UNIVERSITY OF HYDERABAD

School of Physics

M.Sc. (Physics)

Course Structure and Course details

March 2016

Semester I				**Total No. of Credits : 24**
Course No.	Name of the course	Contact hours and Credits		
		Classroom Lectures	Experiments in Laboratories	Total Credits
PY401	Mathematical Methods I	4	---	4
PY402	Classical Mechanics	4	---	4
PY403	Electromagnetic Theory I	3	---	3
PY404	Electronics I	3	---	3
PY405	Quantum Mechanics I	4	---	4
PY406	Physics Lab I *Electronic Circuits Lab.*	1	4	3
PY407	Physics Lab II *Digital Electronics Lab.*	1	4	3

Semester II				**Total No. of Credits : 24**
Course No.	Name of the course	Contact hours and Credits		
		Classroom Lectures	Experiments in Laboratories	Total Credits
PY451	Mathematical Methods II	4	---	4
PY452	Numerical Methods	2	4	4
PY453	Electromagnetic Theory II	3	---	3
PY454	Electronics II	3	---	3
PY455	Quantum Mechanics II	4	---	4
PY456	Physics Lab III *Modern Physics Lab.*	1	4	3
PY457	Physics Lab IV *Microwave and Nuclear Physics Lab.*	1	4	3

Semester III				**Total No. of Credits : 24**
Course No.	Name of the course	Contact hours and Credits		
		Classroom Lectures	Experiments in Laboratories	Total Credits
PY501	Statistical Mechanics	4	---	4
PY502	Solid State Physics	4	---	4
PY503	Particle Physics	4	---	4
PY504	Optics and Laser Physics	4	---	4
PY505	Project	---	---	2
PY506	Physics Lab V *Solid State Physics Lab.*	1	4	3
PY507	Physics Lab VI *Laser Physics Lab.*	1	4	3

Semester IV				**Total No. of Credits : 21**
Course No.	Name of the course	Contact hours and Credits		
		Classroom Lectures	Experiments in Laboratories	Total Credits
PY551	Atomic and Molecular Physics	3	---	3
PY552	Nuclear Physics	2	---	2
PY553	Project	--	---	4
PY554xx	Optional I	4	---	4
PY555xx	Optional II	4	---	4
PY555xx	Optional III	4	---	4

Optional I has to be chosen from Optional Papers A. Optional II and III can be chosen from either A or B.

Optional Papers: A

PY554O1. Advances in Optics and Photonics
PY554O2. Advanced Condensed Matter Physics
PY554O3. Quantum Field Theory
PY554O4. Advanced Electronics

Optional Papers: B

PY555O6. Advanced Statistical Mechanics
PY555O7 General Theory of Relativity
PY555O8. Advanced Quantum Mechanics
PY555O9. Many Body Theory
PY555O10. Phase transitions and Critical Phenomena
PY555O11. Dynamical systems and Chaos
PY555O12. Semiconductor Physics
PY555O13. Probes of Condensed Matter
PY555O14. Liquid Crystals
PY555O15. Quantum Optics
PY555O16. Optoelectronics
PY555O17. Nonlinear Spectroscopy
PY555O18. Lie Groups & Lie Algebra
PY555O19. Ultrafast Phenomena
PY555O20. Advanced Quantum Mechanics and Many body Theory
PY555O21. Low-temperature Techniques
PY555O22. Nanoscience and Nanotechnology
PY555O23 Advanced Particle Physics
PY555O24 Quantum Theory of Solids
PY555O25 Signals and Systems
PY555O26 Advanced Solid State Physics Lab.
PY555O27 Physics of Materials
PY555O28 Ferroelectrics & Electroceramics
PY555O29 Cavity Quantum Electrodynamics
PY555O30 Coherence & Quantum Interference
PY555O31 MEMS Theory & Laboratory
PY555O32 Integrated Optics Theory & Lab.
PY555O33 Advanced Computational Techniques
PY555O34 Nanostructuring by various methods (lasers, ion beams, sputtering etc.)
PY555O35 Optical Cooling
PY555O36 Optical Resonance and Two-level Atoms
PY555O37 Mathematical Methods III
PY555O38 Nonlinear Optics
PY555O39 Experimental Methods

Any student opting to earn an extra credit can do so by choosing an additional project or a reading course or an optional paper.

Semester 1

PY401 Mathematical Methods I

Fourier series and Fourier transforms, their properties & applications. Definition and properties of Dirac delta function.

The method of separation of variables for partial differential equation, boundary value problems involving use of Fourier expansion.

Linear ordinary differential equations with constant coefficients and the Euler equation. The Frobenius method of series solution. Fuch's theorem. Polynomial Solutions.

Geometrical representation of complex numbers. Functions of complex variables. Properties of elementary trigonometric and hyperbolic functions of a complex variable. Differentiation, Cauchy-Riemnann equations. Properties of analytical functions. Contours in complex plane. Integration in complex plane. Cauchy theorem. Deformation of contours. Cauchy integral representation. Taylor series representation. Isolated and essential singular points. Laurent expansion theorem. Poles. Residues at an isolated singular point. Cauchy residue theorem. Applications of the residue theorem.

Laplace transform & applications.

Recommended books :

1.	Mathematics for Physicists	Dennery & Kryzywicki
2.	Orinary differential equations	R. L. Rabenstein
3.	Complex Variables & Applications	R. V. Churchill
4.	Partial Differential Equation for Scientists	G. Stephenson

PY402 Classical Mechanics

A brief and quick review of Newtonian mechanics of a particle and a system particles.

Lagrangian Formalism : force, potentials, conservative systems constrains, generalized coordinates. Lagrange equations, variational principles, conservation theorems and symmetry properties. Lagrangian of a charged particle in an electromagnetic field. Two body central force problem, scattering due to simple potentials like central force fields.

Hamiltonian formalism, conjugate momenta, conservation laws, Hamiltonian of a charged particle in electromagnetic field.

Poisson brackets and their properties, equation of motion. Canonical transformation.

A brief introduction to the Hamilton-Jacobi's Theory and action angle variables.
Theory of small oscillations, normal modes of the system.
The kinematics of rigid body motion, infinitesimal rotations, the Coriolis force, rigid body equations of motion.

Recommended books :

1.	Classical Dynamics	J. B. Marion
2.	Classical Mechanics	H. Goldstein
3.	Mechanics	Landau-Lifshitz
4.	Classical Mechanics	A. K. Raichaudhuri
5.	Classical Dynamics	Jog & Rana

PY403 Electromagnetic Theory – I

Maxwell's equations for electrostatics and magnetostatics in differential and integral form.

Electrostatic potential and electrostatic field due to point charges and continuous charge distributions. Electrostatic field energy. Boundary value problems and their solutions by separation of variables. Method of images and Green functions. Multipole expansion. Electric dipole and quadupole moments. Dielectric materials. Polarization. Maxwell's equations for electrostatics in presence of dielectric materials. Boundary value problems in presence of dielectrics.

Introduction to vector and scalar potentials in electrostatics. Gauge transformations, magnetic field and vector potential for simple steady current configurations. Force and torque on current carrying conductors. Magnetic multipole expansion.

Dia, para and ferro-magnetic materials, Maxwell's equations in presence of magnetic materials.

Time varying fields. Faraday's Laws of induction. Maxwell's equations of electrodynamics. Magnetic field energy. Self and mutual inductance.

Recommended books :

1.	Introduction to Electrodynamics	Griffiths
2.	Electrodynamics of continuous media	Landau & Lifshitz
3.	Classical Fields	Landau & Lifshitz

PY404 Electronics I (3 credits)

p-n Junction diode operational principle, diode circuits and applications as half wave, full wave and bridge rectifier, Filters and wave shaping circuits. Reverse bias breakdown, Zener diode as voltage regulator. Load line.

Transistor Amplifiers : BJT Structure and operational principles, The CE, CB and CC configurations. Load line, operating point, transistor as switch, Transistor biasing, AC models, Voltage amplifier, Power amplifier. Concept of feedback.

Low-frequency amplifiers. The transistor hybrid model and the h-parameters for a transistor. Conversion formulae for the h-parameters of the different transistor configurations. Analysis of a transistor CE amplifier at low frequencies using h-parameters.

The field effect transistor and its small signal model. The CS and CD amplifiers at low frequencies. Biasing the FET. The CS and CD amplifiers at high frequencies.

High frequency models of amplifier circuits. Analysis of a specific BJT or FET amplifiers.

Operational Amplifiers : Differential Amplifiers, Characteristics of an ideal Operational amplifier. Inverting and Non-inverting amplifiers. Summing circuits, integration and Differentiation. Applications of operational amplifiers – zero crossing detector, voltage level detector, smoke detector, phase shifter, instrumentation amplifier, Oscillators and Waveform generators.

Recommended books:

1. Integrated Electronics by Millman and Halkias
2. Electronic Pronciples by Albert Malvino
2. Operational Amplifiers and linear Integrated circuits by Robert Coughlin and Frederick F. Driscoll

PY405 Quantum Mechanics – I

Review of linear algebra and introduction to Hilbert space. Dirac Bra-Ket notations, Fock representation

Schrodinger wave equation. Ehrenfest theorem, stationary states and their properties. Postulates of Quantum Mechanics. The general solution of wave equation and its applications to Harmonic oscillator, delta function potential, potential well in three dimensions. Hydrogen atom and rigid rotator. Wave packets and the uncertainly principle. General formulation of uncertainly principle. Time development of wave packets.

Angular momentum. Commutation relations, eigen-functions of the angular momentum operators, matrix representation of angular momentum operators.

Introduction to perturbation theory.

Scattering Theory, Central force problem, partial wave analysis Born's approximation, optical theorem bound states and resonances. Schrodinger and Heisenberg pictures.

Recommended books :

1.	Quantum Mechanics	L. Schiff
2.	Quantum Mechanics	E. Merzbacher
3.	Practical Quantum Mechanics	S. Flugge
4.	Quantum Mechanics	Mathews and Venkatesan
5.	Quantum Mechanics	M. P. Khanna
6.	Principles of Quantum Mechanics	P. A. M. Dirac
7.	Lectures on Quantum Mechanics	G. Baym

PY406 Physics Lab I - Electronic Circuits Lab.

1. (Diode) Clipping and clamping circuits
2. (Diode) Rectifier circuits
3. Regulated power supply circuit (Zener)
4. Common emitter (single stage) amplifier
5. Common source JFET amplifier
6. Multivibrators (Astable, Monostable, and Bistable)
7. Phase shift oscillator
8. Operational amplifier applications

PY407 Physics Lab II - Digital Electronics Lab.

1. Verification of TTL Ics
2. Universal Gates
3. Adders and Subtractors
4. 7-Segment Display
5. Encoder, Decoder, MUX and DEMUX
6. Arithmetic using Decoder Ics
7. Flip-Flpos (SR, JK, MS-JK)
8. Flip-Flop ICs, Ripple Counters
9. Synchronous counters (up/down/random)

Semester 2

PY451 Mathematical Methods II

Groups, fields, vector spaces, Linear dependence. Basis subspace, Dimension, Linear functions, Linear operators, Inverse and rank of an operator.

Eigenvalues and Eigenvectros. Matrix representation, Change of basis.

Norm and Inner product. Cauchy-Schwarz. Inequality. Orathogonality and completensess. Hermitian, unitary, projection operators. Positive operators. Change of orthonormal basis. Orthogonalization procedure.

Direct sum, quotient and tensor product of vector spaces.

Definitions and examples of physically important finite groups. Point groups, multiplication table, subgroups, cyclic groups, center, classes, cosets, Lagrange Theorem. Representations of finite groups, Irreducible representation characters, orthogonality theorem, Schur's character table. Simple applications to small oscillations and selection rules in molecular spectra.

Recommended books :

1.	Mathematics for Physicists	Dennery & Kryzywicki
2.	Complex Variables & Applications	R. V. Churchill
3.	Linear Vector Spaces	R. R. Halmos
4.	Theory of Finite Groups	L. Jansen and M. Boon

PY452 Numerical Methods

1. Roots of algebraic and transcendental equations : One point and two-point iterative methods
   Such as bisection method, inverse interpolation and Newton Raphson methods.

2. Matrix operations and simultaneous linear equations : Matrix addition, multiplication and inversion. Solution of simultaneous linear equations by matrix inversion methods.

3. Interpolation : Linear interpolation, Lagrangian interpolation, Newton's interpolation (different forms).

4. Integration : Newton-Cotes formulae, Gauss quadrature.

5. Ordinary Differential equations : Initial value problem Taylor's algorithm, Euler's methods, Runge-Kutta, and Predictor-corrector methods.

Recommended books :

1.	Introduction to Numerical Methods	T. R. McCalla

2.	Numerical Methods that work	F. S. Acton
3.	An Introduction to Numerical Analysis	K. E. Atkinson
4.	Numerical Recipes	W. H. Press et.al

PY453 Electromagnetic Theory – II

Maxwell's equations of electrodynamics. Time dependent scalar and vector potentials. Gauge transformations. Coulomb and Lorentz gauges. Wave equation. Plane wave solutions. Polarization. Poynting's theorem. Conservation of energy. Momentum and angular momentum of electromagnetic fields.

Reflection, refraction and dispersion. Propagation in conductors and plasmas. Skin effect. Propagation in Waveguides.

Retarded potentials. Lienard-Wiechert potentials. Radiation from a moving point charge and oscillating electric and magnetic dipoles. Multipole expansion for radiation fields.

Introduction to special theory of relativity. Lorentz transformation. Transformations of electromagnetic fields under Lorentz transformations.

Recommended books :

1.	Introduction to Electrodynamics	Griffiths
2.	Electrodynamics of continuous media	Landau & Lifshitz
3.	Classical Fields	Landau & Lifshitz
4.	Classical Electodynamics	J. B. Marion

PY454 Electronics II

Introduction: Number system, digital signal and gates. Boolean algebra and Simplification of Boolean Functions. Minimization by Korong Maps . Don't care conditions.

Combinational logic design: design concepts, Design procedure, Combinational functions and circuits, binary adder-subtractors, magnitude comparator, Decoder, encoder, multiplexers, demultiplexer. Design of combinational circuits using MUX logic.

Sequential logics: latches, Flip-flops: R-S, J-K, Master slave J-K, D type and T type Flip Flop. Characteristic table and characteristic equation, Excitation tables, state equation, state diagram, state reduction, design of a sequence detector using state table.

Sequential circuit design, Registers, Shift registers, Synchronous Counters, Asynchronous Counters, Arbitrary sequence counter design and construction.

Data Converters: Analog to Digital data converters, Digital to analog data converters.

Memory: RAM, Memory decoding, ROM, PLA, PAL, Any other topic (eg. Logic families,

microprocessors, FPGA) at the discretion of the course instructor.

Reference books:

1. Digital Logic and Computer Design, M. Morris Mano, Prentice-Hall India Pvt. Ltd.
2. Digital Electronics: Fundamental Concepts and Applications, C. E. Strangio, PHI.

PY455 Quantum Mechanics – II

Perturbation methods. Rayleigh-Schrodinger perturbation theory, degenerate case, applications, variational methods. WKB approximation. Time dependent perturbation theory, Fermi's Golden rule. Semiclassical radiation theory, interaction of charged particles with electromagnetic fields, polarizability of a system, Photo-electric effect, Einstein's A, B coefficients.

Spin. Stern Gerlach experiment, Pauli's two component equation, addition of angular momenta. Identical particles, symmetrization postulate, Bose and Fermi-statistics, Pauli exclusion principle. Helium atom, Spin in a time dependent magnetic field, Hartree-Fock method. Symmetry in quantum mechanics, space and time displacements, rotations, space inversion, time reversal, Spin-orbit coupling, j-j coupling, Zeeman effect.

Quantum mechanics of molecules, Born-Oppenheimer approximation.

Relativistic Quantum Mechanics, Klein Gordon equation, Dirac equation, properties of Dirac Matrices, positive and negative energy states. Free Dirac particle in an external electro-magnetic field.

Recommended books :

1.	Quantum Mechanics	L. Schiff
2.	Quantum Mechanics	E. Merzbacher
3.	Practical Quantum Mechanics	S. Flugge
4.	Quantum Mechanics	Mathews and Venkatesan
5.	Quantum Mechanics	M. P. Khanna
6.	Principles of Quantum Mechanics	P. A. M. Dirac
7.	Lectures on Quantum Mechanics	G. Baym

PY456 Physics Lab III - Modern Physics Lab.

1. Charge of an electron (Millikon Oil drop)
2. Band gap of a semiconductor
3. Franck-Hertz Experiment
4. Wavelength of Laser (Scale diffraction)
5. Brewster angle (Polarization)
6. Fresnel Biprism
7. Photoelectric effect
8. Microwave Optics
9. e/m of an electron

PY457 Physics Lab IV - Microwave and Nuclear Physics Lab.

1. Klystron
2. Voltage Standing Wave Ratio (VSWR) + Smith chart
3. Directional Coupler + Magic Tee
4. Horn Antenna (radiation patterns)
5. Dielectric constant of solids (von Hippel's method)
6. Dielectric constant of liquids (liquid plunger method)

1. Nuclear Instrumentation Modules
2. GM Counting System
3. Mass attenuation coefficient of β radiation
4. Gama spectroscopy with SCA
5. Mass attenuation coefficient of γ radiation
6. Gama spectroscopy with MCA

Semester 3

PY501 Statistical Mechanics

Basic Statistical ideas : Probability concepts, states of classical and quantum systems.
Isolated systems : Microcanonical ensemble, statistical entropy, most probable state. Systems in thermal and diffusive contact. Conditions for equilibrium. Canonical and grand canonical ensemble, and partition functions.
Thermodynamics : Extensive and intensive variables, laws of thermodynamics, various thermodynamic potentials and their connection with partition functions.

Ideal Fermi and Bose gases : Distribution functions, classical limit. Electron gas in a metal. Black body radiation. Debye theory. Bose Einstein Condensation.

Elementary ideas about phase transitions of different kinds. Examples of some phase transitions.

Recommended books :

1.	Thermal Physics	C. Kittel
2.	Statistical Physics	L. D. Landau and E. M. Lifshitz
3.	Problems in Thermodynamics and Statistical Physics	P. T. Landsberg (Ed.)
4.	Introduction to Statistical Mechanics	F. Reif

PY502 Solid State Physics

Chemical binding, crystal structure, X-ray diffraction, reciprocal lattice and Brillouin zones.

Lattice vibrations, phonons, thermal properties.

Free electron gas, Band theory of solids, Semiconductors, Transport properties.

Magnetism : Dia-, para-, ferro-, antiferro and ferrimagnetism.

Superconductivity : Experimental survey, Thermodynamics of superconductors, London's equations. High lights of BCS theory results.

If time permits : Elastic properties, Dielectric and Ferroelectric materials, Optical properties of solids.

Recommended books :

1.	Introduction to Solid State Physics	C. Kittel
2.	Solid State Physics	J. S. Blakemore
3.	Principles of Solid State Physics	R. A. Levy
4.	Principles of the Theory of Solids	J. Ziman

PY503 Particle Physics

Special theory of relativity and kinematics.

Classification of fundamental interactions and elementary particles. Yukawa's proposal on meson exchange.

Symmetries and conservation laws.

Nother's theorem in classical mechanics, (ii) continuous space time symmetries and associated conservation laws of momentum, energy, angular momentum. Lorentz invariance, (iii) Symmetries in quantum mechanics. Discrete Symmetries, Parity, Charge conjugation and time reversal (iv) Examples of determination of intrinsic quantum numbers, mass and spin, (v) Charge independence of nuclear forces, isospin and strangeness. Application of isospin invariance to pion nucleaon scattering, (vi) Starngeness charm and other additive quantum numbers, (vii) Resonance and their quantum numbers with special reference to pion nucleaon scattering. Gell Mann Nishijima formula.

Violation and symmetries : Isospin violation in electromagnetaic interactions, Parity non-conservation in weak interactions, CP violations and K^oK^o system.

Experimental techniques : Cycolotron, synchrotron, linear accelerators, colliding beam experiments, intersecting storage rings and stochastic cooling. Detectors for photons, leptons and hadrons.

Recommended books :

1.	Introduction to High Energy Physics	Perkins
2.	Introduction to Particle Physics	Griffiths
3.	Invariance Principles & Elementary Particles	Sakurai
4.	Introduction to Particle & Nuclear Physics	T. Ferbel and A. Das

PY504 Optics and Laser Physics

Laser and its applications (introductory).

General Physical principles behind amplification : Spontaneous emission. Stimulated effects. Lasing action Role of feedback (cavity). Comparison with blackbody radiation.

Cavity design : Caussian beam in spherical mirror cavity, longitudinal and transverse modes. Losses and Q-factor.

Different Laser Systems : Gas Lasers, solid state, free electron, liquid state and excimer lasers. Operation principle and design specifics. Output characteristics.

Modelocking, relaxation oscillations and Q-switching.

Single mode laser theory : (a) Rate equation, (b) Semiclassical theories. Ideas about linewidths.

Recommended books :

1.	An Introduction to Laser & their Applications	O'Shea, Callen & Rhodes
2.	Introduction to Laser Physics	K. Shimoda
3.	Laser Physics	M. Sargent, M. O. Scully & W. E. Lamb
4.	Lasers	Siegman
5.	Lasers	Svelto
6.	Quantum Electronics	Yariv

PY506 Physics Lab V - Solid State Physics Lab.

1. x-ray diffraction
2. Ni resistivity
3. Levitation of a Superconductor
4. B-H loop
5. Hall effect
6. Thin film deposition
7. Measurement of thickness of a film
8. Determination of Tc of a Ferroelectric materials

PY507 Physics Lab VI - Laser Physics Lab.

1. Laser characteristics
2. Gouy phase
3. Pancharatnam phase
4. Speed of light
5. PD-PR characteristics
6. Acousto-Optic effect
7. Electro-Optic effect
8. Magneto-Optic effect
9. Laser Doppler Anemometry

Semester 4

PY551 Atomic and Molecular Physics

Hydrogen atom spectrum, introduction to approximation methods for stationary states - perturbation theory and variational principle.
Fine structure of H atom spectrum: spin orbit interaction and other relativistic corrections , perturbation theory estimates, other hydrogen like systems.
Many electron atoms: central field approximation and the periodic table, Hartree- Fock equations, exchange interaction.
Optical spectra of atoms, spectroscopic terms, Fine structure and hyperfine structure, Zeeman effect, electron paramagnetic resonance and nuclear magnetic resonance.
Molecules and clusters, Born Oppenheimer approximation, electron states in Hydrogen molecule ion and hydrogen molecule. Other diatomic molecules. Rotational, vibrational spectra of diatomic molecules, nuclear spin effects.
Polyatomic molecules, symmetry classification of vibrational states, Rotational states, infra-red spectroscopy and Raman spectroscopy. Atom-atom and electron atom collisions.

Titles of the Books

1. Theory of atomic spectra - Condon and Shortly
2. Quantum Mechanics of one and two electron atoms - Bethe and Salpeter
3. Physics of Atoms and Molecules - Bransden and Joachim

PY552 Nuclear Physics

Properties of Nuclear forces-deutron problem, n-p scattering
Nuclear Shell Model and Collective Model
Alpha Decay-Systematics and theory
Beta Decay-Fermi Theory, Selection Rules
Gamma Decay and Internal Conversion, Selection rules
Nuclear Reactions-Cross Sections, Compound Nucleus
Nuclear Fission and Fusion

Recommended books :

1.	Introductory Nuclear Physics	Kenneth S. Krane, John Wiley (1988)
2.	Physics of Nuclei and Particles	E. Segre
3.	Elements of Nuclear Physics	W. E. Burcham, Longman (1986)
4.	An Introduction to Nuclear Physics	W. N. Cottingham and D. A. Greenwood

Optional Papers A

PY554O1 Advances in Optics and Photonics

Syllabus and books recommended for this course will be provided by the faculty teaching this course.

PY554O2 Advanced Condensed Matter Physics

Elastic properties.
Dielectric and Ferroelectric materials.
Optical properties of solids.

Magnetism: Langevin Diamagnetism and Paramagnetism; Van Vleck Paramagnetism, Crystal-field effects; John-Teller effects; Adiabatic demagnetization; Landau diamagnetism, Pauli paramagnetism, The De Haas-Van Alphen effect, Molecular field theory of ferromagnetism; Heisenberg-exchange interaction; Spin Waves; Slater-Puling Curve; Shape, magnetocrystalline and other types of anisotropy; Origin and observation of ferromagnetic domains; Brief introduction to antiferromagnetism & Ferrimagnetism, Different types of magnetic interactions.

Superconductivity: Basic properties of superconductors. Phenomenological thermodynamic treatment.Two fluid model; Magnetic behaviour of superconductors, intermediate state, London's equations and penetration depth, quantized flux. Pippard's non-local relation and coherence length. Ginzburg-Landau theory, variation of the order parameter and the energy gap with magnetic field, isotope effect; electron-phonon interaction and cooper pairs, brief discussion of the B.C.S. theory, its results and experimental verification; (p- and d- wave pairs). Dc and ac Josephson effects, SQUID; Brief introduction to High temperature superconductors.

PY554O3 Quantum Field Theory

Lagrangian and Hamiltonian formulations, variational principle, Euler-Lagnrange equation, invariance of action and conservation laws, review of field quantization, quantization of guage field, invariance of electromagnetic field under Lorentz transformations, electromagnetic field in the Lorentz guage. Proca field.

Interaction of an electron field with the radiation field, discussion of guage invariance and minimal coupling – CPT theorem.

Covariant perturbation theory, S-matrix expansion in the interaction picture, Feynman diagrams and Feynman rules for Q.E.D. Thompson scattering, Compton scattering and Miller scattering. A brief introduction to charge and mass renormalization, Bethe's treatment of Lamb shift.

Recommended books :

1.	Advance Quantum Mechanics	J. Sakurai
2.	Relativistic Quantum Fields. Vols. I & II	Bjorken and Drell
3.	Quantum Field Theory	Mandl
4.	Particles and Fields	Lurie
5.	Quantum Theory of Fields. Vols. I & II	Weinberg

PY554O4 Advanced Electronics

Syllabus and books recommended for this course will be provided by the faculty teaching this course.

Optional Papers B

PY555O6. Advanced Statistical Mechanics

The Ising model: Multicomponent order parameters: The N-vector model: Exactly soluble models: Ising chain and a few other examples.

The reromalization group (RG) approach, Real-space and momentum-space RG methods and application to simple models.

Quantum fluids: BCS theory of superconductivity, liquid helium

Langevin and Fokker-Planck equations, Fluctuation-dissipation theorem. Linear response theory, non-equilibrium phase transitions.

Recommended books :

1.	Equilibrium statistical physics	M. Plischke and B. Bergesen
2.	Modern theory of critical phenomena	S. K. Ma
3.	A modern course in statistical physics	L. E. Reichl
4.	Statistical Mechanics	J. K. Bhattacharya

PY555O7 General Theory of Relativity

Eotvos experiment, principles of equivalence and principle of general covariance.
Tensor algebra and calculus, metric tensor, Christoffel symbols, geodesics covariant differentiation, parallel transport, curvature and scalar tensor.
Einstein's equation, Schwarchild solution, classic tests of general relativity.
Cosmological principle, Robertson-Wallace metric Hubble constant.
Physics of the early universe.

Recommended books :

1.	Theory of Relativity	P. G. Bergman
2.	Gravitation & Cosmology	S. Weinberg
3.	General Relativity & Gravitation	M. G. Bowler
4.	Introduction to General Relativity	Narlikar

PY555O8. Advanced Quantum Mechanics

Syllabus and books recommended for this course will be provided by the faculty teaching this course.

PY555O9. Many Body Theory

Systems of identical particles, Symmetric and anti-symmetric wave functions;

Interacting electron gas, Hartree and Hartree-Fock Approximations:

Second quantization for bosons and fermions, Time-dependent operators-Schrodinger, Heisenberg and interaction representations, Perturbative treatment of interacting electron gas problem, Random phase approximation.

Green function, Self energy, Dyson equation, Equation of motion method.

Diagrammatic perturbation theory, Wick's theorem, Feynman diagrams, applications to: electron gas, and many boson systems with condensed phase.

Recommended books :

1.	Many Electron Theory	S. Raimes
2.	Quantum Many-Particle Systems	J. H. Negele & H. Orland
3.	Quantum Theory of Solids	C. Kittel
4.	Many Particle Physics	G. D. Mahan
5.	The Many-Body Problem	W. E. Perry
6.	The Many-Body Problem	D. Pines
7.	Green Functions in Solids	E. N. Economou
8.	Interacting Fermi Systems	Nozieres and Pines

PY555O10. Phase transitions and Critical phenomena

Syllabus and books recommended for this course will be provided by the faculty teaching this course.

PY555O11. Dynamical Systems and Chaos

Review of Hamiltonian dynamics: Special emphasis on the Hamiltonian-Jacobi theory and action-angle variable. Solutions of Hamilton's equations etc., canonical transformations, phase space dynamics.

Integrable models: Definition of integrability for Hamiltonian systems, KAM theorem, classical perturbation theory.

Chaos in Hamiltonian systems and maps: Simple chaotic Hamiltonian systems, Lyapunov exponents, Poincare sections, power spectra, Kolmogorov entropy and other systems, noise analysis in electrical circuits, measures of chaos in Hamiltonian systems, simple maps, area preserving maps, fixed point and poincare Birkohoff theorems.

Dynamics of dissipative systems: Dissipative systems and turbulence, strange attractors, Lorentz and Rossler attractors.

Non-linear evolution equations and solitons: KDV equations, inverse scattering, application in particle and condensed matter physics.

Brief introduction to semi-classical and quantum chaos, examples from particle physics and condensed matter physics.

Numerical simulation of chaotic systems.

Text books :

Chaos and Integrability in Non-linear Dynamics	by M. Tabor (Wiley)
Regular and stochastic motion	by Lichtenber & Lieberman
Chaos in Guage Theories	by Biro Muller (World Scientific)

PY555O12. Semiconductor Physics

Intrinsic and Extrinsic Semiconductors. Chemical binding in Semiconductors Typical Examples of Energy Band Calculations, Kinetic phenomena/transport properties, Diffusion of electrons and holes and recombination effects
Characteristic Properties of Semiconductors and their determination.

Elemental Semiconductors (Ge, Si, Se and Te) and their properties, Important semiconductor compounds. Doping/Implantation in Semiconductors.

Defects in Solids: Grain and twin boundaries, Point Defects, line defects and planar defects or dislocations and their effects on solid state properties. Radiation damage in Solids and its effects on lattice and electronic properties, colour centres. Detection and study of defects by XRD, Electron Microscopy, and RBS/Channeling.

Introduction to Disorder: substitutional and structural disorder, short range and long range disorder.

Recommended books :

1.	Introduction to Solid State Physics	C. Kittel
2.	Semiconductors	R. A. Smith
3.	Energy Bands in Semiconductors	D. Long
4.	Solid State Electronics	S. Wang

PY555O13. Probes of Condensed Matter

Investigation of structural and physical properties of solids using the following experimental techniques:

X-ray diffraction, neutron scattering, ion-beam channeling, electron microscopy, EPR/NMR/NQR, Mossbauer spectroscopy, positron annihilation, and other nuclear techniques. Thermal properties-specific heat thermal conductivity, thermal expansion, Differential

Scanning Calorimetry Transport properties-ac and dc conductivity, Hall effect, magnetoresistance
Magnetic susceptibility, Magnetisation, Hystresis
Raman scattering and other optical probes

Recommended books :

1. X-ray Diffraction — H. P. Klug and L. E. Alxander
2. Methods of Experimental Physics Vol.21-Solid –State Physics
3. Nuclear Methods — J. W. Mundy et. al. (Editors)
4. Handbook of Microscopy, Applications in Materials Science.
5. Solid State Physics and Chemistry — S. Amelinckx et al. (Editors)
6. Techniques of Metals Research — R. F. Bunshah (Editor)
7. Other books as prescribed by the instructor

PY555O14. Liquid Crystals

Mesomorphism in anisotropic fluids and amphiphilic systems: Nematic, cholestric and smectic (A, B, C and other exotic) phases of long rod like molecules; Nemataic and columnar phases of discotic molecules; Micelles; Hexagonal, cubic and lamellar phases of amphiphilic molecular systems.

Elastic continuum theory of liquid crystals; Defects and dynamics; Hydrodynamics and equilibrium theories.
Phase transitions and critical phenomena in liquid crystals; Phase diagrams of liquid crystalline mixures; Polar liquid crystals, frustration and re-entrant phenomena; Glassy states; Ferroelectric liquid crystals.

Liquid crystals in electric and magnetic fields; Electro-hydrodynamic instabilities; Kerr effect; Electro- optical effects; Twisted nematics and smectics.

Magnetic resonance and dielectric response in liquid crystals; Order parameters and molecular motions; Studies on oriented solutes.

Liquid crystal displays (active matrix, passive matrix and RMS responding displays) and optical communication devices; Application of liquid crystals in image and signal processing.

Recommended books :

1. The Physics of Liquid Crystals (2^{nd} Edition) — P. G. de Gennes and J. Prost
2. Liquid Crystals (2^{nd} Edition) — S. Chandrasekhar
3. Thermotropic Liquid Crystals-Fundamental — G. Vertogen and W. H. de Jeu

PY555O15. Quantum optics

Quantum theory of Radiation – second quantization; Quantum statistical description of the radiation fields; Coherent states; Photon correlations; Squeezed states and applications; Theory of several process using second quantized formalism; spontaneous emission and stimulated emission; second order process, multiphoton absorption, and ionization with description of some experimental results.

Recommended books :

1.	Introduction to Quantum Optics	Baldwin
2.	Statistical Theory of Radiation	Louisell
3.	Coherence & Quantum Optics	Mandel & Wolf

PY555O16. Optoelectronics

Introduction; Review of optics

Optical waveguides: Planar slab waveguide and circular waveguide (optical fiber); modes, numerical aperture; attenuation and dispersion in waveguides; fabrication and characterization of waveguides; coupling between optical sources and waveguides

Semiconductor optoelectronics: Basic semiconductor and device physics, optical properties of semiconductors, p-n junctions, optical absorption, amplification, semiconductor lasers, photo-detectors and noises, quantum well devices

Optoelectronic devices: EO effect, phase and intensity modulator, interferometric and electro-absorption modulator

Optical communication system

Recent trends: Optoelectronic fibers; organic optoelectronics; photonic crystal fibers

Reference books:

- Introduction to fiber optics, A. Ghatak and K. Thyagarajan, Cambridge University Press, Cambridge, UK 1998
- Fundamentals of photonics, B.A. Saleh and M.C. Teich, Wiley Interscience, NJ, USA 2007
- Fundamentals of optoelectronics, C.R. Pollock, Irwin Inc., USA 1995
- Quantum electronics / Optical electronics, A. Yariv
- Optoelectronics, Wilson and Hawkes
- Optoelectronics and Photonics, Kasap
- Fiber optic communications, Palais

PY555O17. Nonlinear Spectroscopy

Brief introduction to tunable laser sources and linear spectroscopy; Physical principles underlying various spectroscopic techniques and line broadening phenomena; Resonant two

and three level models for nonlinear response to intense laser radiation. Saturation spectroscopy, hole burning; coherent Raman spectroscopy, resonant four wave mixing for coherent anti-stokes Raman scattering; multiphoton ionization methods; life time measurements, Quantum beat spectroscopy, Hanle effect; Picosecond and femtosecond spectroscopic techniques for probing ultra fast dynamics, four wave mixing for determining dephasing times using intense incoherent light.

Recommended books :

1.	Introduction to Nonlinear Spectroscopy	M. D. Levenson
2.	Nonlinear Laser Spectroscopy	V. S. Letokhov & V. P. Chebotayev
3.	Laser Induced Dynamic Gratings	H. J. Eicher, P. Gunter & D. W. Pohl

PY555O18. Lie Groups & Lie Algebra

Continuous groups, Lie groups, examples like transition and rotation groups. Lorentz group, SU(2) 7 SU(3) groups. Statements of Lie's theorem, Lie algebra, standard form of Lie algebra. Casimir invariants, roots and cartan classification of semi-simple Lie groups. Root diagrams for SU(2), SU(3) and SU(N). Dynkin diagrams.

Basic and irreducible representations of SU(2) & SU(N). Young tableau and its uses for Clebsch-Gordon decomposition. Classification of elementary particles in terms of representations of SU(3), SU(4) and SU(6), Dynamical symmetries, symmetry group of hydrogen atom.

Recommended books :

1.	Classical Groups	Wybourne
2.	Lie Groups & their Lie Algebra	Gilmore
3.	Continuous Groups of Transformations	Eisenhart

PY555O19. Ultrafast Phenomena

Syllabus and books recommended for this course will be provided by the faculty teaching this course.

PY555O20. Advanced Quantum Mechanics and Many body Theory

Syllabus and books recommended for this course will be provided by the faculty teaching this course.

PY555O21. Low-temperature Techniques

Production of low temperatures; Principles of gas liquefaction & basic thermodynamics; Liquefaction cycles; Liquefaction and refrigerator systems; Philips liquid nitrogen and liquid

helium plants, storage and transfer of liquid gases; Heat exchangers; Cooling with liquid helium; Dilution refrigerators; Adiabatic demagnetization; Nuclear demagnetization; Heat transfer; Temperature measurement and control; Thermal contact and isolation; Design of cryostats, vacuum techniques and materials for low temperature work. Devices based on superconducting properties.

Recommended books :

1.	Experimental Techniques in Low Temperature Physics	G. K. White
2.	Experimental Cryophysics	F. E. Hoare et al.
3.	Cryogenic Systems	R. Barren

PY555O22. Nanoscience and Nanotechnology

Introduction
Historical Perspective; Finite size effects on physical properties (Optical, Magnetic, Mechanical and Transport properties) of materials; Properties of quantum structures such as quantum dots, quantum wells, nanowires, layered materials.

Fabrication of nanostructured materials and devices
Top-down and bottom-up approaches of nanomaterial synthesis; Physical and Chemical Vapor deposition, Vapour-liquid-solid synthesis, Chemical synthetic protocols; Sol-gel; Hydrothermal synthesis; Mechanical milling; Nanocluster deposition; Other novel methods of nanomaterial synthesis.
Lithographic techniques: electron beam lithography, x-ray lithography, nanoimprint lithography, dip pen lithography.

Characterisation
Scanning probe and tunneling Microscopy; X-ray diffraction; Electron Microscopy; scanning near field optical microscopy; X-ray photoelectron spectroscopy; photoluminescence and Raman spectroscopy with emphasis on information that can be extracted about nanomaterials such as size and shape of particles, crystal structure, nanoscale optical, transport and magnetic behavior.

Special materials
Graphene and other layered materials, carbon nanotubes etc.

Applications
Single electron devices; sensors; resistive memories; nano-electro mechanical systems; plasmonics; drug delivery; therapy and diagnostics; energy harvesting, storage and generation; superhydrophobic surfaces.

Recommended textbooks

Introduction to Nanotechnology , by Charles Poole and Frank Owens (Wiley publishers)

Nanotechnology: Principles and Practices by Sulabha K. Kulkarni, (Springer)

Fabrication Engineering at the Micro- and Nanoscale (The Oxford Series in Electrical and Computer Engineering) 4th Edition by Stephen A. Campbell

PY555O23 Advanced Particle Physics

Advanced Particle Physics (M.Sc. IVth Semester Optional B)

Introduction to Lie Algebra of SU(2) and SU(3) Multiplets
Gell-Mann-Okubo Mass formula
Quark and Quarkonium states
Justification of color

Relativistic kinematics
Scattering cross-section, Life-times
Introduction to S-matrix,
Feynman diagrams and Matrix elements

Electromagnetic form factors,
Basic idea on parton model and deep inelastic scattering

Weak Interactions, V-A theory,
Pion decay, Muon decay
Charged current Neutrino-electron scattering
Neutral current Neutrino-quark scattering
Cabibbo Theory, CKM mechanism,
Gauge Symmetries
Ideas about spontaneous Symmetry breaking
Salam-Weinberg model and its simple tests

Recommended Books:

1. Quarks and Leptons: Halzen and Martin
2. Gauge Theory of Weak Interactions: Walter Greiner and Berndt Muller
3. An Introduction to standard model of particle physics: W. Cottingham, D. Greenwood

PY555O24 Quantum Theory of Solids

- Second quantization
- Fermion Fields, Hartree-Fock Approximation, RPA, Plasmons
- Quantization of Lattice in 3 dimensions and phonons, Specific eat.
- Electron-phonon interaction and resistivity in metals, Electron-phonon interaction in ionic solids and polar semiconductors and Polarons
- Quantization of Spin wave, Ferromagnetic and Anti-ferromagnetic Magnons, Specific heat.
- Superconductivity and BCS theory
- Green's functions and their applications in solid state physics (one or two examples)

Books :

1. Quantum theory of solids – C. Kitten
2. Many particle physics – G. Mahan

PY555O25 Signals and Systems

Basic Continuous-time and Discrete-time signals; LTI Systems and their properties

Time-domain analysis of LTI Systems : Convolution of continuous-time and discrete-time signals; Impulse response and convolution representation of continuous-time and discrete-time signals; modeling and realization of systems described by linear differential and difference equation with constant coefficients.

Frequency domain analysis of continuous time LTI systems : Response of systems to complex exponential signals, Fourier series representation of periodic signals Fourier Transform of a-periodic signals, properties of the Fourier Transform, Frequency response of systems described by linear differential equations with constant coefficients and Form-II realization, Analysis of First and Second order systems.

Laplace Transform analysis of continuous time signals : The Laplace Transform, its region of convergence, properties and its relation to FT; System transfer function, Laplace transform analysis of systems described by linear differential equations with constant coefficients, pole-zero plots and their interpretations.

**Analysis of Ideal filters, filter transformations and their realization-Butterworth, Chebychey, elliptic and inverse filters*

Frequency domain analysis of discrete-time systems : Discrete time Fourier series and Fourier Transform and their properties;
**Discrete Fourier Transform (DFT), properties of DFT, FFT algorithms*

z-Transforms: Definition and properties, rational z-transforms and their regions of convergence, inverse z-transform, z-transform properties, System response function for systems characterized by linear difference equations with constant coefficients.

Sampling: The sampling theorem and aliasing, interpretation in frequency domain
Reconstruction of signals from its samples using interpolating filters-ideal low-pass, zero- and first-order hold.
Frequency domain sampling, decimation and interpolation
Realizztion of discrete-time systems for sampled signals from continuous time specifications.

Probability, random signals, spectral densities, white noise and *1/f* noise, separation of signals from noise.

Signals and Systems: A. V. Oppenheim and A. S. Willsky, Prentice Hall
Digital Signal Processing- A Computer-based Approach: S. K. Mitra, McGraw-Hill
Signals Systems and Transforms: C. L. Phillips and J. M. Parr, Prentice Hall
Introduction to Signals and Systems: D. K. Lindner, McGraw-Hill
Introduction to Digital Signal Processing: Johny R. Johnson

Optional at the discretion of the instructor, if time permits

PY555O26 Advanced Solid State Physics Lab

1. Electrical resistivity of Ni in the temperature range 77K – 770K to separate out different scattering contributions to total resistivity and to study the magnetic phase transition.
2. Thermoelectric power in doped semiconductors down to 77K for the measurement of band gap and the type of carriers.
3. Hysteresis loops of soft and hard magnetic materials using electronic integrator method.
4. Ferromagnetic resonance measurements to determine magnetic anisotropy, spin re-orientation temperature and spin-wave excitations in magnetic systems.
5. Meissner and magnetic suspension.lavitation effect and / or zero – resistance phenomenon in high temperature superconductors.
6. Determination of elastic constants of a cubic crystal by ultrasonic velocity measurements.

PY555O27 Physics of Materials

Chemical bonding in solids, Transition metal oxides: Structure of oxides and methods of structure determination, Perovskites, bronzes, ferrites and various oxide families, Metal – insulator transition. Superconducting materials, Ferroelectricity and related phenomena, Magnetism in oxides, Glasses and glass ceramics.

Metals and alloys: Phase diagrams of single component, binary and ternary systems, diffusion, nucleation and growth. Diffusional and diffusionless transformations. Mechanical properties.

Metallic glasses. Preparation, structure and properties like electrical, magnetic, thermal and mechanical, applications.

Liquid Crystals: Mesomorphism of anisotropic systems, Different liquid crystalline phase and phase transitions, Few applications of liquid crystals.

Polymers: Physical properties and applications of polymers.

Recommended books :

1.	Inorganic solids	D. M. Adams (John-Wiley)
2.	Phase transformation in metal and alloys	D. A. Porter and K. E. Easterling
3.	Fundamental of thermotropic liquid crystals	deJen and Vertogen
4.	Electronic properties of polymers	H. Kuzmany and S. Roth
5.	Metallic glasses	K. Moorjani

PY555O28 Ferroelectrics & Electroceramics

Nature of ceramics. Processing and Microstructural Characterization of ceramic materials. Linear and nonlinear dielectrics. Pyro-, piezo- and ferroelectricity in solids. Ferroelectrics as polar dielectrics. Theories of Ferroelectric phase transitions. Various families of ferroelectrics-Barium Titanate. Lead Titanate. KTP etc.

Domains in ferroelectrics and their experimental observation: Polarization switching mechanisms.

Applications to memories and displays, Non-switching applications including electro-optic, nonlinear-optic, piezoelectric, pyroelectric and elasto-optic applications. Emerging areas such as nanomaterials.

Solid State Ionic materials, Structure, Electrical and electro-chemical Properties and applications to fuel cells, batteries and chemical sensors.

Recommended books :

1.	Introduction to Ceramics	Kingrey
2.	Principles and Applications of Ferroelectric and Related Materials	Lines and Glass
3.	Ferroelectric Materials & their Applications	Xu
4.	Superionic Solids-Principle and Applications	S. Chandra

PY555O29 Cavity Quantum Electrodynamics

Atoms in free space and in a generalized cavity. Weak and strong interactions regimes of cavity QED. Perturbative domain of cavity QED. Fermi Golden Rule, enhancement and inhibition of spontaneous emission, frequency shift. Atom near a mirror, atom in FP cavity. Atom-feild interaction in a high-Q cavity. Vacuum field Rabi splittings. Experimental results on enhancement/inhibition of spontaneous emission, vacuum Rabi splitting. Other cavity QED effects.

Recommended books :

To be prescribed by the Instructor.

PY555O30 Coherence & Quantum Interference

Coherence induced novel effects: Electromagnetic field induced transparency; ultra high refractive index, lasing without inversion, inversion without lasing, control of efficiency of nonlinear optical output by extra resonant intense radiation, elimination of Kerr-nonlinear effects, correlated emission laser. Quantum interference, EPR arguments on quantum interference, Bell's inequality, coincident detection, two photon interferrometry, experimental verification of Bell's inequality, quantum non-demolition measurement, quantum transportation, quantum eraser, quantum computer.

Recommended books :

To be prescribed by the Instructor.

PY555O31 MEMS Theory & Laboratory

Introduction
- An overview of microelectromechanical devices and technologies
- Physics in microscopic world, scaling issues
- MEMS in Electrical technology
- Applications : RF MEMS, Optical MEMS, Lab on a Chip, MEMS based Sensors

Micromachining technologies
- Basics of microfabrication technologies
- Bulk micromachining
- Surface micromachining
- Materials encountered in micromachining processes and their properties
- Silicon in micromachining
- Process steps involved in micromachining
- Etching for micromachining
- Packaging and related issues

Introduction to Microsystem Design
- Modeling Strategies.
- CAD for micromachining
- Introduction to ANSYS.

Case Study
- RF MEMS Switch

Textbooks
1. MEMS & Microsystems, Design and Manufacturing, Tai- Ran Hsu, TMH.
2. RF MEMS: Theory, Design, and Technology, Gabriel M. Rebeiz, Wiley-Interscience.

Reference Books

1. Fundamentals of Microfabrication, Marc Madou, CRC Press, ISBN 0-8493-9451-1
2. Introduction to Microelectromechanical Microwave Systems, H.J. De Los Santos, Artech House.
3. Microsystem Technology W.Menz, J. Mohr, O.Paul, Wiley-VCH.

Laboratory

1. Introduction

- CAD tools for MEMS design and simulation.
- Familiarisation of ANSYS: modeling, material attributes, meshing and elements, choice of solvers, loads and load steps, post processing.
- Coupled field simulation.
- 3D structure drawing in ANSYS
- Design Examples.

2. **Specific cases**

- Simulation of a cantilever structure – Model, Harmonic and Transient analysis.
- Cantilever based chemical sensor design – by mass sensing route.
- Cantilever based RF switch
- Membrane based RF switch
- Membrane based piezoresistive pressure sensor
- Interdigitated structure based MEMS devices
- Optical micromirror
- Any other examples suggested by the instructer.

PY555O32 Integrated Optics Theory & Lab

Semiconductor Lasers: Optical emission - Optical absorption and gain - Gain co-efficient – Quasi Fermi levels and inversion - The semiconductor diode lasers - Modulation in semiconductor lasers - DFB and DBR lasers.
Optical wave guides: The planar wave guide - The longitudinal wave vector β. - Eigen values for the slab waveguide - Optical mode confinement. - Systematic wave guide - Properties of modes - Number of modes in a wave guide - The numerical aperture.
Spatial modes in a step index waveguides: TE and TM modes - Hybrid modes - LP modes - V number and cut-off - HE_{11} mode - Total number of modes in a step index wave guide - Power confinement in a step index wave guide.
Coupling: Coupling of source to fiber using Lens, Prism and grating.
Optical devices: Waveguide modulators: Linear electro-optic effect, and the electro optic phase modulators – Electro optic intensity modulators; Electro-absorption modulators; Acousto-optic modulators.
WDM: Fiber couplerss – Waveguide couplers – Interferometer Multiplexer – Grating filter – Tunable source – Tunable filter
Optical Amplifiers: Semiconductor optical amplifiers. Erbium-doped fiber amplifier.
Optical Detectors – Detector noise.

References

1."Fundamentals of Optoelectronics," C.R. Pollock
2."Fundamentals of Optical Waveguides" Katsunari Okamoto
3. "Optical Electronics in modern communications," A.Yariv
4. "Optoelectronics: an introduction to materials and devices," J.Singh
5. “Laser Electronics” J.T.Verdeyen
6. “Optical Fiber Communications” G. Keiser

Laboratory

1. Connectorization of fibers.
2. Measurement of losses in a fiber.
3. Measurement of Information Capacity of a digital optical communication link
4. Driver for a VCSEL.
5. Fabrication of a planar wave guide.

PY555O33 Advanced Computational Techniques

Syllabus and books recommended for this course will be provided by the faculty teaching this course.

PY555O34 Nanostructuring by various methods (lasers, ion beams, sputtering etc.)

Syllabus and books recommended for this course will be provided by the faculty teaching this course.

PY555O35 Optical Cooling

Brief survey of atomic spectra, including hyperfine interaction. Atomic ensemble, its interaction with resonant radiation, resonance fluorescence, energy momentum conservation, spontaneous emission line width, thermodynamic equilibrium. Optical pumping to new equilibrium state.

Collision studies, microwave transitions, applications of optically pumped ensembles: Magnetometer, atomic clocks, weak interactions. Coupling of centre of mass motion with internal excitation by radiation and its use in cooling atoms, various cooling mechanisms: Doppler cooling, Optical molasses, Thermodynamic limit to lowest temperature, light shifts, gradient cooling – Sisphus cooling, optical pumping and cooling, coherent population trapping states, velocity selective coherent population trapping states. Ultra cold state, velocity distribution and quantum mechanical properties. Atomic maser and applications of cold beams.

Recommended books :

To be prescribed by the Instructor.

PY555O36 Optical Resonance and Two-level Atoms

Resonant interaction of simple atomic systems with intense radiation field; Optical coherent transients such as free induction decay, optical nutation, photon echo, stimulated photon echo, and Ramsey fringes from separated fields; Area theorem, self induced transparency; Spontaneous emission and resonance fluorescence with excitation by intense radiation; Super radiance and cooperative phenomena; optical bistability, chaos in optical systems, spatial temporal patterns.

Recommended books :

1.	Two Level Atom	Allen & Eberly
2.	Lasers	Eberly & Milloni
3.	Lasers & Quantum Optics	Sargent & Meystre

PY555O37 Nonlinear Optics

Coherent interactions of radiation field with gaseous and solid state systems

Nonlinear optics : Introduction, second and third harmonic generation, third order nonliniarites, parametric amplification and oscillation, phase conjugate optics, anisotropic nonlinear media, dispersive media.

Guided wave optics : Planar dielectric wave guides, coupling of radiation to optical wave guides, distributed feedback lasers, electro-optic modulation and mode couplings in wave guides, fabrication of planar optical wave guides.

Optical fibers: step index and graded index fibers, attenuation, dispersion and propagation of light in fibers.

Nonlinear phenomena in guided wave geometry, Quasi phase matching, cascaded second order nonlinearity. Nonlinear optical fibres. Solitons in optical fibres.

Recommended books :

1.	Principles on Non-linear Optics	Y. R. Shen
2.	Non-linear Optics	N. Bloembergen
3.	Non-linear Optics	R. W. Boyd
4.	Non-linear Optics	Butcher & Cotter

PY555O38 Mathematical Methods III

Part 1. Topology and Differential Geometry [25 lectures]

1. Simple introduction to basic Topology: Topological Spaces , Topological Invariants, Topological Equivalence. (10 Lectures)

2. Homotopy: Homotopy Type, Paths, the Fundamental Group, Homotopy groups. Uses of Homotopy in Physics.(Five Lectures)

3. Differentiable Manifolds: Definition of Manifold, Calculus on Manifolds, Differential forms, Connections, Curvature, integration on Differential Forms, Electrodynamics in terms of differential forms.(10 Lectures)

Part 2:Group Theory and Representations[20 lectures)
a) Review of Group Theory and Representations, Representations of finite groups. Application to crystallography.(8 lectures)

b) Lie Groups and Lie Algebras and their representations.(6 lectures)

c) Familiar Lie groups and Lie Algebras in Physics. (6 Lectures)

Books:

1. Main Text: Lectures on Advanced Mathematical Methods in Physics, Sunil Mukhi and N. Mukunda, World Scientific (2010).

2. Topology by E.M. Patterson, University Mathematical Texts .
3. Differential Geometry for Physicists and Mathematicians, Jose P. Vargas World Scientific (2014).
4. Mathematics for Physics, Michael Stone and Paul Goldbart, Cambridge University Press (2009)
5. Falicov,L.M. Group Theory and Its Physical Applications (Lectures in Physics)(Univ of Chicago Press,1966)
6. Lichtenberg, D.B, Unitary Symmetry and Elementary particles (Academic Press,1978)

PY555O39 Experimental methods

Important classes of materials: Metals; Alloys; Metallic composites; Polymers; Ceramics, Glasses and crystals; Preparation of materials: glasses, crystals, thin films.

Phase diagrams, the Phase Rule; soluble, partially soluble and insoluble systems, Solid solutions and compounds; single and multiphase materials; Ordering phenomena in substitutional alloys; super lattices

Characterization : Metallography, microstructural characterization using Optical microscopy; Diffraction techniques; Production of X-rays, crystal Structure determination using X-rays, Neutrons and Electrons; Thermal analysis using DSC,DTA,TGA; Phase transitions; Electron Microscopy: SEM, TEM, STM; Compositional characterization using EDAX, WDS

Properties of Materials:
Electrical and galvanomagnetic properties, Ionic conductivity, Production of magnetic fields and Magnetic properties of materials; basics of Multiferroics - temperature dependence of electrical and magnetic properties; DC and AC methods; Use of Lock-in-amplifier to improve

Signal/noise ratio. Modern experimental techniques using computer interface with data acquisition for automation.

Thermal properties : Specific heat; Thermal sensors, Thermal expansion, Thermal conductivity; Elastic/mechanical properties; Defects in solids: Point defects, vacancies, dislocations; Burgers vector; effect of Irradiation, Strength of materials; work hardening; failure mechanisms; fatigue; micro- and nano-indentation, typical engineering applications.

Vacuum techniques: Vacuum Pumps, pressure gauges; Thin films & applications: Methods of deposition, measurement of thickness, Optical absorption using spectrophotometer, optical properties of materials; Surface studies using AFM, DFM, SNOM

Cryogenic techniques: Cryogenic fluids, cryostats, feed-throughs, temperature control to low temperatures, Properties at low temperatures

Reference Books:

Experimental Physics: Modern Methods by R. A. Dunlap (1997 Ed.) – Oxford University Press
Solid State Chemistry & its applications by Anthony R. West (2007 Ed.)– John Wiley & Sons
Advanced practical physics by Worsnop and Flint
Building Scientific Apparatus by Moore, Davis, Coplan and Greer
Experimental Techniques for Low-Temperature Measurements - Jack Ekin(2006)