DEPARTMENT OF PHYSICS
M.PHIL./PH.D. SYLLABUS

Semester	Code	Course Name	Credits
I	PHY-RS-C501	Research Methodology and computational techniques	4
	PHY-RS-C502	Research Proposal and Preparation	4
	PHY-RS-E503	Advances in Physics*	4
II& III	PHY-601	Dissertation/Project	12

*List of elective papers is given below.

List of Elective Papers

Code	Title
PHY-RS-E503	Atomic, Molecular and Optical Physics
PHY-RS-E504	Solid state Spectroscopy
PHY-RS-E505	High Energy Physics
PHY-RS-E506	Semiconductor Physics and Devices
PHY-RS-E507	Quantum Optics & Quantum Information Processing
PHY-RS-E508	Nonlinear Science: Solitons And Chaos
PHY-RS-E509	Magnetism and Superconductivity
PHY-RS-E510	Semiconductor Laser Physics
PHY-RS-E511	Solar Energy and its Utilization
PHY-RS-E512	Physics of Nanomaterials and Devices
PHY-RS-E513	Plasma Physics
PHY-RS-E514	Thin Film Technology
PHY-RS-E515	Quantum Field Theory
PHY-RS-E516	General Relativity and Cosmology

PHY-RS-C501: Research Methodology and Computational Analysis

Unit I: Computational Techniques

Representing numbers in a computer – machine precision – errors and approximations – concept of computer language – Fortran 90 programming – Matlab syntax – Mathematica syntax, Origin Syntax .Random number generator – Monte Carlo simulation, Fast Fourier Transform.

Unit II: Numerical Techniques

Solution of polynomial and transcendental equations, ordinary differential equations with initial conditions, matrix algebra and simultaneous equations, eigenvalues and eigenvectors of a real symmetry matrix.Numerical differentiation and integration – trapezoidal rule – Simpson' rule – Gaussian quadrature formula.Numerical solution of ordinary differential equations solution by Taylor's series – Euler's method – RungeKutta method with Runge's coefficients. Numerical solution of partial differential equations using finite difference method.

Unit III: Curve Fitting

Error analysis, Importance of sampling, Curve fitting – evaluation of linear parameters – weighted least square fitting – Binomial, poission, Normal distribution, Chi-square goodness of fit test, Random Spectral data analysis.

Unit IV: Technical Writing

Language of Science and technology, Technical presentations design and delivery, Collecting materials for research, Organization of research paper/dissertation – symbols – the observations – tables and figures – equations – thestyle – sentence length – word length – page and chapter format – referencing.

References:

1. R.P. Mishra *Research Methodology: a handbook*, Concept Publishing Company, New Delhi, 2002.
2. Jonathan Anderson and M.E. Poole: *Assignment & Thesis Writing*, John Wiley, 2002.
3. S.D. Sharma: *A Textbook on Scientific and Technical Communication Writing for Engineers and Professionals,* Sarup and Sons, 2007.
4. Robert A. Dey and B. Gastel: *How to Write and Publish a Scientific Paper*, Cambridge, 2006
5. Thomas R. Mc Calla: *Introduction to Numerical methods and Fortran programming*, John Wiley & Sons, Inc. New York 1967.
6. Anthony Rabston: *A First course in Numerical Analysis,* McGraw Mill Co., New York 1965.
7. Evous, D.J*: Software for Numerical Methods,* Academic Press Inc. New York, 1974.
8. E.V. Krishnamurthy: *Numerical Analysis and algorithm,* Wiley Eastern, 1982.
9. S.S. Sastry: *Introduction methods of Numerical analysis,* Prentice Hall of India P. Ltd., 1977.
10. M.K. Jain: *Numerical analysis for Scientists &Engineers*, SBW Publishers, Delhi 1971.
11. Kurt Binder and D.W. Heermann: *Monte Carlo Simulation in Statistical Physics: an Introduction,* Springer, 2010.

PHY-RS-C502: Research Proposal and Preparation

This is a non-lecture paper in which the respective teacher will explain the student about how to prepare synopsis or research proposal. Students will also do literature survey for the relevant topic(s) that he/she is interested in. At the end of the semester he/she will give a presentation and a write-up. He/she will be evaluated on the basis of that.

PHY-RS-E503: Atomic, Molecular and Optical Physics

Unit I: Introduction

Basic Optics: Fourier optics, two beam and multiple beam interference, Fabry-Perot interferometer. Interaction of radiation with matter, light amplification and gain saturation. Laser rate equations, three level and four level systems; Free electron laser, Optical

Resonators: resonator stability; modes of a spherical mirror resonator, mode selection; Qswitching and mode locking in lasers.
Atomic Collisions: Types of collisions, channels, thresholds, cross-sections, potential scattering, general features, Born approximation. Phase shift analysis (low energy), Atomic collisions in solids, nuclear and electronic stopping.

Unit II: One, two and many electron atoms
Schrodinger equation, para and ortho states, Pauli Exclusion Principle, Excited states, doubly excited states, Auger effect, resonance. Central field approximation, Thomas-Fermi model, Hartee-Fock methodand self-consistent field, Hund's rule, L-S and j-j coupling.
Interaction with Electromagnetic fields: Selection rules, spectra of alkalis, Helium and alkaline earths, multiplet structure, Zeeman and Stark effect, Paschen-Back effect

Unit III: Molecular Structure and spectra
Molecular Structure: General nature, Born-Oppenheimer separation, rotation and vibration ofdiatomic molecules, electronic structure of diatomic molecules, structure of polyatomicmolecules.
Molecular spectra: Rotational, vibrational, electronic spectra of diatomic molecules, electronicspin and Hund's cases and nuclear spin, Raman and Infra-Red spectrums.

Unit IV: Resonance Spectroscopy
NMR: Principle, chemical shift, shielding, relaxation process, chemical & magnetic non equivalence, local dia magnetic shielding and magnetic anisotropy, spin splitting, Pascal triangle, coupling constant, mechanism of coupling, quadrapoule broadening and decoupling. Effect of stereochemistry on the spectrum, shift reagent, applications
ESR: Principle and correlation with proton magnetic resonance, derivative curves, g values, hyperfine splitting, Applications.EPR of triplet states; Structural applications to transition metal complexes.
Mössbauer Spectroscopy: Principle, Spectral parameters (Isomer shift, electric quadrupole interactions, magnetic interactions), temperature-dependent effects, structural deductions for iron and tin complexes, applications. Basic concepts of FTIR and Raman and its applications to various materials

References:

1. B. H. Bransden and C. J. Joachain, *Physics of Atoms and Molecules,* Longman, 1996.
2. G. K. Woodgate, *Elementary Atomic Structure*, Clarendon Press, 1989.
3. F. L. Pilar, *Elemntary Quantum Chemistry*, McGraw Hill, 1990.
4. H. E. White, *Introduction to Atomic Spectra,* Tata McGraw Hill, 1934.
5. C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy,* Tata McGraw Hill, 1994.
6. J. M. Hollas, *Modern Spectroscopy*, John Wiley & Sons, 2004
7. C. N. Banwell and E.M. Mc Cash, *Fundamentals of Molecular Spectroscopy*, Tata McGraw Hill, 1994.
8. R.J. Abraham and J. Fishe and P. Loftus, *Introduction to NMR Spectroscopy* John Wiley & Sons. 1994.
9. J. A. Weil, J.R. Balton & J.E. Wertz, *Electron Paramagnetic Resonance: Elementary Theory and Practical Applications.* John Wiley and Sons, 1994.

PHY-RS-E504: Solid state Spectroscopy

Unit I: Atomic Spectroscopy

Free Ion: The Free-ion; free ion terms for d2 and f2 configuration; Spin-orbit Coupling; Energy level states for d2 and f2 configuration; Ground states for fN configuration; Rare earthfree-ions; Coloumb and Spin-orbit energies - Intermediate coupling.

Ligand Field: The concept of ligand field; The scope of ligand field theory; The Physicalproperties affected by ligand fields; Ligand fields and f electron systems; The magneticproperties of actinide element compounds.

Unit II: Group Theory

Sketch of Group theory; Kramer's degeneracy; Crystal field splitting - D3hsymmetry; Product of two representations - Selection rules; Examples of selection rules -D3h symmetry; Applications of theoretical results to the analysis of experimental data.

Unit III: Optical Spectra

Rare Earth Ions: Judd-Ofelt theory for the parametrization of intensities; Radiative properties; Upconversions in rare earths; Luminescent properties of Eu3+ and Tb3+ ions.

Trivalent Rare Earth Ions in Crystal Field: Introduction; Parametrization of crystal field splittings; The spin Hamiltonian; Examples of crystal field parametrization; Model description of the crystal field.

Unit IV: Optical Instruments and Spectral Analyses

Rare Earth Lasers: Introduction; Principles of laser action; Typical rare earth lasers; Nd:YAG and Nd:glass lasers; Energy level scheme of the Nd in YAG.

Spectral Analyses: Spectrographs and Spectrophotometers for UV, VIS and IR regions; Absorptionand Emission spectra; Temperature dependent spectra; Axial, Sigma and Pi polarization spectral measurements.

References

1. B.N. Figgis; *Introduction to Ligand Fields*, Wiley Eastern Limited, New Delhi, 1976.
2. S. Hufner, *Optical Spectra of Transparent Rare Earth Compounds*, Academic Press, London (1978).
3. J. W. Robinson: *Atomic Spectroscopy*, M Dekker, New York, 1990.
4. Joseph Sneddon et al.*: Lasers in analytical atomic spectroscopy*, Wiley VCH, 1997.
5. J. Michael Hollas: *Modern spectroscopy*, John Wiley & Sons, 2004.
6. A. W. Joshi, *Elements of Group Theory for Physicist*, New Age International Publishers, New Delhi, 2005.
7. Michael Tinkham: *Group Theory and Quantum Mechanics*, McGraw Hill, 2003.

PHY-RS-E505: High Energy Physics

Unit I: Introduction

Special theory of relativity and kinematics, Classification of fundamental interactions and elementary particles. Yukawa's proposal on meson exchange. Nother's theorem in classical mechanics, continuous space time symmetries and associated conservation laws of momentum, energy, angular momentum. Lorentz invariance.

Unit II: Symmetries and Conservation Laws
Symmetries in quantum mechanics, Discrete Symmetries, Parity, Charge conjugation and time reversal. Examples of determination of intrinsic quantum numbers, mass and spin. Charge independence of nuclear forces, isospin and strangeness. Application of isospin invariance to pion nucleaon scattering. Starngeness charm and other additive quantum numbers.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^osystem.

Unit III: Theoretical Techniques I
Introduction to Gauge theory of fundamental interactions, Covariant Perturbation theory, Feynman diagrams in momentum space and its applications in QED and QCD.Lie groups: SU(2), SU(3) and SU(5) and their applications: Higgs Mechanism and Goldstone theorem and its application in gauge theories.

Unit IV: Theoretical Techniques II
Feynman Rules for spin 0 and spin ½ particles and their applications ,Parton model, Deep-Inelastic Scattering (DIS), QCD-evolution equations. Standard model of electroweak interaction, Minimal supersymmetric standard model (MSSM), neutrino masses and mixing angles.

Books:

1. T.P. Cheng and Li: *Gauge theory of Elementary Particles*, Oxford University Press, 2000.
2. David Griffiths, *Introduction to Elementary Particles*, Wiley VCH, 2008.
3. Donald Perkins, *Introduction to High Energy Physics*, Cambridge University Press, 2008
4. *G. L. Kane: Modern Elementary Particle Physics*, Addison Wesley, 1993.
5. B. Zwiebach, A first course in string theory, Cambridge University Press, 2004.
6. J. Hartle, Gravity: *An introduction to Einstein's general relativity*, Pearson education, 2003.
7. A. Das and T. Ferbel: *Introduction to Particle & Nuclear Physics*, World Scientific Publishing, 2004.

PHY-RS-E506: Semiconductor Physics and Devices

Unit I: Characterisation of Semiconductors
Review of quantum theory of semiconductors, Semiconductors in equilibrium, Carrier transport in semiconductors, Semiconductor under non-equilibrium. Hall effect: measurement of resistivity, mobility, carrier concentration, diffusivity, Hall coefficient, Haynes-Shockley experiment, mobility, diffusivity and life time of minority carriers.

Unit II: P-N Junctions-Characteristics and Devices
Junction in equilibrium, Continuity of Fermi level across the junction, Junction under forward and reverse bias, Zero bias, Builtin- potential, Electric field in depletion region, Biased junction, Space charge width under electric field, Junction capacitance, Diffusion capacitance, One sided junction, Non-uniformly doped junctions, Linearly graded, Hyper

abrupt etc., Avalanche and Zener Breakdown. Zener diode, Varactor diode, Tunnel diode, Photovoltaic Cell

Unit III: Junction Diodes and Transistors

Metal-semiconductor Junction Diode: Structure, metal semiconductor contacts, energy band diagram for different cases, barrier formation, Schottky barrier diode, Nonideal effects on barrier heights, Current voltage characteristics, Comparison of barrier diode and PN-junction diode, Metal Semiconductor Ohmic Contact, Ideal non-rectifying barriers, Heterojunction, Two dimensional electron gas.

Bipolar Junction Transistor: Structure, Basic principle of operation, Modes of operation, Carrier concentration profile in various regions in forward active mode, current gain and current gain factors, Equivalent circuit models: Ebers-Moil model, Dependence of Ebers-Moll parameters on the structure and operating point, Maximum transition current, Voltage and power rating, Transistor as a switch.

Unit IV: Semiconductor Devices

Photodiode and solar cells, Microwave Devices: IMPATT devices: Read diode, principle of operation, applications, other structures. Gunn devices: Two valley semiconductors, transferred electron mechanism, formation and drift of space charge domain, application to resonant circuit. Semiconductor optical amplifiers, LEDs and LDs: device structure and characteristics, DFB, DBR, and quantum well lasers, Laser diode arrays, Semiconductor photodetectors; PINs and APDs, CCDs and OEICs

References:

1. Adir Bar-lev: *Semiconductor and electronic Devices*, Prentice Hall of India, 1993.
2. Hess, K.: *Advanced Theory of Semiconductor Devices*, Prentice Hall of India, 2000.
3. Roy.D.K. : *Physics of Semiconductor Devices*, University Press, India, 2000.
4. Streetman, B.G.: *Solid State Electronic Devices*, Prentice Hall of India, 2000.
5. Sze, S.M.: *Semiconductor Devices; Physics and Technology*, Wiley Eastern Ltd. 2009.
6. Sze, S. M: *Physics of Semiconductor Devices*, Wiley Eastern Ltd., 2007.
7. Wang, S.: *Fundamentals of Semiconductor Theory and Device Physics*, Prentice Hall of India, 1989.
8. Jasprit Singh, *Semiconductor Devices - Basic Principles*, John Wiley &Sons, Inc., 2002.
9. Zambuto, M.*: Semiconductor Devices*, McGraw Hill, 1989.

PHY-RS-E507: Quantum Optics & Quantum Information Processing

Unit I: Quantum theory of radiation

Review of quantum theory of radiation; Quantization of free electromagnetic field; Fock states, Lamb shifts, Quantum beats, coherent & squeezed states of the field, Quantum distribution theory & partially coherent radition (Q-representation and Wigner- Weyle distribution)

Unit II: Quantum Field Interactions

Field- Field and Photon – Photon interferometry, First & second order Coherence; photon detection & quantum coherence functions. Photon counting & Photon statistics; Classical & Quantum description of TWO source interference, Atom-field interaction- Semiclassical& Quantum theory.

Unit III: Quantum Optics
Laser without inversion & other effects of atomic coherence &interference Resonance flurescence Quantum theory of laser- density operator approach and Heisenberg- Langevein approach, Theory of microMasers. Atom optics. EPR paradox; hidden variable & Bell's theorem; Quantum calculation of the correlation in Bell's theorem; Bell's theorem without inequalities (GHZ equality). Quantum Cryptography (Bennett- Brossard protocol)Qantum Non demolition measurement.

Unit IV: Quantum Computations
Quantum circuits; Quantum search algorithm, Quantum Computers- Physical realization, Condition for quantum computation, Different implementation schemes for quantum computation; Quantum information theory (Distinguishing Quantum states, Data compression, Classical& Quantum information & noisy Quantum channels), Entanglement as physical resonance, Quantum key distribution and security of quantum key distribution.

Books:

1. M.O. Scully & M. Suhail Zubairy: *Quantum optics*, Cambridge University Press, 2002.
2. D. F. Walls and G. J. Milburn: *Quantum optics*, Springer, 2008.
3. M A Nielsen & I L Chuang: *Quantum Computation & Quantum Information*, Cambridge University Press, 2010.
4. Rodney Loudon: *The Quantum theory of light*, Oxford University Press, 2003.
5. Ioan Burda: *Introduction to Quantum Computation*, Universal Publishers, Florida, USA, 2005.

PHY-RS-E508: Nonlinear Science: Solitons and Chaos

Unit I: Introduction
Nonlinear equations in physics: an overview, Non-linear mechanics. Sensitive dependence on initial conditions.Discrete-time systems, Continuous time systems, Phase space, Poincare section, Spectral analysis of time series and power spectra, attractors, Bifurcation diagrams.
Stability: Fixed points, Lyapunov Stability, Asymptotic Stability, Poincare Stability, Lagrange Stability, Periodic and quasi-periodic motions, Logistic map-period doubling, periodic windows, Entropy and direction of time, Prediction of chaotic states-methods of analogues-linear approximation method.

Unit II: Chaotic Motion
Intermittency mechanism (Type I, II and III intermittencies), Bifurcations of homoclinic orbits, saddle point, turbulence, Fractal and fractal dimensions, self-similarity and self-affinity.
Hamiltonian theory, Duffing oscillator- Nonlinear oscillator – Standard map – integrable mapping- Non integrable mappings, Kepler's problem - order and chaos – Simple applications of chaos in physical systems - Quantum chaos-Applications.

Unit III: Solitons & Coherent Structures

Linear waves, wekly nonlinear and dispersive waves, solitonds, Kdv, NLS, Sine-Gordon systems, examples and applications in physics and engineering; Nonlinear optical phenomena second harmonic generation, parametric processes, optical solitons, soliton based all optical communications.

Unit IV: Applications

Non-linear systems, Nonlinear optics - Optical communications - Fluid dynamics - Magnetic systems – Liquidcrystals – Biomolecules - Medical physics - Plasma and Astro physics - Electrical circuits -, management systems, chaos in-earthquake dynamics - quantum physics - statistical mechanics.

References:

1. Thierry Vialar, *Complex and chaotic nonlinear dynamics*, Springer-Verlag, 2009.
2. Ali H. Nayfeh and B. Balachandran, *Applied nonlinear Dynamics*, WILEY-VCH, Verlag, 2004
3. M. Lakshmanan (Ed.,) *Introduction to Solitons*, Springer-Verlag, 1988.
4. M.J. Ablowitz and H. Segur, *Solitons and Inverse Scattering Trasform*, Philadelphia (1981).
5. P.G. Drazin and R.S. Johnson, *Solitons: An Introduction*, Cambridge University Press, 1989.
6. A.J. Licthenberg and M.A. Lieberman *Regular and Stochastic Motion*, Spinger Verlag, Berlin, (1983)
7. J.M. Thompson and H.B. Stewart, *Nonlinear Dynamics and Chaos*, John Wiley and Sons, 1989.
8. A.S. Davydov, *Solitons in Molecular Systems*, Kluwer Academic Publishers, 1991
9. A. Hasegawa and Y. Kodama, *Solitons in Optical Communications*, Oxford Press, 1995.

PHY-RS-E509: Magnetism and Superconductivity

Unit I: Magnetism - I

Static Phenomena : Diamagnetism; Paramagnetism; Crystal-field effects; John-Teller effects; Adiabatic demagnetization; Molecular field theory of ferromagnetism; Heisenberg-exchange interaction; Superexchange; Ruderman-Kasuya and Yosida interaction; Series-expanison and Bethe-Peierls-Weiss methods; Spin Waves; Ginzburg-Landau theory of the ferromagnetism.

Unit II: Magnetism - II

Slater-Puling Curve; Shape, magnetocrystalline and other types of anisotropy; Micromagnetics; Origin and observation of ferromag - neticdomins; Soft and hard magnetic materials; magnetic exchange bias, Different stages of magnetic ordering in alloys; Kondo, spin-glass, cluster spin-glass, inhomogeneous long-range characterization and the relevant theoretical concepts. Applications of bulk and thin film magnetic materials and multi layers.
Dynamic Phenomena: Linear Response Theory: Magnetic response and relaxation; Generalized magnetic susceptibility; Kramers-Kronig relations.

Unit III: Superconductivity I

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; Energy gap and its measurement; magnetization, specific heat and thermal conductivity; electron-phonon interaction and cooper pairs, brief discussion of the B.C.S. theory, its results and experimental verification; (p- and d- wave pairs).

Unit IV: Superconductivity II
Tunneling in SIN and SIS sandwiches, practical details; Coherence of the electron-pair wave, Weak links; dc and ac Josephson effects, superconducting Quantum Interference Devices (SQUID).
Type II superconductivity, magnetization of type-II superconductors, mixed state, surface energy, specific heat, critical currents of type-II superconductors flux lattice, flux flow (creep).
Superconducting materials (only qualitative description) conventional low temperature superconductors, High temperature superconductors, heavy fermions system, boro-carbides.

Books:

1. A. H. Morrish*: Physical Principles of Magnetism*, R. E. Krieger Pub. Co., 1980
2. S. Chikazumi: *Physics of Magnetism*, R. E. Krieger Pub. Co., 1978
3. Wolfgang Nolting, Anupuru Ramakanth: Quantum Theory of Magnetism, Springer, 2009.
4. R. M. White: *Quantum Theory of Magnetism*, Springer, 2007
4. S. Dattagupta: *Relaxation Phenomena in condensed matter* , Academic Press, 198
5. M. Tinkham: *Introduction to Superconductivity*, McGraw Hill, 1996
6. P. G. deGennes: *Superconductivity of Metals and Alloys,* Advanced Book Program, Perseus Books, 1999
7. K. H. Bennemann, J. B. Ketterson: The Physics of Superconductors, Springer Verlag, 2003.

PHY-RS-510: Semiconductor Laser Physics

Unit I: Introduction
Physics of interaction between radiation and atomic systems including: stimulated emission, emission line shapes and dispersion effects. Physics of semiconducting optical materials, degenerate semiconductors and their homojunctions and hetrojunctions.Light emitting diodes (LED's), Junction lasers. Characteristics of diode laser arrays and applications.

Unit II: Double Hetero Structure & Quantum Wells
Double Hetero Structure: Materials and growth techniques – brief outlook, electronic properties of heterojunctions,optical properties of hetero-junctions, lateral mode control.
Quantum Wells: Semiconductor multi quantum wells, density of states in 2-D systems, optical transitions, gain,strained quantum wells, optical and electrical confinement, strained layer superlattices (SLS)

Unit III: Diode Laser Modelling
Rate equations of idealised diode laser, gain compression, small signal rate equations, real laser diodes: InGaAsP/InP quantum well lasers, three level rate equation models for quantum well SCH lasers.

Unit IV: Applications of Laser
Application of lasers in data storage, communication and information technology: CD players, DVDs, laser printers, bar-code scanners, and optical communication; Surface profile and dimensional measurements using diffraction and its variations; High-power laser applications: marking, drilling, cutting, welding, and hardening; laser fusion; Laser Doppler velocimetry, LIDAR, laser spectroscopy, medical applications of lasers.

Books

1. D. Sands*: Diode Lasers*, Institute of Physics, UK, 2005.
2. S. Hooker and C. Webb: *Laser Physics*, Oxford University Press, 2010.
3. W. W. Chow and S. W. Koch: *Semiconductor Laser Fundamentals*, Springer-Verlag, 1999.
4. C. Hammaguchi: *Basic Semiconductor Physics*, Springer-Verlag, 2010.
5. K. Seeger: *Semiconductor Physics*, Springer-Verlag, 2004.
6. L. A. Coldren and S. W. Corzine : *Diode lasers and photonic integrated circuits,* John Wiley & Sons, Inc., 1995.
7. *Eli Kapon: Semiconductor lasers – Part – I., (Fundamentals),* Academic Press, 1999.
8. P. S. Zory Jr.: *Quantum Well Lasers*, Academic Press 1993.

PHY-RS-E511: Solar Energy and Its Utilization

Unit I: Radiation & Energy Storage
Radiation Geometry: Basis earth sun angles - Determination of Solar time - Derived Solar angles - Day length - Solar Radiation measurements - selective surfaces - Heat balance energy lost by radiation, convection and conduction - Physical characteristics of selectives surface - Anti reflection coatings - Solar reflector materials - production methods of coatings.
Energy storage and solar applications: Types of energy storage Thermal storage Latent heat storage – Electrical storage Principle of operation of solar ponds-Non convective solar ponds – Theoretical analysis of solar pond – solar distillation – solar cooking –solar pumping.

Unit II: Fundamentals of Heat Transfer
Transfer of Heat by Conduction: Study heat flow in a slab-steady heat flow in a cylindrical shell- Heat transfer through fins – Transient heat conduction.
Thermal Radiation: Basic laws of radiation – Radiant heat transfer between two black bodies-Radiant heat transfer between grey bodies.
Conduction heat loss Evaluation of convective heat transfer co-efficient –Free convection from vertical planes and cylinders – Forced convection – Heat transfer for fully established flow in tubes.

Unit III: Solar Thermal systems
General description of plate collector – thermal losses and efficiency of FPC –Energy balance equation – Evaluation of overall loss coefficient – Thermal analysis of flat plate collector and useful heat gained by the fluid performance of solar air heaters – Heating and drying of agricultural products Types of drier in use.
Solar concentrators and Receiver geometries – General characteristics of focusing collector systems Evaluation of optical losses – Thermal performance of focusing collectors.

Unit IV: Photovoltaics

Description of the photovoltaic effect – Electrical characteristics calibration and efficiency measurement – silicon solar energy converters – Thermal generation of recombination centers silicon.

Role of thin films in solar cells, Quantum dots, Properties of thin films for solar cells CdSe, CeTe, InP, GaAs, $CdCu_2$, CuIn SnO2, Cd2SnO4 ZnO)- Transport properties of metal films – poly crystalline film silicon solar cells (Photovoltaic characteristics, junction analysis loss mechanisms) Amorphous silicon solar cells (Structural compositional optical and electrical properties)

Books

1. GD. Raj: *Solar energy utilization*, Khanna Publishers, New Delhi, 2005.
2. H.P. Garg and J Prakash: *Solar Energy: Fundamental and Applications,* Tata McGraw Hill, 2000.
3. Charles E.: *Solar cells*, IEEE Press, 1976.
4. K. L. Chopra and S. Ranjan Das: *Thin film solar cells,* Plenum, New York, 1983.

PHY-RS-E512: Physics of Nanomaterials and Devices

Unit I: Physics of quantum dots & wells

Introduction, quantum dots, wires, wells. Density of states in 0, 1 & 2D.Growth of quantum dots – SK quantum dots – basics of semiconductor quantum dots –Electron photon scattering - Exciton dynamics in quantum dots – carrier relaxation inquantum dots – optical spectroscopy of single and multiple quantum dots – basics of metalquantum dots and their applications.

Infinite deep square wells – parabolic wells –triangular wells –sub-band formation in low dimensional system –occupation of sub-bands –quantum wells in hetero-structures, strained layer super-lattices – basics of tunneling transport – current and conductance – current in one dimension – current in two and three dimensions – basis of coherent transport

Unit II: Growth of hetero-structures

Growth of hetero-structures by MBE and MOCVD method – band gap engineering by swipt heavy ion beam methods –modulation doping – 2DEG formation – Strained layers and its effect – wire and dot formation – optical confinement – effective mass approximation in hetero-structures – photon, electron and proton beam lithography methods –methods in the nanoscale device fabrication

Unit III: Photonic devices

Metal semiconductor contacts – space charge region – schottky effect – ohmic contact –Basic microwave technology – tunnel diode – impatt diodes – transferred electron devices – quantum effect devices – light emitting diodes – basics of Solar cells – lasers and quantumwell lasers, VCSEL, Plasmons.

Unit IV: Characteristics of Nanomaterials

Spectroscopy of nanomaterials, bulk, Raman Scattering, STS, TEM, SCM, XRD, Raman spectroscopy.

References:
1. John H. Davies: *The Physics of Low dimensional semiconductors*, Cambridge University Press, 2000.
2. S. M. Sze: *Semiconductor devices: Physics and Technology*, John Wiley &Son, 2009
3. Garnett W. Bryantand Glenn Solomon: *Optics of quantum dots and wires*, Artech House, 2005.
4. Marius Grundmann: *The Physics of Semiconductors: An Introduction including nanophysics and Applications,* Springer, 2010.
5. S. L. Chuang: *Physics of Photonic Devices*, John Wiley & Sons, 2009.
6. Paul Harrison, *Quantum Wells, Wires and Dots,* John Wiley & Sons, 2005.

PHY-RS-E513: Plasma Physics

Unit I: Introduction
Introduction to plasma, definition, concept of temperature– Debye Shielding – The Plasma parameters – Criteria for Plasma.
Applications of Plasma physics (basis ideas) single – Particle motions; uniforms E and B fields – Gravitational field – Non uniform B fields – Gravitational field – Non – uniform B field – Curve B - magnetic mirrors non Uniform E filed Time – varying B field – Adiabatic Invariants.

Unit II: Fluid Models
Fluid theory in plasma, Fluid equations of motion, single fluid magneto-hydrodynamics, magnetic Reynolds number, magnetic equilibrium-the concept of beta, diffusion, resistivity and collision in plasma, Fokker-Plank equation
Waves in Fluid Plasma: Representation of waves – Group velocity – plasma Oscillations – Waves in unmagnetized plasmas – Electron Plasma waves-Langmuir waves and oscillations-ion sound waves, high frequency electromagnetic waves in unmagnetized plasma.

Unit III: Kinetic Theory & Plasma Instabilities
Kinetic Theory: Need for Kinetic theory, $f(v)$ equations by kinetic theory, Vlaslov equations, kinetic effects on plasma waves and in a magnetic field, Landaus treatment, BGK and van Kampen modes – Experimental verification.
Plasma Instabilities: Instability in plasma; streaming instability, ion drag force induced, drift wave instability and parametric instability.
Chaos and time series analysis; Fourier theory, Liapunov exponent, Attractors, self-similarity, Hurst exponent and Fractal dimension

Unit IV: Applications
Waves in space-plasma, plasma turbulence and particle heating. Fundamentals of plasma processing. Gas discharge processes, dc discharge, rf discharge, capacitive and inductively coupled plasma systems, theory and description of different plasma production systems, Dusty plasma. Introduction to controlled thermonuclear fusion, magnetic confinement; Tokamak, Spheromak and ITER.

References
1. Francis F Chen: *Introduction to plasma physics and controlled Fusion*, vol. I: plasma physics, 2nd edition, Springer, 1984.

2. Robert J Goldston and Paul H Rutherford: *Introduction to Plasma Physics*, Institute of Physics, London, 1995.
3. U. S. Unan and U Golkowsky: *Principles of Plasma Physics for Engineers and Scientist*, Cambridge University Press, 2011.
4. Nocholas A Krall and Alvin W Trivelpiece: *Principles of plasma physics*, San Francisco Press, 1986.
5. Donald E. Gurnett and A. Battacharjee: *Introduction to Plasma Physics: With Space and Laboratory Applications,* Cambridge University Press, 2005.
6. M. Kono and M. M. Skoric: *Nonlinear Physics of Plasmas*, Springer-Verlag, 2010.
7. Alexander Piel: *Introduction to Plasma Physics: An Introduction to Laboratory, Space and Fusion Plasmas,* Springer-Verlac, 2010.
8. Richard Dendy: *Plasma Physics: An Introductory Course*, Cambridge University Press, 1996.
9. Richard H Huddlestone and Stanly Leonard: *Plasma Diagnostic Techniques*, Academic Press Inc., 1965.
10. R. J. Shul, S. J. Pearton, *Handbook of Advanced Plasma Processing Techniques*, Springer-Verlac, 2000.
11. I. H. Hutchinson: *Principles of Plasma diagnostics*, Cambridge University Press, 2002.
12. Francis F Chen and Jane P Chang: *Lecture Notes on Principles of Plasma Processing,* Kluwer Academic/Plenum Publishers, 2003.

PHY-RS-E514: Thin Film Technology

Unit I: Introduction
Preparation: Spray pyrolytic process – characteristic feature of the spray pyrolytic process – ion plating– Vacuum evaporation – Evaporation theory – The construction and use of vapour sources– sputtering Methods – Reactive sputtering – RF sputtering - DC planar and magnetron sputtering , atom beam/ion beam sputtering.
Thickness measurement: electrical methods – optical interference methods – multiple beam interferometry – Fizeau – FECO methods – Quartz crystal thickness monitor.
Nucleation & **growth**– Four stages of film growth incorporation of defects during growth.

Unit II: Electrical properties of metallic thin films
Sources of resistivity in metallic conductors – sheet resistance - Temperature coefficient of resistance (TCR) – influence of thickness on resistivity – Hall effect and magneto resistance – Annealing – Agglometation and oxidation.

Unit III: Transport properties of semiconducting and insulating Films
Semiconducting films; Theoretical considerations - Experimental results – Photoconduction – Field effect in thin films – transistors, Insulating films Dielectric properties – dielectric losses – Ohmic contacts – Metal – Insulator and Metal – metal contacts – DC and AC conduction mechanism.

Unit IV: Optical properties of thin films and thin films solar cells
Thin films optics –Theory – Optical constants of thin films – Experimental techniques – Multilayer optical system – interference filers – Antireflection coating, Thin films solar Cells, Single & multi junction solar cells, Role, Progress, and production of thin solar cells – Photovoltaic parameter, Thin film silicon (Poly crystalline) solar cells: current status of bulk

silicon solar cells –Fabrication technology – Photo voltaic performance: Emerging solar cells: GaAs and CdlnSe.

References:

1. L I Maissel and R Glang: *Hand book of Thin films Technology*, McGraw Hill, 1970.
2. K L Chopra: *Thin film Phenomena*, McGraw Hill, 1970.
3. George Hass et al.: *Physics of thin films*, vol. 12, New York Academic Press, 1975.
4. K L Chopra and S R Das: *Thin films solar cells*, Plenum Press, 1983.
5. John A. Venables: *Introduction to Surface and Thin films processes*, Cambridge University Press, 2000.
6. L. Holland: *Vacuum deposition of thin films*, Chapman and Hall, 1966.
7. J C Anderson: *The Use of Thin Films in Physical Investigations*, New York, 1

PHY-RS-E515: Quantum Field Theory

Unit I: Introduction
Scalar Fields: Need for Field Theoretic description, Klein-Gordon Field: Lagrangian formulation, symmetries and conservation laws, canonical quantization, propagators, Feynman diagrams.
Spinor & Vector Fields: Dirac Field: Canonical quantization, propagators, Symmetries: Gauge Symmetries, Gauge Field: Elementary realization of BRST symmetry and gauge fixing.

Unit II: Interactions
Hamiltonian formulation, S-matrix, Interacting Fields and Feynman Diagrams, Yukawa Theory, elementary processes of quantum electrodynamics, radiative corrections.

Unit III: Renormalization
Functional Methods, Systematics of Renormalization, Renormalization and Symmetry, Renormalization Group, Critical Exponents.Wilsonian renormalization.

Unit IV: Non-Abelian Gauge Field
Non-Abelian Gauge invariances, Quantizations, Quantum Chromodynamics, Operator products, effective vertices, Gauge theory with spontaneous symmetry breaking, Higgs mechanism.

References

1. F. Mandl and G. Shaw: *Quantum Field Theory*, Wiley, 1992.
2. T. P. Cheng and L.-F. Li: *Gauge Theory of Elementary Particle Physics*, Oxford University Press, 1984.
3. S. Pokorski: *Gauge Field Theories*, Cambridge University Press, 2000.
4. L. H. Ryder: *Quantum Field Theory*, Cambridge University Press, 1996.
5. D. Bailin and A. Love: *Introduction to Gauge Field Theory*, IOP Publishing, Graduate Student Series in Physics, 1986.
6. F. Mandl and G. Shaw*: Quantum Field Theory*, John Wiley, 2009.
7. P. B. Pal and A. Lahiri: *A First Book of Quantum Field Theory*, CRC Press, 2001.
8. M. E. Peskin, D. V. Schroeder: *An Introduction to Quantum Field Theory*, Addison-Wesley, 1995.

PHY-RS-E518: General Relativity and Cosmology

Unit I: Tensor Analysis
Elements of tensor analysis, Affine transplantation of tensors, concept of the metric tensor and geodesics, Curvature, Reimann Tensor and its properties, Energy Momentum tensor, Ricci Tensor and Einstein tensor. Einstein Equations. Newtonian limit.

Unit II: General Relativity
Foundations of general relativity, Schwarschild solution and its consequences. Schwarzschild and Kerr space times, black hole physics, gravitational radiation, gravitational lensing, cosmological models, observational tests, the early universe, the microwave background, formation of structured dark matter and dark energy, Hawking radiation.

Unit III: Cosmology I
Galaxies and the expanding Universe; Hubble's Law; the age of the Universe; the Big Bang; cosmic microwave background (blackbody radiation); big bang nucleo-synthesis (cosmic abundances, binding energies, matter & radiation).

Unit IV: Cosmology II
Introductory cosmology (the cosmological principle, homogeneity and isotropy, Olber's paradox); cosmological models (critical density, geometry of space, the fate of the Universe); cosmological constant, dark energy and the accelerating Universe.

References

1. Steven Wienberg, *Cosmology*, Oxford University Press, (2008)
2. Robert M Wald, *General Relativity*, University of Chicago Press (1984)
3. Landau, L.D. & Lifshitz, E.M.: *The Classical Theory of Fields*, 2nd ed., Pergamon Press, 1995.
4. Hartle, J. B.: Gravity: *Introduction to Einstein's General Relativity*, Pearson Education, 2003.
5. Peebles, P.J.E.: *Principles of Physical Cosmology*, Princeton University Press, 1993.