Department of Physics

University of Kerala

M.PHIL PROGRAMME IN PHYSICS
SYLLABUS
(Under credit and Semester system w.e.f. 2016 Admissions)

Department of Physics
University of Kerala

M. Phil Programme in Physics

Program Objectives

- To provide training in Research Methodology as a pre Ph.D. course.
- To enhance the fundamental knowledge of the student in theoretical Physics.
- To provide training in undertaking project work, so as to analyze and solve the problem independently.
- To provide training for making technical presentation and publishing results in any chosen topic related to the field of specialization.

Semester No.	Course Code	Name of the Course	Number of Credits
I	PHY-711	Research Methodology	4
	PHY-712	Theoretical Physics	4
	PHY-713 (i)	Nanostructured Materials	4
	PHY-713 (ii)	Inorganic Phosphors	4
	PHY-713 (iii)	Materials for Solid oxide Fuel Cells	4
	PHY-713 (iv)	Materials for Microwave Applications	4
II	PHY-721	Dissertation	20
		TOTAL CREDITS	32

Semester : I
Course Code : PHY-711
Course Title : Research Methodology
Credits : 4

Aim: The aim of this course is to inculcate aptitude skills and proficiency for formulating research problems executing the research plan and critically evaluating the results. The course also envisages to seed and nurture a strong ethical sense in research scholars.

Objectives: The course is designed to carter the needs of a student with no prior training in research methodology other than a brief exposure received during M. Sc. Project work. On completion of the course the student will have a sound knowledge different types of research, how to identify a problem and formulate and execution plan how to do literature survey etc. An exposure to relevant data handling techniques is also included. Students are also introduced to the science and art of reporting and thesis writing. The course also includes social, environmental and ethical perspectives in the area of scientific research.

Module 1: Research Methodology: Meaning of research – Objective of research – Motivation in research – Types of research – Research approaches – Research and Scientific method – Research process – Criteria of research – Important sources of information – Information on organisation involved in physics related research writing research proposal – writing scientific papers – searching for scientific information.

Module II: Quality of research parameters: Citation, h index, impact factor – information on physics related scientific journals ethical issues laboratory safety precautions. Intellectual property rights and patent law – Trade Related aspects of Intellectual Property Rights – Reproduction of published material – Plagiarism.

Module III: Error Analysis: Errors classification and propagation – systematic errors – Random errors – error propagation. Combination of independent terms – Monte Carlo Methods – Probability distribution – properties of probability distributions – Binomial distribution – examples – Poisson distribution – Normal distribution – central limit theorem – Lognormal distribution – Lorentz distribution – Hazard function – exponential distribution – Population Statistics chi-square distribution student's distribution –F distribution – Linear regression analysis Method of least square linear fitting.

Module IV: Material analytical techniques: Structural analysis – XRD, electron diffraction – Imaging techniques – SEM, TEM, AFM & Principal Compositional analysis – XPS, EDAX, ICP, TGA/DTA, Vibrational Spectroscopic Techniques- Raman Spectroscopy, FTIR spectroscopy. Optical Studies – Principle of Optical absorption – Band gap and defect level analysis – Photoluminescence – applications.

Module IV: Spectroscopy for Materials Analysis: Vibrational Spectroscopic Techniques- Raman Spectroscopy, FTIR spectroscopy. Optical Studies- Principle of Optical absorption- Band Gap and defect level analysis – Photoluminescence - applications.

References

- C.R. Kothari, Research Methodology Methods and Techniques, Second Revised Edition, New Age International Limited Publishers, (2004).
- H. J. C. Berendsen, A student guide to Data and Error Analysis, Cambridge University Press, (2011).
- M. P. Marder, Research Methods for Science, Cambridge University Press, (2011).
- Wadehra,B.L. 2000.*Law relating to patents, trademarks, copy right designs and geographical indications*. Universal Law Publishing.

Semester : I
Course Code : PHY-712
Course Title : THEORETICAL PHYSICS
Credits : 4

Aim: To equip the students with advanced knowledge of core theoretical areas of Mathematical Physics and Quantum Physics.

Objectives: To teach advanced concept of mathematical physics, computational methods and relativistic quantum mechanics and quantum field theory.

Course Content

Module I: Review of Mathematical Physics: Illustration of concepts of Vectors. Line, surface and volume integrals by evaluating some cases both direct integration and applying Stokes and Gauss' theorems. Evaluation of reals integrals applying the residue theorem of complex variables. Discussion of standard techniques of solving an integral equation (in one variable) by the method of successive substitutes using numerical examples. Computer simulation in Monte-Carlo simulation. Transformation of co-ordinates in linear space- summation convention- contra-variant and covariant tensors- properties of Kronecker delta- addition, multiplication and contraction of tensors – metric tensor- conjugate metric tensor – associated tensor- tensor calculus.

Module II: Group theory: Definition of a group – elementary properties of group- sub groups – co-sets and classes – cyclic group – homomorphism and isomorphism – representation of finite groups – invariant subspace – properties of representations' – reducibility of a representation – irreducible representations – orthogonally. Lie groups – SO(2) and SO(3) groups – generators of SO(2) – special unitary groups – SU(2) and SU(3) groups and their representations.

Module III: Elements of Relativistic Quantum Mechanics: The Schrödinger relativistic theory (Klein-Gordon equation) – plane wave solutions, interpretation of the results, particle in a coulomb field- success and failure of Schrödinger's relativistic theory. Dirac's relativistic equation – free-particle equation, Dirac's matrices, Covariant form of Dirac equation, Position probability density, expectation values, matrices for α and β, free-particle solutions and energy spectrum – existence of states with negative energy, Significance of negative energy states

Module IV: Relativistic Quantum Mechanics of Dirac Particle: Spin of the Dirac particle, magnetic moment of electron, Dirac particle in electromagnetic fields, Spin-orbit interaction, Dirac's equation for a Central field – the Hydrogen atom, Lamb shift. Relativistic co-variance – Covariance of the Dirac equation – Zitterbewegung, Theory of positron.

Module V: Elements of Field Quantization: Classical Field equation- Lagrangian form Hamiltonian form, Quantization of the field, Quantization of the non-relativistic Schrödinger equation – systems of bosons and fermions. Relativistic fields – the Klein Gordon field, The Dirac field, quantization of the electro-magnetic field.

References

- Aruldhas, G., (2011) Quantum Mechanics, IInd Ed. Prentice-Hall of India Pvt. Ltd., New Delhi.
- Butkov, E., (1968) Mathematical Physics, 1st Ed. Addison Wesley.
- Ghatak, A, K, et.al, (2012) Mathematical Physics: Differential Equations and Transform theory, Ist Ed. Macmillan and Co.Ltd, New York.
- Joshi, A, W., (2011) Elements of Group Theory for Physicists,4thEd.New Age International Publishers Pvt. Ltd., New Delhi.
- Mathews,P,M., and Venkatesan,K.,(1978) A text book of Quantum Mechanics,1st Ed.Tata McGraw-Hill, New Delhi.
- Merzbacher, E., (2011) Quantum Mechanics, 3rdEd.Wiley India Pvt. Ltd.
- Pipes, L, A., and Harvill, L, R., (1982) Applied Mathematics for Engineers and Physicists, McGraw-Hill, New York.
- Rajputh, B, S., (2001) Mathematical Physics, 15th Ed. PragathiPrakashan, Meerut.
- Schiff, L, I., (2010) Quantum Mechanics,3rd Ed. McGraw Hill Book Co. Inc., New York.
- Weber, H, J., and Arfken, G, B., Essential Mathematical Methods for Physicists, 4thEd.Academic Press.
- Wu-Ki Tung, (2006) Group Theory in Physics,1st Ed. World Scientific Publishing Co. Pvt. Ltd., Singapore.

Semester : **I**
Course Code : **PHY-713 (i)**
Course Title : **NANOSTRUCTURED MATERIALS**
Credits : **4**

Aim: To introduce the world of nanomaterials, their characterization and properties.

Objectives: To teach fundamentals of nanomaterials and their properties and also gives an account of present day research in nanoscience.

Module I: Basic solid state physics: Crystals, amorphous materials, unit cell, space lattices, Miller indices, symmetry operations - translation, point operations, hybrid operations, point groups, space groups, common crystal structures, quasi crystals, nano crystals. Bonding in solids- covalent bond, metallic bond, ionic bond, mixed bonds, van der Waals bonds, hydrogen bonds, elastic constants of crystals – elastic stress, elastic strain, dilation, elastic compliance and stiffness constant, elastic energy density, bulk modulus and compressibility, elastic waves in cubic crystals - propagation of waves in the [100] direction and [110] directions. Reciprocal lattice, diffraction from crystals-Bragg law, Laue condition, diffraction of X-rays, neutrons and electrons. Electron energy bands - consequences of periodicity - Bloch theorem, wave mechanics interpretation of energy bands, Kronnig-Penny model, nearly free electron model, zone scheme for energy bands, energy bands in a general periodic potential, solutions near zone boundaries.

Module II: Introduction to Nanomaterials and Characterization techniques: Nanostructured materials -Definition, classification schemes, characteristic features, overview of properties, overview of synthesis techniques.
XRD analysis- Phase identification, determination of crystallite size and microstrain – Hall-Williamson analysis, Warren –Averbach analysis, Fourier analysis, Rietveld refinement, determination of precise lattice parameters, GIXRD.

Module III: Structural Charaterization Techniques: Electron microscopy- Resolution and magnification, scanning electron microscopy and transmission electron microscopy. Scanning Probe Microscopy – Scanning Probe Microscope (SPM), Scanning Tunneling Microscope (STM), Atomic Force Microscope (AFM), Scanning Tunneling Spectroscopy (STS), FMM, Scanning Near field Optical Microscopy (SNOM).

Module IV: Advanced Charaterization Techniques: Raman and IR spectroscopy - general aspects, Raman and IR spectra of nanocrystalline materials, surface modes, breakdown of selection rule, phonon confinement. UV-Visible and PL Spectroscopy, blue shift in semiconductors, Plasmon resonance, effect of defects and dopants in uv-visible absorption and PL emission spectra. Thermal analysis techniques- TGA, DTA, DSC.

Module V: Properties of applications of nanostructured materials: Nanostructured transition metal oxides – Oxides of cobalt, copper, manganese, nickel, tungsten, zinc etc. Synthesis techniques employed, crystal structure, physical properties – band gap, uv-visible absorption and photoluminescence emission. Bulk and nanocrystalline transition metal oxides - electrical conductivity, thermal properties, IR and Raman spectra, effect of grain boundaries on electrical response and their possible technological applications in various fields – energy storage, sensors, catalysis, light emission devices, magnetic storage devices, varistors, etc.

References

- Elements of Solid State Physics – J.P Srivastava PHI Edition 2(2009)
- Elements of X-Ray Diffraction – B.D Cullity, Addison-Wesley Publishing company, Inc (1956).
- G. Cao, Nanostructures and Naomaterials-syntesis, Proeperties and Applications, Imperial College Press, 2004.
- Introduction to Nanoscience and Nanotechnology – K.K Chattopadhyay, A.N Banerjee, PHI New Delhi 2009, Edition 1.
- Introduction to Solid State Physics - C Kittel , Seventh edition, John Wiley and sons, Inc, Singapore (1995)
- Micromachines as tools for Nanotechnology- H Fujita, Spinger 2003, Edition 1.
- Principles of Instrumental Analysis, Skoog, Holler and Nieman, fifth edition.
- Referred Research papers on various aspects of nanostructured materials.
- Solid State Physics – J.S Blackmore Second edition, Cambridge University Press, Cambridge (1985)
- X-Ray diffraction procedure – H.P Klug and L.E Alexander, John Wiley and sons, Inc (1954).

Semester : I
Course Code : PHY-713 (ii)
Course Title : INORGANIC PHOSPHORS
Credits : 4

Aim: To introduce the world of inorganic phosphors and their application in LEDs

Objectives: To teach elements of crystal structure, luminescence, phosphors and solid state lighting technologies.

Module I: Atomic structure and bonding*:* Atomic structure and bonding in materials, Crystal systems, Unit cells and space lattices, Determination of structures of simple crystals by X-ray diffraction, Diffracted intensity calculations, Miller indices of planes and directions, Theoretical density, Concept of amorphous, Single and polycrystalline materials, Imperfections in crystalline solids and their role in influencing various properties.

Module II: Synthesis of Phosphors: Solid state synthesis routes- Dry milling, Wet milling, Planetary ball milling, Vibratory ball milling, Calcination, addition of dopants. Synthesis of nanophosphors- Bottom up and Top down methods, Hydrothermal, sol gel and citrate gel methods.

Module III: Luminescence: Fundamentals of Luminescence–Fluorescence and Phosphorescence, Electronic transitions in an atom, selection rules, Einstein coefficients, Design of phosphors, electronic process leading to luminescence energy transfer between identical and unlike centers

Module IV: Phosphors: Energy migration and concentration quenching, Crystal field splitting, Nephelauxetic effect, Rare earth and their spectral properties, spectral intensities of f-f transition, Judd-Ofelt theory, Rare earth energy levels and electronic states, energy transitions and mixed states Judd-Ofelt Theory.

Module V: Solid State Lighting Techniques: Lighting Quality: CIE Chromaticity diagram, color Temperature, Color rendering index, Lighting efficiency and efficacy, solid state lighting- LED Mechanism behind photon emission, current technology, Inorganic Light emitting diodes, Phosphor converted white LEDs.

References

- Elements of X-ray diffraction, B. D. Cullity, Addison - Wesley Publishing Company, INC.
- Introduction to fine ceramics – Noboru Ichinose, John Wiley & Sons LTD.
- Introduction to solid state physics – S. O. Pillai, New Age Science (2009).
- Luminesdcne from Theory to Applications Edited Cess Ronda, 2007.
- Phosphor Hand book by William M. Yen, S. Shionoya, H. Yamamoto Second edition.
- S. Atkins Inogranic Chemistry 5th edition Oxford University Press.

Semester : **I**
Course Code : **PHY-713 (iii)**
Course Title : **MATERIALS FOR SOLID OXIDE FUEL CELLS**
Credits : **4**

Aim: To introduce solid state fuel cells and their applications

Objectives: To teach crystal structure, ceramic processing, SOFC and SOFC design

Module I: Atomic structure and bonding: Atomic structure and bonding in materials, Crystal systems, Unit cells and space lattices, Determination of structures of simple crystals by X-ray diffraction, Diffracted intensity calculations, Miller indices of planes and directions, Theoretical density, Concept of amorphous, Single and polycrystalline structures, Imperfections in crystalline solids and their role in influencing various properties.

Module II: Fundamentals of ceramic processing & forming*:* Dry milling, Wet milling, Tumbling milling, Planetary ball milling, Vibratory ball milling, Sintering aids and dopants, Green body forming, Mechanical compaction, Powder packing, Uniaxial pressing, Calcination, Kinetics of sintering, Solid sate sintering, Physical characteristics of powders, Driving force for sintering and densification mechanisms, Density analysis, Grain size and microstructure analysis techniques.

Module III: Introduction to Solid Oxide Fuel Cells- Thermodynamics (enthalpy, entropy, Gibbs free energy, reversible process), Electrochemistry (reversible battery, Nernst Equation), Heat and mass transfer Efficiency and open circuit voltage Operational fuel cell voltages, Activation losses, Fuel crossover and internal currents, Ohmic losses, Mass transport or concentration losses, The charge double layer Proton exchange membrane fuel cell, Electrode structure, Water management, cooling and connection, Operating conditions

Module IV: Fuel Cells - Alkaline electrolyte fuel cell, Historical Background and Overview, Types of Alkaline Electrolyte Fuel Cell, Operating Pressure and Temperature, Electrodes for Alkaline Electrolyte Fuel Cells, Cell Interconnections Direct methanol fuel cell, Anode Reaction and Catalysts, Electrolyte and Fuel Crossover, Cathode Reactions and Catalysts, Methanol, Production, Storage, and Safety Solid oxide fuel cell

Module V: Solid Oxide Fuel Cells -SOFC Components, Practical Design and Stacking Arrangements for the SOFC, SOFC Performance, SOFC Combined Cycles, Novel System Designs and Hybrid Systems, Intermediate Temperature (IT) and Low Temperature (LT) SOFCs Hydrogen generation, Hybrid Systems Fuel cell system analysis (simulation of smart power grid)

References

- J. Bard and L. R. Faulkner, Electrochemical Methods: Fundamentals and Applications, 2nd Edition, Wiley 2000 6 A. Faghri and Y. Zhang, Transport Phenomena in Multiphase Systems, Elsevier 2006

- Elements of X-ray diffraction, B. D. Cullity, Addison - Wesley Publishing Company, INC.

- Introduction to fine ceramics – Noboru Ichinose, John Wiley & Sons LTD.
- J. Larminie and A. Dicks, Fuel Cell Systems Explained, 2nd Edition, Wiley (2003)
- O’Hayre, S. W. Cha, W. Colella and F. B. Prinz, Fuel Cell Fundamentals, Wiley (2005)
- S. Srinivasan, Fuel Cells: From Fundamentals to Applications, Springer (2006)
- Xianguo Li, Principles of Fuel Cells, Taylor and Francis (2005)

Semester : I
Course Code : PHY-713 (iv)
Course Title : MATERIALS FOR MICROWAVE APPLICATIONS
Credits : 4

Aim: To introduce materials for microwave applications

Objectives: To teach crystal structure, ceramic processing, electromagnetic theory and microwave characterization of various materials.

Module I: Atomic structure and bonding: Atomic structure and bonding in materials, Crystal systems, Unit cells and space lattices, Determination of structures of simple crystals by X-ray diffraction, Diffracted intensity calculations, Miller indices of planes and directions, Theoretical density, Concept of amorphous, Single and polycrystalline materials, Imperfections in crystalline solids and their role in influencing various properties.

Module II: Fundamentals of ceramic processing & forming: Dry milling, Wet milling, Tumbling milling, Planetary ball milling, Sintering aids and dopants, Dispersants, Green body forming, Mechanical compaction, Powder packing, Uniaxial pressing, Isostatic pressing, Hot pressing, Calcination, Kinetics of sintering, Solid sate sintering, Physical characteristics of powders, Liquid phase sintering and its stages, , Density analysis, Grain size and microstructure analysis techniques,
Electromagnetic theory: Electro Magnetic waves, Ampere's circuital theorem, Faraday's law of electromagnetic induction, Gauss's Law, Maxwell's equations and its derivation, Boundary conditions, Electro Magnetic wave propagation in dielectrics and conductors, Skin depth
.
Module III: Guided waves and wave guides: Guided waves, Transverse Electric, Transverse Magnetic, Transverse Electric and Magnetic modes from Maxwell's equations, Velocities of propagation, Wave guides, Rectangular wave guide, Transverse Electric and Transverse Magnetic waves through rectangular wave guide.

Module IV: Dielectrics: Theory of dielectrics, Dielectric in an electric fields, Dielectric permittivity and dielectric loss, Local field – Lorentz method, Claussius Mossotti relation and its importance, Polarization mechanisms- Interfacial, Ionic, Dipolar and Electronic polarization, Linear and nonlinear dielectrics. Factors affecting the loss factor of ceramics, Resonance, Absorption and Relaxation, Frequency and temperature dependency of dielectric permittivity, Loaded and unloaded quality factor, Microwave Antennas.

Module V: Microwave characterization: Measurement of cavity perturbation techniques, Co-axial line method, Cavity resonator technique, Waveguide method determination of and relative permittivity, shielding efficiency etc.

References

- Dielectrics materials for wireless communication, M. T. Sebastian, Elsevier Oxford (2008).
- Elements of X-ray diffraction, B. D. Cullity, Addison - Wesley Publishing Company, INC.
- Electromagnetic waves and radiating systems- Edward. C. Jordan and Keith. G. Balmain, Prentice Hall India Pvt. Ltd (1996).
- Introduction to ceramics – W. D. Kingery, H. K. Bowen and D. R. Uhlmann, Second edition – John Wiley and sons (1976).
- Introduction to fine ceramics – Noboru Ichinose, John Wiley & Sons LTD.
- Introduction to solid state physics – S. O. Pillai, New Age Science (2009).
- Microwave electronics: Measurements and materials characterization, L F chen, C K ong, C P Neo, V V Varadan and V K V aradan, John Wiley & sons, England (2004).

Semester : II
Course Code : PHY-721
Course Title : DISSERTATION
Credits : 20

Aim: To provide training for doing project work, technical presentation and publishing results in any chosen topic related to the field of specialization.

Objectives: To mold the students to do research, present it and publish it.