Syllabus for Course Work of Ph.D. and M. Phil. in Physics

Semester – 1

Course Structure:

Sr. No.	Course Code	Paper Title	Credit
	Core Paper		
1.	MPH/DPH 101	Research Methodology	4
2.	MPH/DPH 103	Advance Paper-I	4
3.	MPH/DPH 104	Advance Paper-II	4
	Discipline Specific Optional Paper (One Paper needs to be opted)		
4.	MPH/DPH 102A	Materials Science	4
5.`	MPH/DPH 102B	Nanoscience and Nanotechnology	4
6.	MPH/DPH 102C	Molecular Modelling and Computational Techniques	4
7.	MPH/DPH 102D	Fundamentals of Nuclear Structure	4
8.	MPH/DPH 102E	Radiation Physics	4
9.	MPH/DPH 102F	Advanced Optics	4

Mode of Evaluation:

Sessional 30% and End Semester 70%

MPH/DPH 101: Research Methodology

Unit – I **(8 hours)**

Introduction : Definition of Research, Qualities of Researcher, Components of Research Problem, Various Steps in Scientific Research : Hypotheses, Research Purposes, Research Design, Literature searching

Unit – II **(8 hours)**

Design And Planning of Experiments, Time Scheduling: Aims and Objectives, Expected outcome, Methodology to be adapted, Planning of experiments for achieving the aims and objectives, Importance of reproducibility of research work.

Unit – III **(16 hours)**

Statistical Analysis And Fitting Of Data : Introduction to Statistics – Probability Theories - Conditional Probability, Poisson Distribution, Binomial Distribution and Properties of Normal Distributions, Estimates of Means and Proportions; Chi-Square Test, Association of Attributes - t-Test - Standard deviation - Co-efficient of variations. Correlation and Regression Analysis. Introduction to statistical packages, plotting of graphs. Sources of Data: Primary Data, Secondary Data; Sampling Merits and Demerits of Experiments.

Unit – IV **(8 hours)**

Scientific Writing : Structure and Components of Research Report, Types of Report: research papers, Thesis, Research Project Reports, Pictures and Graphs, Citation styles,

References:

HANDBOOK OF RESEARCH METHODOLOGY, August 2017, Edition: 1, Publisher: Educreation

- ISBN: 978-1-5457-0340-3, Project: Research Methodology

1. "How to write and Publish" by Robert A. Day and Barbara Gastel, (Cambridge University Press).
2. "Survival skills for Scientists" by Federico Rosei and Tudor Johnson, (Imperial College Press).
3. "How to Research" by Loraine Blaxter, Christina Hughes and Malcum Tight, (Viva Books).
4. "Probability and Statistics for Engineers and Scientists" by Sheldon Ross, (Elsevier Academic Press).
5. "The Craft of Scientific Writing" by Michael Alley, (Springer).
6. "A Students's Guide to Methodology" by Peter Clough and Cathy Nutbrown, (Sage Publications).

MPH/DPH 103: Advance Paper-I

Unit – I **(10 hours)**

ELECTRODYNAMICS

Electrostatics: Poisson and Laplace's equations, Boundary value problems.

Magnetostatics: Multipole expansions of potentials, Time varying fields, Faraday's law, Maxwell's displacement current, Maxwell's equations, Poynting's theorem, Wave equations, Electromagnetic plane waves, Linear, circular and elliptic polarization, Reflection and refraction of plane waves, Green's function, Gauss variance.

Unit – II **(10 hours)**

MATHEMATICAL METHODS OF PHYSICS

Problem solving using analytical and numerical methods

Linear differential equations and introduction to Special functions (Hermite, Bessel, Laguerre and Legendre); Solutions of differential equations using numerical techniques like Runge-Kutta method and other predictor-corrector methods, finite element method, FTDT method, Monte Carlo simulation, Fourier and Laplace transforms, Group theory and applications, symmetry elements.

Unit – III **(10 hours)**

COMPUTATIONAL TECHNIQUES

Function approximation and errors, Solution of equations: Bisection, Iteration and Newton-Raphson methods, Numerical differentiation, Numerical integration- Trapezoidal, Simpson's 1/3, and Simpson's 3/8 methods, Solution of ordinary differential equations- Euler, Euler modified, and Runga-Kutta methods, Solution of simultaneous linear algebraic equations- Gauss elimination method, Least-square curve fitting- Straight line and polynomial fits.

Unit – IV **(10 hours)**

SPECTROSCOPY

Quantum states of an electron in an atom; Electron spin; Spectrum of Hydrogen, helium and alkali atoms; Fine structure and hyperfine structure, width of spectral lines; LS & JJ coupling; Zeeman, Paschen Back & Stark effect;

X-ray spectroscopy; Electron spin resonance, Nuclear magnetic resonance, Rotational, vibrational, electronic, and Raman spectra of diatomic molecules; Frank – Condon principle.

Basics of laser operation, semiconductor laser, pulsed laser, DFB laser, pico- and femto-second laser and modern applications.

References:

1. J. D. Jackson - Classical Electrodynamics
2. D. J. Griffiths – Introduction to Electrodynamics
3. J. R. Reitz, F. J. Milford, W. Christy – Foundations of Electromagnetic Theory
   Complex Analysis by Churchil
4. Mathematical Methods for Physicist by Arfken and Weber
5. Finite dimensional Vectror Spaces, P. Halmos
6. Mathematics of Classical and Quantum Physics by F. W. Byron and R.. W. Fuller
7. Concepts of Nuclear Physics, B. L. Cohen (Tata McGraw Hill)
8. Nuclear Physics - An Introduction, S. B. Patel
9. Subatomic Physics, Frauenfelder and Hanley (Prentice-Hall)
10. Nuclear Physics, I. Kaplan
11. Nuclei and Particles, Emilio Segre
12. Nuclear Radiation Detectors, S. S. Kapoor, V. S. Ramamurthy
13. Techniques for Nuclear and Particle Physics Experiments, W R Leo
14. Radiation Detection and Measurement, G F Knoll
15. Quantum Physics of Atoms, Molecules, Solids, Nuclei and particles by R. Eisberg and R. Resnick (John Wiley)
16. The elements of Physical Chemistry by Atkins (Oxford)
17. Quantum Chemistry, by I. N. Levine (Prentice Hall)
18. Atomic and Molecular Physics by H. E. While (East-West Press)
19. Molecular Spectra and Molecular Structure, G. Herzberg, D. Van Nostrand Co. Inc.
20. Atomic and Molecular Spectra, Rajkumar.

MPH/DPH 104: Advance Paper-II

Unit – I **(10 hours)**

ADVANCED MATERIALS: CONCEPT AND SYNTHESIS

Physics of Low Dimensional materials: Quantum dots and other nanostructures; advanced functional materials for applications in energy harvesting, nano/microelectronic devices, catalysis, sensors etc.

Critical issues for nanostructure synthesis and strategies. Ball Milling, Sonication, Low temperature Combustion Synthesis (LCS) method, Chemical Vapour Deposition (CVD) technique, Implantation technique by low energy accelerators, Hydrothermal / Solvothermal Synthesis, Sol-gel Method, Aerosol method, Citrate gel (Penchini) method.

Unit – II **(10 hours)**

EXPERIMENTAL TECHNIQUES -1

I. **Structural and Compositional Characterization**

X-ray diffraction (φ scan, ω scan), Scanning Electron Microscopy- Energy Dispersive X-ray Analysis, X-ray Fluorescence, etc.

II. **Optical Characterization**

Fourier Transform Infrared Spectroscopy (FTIR), UV- Vis. Spectroscopy, Room temperature as well as low temperature Photoluminescence

III. **Magnetic and dielectric measurements**

Vibrating Sample Magnetometer (VSM), Mössbauer spectroscopy.

Unit – III **(10 hours)**

EXPERIMENTAL TECHNIQUES -2

I. **X- Ray Photoelectron Spectroscopy:-**

Basic principle, Sample handling and preparation, Depth profiling and interpretation of the spectra recorded after deconvolution – case study ZnO.

II. **Raman Spectroscopy:-**

Basic principle, Brief idea of set up, excitation wavelength choice, Deconvolution of the peaks, analysis of the spectra based on peak position, FWHM of the vibrational modes, area etc.

III. **Scanning Probe Microscopy –**

a) Atomic Force Microscopy: -Basic principle, Brief idea of set up –contact mode, tapping mode etc. Different modes of AFM and its importance. Other modified operation such as MFM etc.

b) Scanning Tunnelling Microscopy: -Basic principle, Brief idea of set up – details of components etc. Different modes of STM and its importance.

IV. **Transmission Electron microscopy: -**

Basic principle, Brief idea of set up, Sample preparation, imaging modes bright field imaging, dark field imaging, Selected area electron diffraction (SAED) etc.

Unit – IV **(10 hours)**

ELECTRONICS AND INSTRUMENTATION

Semiconductor device physics, including diodes, junctions, transistors, field effect devices, homo and heterojunction devices, device structure, device characteristics, frequency dependence and applications; Optoelectronic devices, including solar cells, photodetectors, and LEDs; High frequency devices, including generators and detectors; Operational amplifiers and their applications; Digital techniques and applications (registers, counters, comparators and similar circuits); A/D and D/A converters; Microprocessor and microcontroller basics.

References:

1. Handbook of Advanced Materials, Enabling new designs Edited by James K Wessel, publisher: Wiley Interscience, 2004

2. Precursors Chemistry of Advanced Materials, Edited by lR. A. Fischer, Publisher: Springer.

3. XPS hand book by Briggs

4. IR and Raman spectra by Herzberg

5. Encyclopedia of analytical chemistry. Instrumentation and application (pg 9 – 84) Chapters by Prof. C. V. Dharmadhikari and R. A. Meyer, John Wiley U.K. (2000)

4. TEM: a text book for Material Science; by David B. Williams and C. Barry Carter (Springer Verlag) – 2009

5. Introduction to conventional TEM by Marc DeGraef (Cambridge Solid State Science) 2007

6. Fundamentals of Electronics, Malvino and Leach

7. Semiconductor Devices by S. M. Sze

8. Essentials of Semiconductor Physics by T. Wenckebach (Wiley)

MPH/DPH 102A: Materials Science

Unit-I **(12 Hours)**

Introduction to Materials

Classification of Materials based on Function, Structure, Environmental and Other Effects, Materials Design and Selection, Classification of materials: construction materials, electronic materials, magnetic materials, photonic materials, Biomaterials, Organic materials, Nanostructured materials and Composites.

Unit-II **(10 Hours)**

Structure of Crystalline solid

Crystal structure, Crystallographic: Point, direction and plane, Closed packed structures. Symmetry elements, Symmetry groups, Reciprocal Lattice, Construction of reciprocal lattices of SC, BCC and FCC; Concept of Brillouin zone, Diffraction from crystals and crystal structure study, Crystalline and non-crystalline materials, Crystal imperfections: point defects, miscellaneous imperfections and microscopic examinations.

Unit-III **(10 Hours)**

Microscopy and Microanalysis of materials

Scanning Electron Microscopy, Transmission Electron Microscopy, Atomic Force Microscopy, X-ray Diffraction, UV-visible spectroscopy, Fourier Transform Infra Red Spectroscopy, Raman Spectroscopy, Differential Scanning Calorimetery, Atomic Absorption Spectroscopy, Ellipsometry, Ultrasonic characterization and evaluations etc.

Unit-IV **(12 Hours)**

Science and Technology of thin Films

Basics of the thin film growth: Brief review of kinetic theory, adsorption and desorption, Nucleation and Growth, Epitaxy, Thin film control, Surfaces; Layered Structures, Physical Vapor Deposition, Chemical Vapor Deposition, Chemical Techniques - Spray Pyrolysis, Electro-deposition, Sol-Gel Techniques, Basic thin film characterization: thickness measurement, phase analysis, optical analysis, morphology analysis.

References:

1. The Science and Engineering of Materials, 5th ed, Donald R. Askeland and Pradeep P. Phulé, Thomson Learning, 2006.
3. Materials Science and Engineering: An Introduction, W D Calliester, Jr., John Wiley & Sons, NY, 2007.
3. Science of Materials Engineering, 2nd Edition, C. M. Srivastava and C. Srinivasan, New Age International Publ., New Delhi, 2005
4. Materials Characterization techniques, S. Zhang, L. Li and A. Kumar, CRC Press, Taylor & Francis Group, NY, 2008.
5. Milton Ohring, The Materials Science of Thin Films, Academic Press, Sanden, 1992
6. Kasturi L. Chopra, Thin Film Phenomena, McGraw Hill, NY, 1969
7. Materials Science of Thin Films, Milton Ohring, Second Edition, Acadamic Press, London

MPH/DPH 102B: Nanoscience and Nanotechnology

Unit I **(10 Hours)**

Fundamentals of nanomaterials and nanostructures

Bulk to Nano Transitions. Size effects, Brief History of Nanoscience, Nanotechnology in nature, Synthesis of nanoparticles, nanoclusters, nanocrystals; top-up approach and bottom-up approach, self-assembly.

Semiconducting Nanoparticles, Metal Nanoclusters, Nanocomposites, Nanofluids, Nanotubes, Quantum Dots, Quantum Wires and Quantum Wells, RTD's.

Unit II **(10 Hours)**

Synthesis of Nanomaterials

Critical issues for nanostructure synthesis and strategies.

Ball Milling, Sonication, Low temperature Combustion Synthesis (LCS) method, Chemical Vapour Deposition (CVD) technique, Hydrothermal / Solvothermal Synthesis, Sol-gel Method, Aerosol method, Citrate gel (Penchini) method.

Unit III **(10 Hours)**

Characterization of nanomaterials and nanostructures

Surface morphology, structure, particle size, distribution, thermal behaviour using Scanning Electron Microscopy, Transmission Electron Microscopy, X-ray Diffraction, Atomic Force Microscopy, UV-visible spectroscopy, Fourier Transform Infra Red Spectroscopy, Brunauer-Emmett-Teller (BET), Differential Scanning Calorimetry, Ellipsometry etc.

Unit IV **(10 Hours)**

Properties and Applications of Nanostructured Materials

Mechanical, electrical, magnetic and optical properties of nanomaterials.

Humidity Sensor, Gas Sensor-LPG, Hydrogen, Nitrogen and CO_2, Radiation sensors, Solar cell etc., as Hydrogen Storage Materials and Corrosion-Resistant Materials, Biomedical Applications and other industrial applications.

References:

1. Introduction to Nanotechnology, C. P. Poole and F. J. Owens Pub Wiley & Sons, 2006.
2. Nanostructures & Nanomaterials, Synthesis Properties & Applications, G. Cao, Imperial Press, 2006.
3. Springer Handbook of Nanotechnology, Bharat Bhusan, 2004.
4. Nanomaterials: Synthesis, properties and Applications, A.S. Edelstein
5. Nanostructured Materials: Processing properties and Applications, Carl C. Koch
6. B. D. Cullity, Elements of X-ray Diffraction, AddisionWesely Reading Mass 1978.
7. David D. Brandon and Wayne D. Kaplan Microstructural Characterization of Materials.
8. Dawn Bonnel, Scanning Probe Microscopy and Spectroscopy: Theory, Techniques, and Applications 2000.

9. C. Julian Chen Introduction to Scanning Tunneling Microscopy Monographs on the Physics and Chemistry of Materials.
10. D.J. O'Connor Surface Analysis Methods in Materials Science, Springer 2008.
11. Adam J. Schwartz, Mukul Kumar, Brent L. Adams, and David P. Field Electron Backscatter Diffraction in Materials Science by 2009
12. Robert Cahn Concise Encyclopedia of Materials Characterization, Second Edition: 2nd Edition (Advances in Materials Science and Engineering) Elsevier Publication 2005.
13. Ray F. Egerton, Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM Springer, 2008
14. Joachim Frank Three-Dimensional Electron Microscopy of Macromolecular Assemblies: Visualization of Biological Molecules in Their Native State, Kindle 2006.
15. Materials Science of Thin Films, Milton Ohring, Second Edition, Acadamic Press, London

MPH/DPH 102C: Molecular Modelling and Computational Techniques

Unit I **(7 Hours)**

Computational chemistry and molecular modelling

Coordinate systems, Concept of 2D and 3D structure of macromolecules, Surfaces; Potential energy surface and saddle point.

Unit II **(7 Hours)**

Molecular energetic profile

Introduction to computational softwares for drawing, visualization and simulation of small and large molecules.Basic concept of Chemoinformatics, 3D-Structure file system and Databases.

Unit III **(13 Hours)**

Introduction to Quantum & Molecular Mechanics

Molecular Orbital Theory, The Hartree-Fock method, ab-initio calculation, Semi-empirical methods, Huckel theory, Valence bond theories, Force Field, Geometrical Parameters, Density Functional Theory, Understanding of electrostatic interactions, van der Waals' interaction, Hydrogen bonding, hydrophobic interactions.

Unit 4 **(13 Hours)**

Simulation methods

Minimization, Molecular dynamics, Monte Carlo Simulations, Simulated Annealing, Conformational Search and Conformational Analysis, Understanding of iterations, convergence, protocols and algorithm such as steepest descents, conjugate gradient etc.

References

1. *Computational Chemistry, Introduction to Theory and Application of Molecular and Quantum Mechanics* by Errol Lewars, Springer.

2. *Molecular Modelling : Principle and Application, 2nd Ed.*by Andrew R. Leach, Addison-Wesley Longman Ltd, (February 2001) ISBN: 0582382106.

MPH/DPH 102D: Fundamentals of Nuclear Structure

Unit-I **(8 hours)**

Angular momentum, Second-quantization formalism

Orbital angular momentum, Spin angular momentum, Total angular momentum, Coupling of two angular momenta, Clebsch-Gordan coefficients and 3-j symbols, Coupling of three angular momenta and 6-j symbols, Coupling of four angular momenta and 9-j symbols.

Creation and annihilation operators, Operators in second quantized form.

Unit-II **(8 hours)**

Rotation and irreducible tensors, Symmetry

Rotation, Rotation matrix, Irreducible tensors, Wigner-Eckart theorem, Matrix elements of irreducible tensor operators.

General concepts of symmetry, General symmetry properties of two-nucleon Hamiltonian and two-nucleon states, Time-reversal in nonrelativistic quantum mechanics.

Unit-III **(12 hours)**

Two-nucleon problem

General forms of two-nucleon interaction, Matrix elements of two-nucleon potential – Central potential and noncentral potential, Two-nucleon Schrödinger equation – Uncoupled and coupled radial equations, Electromagnetic moments of deuteron – Magnetic moment, Electric quadrupole moment, Different forms of nucleon-nucleon potential.

Unit-IV **(12 hours)**

Nuclear many-body problem and Microscopic theory

Perturbation theory, Antisymmetrization of wave function, Matrix elements

:Hartree-Fock theory, Basic concept of quasiparticles, Self-consistent Hartree-Fock and Hartree-Fock-Bogoliubov theory, BCS theory.

References

1. *Angular Momentum in Quantum Mechanics* by A. R. Edmonds, Princeton University Press (1957).

2. *Quantum Mechanics* by L.I. Schiff, Tata Mcgraw Hill Education Private Limited Tata Mcgraw Hill Education Private Limited (2010).

3. *Theory of Nuclear Structure* by M. K. Pal, East-West Press Pvt. Ltd. (1992).

Theoretical Nuclear Physics by John M. Blatt and V. F. Weisskopf, Dover (10/2010).

MPH/DPH 102E: Radiation Physics

Unit 1 **(10 hours)**

Interaction of Radiation with Matter

Modes of interaction: ionization, excitation, elastic and inelastic scattering, nuclear interaction, specific ionization, mean free path

Alpha particles/heavy ions/protons: Mechanism of energy loss (ionization and excitation, Bremsstrahlung, Cerenkov radiation), concepts of specific ionization, mass stopping power, relative mass stopping power, linear energy transfer (LET), range energy relationships

Gamma photons: interaction mechanisms (photoelectric effect, Compton scattering, Pair production), attenuation coefficients (linear and mass attenuation coefficient), concept of buildupfactor. Neutrons: elastic scattering, inelastic scattering, capture, fission.

Unit II **(10 hours)**

Radiation units, quantities and Dosimetry

Energy imparted to the medium, specific energy, absorbed dose, KERMA, exposure equivalent dose, effective does, free air chamber, energy absorbed in air per unit exposure, energy and photon fluence per unit exposure, ionization chambers, electrets, film badge, radiophotoluminiscence, thermoluminescence, chemical and optical absorption in plastics, solid state nuclear track detectors (SSNTD).

Unit III **(10 hours)**

Radiation detection: Principles and General properties of radiation detectors

Principles of radiation detection:Gas filled radiation detectors: various regions of gas filled detectors, ionization chambers, proportional counters, GM counters, basic detection mechanism, types of radiation which can be detected, modes of operation.

Scintillation (organic/inorganic) detectors: advantages of scintillation detectors, properties of ideal scintillators, basic electronic blocks in scintillation detector setup etc., radiation detection mechanism of organic and inorganic scintillators, types of scintillators for various applications, photon detection devices (PMT/Photo diodes)

Unit IV **(10 hours)**

Radiation detectors II and spectrometry

Semiconductor Detectors: principles of detection mechanism of semiconductor detectors and its application for gamma and alpha spectrometry

Measurement techniques and gamma spectrometry: background radiation, shielding, geometry, counting techniques, testing and calibration, methods of analysis of compledx gamma spectra obtained using NaI(Tl) and HPGe, spectrum stripping, simultaneous evaluation method, least square method, auto peak search, Compton correction, calibration of spectrometry system.

References:

1. Radon measurements: Etched track detectors edited by Saeed A. Durrani and Radomirilic, World Scientific.
2. Radiation detection and measurement by Glenn F. Knoll, Wiley India Pvt Ltd (2009).
3. Medical Physics: M. F. Khan

MPH/DPH 102F: Advanced Optics

Unit I **12 hours**

Wave nature of light: Light in homogeneous medium, refractive index, group velocity, group index, Review of Maxwell's equations and propagation of electromagnetic waves, reflection and refraction of electromagnetic waves, total internal reflection and evanescent waves, reflection and transmission by films, periodic media, waves in anisotropic media, double refraction.

Unit II **10 hours**

Fourier optics: Basics of Fourier transform operation, spatial frequency and transmittance function, Fourier transform by diffraction and by lens, Spatial-frequency filtering.

Coherence and Interferometry: Basics of coherence theory, spatial and temporal coherence, Michelson stellar interferometer, Fourier transform spectroscopy, Laser speckles.

Unit III **10 hours**

Lasers: Einstein's coefficients, population inversion, threshold condition, resonator cavity, semi-conductor laser, applications of laser technology.

Optical fiber: Modes in optical waveguides, step index and graded index fibers, single mode fibers, attenuation and dispersion in fiber, fabrication and characterization of fiber, applications of fiber technology.

Holography: Simple mathematical analysis, holographic interferometry, character recognition, stress analysis.

Unit IV **12 hours**

Non-linear optics: Wave propagation in anisotropic crystal, origin of optical non-linearity, second and third order non-linear optical processes, Harmonic generation, wave mixing.

Quantum optics: Quantization of electromagnetic field, Fock states, Coherent states, Glauber Sudarshan representation, bunching, anti-bunching, squeezed states, entanglement, generation of quantum light.

Singular optics: Basics of optical vortices, generation and detection of optical vortices and their applications.

References

1. A. Ghatak, Optics, Tata McGraw Hill, New Delhi.
2. E. Hecht, Optics, Pearson Education Inc.
3. A. Ghatak, K. Thyagarajan, Optical Electronics, Cambridge University Press.
4. E. Wolf, Principles of Optics, Cambridge University Press.
5. J. W. Goodman, Fourier Optics, Viva Books Pvt. Ltd., New Delhi.
6. W. T. Silfvast, Laser fundamentals, Cambridge University Press.
7. A. Ghatak, K. Thyagarajan, Lasers: Fundamentals and Applications, Springer.

8. G. P. Agrawal, Fiber optic communication systems, John Wiley and Sons.
9. J. M. Senior, Optical fiber communications: Principles and practice, Prentice Hall of India.
10. Y.R. Shen, The principles of nonlinear optics, Wiley, New York.
11. L. Mandel, E. Wolf, Coherence and Quantum Optics, Cambridge Univ. Press.
12. E. Wolf, Introduction to Coherence and Polarization of Light, Cambridge University Press.
13. M. O. Scully, S. Zubairy, Quantum Optics, Cambridge University Press.
14. Gregory J. Gbur, Singular Optics, CRC Press.
15. K. F. Renk, Basics of laser Physics, Springer.
16. P Yeh, Optical Waves in Layered Media, John Willey & Sons