MOTHER TERESA WOMEN'S UNIVERSITY

DEPARTMENT OF PHYSICS

PH.D. COURSE WORK III

1. ADVANCED NUCLEAR SCIENCE

Unit I

Mass spectrograph – Isotope separation – Nuclear binding energy – Nuclear angular momentum and parity – Nuclear electromagnetic moments – Properties of nuclear forces – Deuteron problem (Binding energy – Spin and parity – Magnetic dipole moment – Electric quadrupole moment) - Neutron - proton scattering - Differential cross section – Scattering length – Phase shift.

Unit II

Liquid Drop Model-Fermi Gas-Model- Nuclear Shell Model
Nuclear Excitations- Collective Modes of Motion: Nuclear Vibrations and Rotations-Deformed and Extremely Unstable Nuclei
Nuclear Decay and Radioactivity- Radioactive Decays- α,β,γ Decay

Unit II

Kinematics and Conservation Laws; Coulomb barrier, Q-value; Centre-of –mass co-ordinate and Laboratory systems; Particle Identification; Cross section, Isospin, Optical Potential. Rutherford scattering, Elastic Scattering, Inelastic Scattering and Coulomb Excitation. Direct Reactions: Types of direct reactions, Transfer Reactions, Breakup reactions and Deep- Inelastic Reactions. Direct reactions as a tool for nuclear Spectroscopy.

Unit III

Fusion Reactions: Compound Nuclear Reactions, Slow neutron resonances, limiting Cross section, phase – shift, neutron width, gamma decay width, Isobaric Analog States, Compound nucleus reaction cross section, Heavy Ion Fusion.
Fission: Spontaneous fission, Hill-wheeler Model, fusion – Fission.

Unit IV

Nucleosynthesis: Hydrogen burning (pp chain and CNO cycle)- Helium burning- Advanced burning stages (carbon-, neon-, oxygen-, and silicon-burning modes)- The s-process- The r-process- Other nucleosynthesis processes (rp-process, p-process)- Explosive nucleosynthesis.
Thermonuclear Reactions in Stars: Cross sections and astrophysical S-factor-Resonant and non-resonant reactions-Reactions with charged particles- Reactions with neutron-Reactions with photons-Electron screening- Reaction rates.

Book for study

1. Introductory Nuclear Physics, Kenneth S. Krane.
2. Concepts of Nuclear Physics, Bernard L. Cohen .
3. Nuclear Physics - An Introduction, S.B. Patel.

4. Techniques for Nuclear and Particle Physics experiments, A How to Approach, W.R. Leo.
5. Introductory Nuclear Physics, Samuel S.M. Wong.
6. Particles and Nuclei: An Introduction to the Physical Concepts, B. Povh, K. Rith, C. Scholz, F. Zetsche

2. Thin Film Technology

Unit I: Vacuum Science and Technology

Kinetic theory of gases - molecular velocities - pressure - gas impingement on surfaces – Gas transport and pumping - gas flow regimes - conductance - pumping speed - vacuum pumps and systems - **Pumps** - rotary mechanical pump - diffusion pump - turbo molecular pump - cryopumps - sputter ion pumps - **systems** - system pumping consideration - vacuum gauges - thermal conductivity vacuum gauges - ionization vacuum gauges.

Unit II: Preparation of thin films

Film deposition methods - introduction - fundamentals of film deposition - thermal evaporation - Spray Pyrolysis - Flame Pyrolysis - molecular beam epitaxy - pulsed laser deposition - DC/RF magnetron sputter deposition - chemical vapour deposition - layer by layer growth and ultra thin films - chemical solution deposition - Langmuir Blodgett films-spin and dip coating

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Unit III: Thickness measurement & Nucleation of Thin Films

Thickness measurement: electrical methods – optical interference methods – multiple beam interferometry – Fizeau – FECO methods – Quartz crystal thickness monitor. Theories of thin film nucleation – Four stages of film growth -incorporation of defects during growth.

Unit IV: Electrical and dielectric Properties of Thin films

Introduction of electrical properties of thin films - measurement of resistivity - conduction in metal films - electrical transport in insulating films - semiconductor contacts and MOS structures - Hall Effect and Magneto Resistance, - photoconduction -field effect thin film transistors- Insulation films - Dielectric properties - dielectric losses - Ohmic contacts – metal insulator and metal contacts - DC and AC conduction mechanism.

Unit V: Optical properties of thin films and thin film solar cells

Thin Film optics - theory - optical constants of thin films - experimental technique-multilayer optical systems - Interferences - filters - Antireflection coatings. Thin film solar cells: Role and progress and production of thin film solar cells - photovoltaic parameters. Thin film Silicon (Polycrystalline) solar cells. Current status of bulk Silicon solar cells - fabrication technology photovoltaic performance - Emerging solar cells: GaAs and CuInSe - Dye-sensitized solar cell (DSSC).

Books for Study:

1. The Materials Science of Thin Films, Milton Ohring (1992) Academic Press.
2. Fundamentals of Vacuum technology, Walter Umrath (1998)
3. Hand book of thin film Technology, L. Meissel and Glang
4. Thin Film Phenomena, K. L. Chopra
5. Thin Film Solar Cells, K. L. Chopra and S. R. Das
6. Physics of Thin Films, Vol 12, Ed George Hass & others.

Books for reference:

1. Vacuum Deposition of thin films, L. Holland
2. The Use of Thin Films in Physical Investigation, J. C. Anderson
3. Thin Film Technology, Berry, Koil and Horris

3. Magnetic Materials

Unit I Theoretical Background

Concept of magnetic moments- magnetic orderings - phase transitions- magnetic susceptibility- magnetization - coercive field and remanance - Langevin's theory of Diamagnetism - Langevin's theory of Paramagnetism and Curie's law – Quantum theory of Paramagnetism- ferromagnetism, antiferro magnetism and ferrimagnetism- magnetic symmetry- basic type of interaction in ordered magnetics- molecular field theory- the Curie and Neel points. Domain structure of ferromagnetic crystals and magnetization processes-Peculiarities of the description of ferromagnetic crystals- magnetostriction anisotropy in ferromagnetic of different symmetry - magnetic anisotropy energy corresponding to zero strains and zero stresses - equilibrium directions of spontaneous magnetization- magnetic anisotropy measurement - Magneto-elastic effect.

Unit II Materials of interest

Soft magnetic materials - hard magnetic materials - thin films – ferrites - weakly ferrimagnetic crystals – reorientation - transition layered magnetic thin films- multilayer- DMS, GMR, CMR (Nano particle).

Unit III Synthesis of Magnetic materials

Preparation of materials for magnetic study- composition- chemical reaction-Kinetics of reaction- Hume Rothery rule- phase transformation – Solid solutions- Vegards law- magnetic phase transition- laboratory techniques- chemical identification to conduct chemical reaction- sample preparation for different studies- ceramic method- furnace operation- temperature control- pellet preparation – Sol-Gel , Co-precipitation- ball milling.

Unit IV: Magnetic properties of Thin films

Electron transport in magnetic multi-layers - GMR - spintronics - spin polarized electron tunneling - interlayer exchange coupling - spin relaxation in magnetic metallic layers and multilayers - non-equilibrium spin dynamics in laterally defined magnetic structures.

Characterization : Particle size density- porosity- lattice constant using X-ray-Mossbauer spectroscopy, NMR, FerroMagnetic Resonance (FMR), Magneto-Optic Kerr Effect (MOKE), Magnetic circular dichroism (MCD), - Hall Effect - Field measurement -Vibrating Sample Magnetometer(VSM) (Low and high field magnetic field and temperature)

Unit V Latest developments and applications

Essentials of crystal field theory- exposure to Ligand field theory- Magnetic sensors- Magnetic multi layer- Magnetic recording media- Stoners model-Andersons model explaining electrical conduction of ferrites (Localized bands) -Neutron scattering –Magnetite.

Text Books

1. Magnetism: Principles And Applications- Derek craik, John Wiley & Sons LTD- 1995
2. Ferrite Materials: Science and Technology, B.Viswanathan, Narosa Publishing, VRK Murthy house 1990

3. Modern Crystallography, L.A.Shuvalov, Berlin, Helidelberg - Springer Verlag, New York 1981
4. Fundamentals of Solid State Physics - B.S.Saxena, P.N.Saxena, Pragati Pragasam R.C.Gupta Meerut 18th, Edition 2000.

4.ELECTRONIC STRUCTURE METHODS – THEORETICAL PHYSICS

Unit I

Molecular mechanics-electronic structure methods-standard orientation geometry-energy-molecular orbitals and orbitals energy-charge distribution-dipole and higher multipole moments

Unit II

Potential energy surface – locating minima-transition structure –predicting IR and Raman spectra –frequencies and intensities-normal modes-zero point energy and thermal energy – polarizability and hyperpolarizability

Unit III

Basis set – minimal basis set – split valence basis set – polarized basis set – diffuse function – high anagular moment basis set

Unit IV

Semi empirical methods-limitations of semi empirical methods-electron correlation and past SCF methods-the limits of Hartree Fock method-MPn method-coupled cluster and quadratic configuration interaction method-density functional theory method

Unit V

Perturbation method for discrete levels-equation in various orders of perturbation theory-non-degenerate case-degenerate case-removal of degeneracy-effect of an electric field on the energy levels of an atom-variation method –upper bound on ground state energy-applications to excited states – hydrogen molecule-exchange interaction-WKB approximation -1-D Schrodinger equation – Bohr – Sommerfield quantum condition – WKB solution of the radial wave equation.

Book for study

1. Exploring chemistry with electronic structure methods-James B. Foresman and Aeleen Frisch
2. A text book of Quantum mechanics – P.M. Mathews and K. Venkatesan

5. NANOSCIENCE AND NANOTECHNOLOGY

UNIT I: INTRODUCTION TO NANOSCIENCE AND NANOTECHNOLOGY

Introduction and classification - What is nanotechnology? - Classification of nanostructures - Nanoscale architecture; Summary of the electronic properties of atoms and solids - The isolated atom - Bonding between atoms - Giant molecular solids - The free electron model and energy bands - Crystalline solids - Periodicity of crystal lattices - Electronic conduction; Effects of the nanometre length scale - Changes to the system total energy - Changes to the system structure - How nanoscale dimensions affect properties.

UNIT II: INORGANIC NANOSTRUCTURES

Overview of relevant semiconductor physics - Quantum confinement in semiconductor nanostructures - The electronic density of states - Fabrication techniques - Physical processes in semiconductor nanostructures - The characterisation of semiconductor nanostructures - Applications of semiconductor nanostructures.

UNIT III: NANOSTRUCTURED MOLECULAR MATERIALS

Introduction; Building blocks - Principles of self-assembly - Self-assembly methods to prepare and pattern nanoparticles - Templated nanostructures - Liquid crystal mesophases - Macromolecules at interfaces - The principles of interface science - The analysis of wet interfaces - Modifying interfaces - Making thin organic films - Surface effects on phase separation - Nanopatterning surfaces by self-assembly - Practical nanoscale devices exploiting macromolecules at interfaces.

UNIT IV: SYNTHESIS - PHYSICAL AND CHEMICAL METHODS

Ball Milling – Electrodeposition - Spray Pyrolysis - Flame Pyrolysis - Inert Gas Condensation Technique (IGCT) – Thermal evaporation – Pulsed Laser Deposition (PLD) – DC/RF Magnetron Sputtering - Molecular Beam Epitaxy (MBE), Sol-Gel Process — Self assembly – Metal Nanocrystals by Reduction - Solvothermal Synthesis - Photochemical Synthesis - Sonochemical Routes – Reverse Micelles and Micro emulsions - Combustion Method – Template Process - Chemical Vapor Deposition (CVD) – Metal Oxide Chemical Vapor Deposition (MOCVD) .

UNIT V: PROPERTIES OF NANOMATRIALS

Structural Properties-Mechanical properties – Electrical Properties- Optical properties- Thermal properties-catalytic properties- Magnetic properties.

References

1. Nanoscale Science and Technology, Robert W. Kelsall, Ian W. Hamley and Mark Geoghegan, John Wiley & Sons, Ltd., UK, 2005.
2. Introduction to Nanotechnology, Charles P. Poole Jr and Frank J. Owens, Wiley Interscience, 2003.
3. Bio-Inspired Nanomaterials and Nanotechnology, Edited by Yong Zhou, Nova Publishers.
4. Nano:The Essentials: Understanding Nanoscience and Nanotecnology, T.Pradeep, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2008.
5. Nanostructures & Nanomaterials: Synthesis, Properties & Applications, Guozhong Gao, Imperial College Press (2004).
6. Nanomaterials : Mechanics and Mechanisms, K. T. Ramesh, Springer 2009.

6.SURFACE ENHANCED SPECTROSCOPY

UNIT-I THEORY OF MOLECULAR VIBRATIONS. THE ORIGIN OF INFRARED AND RAMAN SPECTRA

Electronic, vibrational, rotational and translational energy-electronic structure of molecules-separation of nuclear and electronic motions-vibrations in polyatomic molecules-equilibrium properties. Dipole moment and polarizability-fundamental vibrational transitions in the infrared and Raman regions-symmetry of normal modes and vibrational states-selection rules-the example of ab initio computation of the Raman and infrared spectra conventions for molecular axes-vibrational intensities-definition of cross section-the unit of energy and force constants.

UNIT II THE INTERACTION OF LIGHT WITH NANOSCOPIC METAL PARTICLES AND MOLECULES ON SMOOTH REFLECTING SURFACES

Electric permittivity and refractive index-propagation of electromagnetic waves and the optical properties of materials-frequency dispersion in solid-metals-scattering and absorption computations-Mie computations-reflection-absorption infrared spectroscopy on smooth metal surfaces-reflection coefficients and reflectance-reflection-absorption infrared spectroscopy (RAIRS)-RAIRS EXAMPLE.

UNIT III SURFACE ENHANCED RAMAN SCATERRING (SERS)

Electromagnetic enhancement mechanism-definition of SERS-single particle SERS model systems-spherical model-the spheroidal model-the shape factor, aggregates and fractals-distance dependence-coverage dependence of SERS.

UNIT IV SURFACE ENHANCED INFRARED SPECTROSCPY

Overview-theoretical models of SEIRA- SEIRA active substrates –interpretation of the observed SEIRA spectra-applications of SEIRA-SEIRA of ultrathin films-surface photochemistry and catalytic reactions-electrochemistry-analytical applications.

UNIT V SURFACE ENHANCED FLUORESCENCE SPECTROSCOPY

Review of metal effect on fluorescence-optical properties of metal colloids-theory for fluorophore colloidal interaction-experimental results on MEF-distance dependent MEF-Applications of MEF-mechanism of MEF-perspective of RET.

Reference:

1. Surface Enhanced Vibrational Spectroscopy-Ricardo Aroca
   Department of Chemistry & Biochemistry, University of Windsor, Ontario, Canada
2. Principles of Fluorescence Spectroscopy- J.Lakowicz, 3rd Ed.Springer, New York.

7. SUPERCONDUCTIVITY

UNIT I: Macroscopic Aspects of Superconductivity
Electron- Phonon Interactions, London Equations, Intermediate States, Thermodynamic of the Transition, Critical current in a superconductivity wire, Two- Types of superconductor, Two-Fluid Model.

UNIT II: Ginzburg- Landau Theroy and Vortices in Type II superconductivity

Ginzburg-Landau theory Superconducting order parameter. Motivation for the Ginzburg-Landau free energy (detailed treatment not required), Coherence length, Ginzburg-Landau parameter, type I and type II superconductors. The vortex lattice, Phase coherence and rigidity in the superconducting state.

Isolated Vortices, Intermediate between Vortices, Potential of Vortex near a surface, Dissipation by Vortex Flow, Vortex Pinning, Strong Pinning Limit: The Bean Model.

UNIT III: Superconducting quantum Interference, DC, AC effects and Inhomogeneous Superconductivity:

Josephson effect DC Josephson effect. AC Josephson effect. Inverse AC Josephson effect and Shapiro jumps. Current-source model and the tilted-washboard potential. Superconducting quantum interference device (SQUID).

Semi- Classical Approximation, Vortex core states, S-N-S Junctions and Andreev States, Gapless Superconductivity, Collective modes.

UNIT IV: BCS Theory of Superconductivity:

BCS theory Isotope effect and its significance, Attractive interaction and the formation of Cooper pairs. BCS wave function (detailed treatment not required) as a coherent wave function with a well-defined phase. Implications of BCS. Existence of the energy gap, its temperature dependence and experimental evidence.

UNIT V: High Temperature Superconductivity:

Unconventional superconductors and superconducting technology (outline only) High-temperature superconductors, Alternative pairings (e.g. spin-triplet, d-wave etc). Applications of superconductors, Microscopic theory of superconductivity, Cooper problem, thermodynamic properties.

REFERENCE BOOKS

1.Tilley, D.R. & Tilley, J. *Superfluidity and Superconductivity,* (Bristol: Hilger 1990);

2.Annett, J.F. *Superconductivity, Superfluids and Condensates* (Oxford 2004);

3.Guenault, T. Basic Superfluids (Taylor&Francis 2003);

4.Schmidt, V.V. *The Physics of Superconductors: Introduction to Fundamentals and Applications,* (Springer 1997);

5. Magnetism and Superconductivity by Laurent-Patrick Levy and translated by Stephen Lyle.

8. CRYSTAL GROWTH

UNIT I: Nucleation Theory

Nucleation concept – Homogeneous, heterogeneous nucleation – classical theory – Energy of formation of nucleus – kinetic theory of nucleation – statistical theory of nucleation – nucleation rate – induction period.

UNIT II: Theories of crystal Growth

Two dimensional nucleation theory – Temkins model of crystal growth – limitations of Temkins model – BCF surface diffusion theory – solution of BCF surface diffusion equation, Atmospheric nucleation - condensation of vapour droplets – ice formation –nucleation agents – artificial rain making.

UNIT III: Melt growth

Temperature measurement and control – Starting materials and purification conservative and non-conservative process – Bridgman method –Czochralski method – Verneuil method – Zone melting – Skull melting – Fluid flow analysis in melt growth – theory and experiment.

UNIT IV: Growth from solutions

Measurement of supersaturation – Low temperature solution growth – High temperature solution growth – Accelerated crucible rotation technique (ACRT) – Electrocrystallization – Crystal growth in gel – Growth of biological crystals – Hydrothermal technique – Sol-gel growth – Chemical bath deposition (CBD) – Photochemical deposition (PCD) – unidirectional growth of crystals from solution, Physical Vapor deposition (PVD), Chemical Vapor deposition (CVD), Theory of oraganic crystals, Inorganic, and semi organic crystals.

UNIT V: Vapour growth

Physical vapour transport –chemical vapor transport. Epitaxial growth techniques – Liquid phase epitaxy - vapour phase epitaxy: chloride, hydride, metalorganic - molecular beam epitaxy - chemical beam epitaxy

Reference Books

1. Nucleation, Ed, by A.C. Zxettlemoyer, Marcel- Dekker Publishers, 1969.
2. Modelling Crystal growth rates from solution- by makoto Ohara and Robert C. Reid, 1973.
3. Crystal growth Processes –by J.C. Brice, John Wiley and Sons, Newyork 1986.
4. Crystal Growth – by B.R. Pamplin, 1975, Pergamon Press, London

   Advance Crystal Growth – Edited by P.M.Dryburgh, B.Cockayane and K.G.Barraclough, Prentice – Hall, London, 1986
5. Crystal growth processes and Techniques by- P. Ramasamy.

9. LASER AND OPTICS

1. Lasers: Fundamentals and Types

Basic Construction and Principle of Lasing- Einstein Relations and Gain Coefficient -Creation of a Population Inversion- Three-Level System - Four-Level System -Threshold Gain Coefficient for Lasing- Laser types-He-Ne Laser-CO_2 Laser- Nd:YAG Laser- Semiconductor Laser.

2. Laser Operation

Optical Resonator- Laser Modes- Axial modes- Transverse modes-Modification in Basic Laser Structure- Basic Principle of Mode Locking- Active Mode Locking -Passive Mode Locking-Q-Switching- Pulse Shaping.

3. Laser Beam Characteristics:

Introduction to Gaussian Beam-width-Divergence-Radius of Curvature-Rayleigh Range-Guoy Phase –formulation of ABCD matrix method –ABCD matrix of some optical system-ABCD Law for Gaussian Beam-The Complex Radius of Curvature

4. Focusing of laser beam

Diffraction- limited spot size-tight focusing of light angular spectrum representation of optical near field-aplanatic lens-Focusing of higher-order laser modes-Radially polarized doughnut mode-Azimuthally polarized doughnut mode-applications-applications-near field optical recording-optical tweezers-photonic crystals.

5. Surface plasmons

Introduction-Optical properties of noble metals- Drude–Sommerfeld theory- Surface Plasmon polaritons at plane interfaces- Properties of surface plasmon polaritons- Excitation of surface plasmon polaritons- Surface plasmon sensors

References:

1. Subhash Chandra Singh, Haibo Zeng, Chunlei Guo, and Weiping *Cai -Nanomaterials: Processing and Characterization with Lasers*.- Wiley-VCH Verlag GmbH & Co. KGaA.(2012).
2. Walter Koechner-*Solid state Laser Engineering*-6th edition-Springer
3. L. Novotny and B. Hecht-*Principles of Nano optics*-Cambridge University Press(2006)
4. R.G.Driggers,C.hoffman-*Encyclopedia of Optical Engineering*- Marcel Dekker(2003)
5. W. M. Steen, J.Mazumder- *Laser Material Processing*. - Springer (2010)
6. Bahaa E. A. Saleh, Malvin Carl Teich- *Fundamentals of Photonics*- John Wiley & Sons, Inc.
7. D.L. Mills -*Nonlinear Optics – Basic Concepts*, Springer, Berlin 1998 .
8. B.B. Laud- *Lasers and Nonlinear Optics*, 2nd Edn. New Age International (P) Ltd., New Delhi, 1991

10.ASTROPHYSICS

Unit I: Radio Astronomy

Radio window, Rayleigh Jeans law optical Thickness, Brightness temperature, Radio telescopes, resolution , sensitivity, noise temperature, synthesis of telescopes, interferometry, radio sources, their spectra, thermal and non thermal mechanism (9 hrs)

Unit II: Space Astronomy

Transparency of Earth's atmosphere, X-ray Astronomy, X- Ray telescopes, X-ray emission mechanism, X-ray detection techniques, Scintillation and production mechanism, loss mechanism, Cerenkev radiation detection (9 hrs)

Unit III: The Milky way galaxy & Extra galactic Astronomy

The Morphology of the galaxy, interstellar dust, mass distribution, total mass, kinetics of the milky way, the galactic centre

General characteristic of galaxy classification, surface brightness, masses and rotation curves, dark matter , clusters of galaxies, active galaxies, radio galaxies, quasars, physical processes in active galactic nuclei (AGN), Structure and evolution of AGNs (10hrs)

Unit IV: Cosmology & General Relativity and its applications

Elements of Newtonian Cosmology – Elementary account of BigBang Theory

Elements of Tensor analysis, The equivalence Principle, Christofell's symbol, Curvature tensor, Einstein's Equations, Schwarzschild solution, The Newtonian limit, Classical tests of general relativistic stellar structure (10 hrs)

Unit V: Relativistic Cosmology

Space Time curvature, Robertson – Walker Metric, Open, flat and closed universes-, Big-Bang theory, Elements synthesized in hot big bang, Inflationary cosmology (qualitative) (10 hrs)

Books for Reference

1. Kraus,J.d., Radio Astronomy, Signet Press
2. Kartunenn, Fundamental Astronomy, Springer Verlag
3. Ian Robson, Active Galactic Nuclei
4. Caroll and Ostile, An Introduction to Modern Astronomy, Addison Wesley.
5. Heller.P. Computational Astronomy, Willman Bell
6. Shu F, The physical Universe, University of Science Press
7. Adler, Bazin and Schiffer, Introduction to General Relativity, Mc Graw Hill
8. Ramanamurthy, P.V. & Wolfandale, A.W. , Gamma ray Astronomy, Cambridge University Press
9. Narlikar J.V. Introduction to Cosmology, CUP
10. Chen F.F. Introduction to Plasma Physics, Plenum Press