DEPARTMENT OF PHYSICS
NATIONAL INSTITUTE OF TECHNOLOGY, KURUKSHETRA-136119

Ph.D. course work

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Course No.	Title	Schedule of Teaching				Credit Points
		Lecture	Tutorial	Practical	Total	
PHY101T	Research Methodology	3	--	--	3	3
*Optional Papers	Any 3 of the following courses may be opted	3	--	--	3	3
		3	--	--	3	3
		3	--	--	3	3

Paper-1 Compulsory paper *(Common for all candidates)*

Research Methodology (PHY101T)

***Paper-II, III & IV Optional Papers**

Any three of the following courses may be opted:

**** For Odd Semester**

1. MATERIAL SCIENCE: PHY534T
2. EXPERIMENTAL METHODS IN NANOTECHNOLOGY: PHY535T
3. FOUNDATIONS OF NANOSCALE SCIENCE AND TECHNOLOGY: PHY532T
4. HIGH VACUUM TECHNIQUES: PHY515T
5. X-RAYS & BIOMEDICAL INSTRUMENTATION- PHY513T
6. SOLID STATE PHYSICS : PHY531T

**** For Even Semester**

1. MATERIALS CHARACTERISATION TECHNIQUES- PHY521T
2. NUCLEAR INSTRUMENTATION: PHY523T
3. NANO SENSORS & DEVICES : PHY524T
4. MICRO-ELECTRO MECHANICAL SYSTEM (MEMS) & NANO-ELECTRO MECHANICAL SYSTEMS (NEMS): PHY542T
5. NANOELECRONICS & DEVICES: PHY543T
6. TRANSDUCES: PHY511T (Odd Semester)

**** For Details consult M.Tech.(Instrumentation & Nanotechnology) syllabi.**

Paper-1 *(compulsory paper)*
Research Methodology (PHY101T**)**

Duration of Exam: 3 Hours		Credits	: 3
		Sessional	: 50
L		End Semester Exam	: 50
3		Total	: 100

Note: The question paper will consist of 8 questions (2 from each section). Candidates are required to attempt any 5 questions.

Section A

Introduction of Research Methodology: Concept of research and its applications: characteristics features, objectives, scope, reliability and validity of research, Scientific process: Meaning and Definition, Steps involved in research process, a brief history of scientific process.

Formulation of research problem: Objectives of research problem. Research Design-Meaning, Need and features of good research design, defining problem, preparing research design analysis and interpretation of data, Basic Principles of Experimental Techniques. Importance and relevance of ethics and values in science and technology

Section B

Scientific Methodology: Meaning, Scope, Primary sources of literature survey- journal, patents etc. Secondary sources of literature survey - books, reference books, text books.

Paper Writing and preparation of Dissertation: Basic concepts of paper writing - Steps of paper writing, Methods of presentation, Precautions in preparing the research Dissertation – Concepts of bibliography and annexure, Discussion of results, Drawing conclusions, Giving suggestion and recommendation of concerned persons.

Section C

Computer applications: Fundamental of computers – definition, types of computer, RAM, ROM, CPU, I/O devices. Operating system- definition and types of Operating systems. Use of software's – Word processing software, power point presentation methods, Microsoft Excel and Origin. Introduction to networking and search using internet.

Section D

Statistical Modeling and Error Evaluation: Mean and Median, Accuracy and Precision, Standard deviation, Relative standard deviation, Methods of reporting analytical data, Statistical evaluation of data-indeterminate errors. Correlation and regression, spectral analysis. Error analysis: Absolute and relatives errors. Type of errors in experimental data. Determinate (systematic), indeterminate (random) and gross sources of error and their effects upon the analytical results.

Text and Reference Books:

1. C.R. Kothari : Research Method & Techniques (Second Revised Edition).
2. S.Chandra : Computer Application in Phys Narosa Pub.House
3 J.Toppling : Errors of Observation and Their Treatment

Paper-II (Optional Papers)

Duration of Exam: 3 Hours		Credit	: 3
		Sessional	: 50
L		Theory	: 50
3		Total	: 100

Note: The question papers will consist of 8 questions. Candidates are required to attempt any 5 questions

1. MATERIAL SCIENCE: PHY534T

INTRODUCTION:
Classification of materials, Structure property relationship in material, multiphase materials, Modern materials – polymers, ceramics, composites, nanomaterials.

CRYSTAL IMPERFECTIONS:
Point and line imperfections, Frankel Defects, Schottky defects, dislocations, Burger Vectors, Surface Imperfections, Stacking faults.

DIFFUSION IN SOLIDS:
Fick's law of diffusion, Temperature dependence of diffusion coefficients, The Kirkendall effect, the atomic model of diffusion.

MAGNETIC MATERIALS:
Magnetic behaviour of materials, classification of magnetic materials, Ferromagnetism and Antiferromagnetism, The soft and hard magnetic materials, magnetic bubbles and magnetic bubble memory.

DIELECTRICS:
Polarization and dielectric constant, Basic relationships, Frequency and temperature dependent dielectric constant, Claussius Mossotti equation, dielectric loss factor, basic considerations, relaxation time and activation energy, tangent of dielectric loss angle, displacement and complex dielectric constant and basic equations, ferrites.

SUPERCONDUCTORS:
Zero resistivity, critical magnetic field and critical current density, Meissner effect, Type I & II Superconductors, Josephson effect, High Tc superconductors, BCS theory of superconductivity.

REFERENCE BOOKS:

1. **Material Science and Engineering**
   V.Raghavan
2. **Introduction to Materials Science for Engineers**
   James F.Shackelford
3. **Electrical Properties of Materials**
   G.C.Jain
4. **Material Science**
   A.J.Dekker

2. NUCLEAR INSTRUMENTATION: PHY523T

Detection of nuclear radiations: Introduction, Principle of nuclear detections, various detectors-their characteristics and applications, Interaction of radiations with matter.

Detection devices: Gas ionization based detectors, ionization chambers, G.M.detectors, Proportional counters & their design considerations

Semiconductor radiation detectors: Homogeneous and Junction type (Diffused Junction, surface-barrier Junction, Lithium ion drifted Junction, High purity Ge detector), Characteristics, fabrication and design considerations.

Solid State Nuclear Track Detectors (SSNTD): Basics of track etch generation and applications, detection thresholds, restricted energy loss. Basics of active measurement techniques for environmental radioactivity; beta/gamma radiation survey meter, Alpha Guard and shielding materials.

Amplifiers and instrumentation circuits: Photomultiplier tube, Input amplifiers, fast pulse amplifiers, pulse shaping circuits, pulse height analyzers, coincidence and anti-coincidence circuits

SUGGESTED BOOK:

Nuclear Instrumentation: W.J.Price.
Solid State Nuclear Track Detectors- Principal and Applications: R.L.Fleischer, P. B.Price & R.M.Walker

Techniques for nuclear and particle physics experiments**:** W. R. Leo

3. FOUNDATIONS OF NANOSCALE SCIENCE AND TECHNOLOGY: PHY532T

NANOTECHNOLOGY:

Background, what is nanotechnology, types of nonotechnology and nano-machines, top down and bottom up techniques, atomic manipulation-nanodots, semi-conductor quantum dots, self-assembly monolayers, Simple details of characterization tools- SEM, TEM, STM, AFM.

NANOMATERIALS:

What are nanomaterials? Preparation of nanomaterials- solid state reaction method, Chemical Vapor Deposition, Sol-gels techniques, Electrodeposition, Ball Milling, Introduction to lithography, pulse laser deposition (PLD), Applications of nanomaterials

CARBON TUBES:

New forms of carbon, Carbon tubes-types of nanotubes, formation of nanotubes, Assemblies, purification of Carbon nanotubes, Properties of nanotubes, applications of nanotubes.

OPTICS, PHOTONICS AND SOLAR ENERGY:

Light and nanotechnology, Interaction of light and nanotechnology, Nanoholes and photons, Solar cells, Optically useful nanostructured polymers, Photonic Crystals.

FUTURE APPLICATIONS:

MEMs, Nanomachines, Nanodevices, quantum computers, Opto-electronic devices, quantum electronic devices, Environmental and Biological applications.

REFERENCE BOOKS:

1. Nanotechnology-Basic Science and Emerging Technologies
   Mick Wilson, Kamali Kannangra Geoff Smith, Michelle Simons and Burkhard Raguse, Overseas Press.
2. Nanotechnology-A Gentle Introduction to the Next Big Idea
   Mark Ratner and Daniel Ratner, Prentice Hall
3. Nanotechnology
   Rebecca L Johnson, Lerner Publications.
4. Introduction to Nanotechnogy
   Charles P. Poole Jr., Chapman and Hall/CRS

4. MATERIALS CHARACTERISATION TECHNIQUES: PHY521T

X-Ray Methods:Production and detection of X-rays, X-ray spectra, X-ray absorption and diffraction, Scattering factors (Atomic scattering factor and geometrical scattering factor), Reciprocal lattice, Diffractometers and spectrometers, Methods of analysis: Powder and Laue, Electron microproble analysis.

Surface analysis techniques: Auger, ESCA, ISS, SIMS, methods of surface analysis (principle, instrumentation and detection) Mass spectrometers and spectrographs, Moss bauer spectrometry, Neutron activation analysis, Nuclear magnetic resonance spectroscopy.

Electron microscopy: Electron microscope, construction, contrast, resolving power, depth of focus, specimen preparation, Scanning electron microscopy.

Thermal analysis: Gravimetric analysis, Differential thermal analysis.

BOOKS SUGGESTED:

1. X-ray diffraction methods by BD Culity
2. Instrumental methods of Chemical analysis: Willard Merritt and Dean
3. Methods of Chemical analysis by Ewings
4. Electron microscopy of thin crystrals: Hirsch, Nicholson Pashley and Whelan

HIGH VACUUM TECHNIQUES- PHY515T

Throughput, conductance and impedance, Production of vacuum-Mechanical pumps: Rotary pump, Roots pump & Turbomolecular pump, vapour jet and vapour diffusion pumps, their design Principles, construction, operational characteristics and use. Sorption of gases, gettering and getter-ion pumps, degassing of surfaces. Sputter- ion-pumps, Cryogenic pumps. Principle & working of various types of gauges, Leak detection. Materials, Fabrication techniques and vacuum components. Vacuum plumbing. Ultra high vacuum. Vacuum system design. Applications of high vacuum: vacuum coating, vacuum impregnation, freeze drying, fabrication of ICs, space simulation, ion implantation, particle accelerators, vacuum distillation.

BOOKS SUGGESTED:

1. Vacuum Science and Engineering by CM Van Atta
2. Vacuum Technology by Andrew Guthrie
3. Vacuum Technology – An introduction by LG Carpenter
4. Vacuum deposition of Thin Films by L. Holland
5. High Vacuum Engineering by Alfred E. Barrington
6. Vacuum Technology by A. Roth

MICRO-ELECTRO MECHANICAL SYSTEM (MEMS) & NANO-ELECTRO MECHANICAL SYSTEMS (NEMS):

PHY542T

NANO-AND MICROSCIENCE, ENGINEERING AND TECHNOLOGY:

Introduction and overview, MEMS and NEMS definitions, Taxonamy of Nano-and Microsystems, Materials used for synthesis and Design of MEMS and NEMS.

NANO-AND MICRO SYSTEMS:

Classification and considerations, Biomimetics, Biological analogies, and design–Biomimetics Fundamentals, Biomimetics for NEMS and MEMS, Nano-ICs and Nanocomputer architectures, Biomimetics and nervous systems.

MODELING OF MICRO-AND NANOSCALE ELECTROMECHANICAL SYSTEMS:

Introduction to modeling, analysis and simulation, basic electro-magnetic with application to MEMS and NEMS, modeling developments of micro-and nanoactuators, energy conversion in NEMS and MEMS.

SYNTHESIS, DESIGN AND FABRICATION OF MEMS:

Introduction, Deposition of multilayers, Microfabrication of microcoils / windings of copper, nickel and aluminium through electro deposition method, micromachined polymer magnets, axial electromagnetic micromotors, micromachined polycrystalline SiC microimotors.

REFERENCE BOOKS:

1.Micro-Electro Mechanical and Nano-Electro Mechanical Systems, Fundamental of Nano-and Micro-Engineering

Sergey Edward Lyshevski, Lyshevski Edward Lyshevski,CRC Press

2.Nanomaterials:Synthesis,Properties and Applications

A.S.Edelstein and R.C.Cammarata(edits),Institute of Physics

3.Micro-Electro Mechanical and Nano-Electro Mechanical Systems

Sergy Edward Lyshevski,CRC Press

X-RAYS & BIOMEDICAL INSTRUMENTATION- PHY513T

BIOPOTENTIALS AND ELECTRODES: Origin of Bioelectric potentials. The electrode-electrolyte system. Polarization, polarizable and non-polarizable electrodes. Skin contact impedance. Electrodes for ECG, EEG & EMG, Microelectrodes.
BIOMEDICAL RECORDERS; Electrocardiograph, electroencephalograph & Electromyograph, Blood pressure measurement: direct and indirect methods.
BLOOD FLOWMETERS: Electromagnetic, Ultrasonic, NMR and Laser Doppler Blood flowmeters.
PULMONARY FUNCTION ANALYSERS: Respiratory volumes, wedge and ultrasonic spirometers. Fleisch pneumo-tachometer.

X-RAY IMAGING: X-ray machine. Image intensifiers & image noise. X-ray computed tomography. Emission computed tomography.
MAGNETIC RESONANCE IMAGING: MRI, Benefits and limitations of MRI
ULTRASOUND IMAGING AND THERAPY: Physics of ultrasonic waves. Generation, detection, absorption, reflection and diffraction of ultrasonic waves. Pulse echo system. Ultrasonic scanning: A-scanners & B-scanners. Real time ultrasonic imaging systems. Therapy with ultrasonic waves, Biological effects of ultrasonic waves.
RADIOTHERPY: Radiobiology and radiation physics treatment planning, Particle beam therapy (hadrontherapy), biological effects,
Dosimetry in modern radiation therapy, Dose measurement.

BOOKS SUGGESTED:

1. A handbook of Biomedical Instrumentation by RS Khandpur
2. Biomedical Instrumentation & Measurement by Leslie Cromwell, Fred J Weibell & Erich A Pfeiffer.
3. Medical Instrumentation: Application and Design by Webster.
4. Medicine & Clinical Engineering by Bertil Jacobson & John G Webster.

EXPERIMENTAL METHODS IN NANOTECHNOLOGY: PHY535T

INTRODUCTION:

Review of various experimental techniques used in synthesis, fabrication, and characterization of nano-materials and devices.

EXPERIMENTAL METHODS FOR FABRICATION:

Semiconductor processing techniques- Cleaning, etching, oxidation, Gettering, Doping, Epitaxy; Lithography-Photolithography, Electron beam lithography, X-Ray lithography, Focused Ion Beam Lithography (FIB); Soft Lithography- Micro-contact Printing, Molding, Nanoimprint, Dip-Pen Nanolithography, AFM based Nanolithography ;Experimental techniques used in synthesis of Carbon nanotubes-Arc Discharge, Laser Furnace, Chemical Vapor Deposition(CVD);Template Synthesis.; Self Assembly and Bio/Chemical Methods

EXPERIMENTAL TECHNIQUES FOR CHARACTERIZATION:

Structural Characterization- X-Ray Diffraction (XRD), Small Angle X-Ray Scattering (SAXS), Scanning

Electron Microscopy; Atomic Force Microscopy; Optical Spectroscopy; Raman Spectrometery.

REFERENCE BOOKS:

1. **Nanostructures and Nanomaterials-Synthesis, Properties and Applications**
   Guozhong Cao,Imperial College Press
2. **Nanotechnology-An Introduction to Nanostructuring Techniques**
   Michael Kohler,Wolfgang Fritzsche,Wiley-VCH
3. **Microfabrication and Nanomanufacturing**
   Mark J (ed)Jackson,Taylor and Francis
4. **Carbon Nanotubes:Science and Applications**
   Laurie Kelly, Meyyappan Meyyappen,CRC Press