BHARATHIARUNIVERSITY, COIMBATORE - 641 046
M .Phil ./ Ph.D. - PHYSICS

PART - 1 SYLLABUS
(For the candidates admitted from the academic year 2018-19 onwards)

PAPER – I - **Research Methodology**

PAPER - II - **Advanced Physics**

PAPER – III -
1. **Physics of Nanomaterials and device**
2. **Plasma Physics**
3. **Thin Film Technology**
4. **Molecular quantum mechanics**
5. **Nuclear Phyiscs**
6. **Principles and Methods of Crystal Growth**
7. **Nonlinear Dynamics**
8. **Solar Energy and its Utilization**
9. **Electrochemical Energy Devices**
10. **Computational fluid dynamics**
11. **Atmospheric Physics**
12. **Astronomy, Astrophysics and Cosmology**

PAPER – I RESEARCH METHODOLOGY

Unit - 1 Data Analysis

Approximate numbers and Significant Figures – Rounding of Numbers – Absolute, Relative and Percentage errors – Relation between Relative error and the significant figures – The general formula for errors – Formulas to the fundamental operations of arithmetic and logarithms – Accuracy in the evaluation of a Formula – Accuracy in the Determination of arguments from a tabulated functions – Accuracy of Series approximations – Errors in Determinants - Errors of Observations and Measurement – The law of accidental errors – Examples and exercises for data analysis

Unit – 2 Monte Carlo Method

Random variables – Discrete random variables - Tossing of a coin, Throwing of a die – Continuous random variables - normal random variables – The central limit theorem – General scheme of Monte Carlo method – generating random variables on a computer – tables of random numbers – generators of random numbers – Pseudorandom numbers – transformation of random variables – modelling of discrete random variable – modelling of continuous random variable – von Neumann's method for modelling a continuous random variable – modelling normal variables – evaluating a definite integral - method of computation – sampling – numerical examples – error estimates

Unit – 3 (Theory and Problems)

Least squares approximation of functions: Linear regression – Polynomial regression – Fitting exponential and trigonometric functions

Interpolation: Newton's method for equal and unequal intervals - Cubic spline (CS) methods – Minimizing property – Error in CS and its derivatives – Surface fitting by CS - Inverse interpolation - Double difference - Double interpolation

Numerical optimization: Minimization of a function - finding extreme values of a function – minimization using derivatives – steepest descent method (gradient method)

Integration: Gauss quadrature – double integration

Unit – 4 (Theory and Problems)

Ordinary Differential equation:

Predictor – Corrector method: Adams–Moulton method – Milne's method - Boundary value problem; Finite difference method – shooting method

Solution of Partial differential equations: Types of equations – Derivation of difference equation – Solving of elliptic, parabolic and hyperbolic equations – Explicit, Implicit, Crank Nicholson methods - Boundary conditions: Dirichlet, Neumann, conditions

Finite element method: Introduction – functional – base functions - methods of approximation – Galerkin method – Fininite element method for one dimensional problems

Unit – 5

Fortran programming: Character Set - Constants - Variables – Subscripted variables – Dimension, Common, Parameter statements – Arithmetic, character, and logical operations – List directed and formatted input and output statements – File processing - Control statements (Do, If, Goto structures) - Subprograms – Function subprogram – Subroutine subprogram - **Simple programs:** Ordering of numbers – matrix manipulation – roots of quadratic equation - least square curve fitting

Python: Basic syntax – variables and data types – operators- Control statements: if, if-else, nested if-else – loops (for, while); nested loops – break – continue – pass - Strings and text files; manipulating files and directories – Defining a function - Calling a function – Types of functions – Function arguments – Importing module – math module – Input-Output: printing on screen – reading data from keyboard, opening and closing file – reading and writing files.

Books for study and reference

1. NumericalMathematicalAnalysis, Scarborough J.B
2. Computer Applications in Physics - Suresh Chandra, Mohit Kumar Sharma – Narosa, 3rd edition (2014)
3. Introductory methods of numerical analysis – S.S. Shastry, PHI Learning Ltd, (2010)
4. Ilya M. Sobal , A primer for the montecarlo method, CRC Press.
5. Numerical methods for mathematics, science and engineering, John H. Matthews, PHI 2nd edition (2000)
6. Programming with Fortran 77, Ram Kumar, Tata McGraw Hill, (1994)
7. Fundamentals of Python: First Programs Author: Kenneth Lambert Publisher: Course Technology, Cengage Learning, 2012 ISBN-13: 978-1-111-82270-5
8. Making Use of Python, Rashi Gupta, Wiley Publishing, Inc., New York, 2002

PAPER-II- ADVANCED PHYSICS

UNIT-I: Optical, Non-Linear and Electro-Optical Effects of Crystals

Double refraction - Optical indicatrix – Effect of crystal symmetry on optical indicatrix – Wave surface: Uniaxial and Biaxial crystals

Non-Linear Optics: Harmonic generation – Second Harmonic Generation – Phase matching – Third Harmonic Generation – Optical Mixing - Sum and difference frequencies – Parametric generation of light – Self-focusing of intense light beams

Electro-Optic Effect: Phase retardation – Longitudinal electro-optic modulators: Amplitude modulation – Phase modulation of light – Transverse electro-optic modulators – Electro-optic beam deflection.

Unit – II: Fundamentals of Semiconductors
Carrier effective masses and band structure – Semiconductor statistics; energy distribution functions, density of states function, density of carriers in intrinsic and extrinsic semiconductors, compensation in semiconductors, band tail states – Absorption in semiconductors; matrix elements and oscillator strength for band to band transitions, indirect intrinsic transitions, exciton absorption, donor-acceptor and impurity-band absorption, low-energy absorption - Absorption in quantum well and quantum confined Stark effect

Unit-III: Material synthesis techniques
Gas-Phase Synthesis – Vapor condensation synthesis – Vapor reaction synthesis – Aerosol synthesis

Liquid-Phase Synthesis – Chemical precipitation and co-precipitation – Hydrothermal synthesis – Forced hydrolysis – Sol-gel synthesis – Solvothermal synthesis and nonhydrolytic route – Microwave heating synthesis – Synthesis in microemulsions or reverse micelles – Sonochemical synthesis – Electrochemical synthesis – Synthesis in supercritical fluids

Solid-Phase Synthesis – Mechanical milling – Mechanochemcial processing – Cryochemical processing – Self-combustion method – Solid-state synthesis – Colloidal assembly method – Selective leaching of a single-phase solid-solution method.

UNIT IV: Characterization Techniques-I
(Working Principle, Instrumentation and Applications only**)**

Diffraction Techniques: Powder X-ray diffraction – Single crystal X-ray diffraction – Neutron diffraction.

Spectroscopic Techniques:
Optical spectroscopy: Ultraviolet-Visible-near Infrared (UV-vis-NIR) – Diffuse Reflectance Spectroscopy (DRS) - Fourier Transform Infrared (FTIR) – RAMAN - Optical Emission Spectroscopy (OES) - Photoluminescence spectroscopy – Fluorescence spectroscopy.

Surface spectroscopy: Auger Electron Spectroscopy (AES) – X-ray Photoelectron Spectroscopy (XPS) – Extended X-ray Absorption Fine Structure (EXAFS)

Electronic spectroscopy: – Nuclear Magnetic Resonance (NMR) – Electron Spin Resonance (ESR) - Mossbauer spectroscopy

Ion spectroscopy: Secondary Ion Mass Spectroscopy (SIMS) - Rutherford back scattering (RBS) – Proton induced X-ray emission (PIXE) - Accelerator mass spectrometry

UNIT V: Characterization Techniques-II
(Working Principle, Instrumentation and Applications only**)**

Elemental Techniques: Atomic Absorption Spectroscopy (AAS) - Induction Coupled Plasma-Mass Spectroscopy (ICP-MS) – CHN Analysis – Energy Dispersive X-ray Analysis (EDAX) – Gas Chromatography-Mass Spectroscopy (GC-MS)

Microscopic Techniques: Optical microscopy – Atomic force microscopy (AFM) – Field-emission scanning electron microscopy (FESEM) – Transmission electron microscopy (TEM)

Thermal, Electrical and Magnetic Techniques: TG/DTA – DSC – Four probe method – Two probe method– Impedance analysis – Hall Effect method – Vibrating sample magnetometer (VSM) – Superconducting quantum interference device (SQUID) – Magneto Optic Kerr effect (MOKE).

Books for study and reference

1. Physical Properties of Crystals, Their Representation by Tensors and Matrices by J.F. Nye, 1985, Oxford University Press, New York.
2. Lasers and Non-Linear Optics, by B.B. Laud, Chapter-13, Wiley Eastern Ltd., 1985.
3. Quantum Electronics, by AmnonYariv, Chepter-14, John Wiley & Sons, Inc., 1975, New York.
4. Semiconductor opto-electronic devices (II nd Edition) – P. Bhattacharya, Prentice Hall, 2011.
5. Ceramic Nanoparticle Synthesis, *Encyclopedia of Nanoscience and Nanotechnology*, X. Feng, M. Z. Hu, Edited by H. S. Nalwa, Volume: 1, Pages (687-726).
6. Elements of X-ray diffraction (Second Edition), B.D. Cullity.
7. Basic Principles of Spectroscopy – Raymond Chang, McGraw Hill International book company.
8. Fundamentals of Molecular Spectroscopy by Banwell.
9. Instrumental Methods of Chemical Analysis, B. K. Sharma, 2001 GOEL Publishing House.
10.Characterization of Nanophase Materials, Zhong Lin Wang, Wiley-VCH.
11. Measurement Instrumentation and Experiment Design in Physics and Engineering, M. Sayer, A. Mansingh,Prentice Hall of India Private Limited, (2000).
12. Analytical Techniques for Thin Films, K. N. Tu, R. Rosenberg, Academic Press, INC. 1988.
13. Fundamentals of surface and thin film analysis – Leonard C. Feldman and James W. Mayer, P T R Prentice Hall, 1986.

PAPER – III - 1. PHYSICS OF NANOMATERIALS AND DEVICE

Unit-I: Electron Confinement in Quantum Structures

Quantum Wells:Density of States of a Two-Dimensional electron Gas**-**Quantum effects in a Continuum-Electron Spectrum**-**Two-dimensional Electron Motion in a Smooth Potential**;** Quantum Wires:Wave Functions and energy Subbands-Density of States for a One-Dimensional Electron Gas;Quantum Dots:Wave Functions and Energy levels**-**Density of States for Zero-Dimensional Electrons**;** Coupling between Quantum WellsSuperlattices:Density of States; Excitons in Quantum Structures:**-**Excitons in Quantum Wells; Coulomb Bound States and Defects in Quantum Structures: Coulomb Bound States of Impurities-Interfacial Defects.

Unit-II: Physics of Quantum Wells

Quantum wells and low dimensional systems: Introduction-infinite deep square well of finite depth-parabolic wells-triangular wells-low dimensional systems-occupation of subbands-quantum wells in heterostructures -Tunneling transport: Basics-current and conductance-current in one dimension-current in two and three dimensions.

Unit-III: Growth of Heterostructures and Field Effects

Heterostructures: General properties of heterostructures-Growth of heterostructures: MBE and MOCVD method-band engineering. Doped Heterostructures: Modulation doping-construction of band diagrams- Modulation doped field effect transistor (2DEG)layer formation-Strained layers: Structural aspects of strained layers- Effect of strain on band structure. Wire and dot formation-optical confinement-effective mass approximation in heterostructures. Optical and electron beam lithography methods; Field effects: Electric and magnetic field effect in the heterostructures-quantum Hall effect.

Unit-IV: Field Effect Devices

Basics of MESFET-MESFET Device Characteristics; Non Ideal Effects: Channel Length Modulation-Velocity Saturation Effects- Sub threshold and Gate Current Effects-Equivalent Circuit and Frequency Limitations; High Electron Mobility Transistors; MOSFET: MOS structure-Energy Band Diagram-Effect of Depletion Layer Thickness and work Function difference- Flat Band Voltage-Threshold Voltage-Charge Distribution; Capacitance Voltage characteristics of MOS structure: Ideal C-V characteristics-Frequency Effect- Fixed Oxide and Interface Charge Effects; Basics of MOSFET operation: MOSFET Structure-Current Voltage relationship (Both concept and mathematical Relationship)-Velocity Saturation-Channel Length Modulation-MOS memory structures-Basics of MODFET.

Unit V

Microwave and Photonic devices

Microwave devices: Basics of Microwave Technology-Tunnel diode-Impatt diode-transferred electron devices-quantum effect devices-hot electron devices; Photonic devices: Radiative transitions and optical absorption-Light emitting diodes-Semiconductor lasers-Photodetectors-Solar cells

Reference Books:

Unit-I:

***Vladimir V.Mitin*., "**Quantum Heterostructures (Microelectronics and Optoelectronics)", published by the Press Syndicate of the University of Cambridge, Cambridge University Press 1999

Unit-II:
John H. Davies,"The Physics of Low Dimensional Semiconductors", published by the Press Syndicate of the University of Cambridge, Cambridge University Press 1998
Unit-III:
Growth of heterostructures -***John H. Davies,***"The Physics of Low Dimensional Semiconductors", published by the Press Syndicate of the University of Cambridge, Cambridge University Press 1998
Field effects-***Marius Grundmann***"The Physics of Semiconductors: An Introduction Including Devices and nanophysics", published by Springer, Springer- Verlag Berlin Heidelberg 2006, Germany
Unit- IV:
MESFET, MOSFET -***Donald A Neamen***, "Semiconductor Physics and devices", published by McGraw Hill Education (India) Private Limited, New Delhi – Fourth Edition
MOS memory structures, MODFET-) – ***Simon Sze***, "Semiconductor Devices (Physics &Technology)", published by Wiley India Private Limited, New Delhi – Third Edition
Unit- V:
Simon Sze, "Semiconductor Devices (Physics &Technology)", published by Wiley India Private Limited, New Delhi – Third Edition

PAPER III - 2. PLASMA PHYSICS

UNIT I : Fundamentals of Plasma
Plasma state – characterization : Occurrence of Plasma in nature – Definition of Plasma – 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 :Plasma as a fluid
Equation of motion – Fluid drifts perpendicular to B fluid drifts parallel to B – The plasma approximation, Equilibrium and stability:Hydromagnetic Equilibrium – The concept of diffusion of Magnetic field into a plasma classification of instabilities – Two stream Instability – The gravitational instability - Resistive Drift waves – The weibel instability .

UNIT III – Plasma wave
Representation of waves – Group velocity – plasma Oscillations – Electron Plasma waves – sound waves – Ton waves – Validity of plasma approximation – comparison of ion and Electron waves – Electromagnetic waves with Bo = O – Experimental applications – Electromagnetic waves perpendicular to Bo Experimental consequences – Hydromagnetic waves – Magnetosonic waves Summary of Elementary plasma waves – The CMA Diagram .

UNIT IV : Kinetic Theory
The meaning of f (v) Equations by Kinetic theory – Derivations of the fluid equation – plasma Oscillations and Landau damping – The meaning of Landau Damping –Physical derivation of

Landau Damping – BGK and van Kampen modes – Experimental verification – Kinetic effects in a Magnetic field .

UNIT V:Plasma Diagnostics
Electrical methods : Langmuir probe - spectroscopic methods – Line spectrum of a plasma – low density plasma – high density plasma ionization state of a plasma – particle methods : Beam of charged particle to measure electric field in a plasma – measurement of the density of natural particles and charged particles .

Books for study and reference:

1 .Frencies Fchen : introduction to plasma and controlled Fusion vol . plasma physics (Plenum press)
2 . I M podgomyl : Topics in plasma diagnostics (Plenum press)
3 .Nocholas A Krail and Alvin W Trivelpiece – Principles of plasma physics (McGraw HillkogkushaLtd .
4 . Richard H Huddlestone and stanely Leonard – plasma Diagnostic Techniques (Academic Press)

PAPER III -3. THIN FILM TECHNOLOGY

UNIT – I : Vacuum Technology and Physical deposition methods
Oil-sealed rotary pumps - Diffusion pump - Turbo molecular pump - Cryogenic pump - Thermal conductivity gauges - Ionization gauges - Vacuum evaporation method (Clausius-Clapeyron's equation - Kinetic theory of gases - Evaporation theory - Construction and use of vapor sources) - Sputtering methods (Sputtering yields and thresholds - Theoretical models - Magnetically supported glow discharge - Reactive sputtering - RF sputtering).

UNIT – II : Chemical methods and Growth Mechanism
Sol gel method - Spray pyrolytic process - Chemical bath deposition method - Langmuir-Blodgett technique - Theories of thin film nucleation - The four stages of film growth - Incorporation of defects during film growth.

UNIT – III : Thickness Measurements and Electrical Properties of Metallic Thin Films
Multiple beam Interferometry - Interference Spectroscopy – Ellipsometry - Sources of resistivity in metallic conductors - Commonly measured quantities of thin films - Influence of thickness on the resistivity of structurally perfect film (Theory) - Theories of conduction in discontinuous films.

UNIT – IV : Transport Properties of Semiconductor and Insulator Thin Films
Metal-Insulator contacts - Theory of isothermal tunneling - High Field effects - Space charge limited currents - Tunnel cathode emitter - DC conduction mechanisms - Dielectric loss - AC conduction mechanisms - Hall effect - Hot probe technique - Carrier type and concentration.

UNIT –V : Optical properties of thin films and solar cells

Reflection and transmission at optical interfaces - Thin film interference - Multilayer reflectivity (Rouard's and transfer matrix models) - Interference filters - Absorption phenomenon in semiconductors - Transport of photocarriers - Photoconductivity - Junctions in dark - Homojunction - Heterojunction – Effect of illumination on junction behavior - Photovoltaic parameters - Design and optimization of solar cells.

Books for study

1. Handbook of Thin Films Technology, Ed: L. I. Maissel, and R Glang, McGraw-Hill Inc., USA, 1970.
2. Thin Film Phenomena, Ed: K. L. Chopra, McGraw-Hill Inc., USA, 1969.
3. Thin Films Solar Cells, Ed: K. L. Chopra and S. R. Das, Plenum Press, NY, USA, 1983.

Books for Reference

1. Physics of thin films Vols. 4 to 9, Editors, Georg Hass and others, Academic Press, New York, USA.

PAPER – III - 4. MOLECULAR QUANTUM MECHANICS

Unit I: Many-Electron systems

The Hartree-Fock self-consistent field method - Electron correlation - The atomic Hamiltonian- The Condon-Slater rules - The Born-Oppenheimer approximation - The Hydrogen molecule ion - Approximate treatments of H_2^+ ground electronic state - Molecular orbitals for H_2^+ excited states - Molecular orbital configurations of homonuclear diatomic molecules - The hydrogen molecule – The valence bond treatment of H_2 – Electron probability density

Unit II: Electron correlated methods

The Hartree-Fock method for molecules – MO treatment of heteronuclear diatomic molecules - Rayleigh-Schrödinger many body perturbation theory - Basis functions – Configuration interaction (CI) wave functions; multiconfiguration SCF (MCSCF), complete active space SCF (CASSCF), multireference CI (MRCI) – Coupled cluster methods

Unit III: Molecular properties, semi-empirical and molecular mechanics methods

Population analysis – Dipole moment – Molecular geometry and conformations – Molecular vibrational frequencies and thermochemical properties – Huckel MO method – Extended Huckel method – The formulation of CNDO, INDO, MNDO, AM1 and PM3 methods – Potential energy (force field) in molecular mechanics – Various energy terms in force field – Newtonian and Hamiltonian dynamics – Phase space trajectories – Classification of dynamical systems – Determination of properties

Unit IV: Density Functional Theory

Electron density - The original idea: The Thomas-Fermi model – The traditional Thomas-Fermi and Thomas-Fermi-Dirac models – Three theorems in Thomas Fermi theory - Thomas-Fermi-Dirac-Weizsacker model – The Hohenberg-Kohn theorems – Kohn-Sham equations – Derivation of Kohn-Sham equations – Kinetic energy functional – Local density approximation (LDA) – Density gradient and kinetic energy density corrections – Adiabatic connection methods

Unit V: Reactivity parameters, TDDFT, Plane waves and Pseudopotentials
Reactivity parameters; chemical potential, electronegativity, chemical hardness, softness and Fukui function – Time-dependent density functional theory: Runge-Gross Theorem - Time-dependent Kohn-Sham equation -Linear response - Excitation energies (Casida's equations) - Plane waves and the Brillouin zone – Bloch's theorem – Integrals in K space – Choosing K points in the Brillouin zone – Energy cutoffs – Pseudopotentials – Norm-conserving pseudopotentials – Ultrasoftpseudopotentials – Projection augmented waves

Books for study:

1. Quantum Chemistry – Ira. N. Levine, Vth Edition; Prentice-Hall of India, New Delhi, 2000
2. Ab initio molecular orbital theory – W. J. Hehre, L. Radom, P. V. R. Schleyer and J. A. Pople; John Wiley & Sons, New York, 1985.
3. Essential of Computational Chemistry - Theories and Models ,IInd Edition, Christopher J. Cramer; John Wiley & Sons, England, 2004.
4. Modern quantum chemistry – Introduction to advanced electronic structure theory – Attila Szabo and Neil S. Ostlund, Dover publications INC, New York, 1996.
5. Molecular dynamics simulation – Elementary methods - J.M. Halie, John Wiley & sons, Inc., 1997
6. Density functional theory of atoms and molecules – R. G. Parr and W. Yang; Oxford University press, New York, 1989.
7. Electronic structure – Basic theory and Practical methods – Richard M. Martin, Cambridge University Press, UK, 2005
8. Time-Dependent Density-Functional Theory: Concepts and Applications – CarstenUllrich, 1st Edition, Oxford University Press, 2006
9. Density functional theory – A practical introduction – David S. Sholl, and Janice A. Steckel – John Wiley & sons, Inc., 2009

PAPER – III -5. NUCLEAR PHYSICS

UNIT - I

Nuclear models Derivation of Hartree-Fock equations - Hartree-Fock calculation and various observed quantities - Practical aspects of Hartree-Fock calculation
Macroscopic- microscopic approach:

Liquid Drop Model - Potential energy mapping and the fission barrier: Symmetric deformations- *Nilsson Model* for deformed single-particle wave functions- single particle calculation of deformation energy - Strutinsky Hybrid model

UNIT -II

Scattering by Nuclei and scattering theory for reactions
Optical model - Electromagnetic forces: scattering of electrons and protons by nuclei - Scattering of pions by nuclei– The scattering matrix - Conservation and reciprocity theorems for nuclear reactions
Statistical models of nuclear decay process
Compound nucleus : Formation - Level Density - Weisskopf theory of evaporation from the compound nucleus- Fusion- Statistical models for fission at low excitation energies

UNIT – III

Nuclear Astrophysics

Nucleosynthesis processes in stellar evolution and explosions : Explosive burning - Explosive He burning - Explosive C- and Ne- burning - Explosive O burning - Explosive Si- burning - The r-process

Overview of stellar nucleosynthesisprocesses : Stellar hydrogen burning through the pp-chains and the CNO cycles - Stellar helium burning and neutron sources for the s-process

Neutron Stars

Introduction - Neutron star properties: masses- Equation of state - Nuclear matter

UNIT – IV

*Elements of Quantum Field Theory*TheLagrangian-Hamltonian formalism - The classical fields - Quantization of the field - The Schrodinger field - Quantization into Bosons - Quantization into Fermions - Relativistic fields

*The Dirac Field :*Plane wave solutions of the Dirac equation - Lagrangian density for the Dirac field- *The Scalar Fields :* One-component real field - Fourier decomposition of the field

UNIT-V

Experimental Methods: Coincidence technique (introduction)– Special techniques : Introduction - Time of flight technique - Pulse shape discrimination - Recoil distance measurement

Particle induced X-ray emission (PIXE) - M*ö*ssbauer spectroscopy - Accelerator mass spectroscopy

Reference :

1. Theory of Nuclear Structure – M. K. Pal, Affiliated East-West Press pvt. Ltd., (1982)
2. Nuclear Fission – Robert Vandenbosch and John R. Huizenga – Academic Press, New York and London, (1973)
3. Elements of Nuclei – P. J. Siemeno and A. S. Jensen, Addison Wesley Publishing company, Inc. California, (1987)
4. Theoretical Nuclear Physics - John M. Blatt and Victor F. Weisskopf, John Wiley sons, New York, London (1952)
5. Statistical Models for Nuclear decay from Evaporation to Vapourization – A. J. Cole, Institute of Physics Publishing Ltd., Bristol and Philadelphia, (2000)
6. Nuclear and Particle Astrophysics - Proceedings of the Mexican School on Nuclear Astrophysics, held in Guanajuato, Mexico August 13-20, 1997; Edited by J. G. Hirsch and D. Page, Cambridge University Press (1998), United Kingdom
7. Relativistic Quantum Mechanics and Quantum Field Theory - V. Devanathan, Narosa Publishing House Pvt. Ltd, New Delhi (2011)
8. Nuclear Radiation Detection, Measurements and Analysis - K. MuraleedharaVarier, Narosa Publishing House Pvt. Ltd, New Delhi (2009)
9. Nuclear Physics problem based approach including MATLAB - Hari M. Agrawal, PHI Learning Private Limited, Delhi (2016)

PAPER – III - 6.PRINCIPLES AND METHODS OF CRYSTAL GROWTH

Unit – I: Fundamentals of Crystal Growth
Importance of crystal growth – Classification of crystal growth methods – Basic steps: Generation, transport and adsorption of growth reactants – Nucleation: Kinds of nucleation – Classical theory of nucleation: Gibbs Thomson equations for vapour and solution – Kinetic theory of nucleation – Becker and Doring concept on nucleation rate – Energy of formation of a spherical nucleus – Statistical theory on nucleation: Equilibrium concentration of critical nuclei, Free energy of formation.

Unit – II: Theories of Crystal Growth
An introductory note to Surface energy theory, Diffusion theory and Adsorption layer theory – Concepts of Volmer theory, Bravais theory, Kossel theory and Stranski's treatment – Two-dimensional nucleation theory: Free energy of formation, Possible shapes and Rate of nucleation – Mononuclear, Polynuclear and Birth and Spread models – Modified Birth and Spread model – Crystal growth by mass transfer processes: Burton, Cabrera and Frank (BCF) bulk diffusion model, Surface diffusion growth theory.

Unit – III: Experimental Crystal Growth-Part-I: Melt Growth Techniques.
Basics of melt growth – Heat and mass transfer – Conservative growth processes: Bridgman-Stockbarger method – Czochralski pulling method – Kyropolous method – Non-conservative processes: Zone-refining – Vertical and horizontal float zone methods – Skull melting method – Vernueil flame fusion method.

Unit – IV: Experimental Crystal Growth-Part-II: Solution Growth Techniques.
Growth from low temperature solutions: Selection of solvents and solubility – Meir's solubility diagram – Saturation and supersaturation – Metastable zone width – Growth by controlled evaporation of solvent, slow cooling of solution and temperature gradient methods– Crystal growth in Gel media: Chemical reaction and solubility reduction methods – Growth from high temperature solutions: Flux growth Principles of flux method – Choice of flux – Growth by slow evaporation and slow cooling methods – Hydrothermal growth method.

Unit –V Experimental Crystal Growth-Part-III: Vapour Growth Techniques.
Basic principles – Physical VapourDeposition (PVD): Vapour phase crystallization in a closed system – Gas flow crystallization – Chemical Vapour Deposition (CVD): Advantageous and disadvantageous – Growth by chemical vapour transport reaction: Transporting agents, Sealed capsule method, Open flow systems – Temperature variation method: Stationary temperature profile, Linearly time varying temperature profile and Oscillatory temperature profile.

Books for Study and Reference
1. 'Crystal Growth Processes' by J.C. Brice, 1986, John Wiley and Sons, New York.
2. 'Crystallization' by J.W. Mullin, 2004, Elsevier Butterworth-Heinemann, London.
3. 'Crystal Growth: Principles and Progress' by A.W. Vere, 1987, Plenum Press, New York.
4. 'Crystals: Growth, Morphology and Perfection' by Ichiro Sunagawa, 2005, Cambridge University Press, Cambridge.
5. 'Crystal Growth' by B.R. Pamplin, 1975, Pergamon Press, Oxford.

PAPER – III – 7. NONLINEAR DYNAMICS

UNIT – I

Linear and Nonlinear systems – Mathematical models examples – Mathematical Implications of Nonlinearity: superposition principle – Linear oscillators & Predictability – Nonlinear oscillators – Resonance and Hysteresis.

UNIT – II

Autonomous and Nonautonomous systems – Phase plane trajectories – stability, attractors &repellers, - equilibrium points and stability – limit cycle – Bifurication – Period doubling phenomenon –onset of chaos – Logistic map – Route to chaos – Lorentz systems – Sensitivedependence on initial condition – controlling of chaos.

UNIT – III

Integrability&separability – Painleve analysis – singular points – P-analysis of ordinary differential equations – symmetries – Integrals of motion – Painleve analysis of partial differential equations – Laxpair and integrable properties .

UNIT – IV

Linear wave propagation (nondispersive and dispersive) – Fourier transform and solution ofintial value problem – wave packet and dispersion – Nonlinear Dispersive system – Scott Russel`s phenomenon –cnoidal waves and Korteweg-de Vries equation – Fermi Pasta Ulam phenomenon-Numerical experiments of Zabusky and Kruskal – birth of solitons.

UNIT V: Non Linear Optics

AKNS Linear eigen valve problems – standard soliton equation – Inverse scattering trnsform method – soliton solutions of KdV equation – Hirota’s Direct method and ‘N’ soliton solutions.

Introduction-Nonlinear Optical Media-The Nonlinear Wave Equation-Scattering Theory - Born Approximation-Second-order - Four-Wave Mixing (FWM) - Optical Phase Conjugation (OPC)-Use of Phase Conjugators in Wave Restoration.

<u>Books for study:</u>

1. M. Lakshmanan and S. Rajasekar, Nonlinear Dynamics, Integrability, chaos and patterns, springer (2003)
2. M.J. Ablowitz and PA Clarkson, Solitons, Nonlinear Evolution Equations and Inverse Scattering (Cambridge University Press, Cambridge 1991)
3. Principles of Nano optics -L. Novotny and B. Hecht-Cambridge University Press(2006)
4. Nonlinear Optics - D.L. Mills - Basic Concepts, Springer, Berlin 1998.
5. Lasers and Nonlinear Optics -B.B. Laud-2nd Edn. New Age International (P) Ltd., New Delhi, 1991

PAPER-III – 8. SOLAR ENERGY AND ITS UTILIZATION

UNIT 1 ; 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 selective surface -
Anti reflection coatings - Solar reflector materials - production methods of coatings.

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.
Convention 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: Photo voltaics:
Description of the photovoltaic effect – Electrical characteristics calibration and efficienc measurement – silicon solar energy converters – Thermal generation of recombination centers silicon.
Role of thin films in solar cells Properties of thin films for solar ellsCdSe, Cete, In P, Ga As, Cd C_{u2}, Cu In SnO_2, Cd_2SnO_4ZnO)- Transport properties of metal films – poly crystalline film silicon solar cells (Photovoltaic characteristics, junction analysis loss mechanisms) Amorpho silicon solar cells (Structural compositional optical and electrical properties)

Unit- V: 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 – Theortical analysis of solar pond – so distillation – solar cooking –solar pumping.

Books of Study and Reference:

1. Solar energy utilization GD. Raj. 1996
2. Treatise on solar energy volume I fundamentals of Solar Energy –H.P. Garg.1982
3. Thermal performances testing of FPC and CPC –GD Raj
4. Solar cells – Charles E. Backus IEEE Press (1976)
5. Thin film solar cells KasturiLalchopra and suhitRanjan Das, (1983)
6. Solar energy Utilization G.D Raj (1996)

PARER – III – 9. ELECTROCHEMICAL ENERGY DEVICES

UNIT – I Fundamentals of electrochemistry

Electrochemical cell thermodynamics – Standard potential – Some uses of standard potentials – Measurement of cell potentials – Formal potentials – Thermodynamics of the transfer of ions between two phases – Thermodynamic data derived from standard and formal potentials – Reference and indicator electrodes – Ion-selective electrodes – Chemical analysis by potentiometry – Electrode reactions and cell assembly – Nature of electrode reactions – Electron Transfer – Mass Transport – Linear diffusion in a plane electrode – Interaction of electron transfer and mass transport – Coupled Chemical Reactions – Adsorption – Phase formation.

UNIT – II Electrode Interface and Electrode Kinetics

Electrical double layer – Outer Helmholtz plane (OHP) – Inner Helmholtz plane (IHP) – Potential difference across electrified interfaces – Helmholtz Perrin theory – Gouy Chapman model – Stern model – Electrode kinetics – Exchange current density – Butler-Volmer equation –– Polarizable and non-polarizable interfaces – Mass transport versus charge-transfer limitation – Nernst diffusion layer thickness – Potential control versus current control – Over potential and types – Experimental Tafel equation – Single-step electrode reaction – Symmetry factor β – Multi-step electrode reactions – Charge transfer coefficient and its relation to β – Steady state and quasi-equilibrium – Calculation of Tafel slope – Reaction orders in electrode kinetics.

UNIT – III Electrodes and electrolytes

Working electrodes – Electrode materials – Elecrode geometry – Hydrodynamic electrodes – Chemically modified eletrodes – Reference elctrodes and Standard hydrogen elctrode – Electrodes of the second kind as reference electrodes – Practical problems – Electrolytes – Ionic transport – Ionic solutions – Aqueous electrolyte solutions – Non-aqueous electrolytic solutions.

UNIT – IV Electrochemical Techniques

Linear sweep voltammetry – Cyclic voltammetry – Pulse voltammetry – Square-Wave Voltammetry – Chronocoulometry – AC voltammetry – Stripping voltammetry – Chronoamperometry – Chronopotentiometry – Galvanostatic charge-discharge – Electrochemcial Impedance Spectroscopy – UV/Vis/NIR Spectroelectrochemistry.

UNIT – V Applications

Capacitor principles – Electrochemical capacitors – Electric Double Layer Capacitors – Chemistry of secondary batteries – Intercalation processes – Charge characteristics – Polymer, thin-film and solid-state Li-ion batteries – Classification of fuel cells – Alkaline fuel cells – Solid oxide fuel cells – Direct methanol fuel cells – Proton exchange membrane fuel cells – Electrochemical biosensors – Gas sensors – Sensor arrays – Photoelectrochemical cells – Selection criteria for electrodes – Structure and dynamics of electrode/electrolyte interface.

Books for study:

1. Electrochemistry, Philip. H. Rieger, II-Edition, Chapman and Hall, 1993.
2. Instrumental Methods in Electrochemistry, Southampton Electrochemistry Group, Published by Woodhead Publishing Limited, 2011
3. Atkins Physical Chemistry, Peter Atkins, Oxford University Press, 2006
4. J. O. M. Bockris& A. K. N. Reddy, “Modern Electrochemistry”, Vol. 2A, II Edition, Springer International, 2000.
5. ElizerGileadi, “Electrode Kinetics for Chemists, Chemical Engineers, and Materials Scientists”, Wiley-VCH, 1993.
6. Joseph Wang, Analytical Electrochemistry, II Edition, Wiley-VCH, 2000.
7. Electroanalytical Methods – Guide to experiments and applications, Editor Fritz Scholz (Ed.), Springer, 2010.
8. G. Q. Max Lu (Ed.), “Supercapacitors - Materials, Systems and Applications”, Wiley-VCH, 2013.
9. David Linden & Thomas B. Reddy, “Handbook of Batteries”, III Edition, McGraw-Hill Handbooks, 2002
10. Xianguo Li, “Principles of Fuel Cells”, Taylor and Francis, 2006.
11. B. Viswananthan and M.AuliceScibioh, “Photoelectrochemistry – Principles and Practices”, Narosa Publishing House. Pvt.ltd, 2014.

PAPER – III – 10. COMPUTATIONAL FLUID DYNAMICS

UNIT – I

Introduction to equations governing fluid flow and heat transfer - Conservation of mass, conservation of energy, expanded and special forms of Navier-Stokes equations - Potential theory- Boundary layer theory - Compressible flows - Turbulent flows.

UNIT – II

Introduction to finite differences, Difference equations, Discretization – Finite difference method: Explicit, implicit and Crank-Nicholson methods – Convergence and stability conditions - ADI – Boundary conditions - Applications to steady and transient heat conduction equations.

UNIT – III

One- and two- dimensional steady & transient conduction - Steady one-dimensional convection and diffusion - Solution methodology: upwind scheme, exponential scheme, hybrid scheme, power law scheme – Explicit, Implicit, Crank-Nicolson schemes – Stability criterion.

UNIT- IV

Representation of the pressure gradient term and continuity equation - Staggered grid - Momentum equations – Pressure and velocity corrections - Pressure correction equation - SIMPLE algorithm - Boundary conditions for the pressure correction method.

UNIT – V

Grid generation – General transformation of the equations - Form of the governing equations suitable for CFD – Boundary fitted co-ordinate systems – Elliptic grid generation - Adaptive grids - Modern developments in grid generation.

References

1. J.D. Anderson, Jr., (2000), Computational Fluid Dynamics – The basics with applications, McGraw-Hill, Incs.
2. S.V. Patankar, "Numerical Heat Transfer and fluid flow", Hemisphere publishing corporation, 1994.
3. Jaluria and Torrance, "Computational Heat transfer", Hemisphere publishing corporation, 1986.
4. J.D.Anderson, Jr., Computational Fluid Dynamics – the basic with applications, MGH, ISE, 1995.
5. K.A.Hoffman, Computational Fluid Dynamics for Engineering, Engineering education system, Austin, Texas, 1989.
6. K. Muralidhar, T. Sundarajan, "Computatioanl Fluid Flow and Heat Transfer", Narosa Publishing HoZuse, New Delhi, 1995.

PAPER – III – 11. Atmospheric Physics

Unit I: Physical & Dynamic Meteorology

Evolution of the Earth's Atmosphere, Chemical composition, Thermal Structure, Thermodynamics of the Atmosphere, Adiabatic Process-Potential Temperature-Clausius-Clapyeron Equation, Black Body Radiation, Atmospheric Scattering, Rayleigh scattering, Mie scattering, Solar constant Solar, Terrestrial Radiation, Heat Balance of Earth Atmosphere System, Albedo, Fundamental Forces-Structure of Static Atmosphere-Momentum, Continuity and Energy Equations-Thermodynamics of Dry Atmosphere, Circulation Theorem, Vorticity, Potential Vorticity and its applications, Planetary boundary layer.

Unit II: Greenhouse Gases in the Atmosphere

Greenhouse effect, Global warming, Air Pollution and Pollutants, Stratospheric ozone, Tropospheric ozone, Ozone chemistry in troposphere and stratosphere, Photochemical production and destruction of ozone, Precursor gases, CO and CO_2, Methane, Nitrous oxide, Hydrocarbons, Biogeochemical cycle, Satellite retrieval of trace gases, Trace gases and climate change, Potential impacts of climate change,Radiative forcing due to trace gases.

Unit III: Particulate Matter in the Atmosphere

Atmospheric Aerosols, Classification, Sources, Size distribution, Aerosol monitoring techniques, Residence time of Aerosols, Tropospheric Aerosols, Stratospheric Aerosols, Importance of Aerosol research, Satellite Aerosol remote sensing over land,

Unit IV: Climate & Monsoon Dynamics

Types of Climate, Climate Classification, Monsoon regions in tropics, Summer and winter circulation monsoon over India, General monsoon circulation (Balance of Mass, Radiation, Angular momentum, Flow across Equator, Global Relationship), Onset and withdrawal features, Monsoon depressions, Other synoptic systems, Orographic effects, Walker Circulation, Southern Oscillations, El Nino and La Nina.

Unit V: Radar & Satellite Meteorology

Radar Principles and Technology, Radar Signal Processing & Display, Weather Radar-Observation of Precipitating Systems, Estimation of Precipitation, Radar observation of Tropical Storms & Cyclones, Use of Weather Radar in Aviation, Clear Air Radars, Observation of a Clear Air Phenomena, Characteristic features of satellite imageries, Different type of satellite images : Visible, IR, Water Vapour, Microwave, Cloud features associated with Jet Strearn, Western disturbances and tropical cyclones, General aspects of cloud and precipitation processes, Nucleation of liquid, water, ice, water vapour, Growth processes of droplets.

Books for study and References:

1. The Atmosphere-Frederick K. Lutgens and Edward J. Tarbuk, 12th Edition, Boston, Pearson, c2013.
2. Dynamic Meteorology-J.R. Holton- 4th Edition, Academic Press- New York, 2004.
3. The Earth's Atmosphere**,** Its Physics and Dynamics by KshudiramSaha, Springer, 2008.
4. Stratosphere Troposphere Interactions, An introduction by K. Mohanakumar, Springer, 2008.
5. Fundamentals of Physics and Chemistry of the Atmosphere by Guido Visconti, Springer, 2016.
6. Atmospheric Radiation: Theoretical Basis by R.M Goody and Y.L Yung, 2nd Edition, Oxford University Press, 1995.
7. The Physics of Monsoons-R.N. Keshvamurthy& M. Shankar Rao-Allied Publishers, 1992.
8. Atmospheric Science, An introductory survey by John Wallace and Peter Hobbs, 2nd Edition, Academic Press, 2006.
9. Atmospheric Pollution by J.C Jones, Ventus Publishing Aps, 2008.
10. Radar Meteorology by Henry Sauvegeot, Published by Artech House, Incorporated, 1992.

PAPER – III – 12. ASTRONOMY, ASTROPHYSICS AND COSMOLOGY

Unit I: Astronomy

Introductory History of Astronomy, Kepler's Laws of Planetary Motion, Newtonian Concept of Gravity, Overview of the major constituents of the universe, Formation of Solar System, planet types, planet atmospheres, extra solar planets, Methods of detection of extra solar planets, Distance measurements in astronomy, Hubble's law

Unit II: Stellar and Galactic Astrophysics

Stars-general Distances to stars, trignometric parallax, Stellar brightness, luminosity, flux, apparent magnitude, magnitude system, distance modulus, colour index, extinction, colour temperature, effective temperature, Stellar masses and radii, measuring masses, binary stars, visual binary, eclipsing binary, spectroscopic binary, Measuring stellar radii, Stellar spectra, colours of stars, Motion of stars, radial velocity, proper motion, spectral classification of stars, luminosity classification of stars, HR diagram, Stellar population, Population I and II, Star clusters, open clusters, globular clusters, Variable stars, Energy generation in stars, PP chain, Sources of stellar energy, gravitational collapse, fusion reactions (p-p chain, CNO cycle, triple α reactions); formation of heavy elements, Hertzsprung-Russell diagram, evolution of low-mass and high-mass stars; Chandrasekhar limit; Pulsars, neutron stars, Red Giants, White Dwarfs, Novae And Supernovae, Neutron Stars-Pulsars, Black holes, Milky way, Hubble classification of galaxies, Spiral galaxies, Elliptical galaxies, Irregular galaxies, Dwarf galaxies.

Unit III: Elements of General Relativity

Curved space-time, Eotvos experiment and the equivalence principle, Equation of geodesic, Christoffel symbols, Schwarzschild geometry and black holes, FRW geometry and the expanding universe. Riemann curvature, Einstein equations.

Unit IV: Cosmology

Hubble's observation and expanding universe, Friedmann cosmology, Red shift and expansion, Big bang theory, Constituents of the universe, Dark matter and dark energy (as a nonzero cosmological constant), Early universe and decoupling, Neutrino temperature, nucleosynthesis, relative abundances of hydrogen, helium, deuterium, Radiation and matter-dominated phases, Cosmic microwave background radiation, its isotropy and anisotropy properties, COBE and WMAP experiments, CMBR anisotropy as a hint to large scale structure formation, Inflation.

Unit V: Experimental Techniques

Telescopes and Detectors – optical, infrared, radio, x-rays, gamma-rays, neutrinos and cosmic rays, Gravitational radiation, Detection of dark matter and Dark Energy Astronomy from Space, Imaging – focal plane imagers, PSF and deconvolution, interferometry Photometry, Spectroscopy, Polarimetry, Astrometry, Solar telescopes, Surveys, Astronomical databases, Virtual Observatory.

Books for study and References:

1. T. Padmanabhan: Theoretical Astrophysics, volume 1-3, Cambridge University Press, 2000.
2. S. Weinberg: Gravitation and Cosmology, John Wily and Sons, New York, 1972.
3. M. Rowan-Robinson: Cosmology, 3rd Edition, Oxford University Press, New York, 1996.
4. E.W. Kolb and M.S. Turner: The Early Universe, Avalon Publishing, 1994.
5. J.V. Narlikar: Introduction to Cosmology, 3rd Edition, Cambridge University Press, 2002.
6. Shu F.: The physical universe, University of California, 1982.
7. Bradley W. Carroll & Dale A. Ostlie:An introduction to Modern Astrophysics, 2nd Edition, Cambridge University Press, 2007.
8. T.T. Arny: Explorations, An Introduction to Astronomy, McGraw Hill, New York, 2007.
9. M. Zeilik and E.V.P. Smith: Introductory Astronomy and Astrophysics, 2nd Edition, Saunders College Publishing, Philadelphia, PA, USA, 1987.
10. D. Clayton: Introduction to Stellar Evolution and Nucleosynthesis, The University of Chicago Press, Chicago and London, 1968.
11. A. Liddle: An Introduction to Modern Cosmology, 3rd Edition, John Wiley and Sons Ltd, 2015.
12. J.B. Hartle: Gravity, Dorling Kindersley Pvt. Ltd, 2003.
13. V. Mukhanov: Physical Foundations of Cosmology, Cambridge University Press, 2005.
14. C.R. Kitchin, Astrophysical Techniques, Taylor and Francis Group, LLC, 1995.