Ch. Charan Singh University, Meerut
Department of Physics

Syllabus
for
Master of Philosophy (M.Phil.)
(Physics)
w.e.f.
Academic Session 2016-17 Onward

Courses offered

- **Research Methodology (Compulsory)**
- **Emerging trends in Experimental Techniques in Physics (Compulsory)**
- **Advanced Microelectronics Processing**
- **Materials Science and Energy Devices**
- **Advanced Condensed Matter Physics**
- **Atomic Collision Theory**
- **Computer Programming in Fortran-90**
- **Project Thesis**

Notes:

1. Each Theory course comprises of 60 Lectures of 1 Hour duration.
2. Each Semester shall comprise of 2 courses. There shall be 12 Lectures per week for theory teaching. The courses named "Research Methodology" and "Emerging trends in Experimental Techniques in Physics" are compulsory in compliance to UGC Extraordinary Gazette no. 278, July 5, 2016 for the purpose of exemption from Pre-Ph.D. Course work in Physics. The remaining two courses shall be offered from above list depending upon the availability of the expert faculty
3. Each course is of 100 Marks. Out of 100 marks, for 80 Marks Students will be evaluated by semester end examination and for 20 marks, Internal assessments will be done by the course teacher through quiz/seminar/assignments etc.
4. Student will compulsorily engaged themselves in Project thesis work for 6 hours per week.
5. Students are required to secure minimum 75% attendance (as per university rules) in each theory course to qualify for appearing in Semester end examination.

M.Phil. (Physics) (Compulsory Course no.1)
RESEARCH METHODOLOGY

Introduction: Introduction and definition of research, Objectives of research, Motivation in research, Classification of research- experimental and theoretical, Fundamental and applied, Quantitative and qualitative, Identifying and formulating the research problem, Assessment of current status of the topic chosen, Literature review and reference collection, Introduction to peer-reviewed and open access journals, E-Journals and e-books, Review and monographs, Impact factor of a journal, h-index, i-10 index, Various tools for literature review, Ethics in research.

Data Interpretation, Error and Statistical Analysis:
Sources types, Acquisition and interpretation of data, Tabulation, Drawing and analysis of graphical representation of data using MS-Excel, ORIGIN etc, Incorporation of error bars in graphs, Units, Abbreviations and nomenclature used in scientific writing, Types of errors: Gross error, Systematic error, Random error and analysis of errors. Statistical analysis of data (arithmetic mean, deviation from mean, average deviation, standard deviation, chi-square), Correlation and regression, Least square curve fitting, Gaussian distribution, Conversion of images in specific dpi (data per inch).

Scientific Report Writing, Presentation and Intellectual Property:
Significance of report writing, Layout of research report and research paper, Different steps in writing, Report and research paper, Writing references, Research and scientific writing ethics, Issues of authorship, Conflict of interest, Research misconduct, Plagiarism, Preparation of Power point scientific presentation and poster presentation, Introduction to Intellectual Property (IP) and Intellectual Property Right (IPR), Fields of Intellectual Property Protection: Patents, Copyright and related rights, Trademarks Industrial Designs and Integrated Circuits (IC's), Geographical Indications.

Information and Communication Technology (ICT):
Meaning of ICT, Advantages, Disadvantages and uses, Computers and internet: Networking, Different LAN and WAN connections, Connection to a network, Web Browsers, Basics of internet and internet security, Analyzing data using MATLAB or any other related software.

Text and Reference Books:

1. Research Methodology: Methods and Techniques by CR Kothari and G. Gaurav, New Age International (2014).
2. Research Methodology a step by step guide for beginners by Ranjit Kumar.
3. Research Methodology Methods and Statistical Techniques by Santosh Gupta
4. Statistical Methods by SP Gupta.
5. Research Design, Qualitative, Quantitative and mixed methods approaches by W. Creswell, third edition.
6. Information Communication Technologyby Tim Shortis.
7. Getting Started with MATLAB 7, Rudra Pratap, Oxford University Press (2006).

M.Phil. (Physics) (Compulsory Course no.2)

EMERGING TRENDS IN EXPERIMENTAL TECHNIQUES IN PHYSICS

Vacuum Science: Introduction, Important areas of applications, Gas kinetics, Gas flow, Viscous, Molecular and transition flow regimes, Vacuum technology-pumping speed, throughput & pump down time, Measurements of pressure, Production of vacuum-Mechanical pump, Diffusion pump, Turbo molecular pump, Getter and Ion pumps, Cryopumps, High vacuum and ultra high vacuum systems, Materials for vacuum and de-gassing properties.

Materials (thin and bulk) Preparation Techniques: Fundamentals of Film growth, Physical Vapor Deposition (PVD)- Evaporation, Flash evaporation, Electron beam evaporation, Laser evaporation technique, Arc evaporation, Molecular beam epitaxy (MBE), Sputtering, Chemical Vapor Deposition (CVD), Synthesis of NSM's, Top down and Bottom up approaches, Crystal Growth techniques.

Ion Beam Based Techniques in Materials Science: Basic ion bombardment processes in solids: General phenomenon, Ion penetration and stopping, Ion range parameters, Channelling, Components of an ion implanter, Ion implantation, radiation damage and structure change, Phase transformations, Pion beam mixing, Radiation enhanced diffusion, Diffusion by vacancies, Self-diffusion and impurity diffusion, Impurity incorporation.

Spectroscopic Studies: Basic components of spectrograph, Raman spectrometer, Spectroscopic techniques: Study of transmission, Absorption and reflection spectra, Determination of thickness, Refractive index, Energy band gap of semiconductor thin films, Rutherford Backscattering Spectrometry (RBS): Principles, Kinematics and instrumentation.

Structure and Surface Studies: XRD method for crystal structure and particle size determination, Interaction of electron beam with specimen, Electron Microscopic studies: SEM attached with EDAX and TEM, Scanning Probe Microscopy (SPM): STM and AFM and their applications in materials characterization, X-ray photoelectron spectroscopy (XPS) or ESCA: Principle, Instrumentation, Methodology, Quantitative analysis and Applications.

Texts and Reference Books:

1. Vacuum Physics and Techniques by T.A. Delchar.
2. Introduction to Solid State Physics by Charles Kittel.
3. Dielectric Behaviors and Structure by Smith.
4. Dielectric Materials and Application by Von Hipple.
5. Electrical Engineering Materials by A.J. Dekker.
6. Thin Film Phenomena by K.L Chopra.
7. Methods of Experimental Physics, Vol. 17, Editor L. Marton.
8. Experiments in Modern Physics by H. Mark and N. Thomas Olso
9. Vacuum technology by Andrew Guthrie

M.Phil. (Physics) (Course no.3)

ADVANCED MICROELECTRONIC PROCESSING

Review of Semiconductors and survey of IC processing, CMOS process overview, Moore's Laws, Oxidation Process, Crystal orientation, Doping effects, Impurities; Defects, Crystal Growth, Impurities in CZ, Gettering, oxygen in Si, Basic oxidation processes, Oxidation kinetics, Doping effects, Thin oxides; Diffusion, Fick's laws, Fick's 2^{nd} law, Vacancy-Impurity interactions, Diffusion profiles, Boron & phosphorus diffusion, Ion implantation, Implantation, Implant damage, Annealing of implants; Applications, Evaluation techniques, Evaluations of doped layers, Irvin Curves, Deposited thin films, Kinetic gas theory, Step coverage, Physical Vapor Deposition, Thermal evaporation, Sputtering, Chemical Vapor Deposition, Poly, Oxide, Nitride, Epitaxy, Autodoping, Pattern shift; Metallization, Electro migration, Contacts, CMP, Lithography, Optical transfer, Masks, Mask aligners, Photoresists, Photoresist process, Advanced Lithography, X-ray Lithography. Electron beam lithography, Ion beam lithography; Focused ion beam (FIB) lithography, LIGA process, Micro contact & Imprint lithography, Etching: bias & selectivity, Etching techniques; Wet, chemical, Plasma etching, Plasma processing; Yield considerations and contamination, Relevant techniques for metallization, interconnects

MEMS (microelectromechanical systems) and microelectronic technology and applications, Material issues for MEMS/microelectronics, Micro sensors, Micro actuators.

Texts and Reference Books:

1. J. Plummer, M.Deal, and P. Griffin, Silicon VLSI Technology, Upper Saddle River, New Jersey; Prentice Hall, Inc., 2000.
2. S.A. Campbell, The Science and Engineering of Microelectronic Fabrication: Oxford University Press, 1996
3. VLSI Fabrication Principles by S.K. Ghandhi; VLSI Technology editor S.M.Sze
4. Device Electronics for Integrated Circuits by R.S. Muller and T.I. Kamins
5. MOS Physics and Technology by E.H. Nicollian and J.R. Brews
6. Physics of semiconductor Devices ed. S. Sze , Solid State Electronic Devices, Streetman

M.Phil. (Physics) (Course no.4)

MATERIALS SCIENCE AND ENERGY DEVICES

Elementary Materials Science Concepts: Thermally activated processes, Phase diagram, Gibbs Phase Rule, Lever Rule, Interpretation of phase diagrams, Determination of phase amounts, Binary eutectic systems, Eutectoid and peritectic reactions, Homogeneous and heterogeneous nucleation.

Classification of Materials: Materials properties and requirements, Engineering materials: Metals, Semiconductors, Dielectrics, Polymers, Composites, Glasses, Ceramics and Biomaterials.

Advanced Materials: Meta materials, Smart materials, Topological Insulators and their applications.

Solar Energy and Materials Aspects: Importance of energy materials and devices in present technology, Basic of photovoltaic energy conversion, Optical properties of Solids, p-n junction solar cell, Transport equation, Current density, Open circuit voltage and short circuit current, Single crystal silicon and amorphous silicon solar cells, Elementary ideas of advanced solar cells (Tandem solar cells, Solid liquid junction solar cells, Dye sensitized, Organic solar cells), Introduction to PV panels, Domestic and industrial applications.

Hydrogen Energy: Photoelectrolysis and photocatalytic process, Brief discussion of various storage processes, Special features of solid hydrogen storage materials, New storage modes, Various factors relevant to safety, Hydrogen sensors, Use of hydrogen as fuel, Use in vehicular transport, Hydrogen for electricity generation, Fuel cells, Various type of fuel cells, Applications of fuel cell, Elementary concepts of hydride batteries.

Super capacitors and Batteries: Capacitor principles, General properties of capacitors, Electrochemical capacitors, Electrochemical interface, Double-layer capacitors: Li-ion based hybrid supercapacitors, General properties of battries, Introduction of various types of battries: Ni- based, Li- based and advance batteries.

Text and Reference Books:

1. Materials Science and Engineering by V. Raghavan
2. Materials Science and Engineering: An Introduction by William D. Callister Jr.
3. Fundamentals of Ceramics by M.W. Barsoum (Taylor & Francis)
4. Electroceramics: Materials Properties Application by A. J. Moulson & J.M. Herbert (Wiley)
5. Electrochemical Supercapacitors-Scientific Fundamentals and Technological Applications, by B. E. Conway,
6. Electrochemical Supercapacitors for Energy Storage and Delivery: Fundamentals and Applications, by Aiping Yu, Victor Chabot, Jiujun Zhang,
7. Solar Cell Devices-Physics by Fonash
8. Fundamentals of Solar Cells Photovoltaic Solar Energy by Fahrenbruch & Bube Phoptoelectrochemical Solar Cells by Chandra
9. Hydrogen as an Energy Carrier Technologies Systems Economy by Winter & Nitch (Eds.)
10. Hydrogen as a Future Engery Carrier by A. Zuttel, A. Borgschulte and L. Schlapbach
11. Battery Reference book third edition by T.R. Crompton

M.Phil. (Physics) (Course No. 5)

ADVANCED CONDENSED MATTER PHYSICS

Theory of Solids: Resume of independent electron approximation, Beyond the Independent-Electron Approximation: The Hartree Equations and their inadequacy, The Hartree-Fock equations, Application of the Hartree and the Hartree-Fock methods to a Free-electron gas, Calculation of the exchange energy and the ground-state energy.

Quantum Confined Electron Systems: Two-Dimensional electron gas, Theoretical description of electron states: Infinite potential well model; Energy sub-bands, Density of states; One-Dimensional electron gas, Infinitely deep rectangular quantum wires, Density of states, Quantum dots.

Magnetic Materials: Ion-ion interactions, Phonons, Spin-spin interactions, Magnons, Dia-magnetism, Paramagnetism, Magnetic hysteresis, Soft magnetic materials: Eddy currents, Electrical steel, Losses in electromagnets, Special Alloys and Soft Ferrites, Hard magnetic Materials (Spinel, Garnet, Hexaferrite and perovskite), Spintronics, Colossal magnetoresistance, Dilute Magnetic Semiconductors (DMS), Multiferroic, Fine particles and thin films, Single domain and multidomain, Coercivity of fine particles, Superparamagnetism in fine particles, Domain wall in films.

Superconductivity and Superfluity: Super fluidity, Landau's criteria, Coherence length and penetration depth, Superconductivity, BCS Theory, High T_c superconductivity, Flux quantization**,** Superconducting materials: Alloy and layered high temperature superconductors (oxide and iron based superconductors), Mono- and multi-layered cuprates, Structure, Processing, Properties, Iron based layered superconductors (structure, processing and properties), Applications of superconductors.

Text and Reference Books:

1. Solid state physics by Gerald Burn.
2. Solid State Physics by Neil W. Ashcroft and N. David Mermin
3. The Wave Mechanics of Electrons in Metals by Stanley Raimes
4. Quantum Wells, Wires and Dots (Theoretical and Computational Physics) by Paul Harrison
5. Low-Dimensional Semiconductors by M. J. Kelly
6. Introduction to Solid State Theory; Otfried Madelung; Springer.
7. Quantum Theory of Solids; C. Kittel; John Wiley and sons.
8. B.D. Cullity, Introduction to Magnetic Materials, Addison-Wesley Pub., California, London
9. J.P. Jakubovics, Magnetism and Magnetic Materials, Institute of Materials, London, 1994.
10. C.P. Pool Jr., H.A. Farach and R.J. Creswick, Superconductivity, Academic Press, 1995.
11. N. L. Wang, H. Hosono, P. Dai, Iron-based Supercodnuctors: Materials, Properties and Mechanism, Pan Stanford.

M.Phil. (Physics) (Course no.6)

COMPUTER PROGRAMMING IN FORTRAN 90

Introduction to computer programming languages, Algorithm, Flow chart, FORTRAN language fundamentals, FORTRAN character set, Constants and variables, IMPLICIT declaration, Expressions and assignment statements, Arithmetic expressions, Arithmetic assignment statement, Character expression and character assignment, Logical expressions, Problems due to rounding of real numbers, Mixed mode expressions, Special functions.

Input/Output Statements: FORMAT statement, List directed I/O statements, Format directed I/O statements, Printing character strings.

Control Statements: Relation operators, Unconditional arithmetic IF statement, Logical IF statement, Structured IF statement, DO statements and END statements.

Subscripted Variables: Use of multiple subscripts, Subscript expressions, DIMENSION statement, DO type notation for I/O statements.

Subprograms: Program structure, Main program, Statement function, Function subprograms, Subroutines, CALL statement, COMMON statement, Labeled COMMON statement, Placement of array elements in COMMON, EQUIVALENCE statement.

Files and general I/O statements, OPEN statement, CLOSE statement, DATA statement, double precision facility, Use of complex quantities. Simple Computer programs for numerical integration, Matrix operations, Straight line curve fitting, Solution of ordinary differential equations by Runge Kutta Method.

Text and Reference Books:

1. Computer Programming in FORTRAN 90 and 95 by V. Rajaraman
2. Computer Programming and Numerical Analysis by N. Datta
3. Numerical methods by E. Balagurusamy.

M.Phil. (Physics) (Course no.7)

ATOMIC COLLISION THEORY

Potential Scattering: The Lippmann- Schwinger equation and scattering amplitude, Born series, T-matrix, Partial wave analysis of the Lippmann-Schwinger equation. The Hulthein Kohn variational principle, The Schwinger variation principle, Minimum principle in scattering theory, Semi classical eikonal approximation for scattering wave-function and amplitude, Relation between the eikonal approximation and the Born series.

Electron-Atom Scattering: Basic scattering equation, Role of Pauli exclusion principle, High energy (Weak interaction) approximation, Glauber, Born, Bethe, Born-Oppenheimer, Ochkur, Ochkur-Rudge approximations, Low energy approximation, close coupling, Pseudo-state expansion and polarized orbital methods, Adiabatic and non-adiabatic polarization potentials, Semiclassical exchange potential, Intermediate energy approximation, Plane wave, Optical eikonal Born series methods, Non-spherical potentials, Elastic and inelastic scattering of electrons by H and H_2 molecules.

Polarization Effects in Electron Scattering: Concept of polarized electrons, Pure spin states, Density matrices and polarization, Scattering of relativistic electrons with spin by a central field, Polarization and Lorentz transformation, Sherman function, Left- right asymmetry, The role of spin polarization in scattering and simple physical description of polarization phenomena, Polarization phenomena in elastic and inelastic exchange scattering, Moller scattering, Fano effect, Autoionizing transitions and multiphoton ionization, Collisional ionization of polarized atoms, Penning ionization.

Text and Reference Books:

1. Quantum collision Theory by C. J. Joachain
2. Theory of collisions of electrons with atoms and molecules by S.P. khare
3. Topics in Atomic Collision by S. Geltman
4. Electrons and Photons interaction with atoms ed. Kleippopen and McDowell
5. Atomic Collision Theory by Bransden
6. Theory of Ion-Atom Collision by McDaniel and McDowell
7. Polarizes Electrons by Kessler
8. Theory of Atomic Collisions by Mott and Massey
9. Potential scattering by Burke