applications with the 8085*, 5th edition, (Prentice Hall, 2002).

PI 509: Fiber Optics and Optoelectronics (L2-T1-P0-CH3-CR3)

Introduction to nature of light, optical fiber modes and configurations, mode theory for circular waveguides, single mode and graded-index fibers, fiber materials, fiber fabrication, mechanical properties of fibers.

Attenuation in optical fibers, signal distortion in optical fibers, pulse broadening mechanism, mode coupling, design optimization of single mode fibers. Source to fiber launching, fiber to fiber joints, LED coupling to multimode and single mode fiber, fiber splicing, optical fiber connector, non-linear effects in fibers, Raman scattering and Brillouin scattering in fibers, fiber Bragg gratings, communication network using fibers, WDM system.

Optical sources: Basic physics of semiconductor optoelectronic devices, light emitting diodes (LEDs), laser diode, light source linearity, modal partition and reflection noise, reliability consideration, fiber laser, fiber based optical amplifier.

Optical detectors: Physical principles of photodiodes, PIN and avalanche photodiode, photo detector noise, detector response time, photodiode materials.

Text Books:

1. Ghatak, A. K. and Thyagarajan, K., *Introduction to Fiber Optics*, (Cambridge Publisher, 2004).
2. Keiser, G., *Optical Fiber Communications*, (McGraw-Hill, 2010).

Reference Books:

1. Kasap, S. O., *Optoelectronics and Photonics Principle and applications*, (Pearson, 2009).
2. Sandbank, C. P., *Optical Fiber Communication Systems*, (John wiley &Sons, 1980).
3. Franz, J. H. and Jain, V. K., *Optical communications Components and systems*, (Narosa, 2009).

Course Code	Course Name	L-T-P	CH	CR	Remarks
	High Energy Physics				
PI 501	Quantum Field Theory	2-1-0	3	3	
PI 502	Quantum Electrodynamics	2-1-0	3	3	
PI 555	Particle Physics I	2-1-0	3	3	
PI 556	Particle Physics II	2-1-0	3	3	
PI 412	Plasma and Astrophysics	2-1-0	3	3	

PI 501: Quantum Field Theory (L2-T1-P0-CH3-CR3)

Introduction to fields: Lagrangian and Hamiltonian formulation of continuous systems, introduction to relativistic field theories, Noether's theorem, Four-vector notations, Lorentz transformations, natural units.

Many particle systems: Non-relativistic quantum systems, free fields, Klein-Gordon equation, non-relativistic many particle systems, relativistic free scalar fields, Dirac equation, antiparticles, free Dirac fields.

Field quantization: Action principle, quantization of scalar fields, quantization of Dirac fields, quantization of vector fields, Lorentz transformation and invariance, parity, charge conjugation and time reversal, CPT theorem.

Interactions among fields: Interactive pictures, S-matrix, Wick's theorem, second-order processes, position space Feynman rules, momentum space Feynman rules, cross-sections.

Text Books:

1. Griffiths, D., *Introduction of Elementary Particles,* (Wiley-VCH Verlag, 2008).
2. Halzen, F. and Martin, A. D., *Quarks and Leptons: An Introductory Course in Modern Particle Physics,* (Wiley India, 2008).
3. Ryder, L. H., *Quantum Field Theory,* (Cambridge University Press, 1996).

References Books:

1. Peskin, M. E. and Schroeder, D. V., *Introduction to Quantum Field Theory,* (Westview Press, 1995).
2. Weinberg, S., *The Quantum Theory of Field, Vol. I, II, III* (Cambridge University Press, 2000).
3. Mandl, F. and Shaw, G., *Quantum Field Theory,* (John Wiley and Sons, 2010).
4. Perkins, D. H., *Introduction to High Energy Physics,* (Cambridge University Press, 2000).
5. Aitchison, I. J. R. and Hey Gauge, A. J. G., *Theories in Particle Physics,* (Taylor and Francis Group, 2002).
6. Chang, S. J., *Introduction to Quantum Field Theory,* (World Scientific Publishing, 1989).

PI 502: Quantum Electrodynamics **(L2-T1-P0-CH3-CR3)**

Classical electromagnetic fields; Quantization of electro-magnetic fields, Electron-electron scattering, Compton scattering, vacuum polarization, electron self-energy, zero temperature Fermi and Bose systems.
Path Integral Formalism*:* Hamiltonian path integrals, Scalar field theories, Dyson-Schwinger equation, Femion systems.
Gauge theories: Path integral formalism and Maxwell fields, Yang-Mills fields, path integral and Feynman rules, renormalization of QED, non-Abelian gauge theories, gauge field self-energy, spontaneous breaking of symmetry, Higgs mechanism; renormalization group.

Text Books:

1. Griffiths, D., *Introduction of Elementary Particles*, (John Wiley and Sons, 1987).
2. Halzen, F., and Martin, A. D., *Quarks and Leptons: An Introductory Course in Modern Particle Physics*, (John Wiley and Sons, 2008).
3. Ryder, L. H., *Quantum Field Theory*, (Cambridge University Press, 1996).

Reference Books:

1. Peskin, M. E. and Schroeder, D. V., *Introduction to Quantum Field Theory*, (Addison Wesley, 1995).
2. Weinberg, S., *The Quantum Theory of Fields* (Vol. I, II, III), (Cambridge University Press, 2005)
3. Mandl, F. and Shaw, G., *Quantum Field Theory* (John Wiley and Sons, 2010).

PI 555: Particle Physics I **(L2-T1-P0-CH3-CR3)**

Conservation laws: strong, weak and electromagnetic interactions, invariance under charge (C), parity (P) and time (T) operators, non-conservation of parity in weak interactions.

Quark model: Quark model of mesons and baryons; quarks, gluons and colours, colour factors, symmetry groups - SU(2), SU(3), eightfold way of classification, discovery of J/Ψ and upsilon, quark masses.

Parton Model: Probing charge distribution with electrons, form factors, electron-proton scattering - proton form factor, elastic electron-proton scattering, Partons, Bjorken scaling Structure of hadrons: Quantum chromodynamics - dual role of gluons, gluon emission cross-section, scaling violation.

Text Books:

1. Griffiths, D., *Introduction of Elementary Particles*, (John Wiley and Sons, 1987).
2. Halzen, F., and Martin, A. D., *Quarks and Leptons: An Introductory Course in Modern Particle Physics*, (John Wiley and Sons, 2008).
3. Ryder, L. H., *Quantum Field Theory*, (Cambridge University Press, 1996).

Reference Books:

1. Peskin, M. E. and Schroeder, D. V., *Introduction to Quantum Field Theory*, (Addison Wesley, 1995).
2. Weinberg, S., *The Quantum Theory of Fields* (Vol. I, II, III), (Cambridge University Press, 2005).
3. Mandl, F. and Shaw, G., *Quantum Field Theory* (John Wiley and Sons, 2010).
4. Perkins, D. H., *Introduction to High Energy Physics*, (Cambridge University Press, 2000)
5. Huang, K., *Quarks, Leptons and Gauge Field*, (World Scientific, 1992)
6. Aitchison, I. J. R. and Hey, A. J. G., *Gauge Theories in Particle Physics*, (Adam Hillier, 2004)
7. Chang, S. J., *Introduction to Quantum Field Theory*, (World Scientific, 1990)

PI 556: Particle Physics II **(L2-T1-P0-CH3-CR3)**

Weak Interactions: V-A theory, nuclear β -decay, neutrino-quark scattering, Cabibbo angle, weak mixing angle, CP violation.

Gauge theory: Local and global gauge theory, non-Abelian gauge theory, spontaneous symmetry breaking, Higg's mechanism, Goldstone theorem.

Unification of interactions: Electro-weak interaction, Weinberg-Salam model, grand unified theories, proton decay, neutrino oscillations and neutrino masses, elements of super-symmetry, elements of string theories, present experimental status.

Text Books:

1. Griffiths D., *Introduction of Elementary Particle*, (Wiley-VCH Verlag, 2008).
2. Halzen, F., and Martin, A. D., *Quarks and Leptons: An Introductory Course in Modern Particle Physics, (*Wiley India, 2008).
3. Ryder, L. H., *Quantum Field Theory,* (Cambridge University Press, 1996).

Reference Books:

1. Peskin, M.E. and Schroeder, D.V., *Introduction to Quantum Field Theory, (*Addison Wesley, 1995).
2. Weinberg, S., *The Quantum Theory of Fields (Vol. I, II, III)*, (Cambridge University Press, 2000).
3. Mandl, F., and Shaw, G., *Quantum Field Theory,* (John Wiley & Sons Inc, 1984).
4. Perkins, D. H., *Introduction to High Energy Physics*, 4th edition, (Cambridge University Press, 2000).
5. Huang, K., *Quarks, Leptons and Gauge Field*, 2nd edition, (World Scientific, 1991).
6. Aitchison, I. J. R. and Hey Gauge A. J. G., *Theories in Particle Physics*, (Taylor and Francis, 2002).
7. Chang, S. J., *Introduction to Quantum Field Theory,* (World Scientific, 1989).

PI 412: Plasma and Astrophysics **(L2-T1-P0-CH3-CR3)**

(Same as given under Astrophysics)

Course Code	Course Name	L-T-P	CH	CR	Remarks
		Photonics			
PI 509	Fiber Optics and Optoelectronics	2-1-0	3	3	
PI 557	Photonics	2-1-0	3	3	
PI 517	Microwave systems and Antenna Propagation	2-1-0	3	3	
PI 546	Fourier Optics and Holography	2-1-0	3	3	
PI 558	Quantum Electronics	2-1-0	3	3	
PI 559	Nanophotonics	2-1-0	3	3	

PI 509: Fiber Optics and Optoelectronics (L2-T1-P0-CH3-CR3)

(Same as given under Electronics)

PI 557: Photonics (L2-T1-P0-CH3-CR3)

Non-linear photonics: Non-linear optical media, second-order and third-order non-linear optics, three-wave mixing, frequency and phase matching, self phase modulation, self focusing, spatial soliton, Raman amplification, Brillioun devices.

Electro-optic effects, intensity modulators, phase modulators, travelling wave modulators, Acousto-optic devices: Photoelastic effect, acousto-optic diffraction, acousto-optic modulators.

Magneto-optic devices: Magneto-optic effects, Faraday effect, magneto-optic Kerr effect, Integrated optical modulators: Phase and polarization modulation, Mach-Zehnder modulator, coupled waveguide modulator.

Photovoltaic devices: Photovoltaic device principles, equivalent circuit of solar cell, temperature effects, solar cell materials, devices and efficiencies.

Photonic switches, photodetectors, optical memory devices, optical communication devices.

Text and Reference Books:

1. Shen, Y. R., *Principle of Non-Linear Optics*, (Wiley India, 2013).
2. Di Bartolo, Baldassare, Collins, John (Editors), *Nano-optics for Enhancing Light-Matter Interactions on a Molecular Scale: Plasmonics, Photonic Materials and Sub-Wavelength Resolution*, (Springer, 2012).
3. Boyd, R. W., *Non-Linear Optics*, (Elsevier, 2006) Second edition.
4. Fukuda, M., *Optical Semiconductor Devices*, (John Wiley & Sons, 2005).
5. Chuang, S. L., *Physics of Photonic Devices*, (Wiley Series, 2009).

PI 517: Microwave Systems and Antenna Propagation (L2-T1-P0-CH3-CR3)

(As under Electronics)

PI 546: Fourier Optics and Holography **(L2-T1-P0-CH3-CR3)**

Analysis of 2-dimensional signals: Fourier series, 2-dimensional signals, Fourier transform (FT) theorems, sampling theorem.

Diffraction Theory: Huygens' diffraction theory, Kirchhoff's diffraction theory, Fresnel diffraction, Fraunhofer diffraction, Talbot imaging.

Wave-optics analysis of coherent systems: Conditions for imaging and Fourier transformation by a lens, optical transfer function (OTF) of a lens.

Recording Materials: Photographic emulsions, thermoplastics, photopolymers, photo-refractives, spatial light modulators (SLM), charge coupled devices (CCD) and CMOS.

Applications: Filter types, Abbe-Porter experiment, 4-f optical processor, Zernike phase-contrast, Vander Lugt Filter, joint transform Correlator, matched filtering, inverse filter, processing of side looking radar (SAR) data.

Holography: Recording and reconstruction, hologram types: thin, thick, transmission, reflection, amplitude and phase, computer generated holograms, hologram interferometry (HI), applications of HI, digital holography.

Text Books:

1. Goodman, J., *Introduction to Fourier Optics*, 3rd edition, (Roberts and Company Publishers, 2004) (ISBN-10: 0974707724).
2. Steward, E. G., *Fourier Optics: An Introduction*, 2nd edition, (Dover Publications, 2011) (ISBN-10: 0486435040).
3. Hariharan, P., *Optical Holography: Principles, Techniques and Applications*, (Cambridge University Press, 1996) (ISBN-10:0521433487).
4. Sirohi, R. S., *Wave Optics and Applications*, (Orient Longman, 1993).

Reference Books:

1. Voelz, D. G., *Computational Fourier Optics: A MATLAB Tu*torial (SPIE Tutorial Texts Vol.TT89), (SPIE Press, 2011) (ISBN-10: 0819482048).
2. Gaskill, J. D., *Linear Systems, Fourier Transforms, and Optics*, (Wiley-Interscience, 1978) (ISBN-10: 0471292885).

PI 558: Quantum Electronics **(L2-T1-P0-CH3-CR3)**

Introduction to quantum electronics, review of electromagnetic theory, quantization of the electromagnetic field, coherent states.

Gaussian beams, optical resonators and rate equations, types of lasers.

Physical origin of nonlinear polarization, second harmonic generation, birefringence and quasi-phase matching, self-phase modulation, optical soliton.

Stimulated Raman scattering, higher-order nonlinearlities and phase conjugation, Q-switching and mode-locking.

Propagation in wave guides, photonic crystals, negative dispersion.

Text Books:
1. Yariv, A., *Quantum Electronics*, 3rd edition, (Wiley, 1989).
2. Saleh, B. E. A. and Teich, M. C., *Fundamentals of Photonics*, (John Wiley and Sons, 1991).

PI 559: Nanophotonics **(L2-T1-P0-CH3-CR3)**

Review of Maxwell's equations, light-matter interaction, radiating dipole, radiation pressure, spontaneous and stimulated emissions.

Optical properties of noble metals and semiconductors, Drude Somerfield theory, surface plasmon and polariton, evanescent wave, localized surface plasmon, SERS, surface plasmon based sensors.

Diffraction limit, near-field optics, super resolution spectroscopy, nanoscale optical microscopy, two photon and multi photon absorption processes, optical tweezer and vortices, phase conjugation and frequency mixing, elements of quantum communication.

Electromagnetics in mixed dielectric media, symmetries and solid state electromagnetism, 1-D, 2-D and 3-D photonic crystals, dispersion relation, photonic crystal fiber, opals, OLED, quantum well and quantum dot lasers, photo-luminescence and bio-luminescence.

Application in nano-optics and bio-photonics.

Text Books:
1. Maier, S. A., *Plasmonics: Fundamentals and Applications*, *illustrated* edition (Springer, 2007).
2. Boyd, R. W., *Non-Linear Optics*, 2nd edition (Elsevier, 2006).
3. Haus, J. W., *Fundamentals and Applications of Nanophotonics*, (Elsevier, 2016).

Reference Books:
1. Di Bartolo, Baldassare, Collins, John (Editors), *Nano-optics for Enhancing Light-Matter Interactions on a Molecular Scale: Plasmonics, Photonic Materials and Sub-Wavelength Resolution*, (Springer, 2012).
2. Winn, J. N., Joannopoulos, J. D. and Johnson, S. G., *Photonic Crystal: Molding the flow of Light*, (Princeton Univ. Press, 2008).
3. Shen, Y. R., *Principle of Non-Linear Optics*, (Wiley India, 2013).
4. Fukuda, M., *Optical Semiconductor Devices*, (John Wiley & Sons, 2005).
5. Chuang, S. L., *Physics of Photonic Devices*, (Wiley Series, 2009).
6. Novotny, L. and Hecht, B., *Principles of Nano-optics*, (Cambridge Univ. Press, 2009).

Course Code	Course Name	L-T-P	CH	CR	Remarks
	Plasma Physics				
PI 521	Fundamental of Plasma Physics	2-1-0	3	3	
PI 524	Plasma Generation and Application	2-1-0	3	3	
PI 525	Nonlinear Plasma Physics	2-1-0	3	3	
PI 510	Advanced Material Science	2-1-0	3	3	
PI 505	Basic Astronomy & Astrophysics	2-1-0	3	3	
PI 515	High Energy and Extragalactic Physics	2-1-0	3	3	
PI 412	Plasma and Astrophysics	2-1-0	3	3	

PI 521: Fundamentals of Plasma Physics **(L2-T1-P0-CH3-CR3)**

Plasma State: Ionized gas, Saha's ionization equation, Collective degrees of freedom, Definition of Plasma, Concept of Plasma temperature, Debye shielding, Quasi-neutrality, Plasma parameters, Plasma approximation, Natural existence of Plasma.

Single-particle motion: Dynamics of charged particles in electro-magnetic fields, Particle drifts, EXB drifts, Grad-B drift, Curvature drift, Polarization drift, Adiabatic invariants and their technological applications.

Kinetic theory of Plasma: Vlasov equations, Solution of linearized Vlasov equation, Langmuir waves, Ion-sound waves, Wave-particle interaction and Landau damping.

Fluid theory of Plasma: Plasma oscillations, Electron-acoustic waves, Ion-acoustic waves Electrostatic ion-waves perpendicular to magnetic field, Electromagnetic waves perpendicular to magnetic field.

Equilibrium and stability: Plasma instabilities and classification, Two-stream and gravitational instabilities.

Text Books:

1. Nicholson, D.R., *Introduction to Plasma Theory* (Wiley, USA, 1983).
2. Swanson, D. G., *Plasma Waves* (IoP, Bristol, 2003).
3. Bittencourt, J. A., *Fundamentals of Plasma Physics* (Springer, New York, 2004).
4. Bellan, P. M., *Fundamentals of Plasma Physics* (Cambridge, UK, 2006).
5. Cap, F. F, *Handbook on Plasma Instabilities* (Academic Press, New York, 1976).

Reference Books:

1. Piel, A., *Plasma Physics: An Introduction to Laboratory, Space and Fusion Plasmas* (Springer, Heidelberg, 2010).
2. Chen, F. F., *Introduction to Plasma Physics and Controlled Fusion*, 2nd ed. (Plenum, New York, 1984).
3. Kono, M. and Skoric, M. M., *Nonlinear Physics of Plasmas* (Springer, Berlin, 2010).
4. Pecseli, H. L., *Waves and Oscillations in Plasmas* (CRC Press, New York, 2013).
5. Smirnov, B. M., *Theory of Gas Discharge Plasma* (Springer, Switzerland, 2015).
6. Spitzer, L., Physics of Fully Ionized Gases (John Wiley & Sons, New York).

PI 524: Plasma Generation and Applications **(L2-T1-P0-CH3-CR3)**

Basic principles of gas discharge physics: Electrical breakdown, Generation of thermal and non-thermal plasma, DC and RF (radiofrequency) discharges, Microwave discharge, Dielectric barrier discharge.

Fundamentals of vacuum technology: Vacuum pumps- rotary, diffusion and turbo-molecular pumps, Low pressure measurement systems in laboratory plasma- pressure gauges.

Plasma diagnostic methods: Electric probes (Langmuir and emissive probe), Electric probe characteristics and measurement of plasma parameters (plasma potential, electron & ion density, electron temperature etc.), Magnetic probes, Mass and optical spectroscopy.

Application of Plasma Physics: Thermonuclear fusion- present status and problems, Requirements for fusion plasmas- confinement, beta, power and particle exhaust, Tokamak fusion reactors.

Dusty plasma in laboratory and space, Dust charging processes, Waves in dusty plasma, Dust crystal.

Laser plasma interaction, Inertial confinement, High-harmonic generation, Laser wakefield electron accelerator, X-ray laser.
Plasma engineering, Industrial applications of plasma.

Text Books:

1. Chen, F. F., *Introduction to Plasma Physics and Controlled Fusion*, 2nd edition, (Plenum, New York, 1984).
2. Hutchinson, I. H., *Principles of Plasma Diagnostics*, 2nd edition, (Cambridge University Press, 2002).
3. Shukla, P. K. and Mamun, A. A., *Introduction to Dusty Plasma Physics* (IoP, Philadelphia, 2001)
4. Vinod, K., *Astrophysical Plasmas and Fluids* (Springer, New Delhi, 1998).
5. Kruer, W. L., *The Physics of Laser Plasma Interactions* (Cambridge University Press, Cambridge 1988).
6. Lieberman, M. A. and Lichtenberg, A. J., *Principles of Plasma Discharges and Materials Processing* (John Wiley, New York, 1994).

Reference Books:

1. Nicholson, D. R., *Introduction to Plasma Theory* (John Wiley & Sons, New York, 1983).
2. Smirnov, B. M., *Physics of Ionized Gases* (John Wiley & Sons, New York, 2007).
3. Huddlestone R. H. and Leonard S. L., Plasma Diagnostic Techniques (Academic Press, Cambridge, 1965).

PI 525: Nonlinear Plasma Physics **(L2-T1-P0-CH3-CR3)**

Nonlinear Debye shielding, Evacuation of the Debye sphere, Basics of exotic plasma effects: Plasma as exotic medium, Shielding in three spatial dimensions.

Weakly nonlinear processes: Concept of nonlinearity and dispersion, Weakly nonlinear and weakly dispersive waves, Wave energy alteration with dispersion and dissipation mechanisms, Shock & soliton formation, Nonlinear wave equations and asymptotic integrations.

Strongly nonlinear processes: Excitation of strongly nonlinear and strongly dispersive waves, Energy integral methods, Nonlinear coherent structures in complex plasmas, Astrophysical-cosmic-space applications.

Text Books:

1. Chen, F. F., *Introduction to Plasma Physics and Controlled Fusion*, 2nd ed. (Plenum, New York, 1984).
2. Bittencourt, J. A., *Fundamentals of Plasma Physics*, 3rd ed. (Springer, New York, 2004).
3. Bellan, P. M., *Fundamentals of Plasma Physics* (Cambridge, UK, 2006).
4. Piel, A., *Plasma Physics: An Introduction to Laboratory, Space and Fusion Plasmas* (Springer, Heidelberg, 2010).
5. Pecseli, H. L., *Waves and Oscillations in Plasmas* (CRC Press, New York, 2013).

Reference Books:

1. Swanson, D. G., *Plasma Waves* (IoP, Bristol, 2003).
2. Kono, M. and Skoric, M. M., *Nonlinear Physics of Plasmas* (Springer, Berlin, 2010).
3. Hasegawa, A., *Plasma Instabilities and Nonlinear Effects* (Springer, Berlin, 1975).
4. Davidson, R. C., *Methods in Nonlinear Plasma Theory* (Academic Press, New York, 1972).
5. Nicholson, D.R., *Introduction to Plasma Theory* (Wiley, USA, 1983).

PI 510: Advanced Materials Science **(L2-T1-P0-CH3-CR3)**

(As under Condensed Matter Physics)

PI 505: Basic Astronomy & Astrophysics **(L2-T1-P0-CH3-CR3)**

(As under Astrophysics)

PI 515: High Energy & Extragalactic Astrophysics **(L2-T1-P0-CH3-CR3)**

(As under Astrophysics)

PI 412: Plasma and Astrophysics **(L2-T1-P0-CH3-CR3)**

(As under Astrophysics)

Course Code	Course Name	L-T-P	CH	CR	Remarks
		Nano-Science			
PI 520	Nanostructures	2-1-0	3	3	
PI 543	Surface Science	2-1-0	3	3	
PI 559	Nanophotonics	2-1-0	3	3	
PI 554	Soft Condensed Matter Physics	2-1-0	3	3	
PI 560	Nanobiophysics	2-1-0	3	3	
PI 561	Nanomagnetism	2-1-0	3	3	

PI 520: Nanostructures **(L2-T1-P0-CH3-CR3)**

Introduction to nanoscale materials: Quantum mechanical treatment, parabolic well, rectangular well, triangular well, cylindrical well and spherical well; quantum well, quantum wire and quantum dots, quantum size effect, size and dimensionality effects of density of states, Bohr excitons, strong and weak confinements, oscillator strength; blue-shift energy and effective mass approximation model, semiconductor nanoparticles, nanorods and nanotubes, metallic nanostructures, carbon nanotubes, graphene and layered systems.

Surface properties: Phonons in nanostructured systems, surface optic phonons, surface plasmons, interfacial charge transfer, grain growth, surface defects, Langmuir relation, Ostwald ripening, Hall-Petch relation, grain correlated properties.

Synthesis techniques: Top-down vs. bottom-up techniques, sol-gel method, solution growth and hydrothermal routes, mechanical milling and solid state reaction techniques, chemical and photochemical reduction routes, thermal evaporation and e-beam evaporation methods, molecular beam epitaxy.

Analytical tools: X-ray diffraction, optical absorption and emission spectroscopy, Raman spectroscopy, scanning and transmission electron microscopy.

Green nanotechnology, challenges in nanotechnology.

Text Books:

1. Cao, G. and Wang, Y., *Nanostructures and Nanomaterials: Synthesis, Properties and Applications*, 2nd edition, (World Scientific, 2011).
2. Rao, C. N. R., Thomas, P. J. and Kulkarni, G. U., *Nanocrystals: Synthesis, Properties and Applications*, (Springer-Verlag, 2007).
3. Poole, Jr. C. P. and Owens, F. J., *Introduction to Nanotechnology*, (Wiley, 2003).
4. Deb, P., *Kinetics of Heterogeneous Solid State Processes*, (Springer, 2013).
5. Nouailhat, A., *An Introduction to Nanosciences and Nanotechnology*, (Wiley 2007).

Reference Book:

1. Ariga, K., *Manipulation of Nanoscale Materials: An Introduction to Nanoarchitectonics*, (Royal Society of Chemistry, 2012).

PI 543: Surface Science **(L2-T1-P0-CH3-CR3)**

Surface and its specificity, surface structure, Terrace-Ledge-Kink model, binding sites and diffusion, surface diffusion model, bulk electronic state, surface electronic state, Energy levels at metal interfaces, structural defects at surfaces - point defects, steps, faceting, adatoms, dislocations.

Growth and epitaxy, growth modes, interfaces, surface energy and surface tension, surface plasmonics.

Non-equilibrium growth, Langmuir-Blodgett films, self-assembled monolayers, thermodynamics and kinetics of adsorption and desorption, binding energies and activation barriers, adsorption isotherms, rate of desorption, lateral interaction.

Chemisorption, physisorption and dynamics, heterogenous catalysis process.

Atomistic mechanisms of surface diffusion – hopping mechanism, atomic exchange mechanism, tunneling mechanism.

Surface analysis: scanning probe microscopy, photoelectron spectroscopy, Auger electron spectroscopy, electron energy loss spectroscopy, low energy electron diffraction.

Text Books:

1. Deb, P., *Kinetics of Heterogeneous Solid State Processes*, (Springer, 2013).
2. Oura, K. Lifshits, V. G. Saranin, A. A. Zotov, A. V. and Katayama M., *Surface Science: An Introduction*, 2^{nd} edition, (Springer, 2010).
3. O'Connor, D. J. Sexton, B. A. and Smart R. S. C., *Surface Analysis Methods in Materials Science*, 2^{nd} edition, (Springer, 2010).
4. Desjonqueres, M.-C. and Spanjaard, D., *Concepts in Surface Physics*, 2^{nd} edition, (Springer, 2002).
5. Kolasinski, K. W., *Surface Science, Foundations of Catalysis and Nanoscience*, (Wiley, 2002).

Reference Book:

1. Richardson, N.V. and Holloway, S., *Handbook of Surface Science,* Vol. 4, (Elsevier, 2014).

PI 559: Nanophotonics **(L2-T1-P0-CH3-CR3**)

(As under Photonics)

PI 554: Soft Condensed Matter Physics **(L2-T1-P0-CH3-CR3)**

(As under Condensed Matter Physics)

PI 560: Nanobiophysics **(L2-T1-P0-CH3-CR3)**

Amphipathic molecules and packing parameters, prokaryotic and eukaryotic cells, properties of polysaccharides, proteins, lipids and nucleic acids. Structure and function of biological membranes. Electrokinetic phenomena, Electric double layer, Excitable membranes, Action potential, Hodgkin-Huxley model and ion channels. Free energy and entropy. Diffusion and sub-diffusion, Brownian and non-Brownian motion, life at low Reynold number.

Biosynthesis and characterization of nanoparticles, nano-bio conjugation, FRET, biopolymers, motor proteins, Staining of cells, organic and inorganic markers, cytotoxic and membrane stability tests, Artificial photo-synthesis. Elements of nanotoxicology and immunology.

Bio-imaging and analysis, fluorescence and confocal microscopy, FRAP, TIRF, STED and STORM. Linear and circular dichroism and related analytical tools. Monte Carlo and MD simulation techniques.

Gene structure and function, DNA sequencing, Gel-electrophoresis. Polymerase chain reaction (PCR), DNA chip and computing.

Applications in biosensors, diagnostics and therapeutics.

Text Books:

1. Niemeyer, C. M. and Mirkin, C. A., *Nanobiotechnology: Concepts, Applications and Perspectives*, (Wiley-VCH, 2004).
2. Cotteril, R., *Biophysics: An introduction*, 1st edition (Wiley, 2009).

Reference Books:

1. S. Dumitriu (Editor), *Polymeric biomaterial*, (Marcel Dekker, 1989).
2. Lodish, H., Berk, A., Matsudaira, P., Zipursky, S. L., Baltimore, D., Darnell, J., *Molecular Cell Biology*, 5th Edition, (Macmillan Higher Education, 2004).
3. Calladine and Drew, A. P., *Understanding DNA*, (Academic Press, 2004).
4. Yagle, P., *The membranes of cells*, (Academic press, 1993).
5. Glaser, R., *Biophysics*, 1st edition (Springer, 2001).
6. Brown, T. A., *Genomes*, 2nd edition, (Wiley-Liss, 2002).
7. Donbrow, M., (Editor), *Microcapsules and Nanoparticles in Medicine and Pharmacy*, (CRC Press, 1992).
8. Grigorenko, E. V., *DNA Arrays: Technologies and experimental strategies*, (CRC Press, 2002).
9. Gregoriadis, G., *Liposomes in Biological systems*, (Wiley-Blackwell, 1980).
10. Nelson, P., *Biological Physics: Energy, Information and Life*, (Freeman, 2007).

PI 561: Nanomagnetism **(L2-T1-P0-CH3-CR3)**

Classical and Quantum Magnetism, Magnetism of Atoms, Magnetic Ordering, Micromagnetism, Domain and Hysteresis, Paramagnetism, Ferromagnetism, Anti-ferromagnetism, Ferrimagnetism, Magnons, Exchange Interactions.

Magnetic Anisotropy, Order and Broken Symmetry, Consequences of Broken Symmetry, Landau theory of Ferromagnetism, Heisenberg and Ising model, Domain and Domain Walls, Equation of Motion for Domain Walls.

Nanoscale Magnetism, Superparamagnetism, Stoner-Wohlfarth model, Interparticle Interaction.
Magnetoresistance - Magnetoresistance of Ferromagnets, Anisotropic Magnetoresistance.

Giant Magnetoresistance, Spintronics, Molecular magnetism.
Nuclear Magnetic Resonance, Magnetic Resonance Imaging.

Neutron Diffraction, SQUID.

Text Books:

1. Coey, J. M. D., Magnetism and Magnetic Materials, (Cambridge University Press, 2009).
2. Cullity, B. D. and Graham C. D., Introduction to Magnetic Materials, 2nd Edition, (Wiley IEEE Press, 2008).

Reference Books:

1. Peddie, W., Molecular Magnetism, (Nabu Press, 2011).
2. Spaldin, N. A., Magnetic Materials: Fundamentals and Applications, 2nd Edition, (Cambridge University Press, 2010).

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