RASHTRASANT TUKADOJI MAHARAJ
NAGPUR UNIVERSITY

TWO YEAR POSTGRADUATE PROGRAMME

M. Sc. Physics

(Courses effective from Academic Year 2023-24)

SYLLABUS as per NEP-2020

Semester I - IV

Scheme of Teaching and Examination for M. Sc. (Physics)

As per NEP 2020 Structure and Credit Distribution of PG Degree Program

for Two Year Choice Based Credit System (Semester Pattern)

Effective from 2023-2024

<u>Semester I</u>

S N	Course Category	Name of Course	Course Code	Teaching Scheme (hrs.)			Total (Hrs)	Total Credit	Examination Scheme						
									Theory				Practical		
				(Th)	TU	P			Exam Hrs.	SEE	CIE	Min.	SEE	CIE	Min.
1	DSC	Mathematical Physics	MPH1T01	4	-	-	4	4	3	80	20	40	-	-	-
2	DSC	Electronics	MPH1T02	4	-	-	4	4	3	80	20	40	-	-	-
3	DSE	Elective 1 (Choose any One) 1. Energy Devices 2. Experimental Techniques in Physics	MPH1T03	4	-	-	4	4	3	80	20	40	-	-	-
4	RM	Research Methodology	MPH1T04	4	-	-	4	4	3	80	20	40	-	-	-
6	LAB 1	Practical -1 (General and Research Methodology)	MPH1P01	-	-	6	6	3	2-6*				50	50	50
7	LAB 2	Practical -2 (Electronics)	MPH1P02	-	-	6	6	3	2-6*				50	50	50
Total				16	-	12	**28**	**22**	**-**	**320**	**80**	**160**	**100**	**100**	**100**

Marks of Theory Component = 400; Marks of Practical Component = 200; TOTAL = 600

Semester II

S N	Course Category	Name of Course	Course Code	Teaching Scheme (hrs.)			Total (Hrs.)	Total Credit	Examination Scheme						
									Theory				Practical		
				(Th)	TU	P			Exam Hrs.	SEE	CIE	Min	SEE	CIE	Min.
1	DSC	Complex Analysis & Numerical Methods	MPH2T05	4	-	-	4	4	3	80	20	40	-	-	-
2	DSC	Statistical Physics	MPH2T06	4	-	-	4	4	3	80	20	40	-	-	-
3	DSE	Elective 2 (Choose any one) 1. Spectroscopy 2. X-Rays	MPH2T07	4	-	-	4	4	3	80	20	40	-	-	-
4	OJT	OJT	MOJ2P01	-	-	8	8	4	3-8*	-	-	-	50	50	50
5	LAB 1	Practical -1 Computational	MPH2P03	-	-	6	6	3	2-6*	-	-	-	50	50	50
6	LAB 2	Practical -2 General	MPH2P04	-	-	6	6	3	2-6*	-	-	-	50	50	50
Total				12	-	20	**32**	**22**		**240**	**60**	**120**	**150**	**150**	**150**

Marks of Theory Component = 300; Marks of Practical Component = 300; TOTAL = 600

Semester III

S N	Course Category	Name of Course	Course Code	Teaching Scheme (hrs.)			Total (Hrs.)	Total Credit	Examination Scheme						
									Theory				Practical		
				(Th)	TU	P			Exam Hrs.	SEE	CIE	Min.	SEE	CIE	Min.
1	DSC	Classical Mechanics	MPH3T08	4	-	-	4	4	3	80	20	40	-	-	-
2	DSC	Quantum Mechanics - I	MPH3T09	4	-	-	4	4	3	80	20	40	-	-	-
3	DSC	Electrodynamics	MPH3T10	4	-	-	4	4	3	80	20	40	-	-	-
4	DSE	Elective 3 (Choose any one) 1. Materials Science 2. Basic Nanoscience & Nanotechnology	MPH3T11	4	-	-	4	4	3	80	20	40	-	-	-
5	LAB	Practical -1 (Electives)	MPH3P05	-	-	4	4	2	2-6*	-	-	-	50	50	50
11	RP	Research Project/ Dissertation (Core)	MRP3P01	-	-	8	8	4	3-8*	-	-	-	50	50	50
Total				16	-	12	**28**	**22**		**320**	**80**	**160**	**100**	**100**	**100**

Marks of Theory Component = 400; Marks of Practical Component = 200; TOTAL = 600

Note: *For elective 3, if student choose Materials Science in Semester – III must choose only Properties of Materials as elective 4 in Semester – IV. Similarly, if student choose Basic Nanoscience & Nanotechnology in Semester – III as elective 3 must choose only Applied Nanoscience & Nanotechnology as elective 4 in Semester – IV.*

Semester IV

SN	Course Category	Name of Course	Course Code	Teaching Scheme (hrs.)			Total (Hrs)	Total Credit	Examination Scheme						
									Theory				Practical		
				(Th)	TU	P			Exam Hrs.	SEE	CIE	Min	SEE	CIE	Min
1	DSC	Nuclear & Particle Physics	MPH4T12	4	-	-	4	4	3	80	20	40	-	-	-
2	DSC	Quantum Mechanics II	MPH4T13	4	-	-	4	4	3	80	20	40	-	-	-
3	DSC	Solid State Physics	MPH4T14	4	-	-	4	4	3	80	20	40	-	-	-
4	DSE	Elective 4 (Choose any one) 1.Properties of Materials 2. Applied Nanoscience & Nanotechnology	MPH4T15	4	-	-	4	4	3	80	20	40	-	-	-
5	RP	Research Project / Dissertation (Core)	MRP4P02	-	-	12	12	6	4-12*	-	-	-	100	100	100
Total				16	-	12	**28**	**22**		**320**	**80**	**160**	**100**	**100**	**100**

Marks of Theory Component = 400; Marks of Project Component = 200; TOTAL = 600

2 Years-4 Sem. PG Degree (88 credits) after Three Year UG Degree or
1 Year-2 Sem PG Degree (44 credits) after Four Year UG Degree

Total Credits for Four Semesters (Two Year Course): 4 * 22 = 88

Total Marks for Four Semesters (Two Year Course): 4 * 600 = 2400

Basket for ELECTIVE (DSE) Category Courses (Physics)

Semester	Course Category	Name of Course (Choose either A or B in each elective subject)	Course Code
I	Elective 1	A. Energy Devices	MPH1T03
		B. Experimental Techniques in Physics	
II	Elective 2	A. Spectroscopy	MPH2T07
		B. X-Rays	
III	Elective 3	A. Materials Science	MPH3T11
		B. Basic Nanoscience & Nanotechnology	
IV	Elective 4	A. Properties of Materials	MPH4T15
		B. Applied Nanoscience & Nanotechnology	

Note: *For elective 3, if student choose Materials Science in Semester – III must choose only Properties of Materials as elective 4 in Semester – IV. Similarly, if student choose Basic Nanoscience & Nanotechnology in Semester – III as elective 3 must choose only Applied Nanoscience & Nanotechnology as elective 4 in Semester – IV.*

Abbreviations:

DSC: Discipline Specific Course, **DSE**: Discipline Specific Elective **SEE:** Semester End Examination**, CIE:** Continuous Internal Evaluation, **OJT:** On the Job Training (Internship/Apprenticeship), **FP:** Field Project, **RM:** Research Methodology, **RP**: Research Project

Syllabus of M Sc (Physics)
as per NEP-2020 implemented from 2023-24

Programme Objectives (POs):

M Sc (Physics) programme is meant to systematize and give a method and structure to learner experiences with imparting students with an in-depth knowledge and understanding through the core courses which form the basis of Physics. The elective courses are designed for more specialized and/or interdisciplinary content to equip students with a broader knowledge base. The recent developments in physical sciences, has been included in the curricula to meet out the present day needs of academic and research, institutions, and industries. Research methodology, on the job training and research-based projects included in the curricula will enrich the students towards new findings leading to inspiration for research degree and orientation for job opportunities. After completing this Programme the learner,

PO 1: will have knowledge of fundamental laws and principles of physics along with their applications in diverse areas.

PO 2: will develop teaching and research skills which might include advanced Laboratory techniques, numerical methods, computer interfacing, etc.

PO 3: will become effective teacher and/or researcher; and will be able to exhibit good scientific knowledge and temperament in diverse fields/environment.

PO 4: will develop the skill to plan, execute and report on experimental and/or theoretical physics problems with effective scientific approach in future endeavour.

Programme Specific Outcomes (PSOs):

While studying M.Sc., Physics Programme, the learner shall be able to

PSO 1: provide well defined study of theoretical and experimental physics to impart in depth understanding in fundamental aspects of all core areas of Physics.

PSO 2: acquire core as well as specialized/disciplinary knowledge in physics.

PSO 3: equip the student to pursue research and development in any areas of theoretical, experimental, and computational physics.

PSO 4: learn how to design and conduct experiments demonstrating them understanding of scientific methods/processes/phenomena; and understand analytical methods required to interpret and analyse results and draw conclusions.

PSO 5: bridge the gap between textbook knowledge and practical problems through well-designed laboratory sessions.

PSO 6: develop written and oral communications skills in communicating physics- related topics; and realize and develop an understanding of the impact of science particularly physics on the society.

PSO 7: apply conceptual understanding and critical thinking of the physics to general real-world situations; and learn to analyse physical problems and develop correct solutions using theoretical and experimental techniques/tools and skills.

Semester - I

Paper 1 (Core 1) Mathematical Physics (MPH1T01)

Course Outcomes (COs):

On completion of the course the students will be able to,

- Understand the methods of mathematical physics.
- Understand the basic elements of mathematical physics and demonstrate an ability to use vector analysis in the solution of physical problems.
- Analyse the various types of matrix operations for solving problems in various branches of physics.
- Apply mathematical skills to solve problems in quantum mechanics, electrodynamics, and other fields of theoretical physics.
- Impart knowledge about various mathematical tools employed to study physics problems.

Unit I

Fourier Series: Definition, Dirichlet's condition, Functions defined in two are more subranges, Half Range Series, Change of interval and functions having Arbitrary Period. **Fourier transform,** Convolution theorem, Parseval's identity, Applications to the solution of differential equations,

Unit II

Laplace transform of elementary functions – Unit step functions, Shifting Theorems, Impulse function, Periodic functions, Convolution Therem, Evaluation of integrals.
Inverse Laplace transforms – Methods of finding Inverse Laplace transforms, Shifting Properties, Inverse Laplace transform of Derivatives, Integrals– Heaviside expansion formula – Solutions of simple, differential equations

Unit III

Linear vector spaces - linear independent bases, Dimensionality, inner product, matrices, linear transformation,
Matrices- Inverse, Orthogonal and Unitary matrices, Cayley Hamilton theorem, eigen vectors and eigen value problem, Diagonalization, Complete orthonormal sets of function.

Unit-IV

Special Function- Hermite, Legendre, Laguerre polynomials, Generating Function and recursion relations, differential and integral form.

Reference Books:

1. Matrices and Tensor in Physics: A.W. Joshi
2. Mathematical Physics: H. K. Dass
3. Vector analysis – Newell
4. Mathematical Physics, B. S. Rajput

Paper 2 (Core 2) Electronics (MPH1T02)

Course Outcomes (COs):

On completion of the course the students will be able to,

- Learn the general characteristics of important semiconductor materials and PN-junction for the construction of various types of transistors.
- Understand the use of semiconductor devices in linear and digital circuits.
- Analyse and design basic op-amp circuits, particularly various linear and non-linear circuits, active filters and signal generators, and data converters.
- Evaluate the characteristics of classification of memories and sequential memory and analyse the working of various A/D and D/A Converters.
- Understand the basic principle of amplitude, frequency and phase modulation in Communication Electronics.

Unit I

Electronics Semiconductor discrete devices (characteristic curves and physics of p-n junction), Schottky, Tunnel and MOS diodes, Bipolar junction transistor, junction field effect transistor (JFET),Metal-oxide-Semiconductor Field effect transistor (MOSFET),unijunction transistor(UJT) and sillicon controlled rectifier (SCR), Opto-electronic devices (Photo-diode, solar cell, LED, LCD and photo transistor), Diffusion of impurities in silicon, growth of oxide.

Unit II

Applications of semiconductor devices in linear and digital circuits- Zener regulated power supply, Transistor (bipolar, MOSFFT, JFET) as amplifier, coupling of amplifier stages (DC, RC and Transformer coupling), RC-coupled amplifier, dc and power amplifier Feedback in amplifiers and oscillators (phase shift, Hartley, Colpitts and crystal controlled) clipping and clamping circuits. Transistor as a switch OR, AND and NOT gates (TIL and CMOS gates).

Unit III

Digital integrated circuits- NAND and NOR gates building block, X-OR gate, simple combinational Circuits -Half and full address, Flip-Flops, Multivibrators (using transistor) and sweep geneator (using transistors, UJT and SCR). shift registers, counters, A/D and D/A coverters, semiconductor memories (ROM, RAM, and EPROM, basic architecture of 8 bit microprocessor (INTEL 8085). Linear integrated circuits- Operational amplifier and its applications-Inverting and noninverting amplifier, adder, integrator, differentiator, waveform generator, comparator and Schmittrigger, Butterwoth active filter, phase shifter,

Unit IV

Communication Electronics-Basic principle of amplitude frequency and phase modulation. Simple circuits for amplitude modulation and demodulation, digital (PCM) modulation and demodulation. Fundamentals of optical communication, Microwave Oscillators (reflex, klystron, megnetron and Gunn diode), Cavity resonaters. Standing wave detector.

Reference Books:

1. A. Malvino and D. J. Bates: Electronic Principles (Mc Graw Hill Education, India)
2. Boylstad & Neshishkey, “Electronic Devices & Circuits” , PHI
3. Milliman, J. Halkias, “integrated elctronics”, Tata McGraw Hill
4. J. J. CatheySchaum’s Outlines “Electronic Devices & Circuits” Tata McGraw Hill.
5. J. D. Ryder, “Electronics Fundamentals and Applications”, John Wiley-Eastern Publ.
6. A. P. Malvino, D.P. Leach, “Digital Principles and Applications”, McGraw Hill Book Co., 4th Edition (1986).
7. Ramakant A. Gayakwad, “Op-amps and Linear Integrated Circuits” PHI
8. Anil Maini, Varsha Agrawal, “ Electronic Devices and acircuits” Wiley
9. George Kennedy, “ Electronic Communication Systems”, Tata McGraw Hill.
10. Dennis Roddy, John Coolen, “Electronic Communication Systems ”, Pearson.

Paper 3 (Elective -1A) Energy Devices (MPH1T03A)

Course Outcomes (COs):

On completion of the course the students will be able to,

- Understand the need of energy storage and strategies for sustainable energy development.
- Learn the fundamental mechanism of energy devices, theoretical model and thermodynamic aspects of energy harvesting and storage.
- Understand the concept of energy storage in capacitors, supercapacitor, and rechargeable batteries.
- Describe the conceptual idea for various types of fuel cells with advantages and disadvantages.
- Understand the construction and working principle of various types of solar cells.

Unit-I

Energy need and goals for our environment, strategies for sustainable energy development, focus greenhouse emission and present energy technology, global renewable energy needs and probable solutions. Fundamental concepts: Introduction, types of energy devices, fundamental mechanism of energy devices, theoretical model and thermodynamic aspects of energy harvesting and storage. Advanced materials for alternative energy technology in solid state batteries, fuel cell and solar cell:

Unit-II

Energy storage: Introduction of Present storage technologies: capacitors, supercapacitor, pseudocapacitor and rechargeable batteries. Solid state batteries, chemical kinetics and its use to develop rate equations and the basic current-voltage behavior for electrochemical events. Concepts of diffusion, migration, and convection are developed for charged and uncharged species-flow through batteries, metal-air batteries and Li-S and Na-S batteries..

Unit-III

Hydrogen Energy: Fundamental aspect of fuel cell and electrolyzer systems- Fuel cells –advantages and disadvantages, classification, efficiency- emf of fuel cells, hydrogen/oxygen fuel cell, criteria for the selection electrode and electrolyte, methanol fuel cell, solid oxide fuel cells, phosphoric acid fuel cells, molten carbonate fuel cell, proton exchange membrane fuel cell, biochemical fuel cell.

Unit-IV

Solar Cells: principle of photovoltaic technology, thermodynamics, and their physical properties.Fundamental limits of photovoltaic, theoretical limits of solar-cells. Source of radiation – solar constant– solar charts – Measurement of diffuse, global and direct solar radiations. Photovoltaic cell materials, their processing and characterizations, Principles of Si-solar cells, thin-film solar cells, multi-junction solar cells, dye-sensitized solar cell.

References:

1. High-Efficiency Solar Cells: Physics, Materials, and Devices (Springer Series in Materials Science)Author: Xiaodong Wang and Zhiming M. Wang
2. Physics of Solar Cells: From Basic Principles to Advanced Concepts Author: Peter Würfel
3. Dye-sensitized Solar Cells by Kuppuswamy Kalyanasundaram
4. Energy Storage: Fundamentals, Materials and Applications by Robert Huggins
5. Lithium-Ion Batteries: Science and Technologies edited by Masaki Yoshio, Ralph J. Brodd,AkiyaKozawa
6. Hydrogen and Fuel Cells: Emerging Technologies and Applications By Bent Sørensen.

Paper 3 (Elective -1B) Experimental Techniques in Physics (MPH1T03B)

Course Outcomes (COs): On completion of the course the students will be able to,

- Understand the different types of radiation and the concept of detection of radiation using various detectors.
- Learn the fundamental aspect of classification of sensors and their principle of operation.
- Describe the principle of working of TGA, DTA, DSC used for thermal analysis.
- Understand the experimental technique for magnetic characterization using VSM and dielectric properties using impedance analyser.
- Explain the spectroscopic techniques of FTIR, UV-VIS, DRS, XPS, ESR, NMR used for materials characterization.

Unit 1

Different types of radiation (X-rays, UV-VIS, IR, microwaves and nuclear) - their role in materials characterization- sources - concept of detection and different Detectors: gamma-rays, X-rays, UV-VIS, IR, microwaves and nuclear detectors.

Sensor's characteristics, Classification of sensors, Operation principles of sensors such as electric, dielectric, acoustic, thermal, optical, mechanical, pressure, IR, UV, gas and humidity with examples

Unit-II

Thermal analysis: Principle, Instrumentation and Working: Thermo-gravimetric (TGA), Differential Thermal Analysis (DTA), Differential Scanning Calorimetry (DSC); Phase diagram determination by thermal analysis technique. Graphical analysis affects various factors. Numerical

Unit III

Magnetic Characterization: Principle, Instrumentation and Working of Vibrating Sample Magnetometer (VSM), Analysis of Hysteresis loop, SQUID Technique: Principle, Instrumentation and Working. Numerical

Dielectric properties: Dielectric polarization. AC response. Instrumentation and working of impedance analyzer, Measurement of complex dielectric constant, dielectric relaxation mechanism,

Unit IV

Spectroscopic characterization (principle, instrumentation and working): Infra-Red (IR), Fourier Transform Infra-Red (FTIR), Ultraviolet-Visible (UV-VIS), Diffused Reflectance Spectroscopy (DRS), X-ray Absorption (XPS), Electron Spin Resonance (ESR), Nuclear Magnetic Resonance (NMR).

Reference Books:

1. Nuclear Radiation Detectors, S.S. Kapoor, V. S. Ramamurthy, (Wiley-EasternLimited, Bombay)
2. Instrumentation: Devices and Systems, C.S. Rangan, G.R. Sarma and V.S.V. Mani,Tata Mc Graw Hill Publishing Co. Ltd.
3. Instrumental Methods of Chemical Analysis, G. Chatwal and S. Anand, HimalayaPublishing House
4. Instrumental Methods of Analysis by H.H. Willard , L.L. Merritt, J.A. Dean, CBSPublishers
5. Characterization of Materials, John B. Wachtman & Zwi. H. Kalman, Pub. ButterworthHeinemann (1992)
6. Elements of X-ray diffraction, Bernard Dennis Cullity, Stuart R. Stock, (Printice Hall,2001 - Science – 664

Paper 4 (RM) Research Methodology (MPH1T04)

Course Outcomes (COs): On completion of the course students will be able to,

- Understand the basic concepts regarding importance of research.
- Impart knowledge about research problems identification, research question and formulation of hypotheses.
- Understand the differences of qualitative vs. quantitative research methodology, field experiments vs. laboratory experiments.
- Execute the methods of data collection and strategies of data processing and analysis.
- Learn the ethical issues including copy right, royalty, intellectual property rights, patent law, and plagiarism in publishing research.

Unit-1

Foundations of Research: Meaning, objectives, motivation and significance of research, types and parameters of research, research process, research methods versus methodology, research and scientific method, importance, research process, criteria of good research, multidisciplinary and interdisciplinary research, creativity in research.

Unit-2

Research Problem, Literature Review & Hypotheses:

Concept and need, identification of research problem, defining and delimiting research problem. Meaning, necessity, sources and functions of literature review. Precautions in library use. variables and their linkages, characteristics of good hypothesis. Research question and formulation of hypotheses-directional and non-directional hypotheses, basis for hypotheses.

Unit-3

Research Design & Measurements: Need for research design, pure and applied research design, exploratory and descriptive design methodology, qualitative vs. quantitative research methodology, field studies, field experiments vs. laboratory experiments, research design in social and physical sciences. Execution of the research - Observation and Collection of data - Methods of data collection – Sampling Methods- Data Processing and Analysis strategies - Data Analysis with Statistical Packages - Hypothesis-testing - Generalization and Interpretation.

Unit-4

Ethics in Scientific Research: Environmental impacts - Ethical issues - ethical committees - Commercialisation – Copy right – royalty - Intellectual property rights and patent law – Trade Related aspects of Intellectual Property Rights – Reproduction of published material – Plagiarism - Citation and acknowledgement - Reproducibility and accountability.

Reference books:

1. Kothari ,C.R.,**1985**, Research Methodology-Methods and Techniques, New Delhi, Wiley Eastern Limited.
2. Kumar,Ranjit, **2005**,Research Methodology-A Step-by Step Guide for Beginners,(2nd Ed.) ,Singapore,Pearson Education.
3. Peter, Pruzan, **2016**, Research Methodology-The Aims, Practices and Ethics of Science, Springer International Publishing Ltd.
4. Bendat, J. S. and A. G. Piersol (2010). Random Data: Analysis and Measurement Procedures. 4th edition. New York, USA: John Wiley & Sons, Inc.
5. Wadehra, B.L. 2000. Law relating to patents, trade marks, copyright designs and geographical indications. Universal Law Publishing.
6. Sinha, S.C. and Dhiman, A.K., 2002. Research Methodology, Ess Ess Publications. 2 volumes

Semester I Practical (Lab 1 & Lab 2)

Practical 1: General and Research Methodology (MPH1P01)

1. Study of Focault pendulum
2. Study of Bifilar pendulum
3. Fibre optics
4. Study of waveguide
5. Thickness of thin wire with lasers
6. Measurement of wavelength of He-ne laser light using ruler.
7. To study Faraday effect using He-Ne laser.
8. Simulation of simple pendulum
9. Simulation of compound pendulum
10. Simulation of planetary motion.
11. Study of B-H Curve
12. Particle size distribution using ImageJ software.
13. Thermal analysis of thermogravimetry and differential scanning calorimetry data
14. Crystallite size determination from X-ray diffraction data
15. Analysis of research impact from published research papers.
16. Plot and analysis of given data using Microsoft excel and/or origin.

Practical 2: Electronics (MPH1P02)

1. Design of a regulated power supply.
2. Characteristics and applications of silicon controlled rectifier.
3. Design of common emitter Power transistor amplifier.
4. Experiments on bias stability.
5. Negative feedback (Voltage series / shunt and current series / shunt).
6. Astable, Monostable and Bistablemultivibrator.
7. Experiment on FET and MOSFET characterization and application as an
8. amplifier.
9. Experiment on Uni-junction transistor and its application.
10. Digital – I: Basic, TTL, NAND and NOR.
11. Digital – II: Combinational logic.
12. Flip-Flops.
13. Study of modulation (FM, AM, etc.).
14. Operational Amplifier.
15. Differential Amplifier.
16. Microprocessor.

Semester - II

Paper 5 (Core 3) Complex Analysis and Numerical Methods (MPH2T05)

Course Outcomes (COs):
On completion of the course students will be able to,

- Represent complex numbers, analyse limit, continuity, and differentiation of functions of complex variables.
- Learn analytic functions, Cauchy Reimann conditions, how to find roots of nonlinear equations numerically and understand how iterations work.
- Interpolate with evenly or unevenly spaced data.
- Interpret and apply the basic methodology of numerical differentiation and numerical integration to a broad range of physics problems.
- Enrich with various computational methods like Euler, Newton-Raphson and Runge-Kutta etc. to solve the problems.

Unit I
Definition of Complex Numbers, Equality of Complex Number, Complex Algebra, Conjugate Complex Numbers, Geometrical representation of Complex Number, Geometrical representations of the sum, difference, product and quotient of Complex Number, Cauchy-Rieman Conditions, Analytic functions, Multiply connected regions, Cauchy Theorem, Cauchy Integration formula, Derivatives

Unit II
Singularities- Poles, Branch Points, Calculus of Residues-Residues Theorem, Cauchy Principle value, Pole Expansion of Meromorphic Functions, Product expansion of entire Functions,

UNIT III
Methods for determination of zeros and linear and non-linear single variable algebraic and transcendental equations, (Bisection method, false position method, iteration method, Newton-Raphson method, secant method), Finite differences. Newton's formulae (no proofs)

Unit IV
Lagrange's interpolation, Divided differences. Numerical integration, trapezoid rule, Simpson's 1/3rd rule, Simpson's 3/8th rule, Linear least squares. Euler and Runge-Kutta methods for solving ordinary differential equations. (No proofs)

Reference Books:

1. Mathematical Physics, Rajput B S,
2. Introductory Methods of Numerical Analysis: S S Sastry
3. Computer Oriented Numerical Methods: V Rajaraman
4. Complex variables and Applications, R. V. Churchill, 7th Edition McGraw Hill
5. Computer oriented Numerical Methods: R.S.Salaria
6. Mathematical Physics: H.K.Dass
7. Higher Engineering Mathematics : B. S. Grewal

Paper 6 (Core 4) Statistical Physics (MPH2T06)

Course Outcomes (COs):
On completion of the course students will be able to,

- Understand various models in statistical mechanics and apply statistical tools to solve the problems in Physics.
- Identify the connection between statistical mechanics and thermodynamics.
- Understand Bose's concept of fifth state of matter and any possibility of sixth state of matter or not.
- Understand the significance and characteristics of phase transitions and critical phenomena.
- Learn Einstein's theoretical analysis and Langevin theory of Brownian motion.

Unit I
Fundamentals of classical statistical mechanics, microstate and macrostate, distribution function, Liouville's theorem, Gibbs Paradox, ensembles (micro-canonical, canonical and grand-canonical), partition function, free energy and connection with thermodynamic quantities, energy and density fluctuations

Unit II
Fundamentals of quantum statistical mechanics, BE and FD Statistics, Symmetry of wave functions, Boltzmann limit of Bosons and Fermions, Ideal Bose system: Bose-Einstein condensation, Behaviour of ideal Bose gas below and above Bose temperature, Photons and liquid helium as bosons, Superfluidity of He^4

Unit III
Ideal Fermi system: Weak and strong degeneracy, Fermi function, Fermi energy, Behaviour of ideal Fermi gas at absolute zero and below Fermi temperature, Fermionic condensation, Free electrons in metals as fermions, Electronic specific heat, Determination of Fermi temperature, Cluster expansion for classical real gas, Virial equations of states.

Unit IV
Introduction to Phase Transitions; First Order Phase Transition (Clausius-Clapeyron Equation); Phase Transition of Second Order; Order Parameter; Landau Theory of Phase Transition of Second Order; Ising Model of Phase Transition of Second Order; Time Dependant Correlation Function; Power Spectrum of Fluctuation; Brownian Motion, Einstein's theoretical analysis of Brownian motion, Langevin theory of Brownian motion.

Text and Reference Books:

1. Fundamentals of Statistical Physics: B. B. Laud
2. Statistical Mechanics: R. K. Pathria
3. Statistical Mechanics: S. K. Sinha
4. Statistical and Thermal Physics: F. Reif
5. Statistical Mechanics: K. Huang
6. Statistical Mechanics: Loknathan and Gambhir
7. Statistical mechanics: R. Kubo
8. Statistical Physics: Landau and Lifshitz

Paper 7 (Elective - 2 A) Spectroscopy (MPH2T07A)

Course Outcomes (COs): On completion of the course students will be able to,

- Explain Zeeman effect, Stark effect and hyperfine structure of spectral lines of hydrogen.
- Analyse the information from IR rotational vibration spectroscopy to determine the bond lengths of heteronuclear diatomic molecules and applications of FTIR spectroscopy.
- Explain Raman effect and application of Raman spectroscopy.
- Describe the Bloch Equation and principle of High-Resolution NMR Spectrometer.
- Understand molecular vibrations with the interaction of matter and electromagnetic waves and explain the Mossbauer Effect.

Unit I

Quantum states of an electron in an atom. Electron spin. Spectrum of helium and alkali atom. Features of one-electron and two electron atoms, Relativistic corrections for energy levels of hydrogen atom, hyperfine structure and isotopic shift, width of spectrum lines, LS & JJ couplings, Hund’s rules, Spectral transitions of helium, Spectral terms of equivalent electrons, Zeeman effect, Paschen-Bach effect, Stark effect, Lamb shift, X-ray spectra, Moseley’s law.

Unit II

Types of molecules, rotational spectra of rigid diatomic molecules, isotope effect in rotational spectra, intensity of rotational lines, non–rigid rotor, rotational spectra of polyatomic molecules. Stark effect. Microwave spectroscopy. Basics of IR spectra, vibrating diatomic molecule, diatomic vibrating rotator, asymmetry of rotation-vibration band, vibrations of polyatomic molecules, rotation-vibration spectra of polyatomic molecules, analysis by IR technique, Fourier transform IR spectroscopy and structure determination.

Unit III

Classical and quantum theory of Raman scattering, rotational Raman spectra, vibrational Raman spectra, mutual exclusion principle, Raman spectrometer, Fourier transform Raman spectrometer, Structure determination of various types of molecules using Raman spectroscopy, Study of phase transitions and proton conduction in solids using Raman spectroscopy, Resonance Raman scattering, Surface enhanced Raman scattering. Photoacoustic Raman scattering.

Unit IV

Electronic spectra of diatomic molecules, progressions and sequences, Franck – Condon principle, Rotational fine structure of electronic-vibrational spectra, Fortrat parabola, Dissociation and predissociation energy, Photoelectron spectroscopy, NMR spectrometer, NMR spectra of solids, NMR imaging, ESR spectroscopy, Mossbauer spectroscopy, Laser spectroscopy.

Reference Books:

1. Physics of Atoms and Molecules: Bransden and Joachain.
2. Introduction of Atomic Spectra, H.E. White, McGraw Hill
3. Spectroscopy (Vol. 2 & 3), B.P. Straughan & S. Walker, Sciencepaperbacks 1976
4. Molecular Spectra and Molecular Spectroscopy (Vol. 1), G. Herzberg
5. Introduction to Atomic Spectra: HG Kuhn
6. Fundamentals of molecular spectroscopy, C.B. Banwell
7. Introduction to molecular Spectroscopy, G. M. Barrow
8. Raman Spectroscopy, D.A. Long, McGraw Hill international, 1977
9. Introduction to Molecular Spectroscopy, G.M. Barrow, McGraw Hill
10. Molecular Spectra and Molecular Structure, Vol. 1, 2 & 3. G.Herzberg, Van Nostard.
11. Infra-Red Spectra of Complex Molecules, L.J. Bellamy, Chapman & Hall. Vol. 1 & 2
12. Laser Spectroscopy techniques and applications, E.R. Menzel, CRC Press, India
13. Molecular Structure and Spectroscopy, G. Aruldas, Prentice Hall India.
14. NMR spectroscopy, H. Gunther, 2nd edition John Wileny and Sons, 1995.

Paper 7 (Elective - 2 B) X-Rays (MPH2T07B)

Course Outcomes (COs):
On completion of the course students will be able to understand,

- Basic concepts of production of X-rays, Designing concepts conventional of X-ray generators, Basics of Advanced radiation source Synchrotron and its advantages over conventional sources.
- Interaction of X-rays with the matter and applications of X-rays based on different physical processes involved after interaction of x-rays with matter.
- The method of X-ray radiography and its applications in medical and industrial fields.
- Designing concepts of different X-ray spectrographs. Different theoretical concepts regarding X-ray spectra and their interpretation.
- Interpretation of X-ray absorption spectra. Experimental techniques for obtaining X-ray absorption spectra and its important applications.

Unit I

Continuous and characteristic X-ray spectra. X-ray emission from thick and thin targets. Efficiency of X-ray production.Various types of demountable and sealed X-ray tubes.
Basics of high-tension circuits and vacuum systems used for the operation of X-ray tubes.
Synchrotron radiation: Production and properties of radiation from storage rings, Insertion devices.

Unit II

Physical process of X-ray absorption. Measurement of X-ray absorption coefficients. Units of dose and intensity. Radiography, Microradiography and their applications. X–ray fluorescence: Fluorescence yield. Auger effect.X–ray fluorescence analysis and its applications. Techniques and applications of Photoelectron spectroscopy and Auger electron spectroscopy.

Unit III

Experimental techniques of wavelength and energy dispersive x-ray spectroscopy. Bragg and double crystal spectrographs. Focusing spectrographs. Dispersion and resolvingpower of spectrographs, Photographic and other methods of detection, resolving power ofdetectors.
X–ray emission and absorption spectra. Energy level diagram. Dipole and forbidden lines, Satellite lines and their origin, Regular and irregular doublets. Relative intensities of X- ray lines.

Unit IV

Chemical effects in X-ray spectra. White line, Chemical Shifts of absorption edges, Fine structures (XANES and EXAFS) associated with the absorption edges and their applications.
Dispersion theory applied to X-rays, Calculation of the dielectric constant, Significance of the complex dielectric constant, Refraction of X-rays, Methods for measurement of refractive index

Reference Books:

1. A. H. Compton and S. K. Allison: X-rays in Theory and Experiment
2. J. A. Nielsen and D. Mc. Morrow: elements of Modern X-ray Physics.
3. M. A. Blokhin: X-ray Spectroscopy.
4. E. P. Bertin: Principles and Practice of X-ray Spectrometric Analysis.
5. C. Bonnelle and C. Mande: Advances in X-ray Spectroscopy.
6. D. C. Koningsberger and R. Prins: X-ray Absorption Principles, Applications, Techniques of EXAFS, SEXAFS and XANES.
7. C. Kunz: Synchrotron Radiation.

Semester II Practical (Lab 1 & Lab 2)

Practical 1: Computational (MPH2P03)

1. To find the largest or smallest of a given set of numbers.
2. Bubble sort.
3. To generate and print first hundred prime numbers.
4. Matrix multiplication.
5. To generate and print an odd ordered magic square.
6. Other exercises involving conditions, loop and array
7. Lagrange Interpolation.
8. Method of successive approximation
9. Bisection Method
10. Newton-Raphson Method.
11. Gaussian Elimination
12. Linear Least Squares Fit.
13. Simpson's rule integration.
14. Computation of special functions

Practical 2: General (MPH2P04)

1. Determination of e/m of electron by normal Zeeman effect using Febry Perot Etalon.
2. Determination of Lande's factor of DPPH using ESR spectrometer
3. Determination of e/m by Thomson method.
4. Determination of e/m by Busch's helical beam method.
5. Determination of Plank's constant.
6. Determination of Stephan's constant.
7. Study of paramagnetic to ferromagnetic phase transition.
8. Study of Paramagnetic salt by Guoy's balance
9. Differential scanning Calorimetry
10. Simulation of Ising model.
11. Location of critical point in Ising model using Binder cumulant.
12. Simulation of random walk.
13. Simulation of mean field model of para-ferro transition.
14. Numerical solution of particle in a box.
15. Simulation of Maxwell's velocity distribution.

Semester - III

Paper 8 (Core 5) Classical Mechanics (MPH3T08)

Course Outcomes (COs):
On completion of the course students will be able to,

- Interpret the notion of degrees of freedom, identify them for a given mechanical system and DÁlembert's principle, Formulation of Lagrangian mechanics and problem solving.
- Describe the Canonical transformations and generating functions and properties of Poisson's bracket.
- Enable to solve Hamilton-Jacobi equations and use it for the solution of harmonic oscillator problem.
- Demonstrate an understanding of intermediate classical mechanics topics such as coordinate transformations, oscillatory motion, gravitation and other central forces, and Lagrangian mechanics.
- Evaluate the Central Force Problems and Relativistic Mechanics.

Unit-I

Survey of elementary principles of mechanics of a particle, Dynamical systems, Phase space dynamics, stability analysis, constraints & their classifications, D'Alemberts Principle, Variational Principle, Lagrange's equation, Hamilton's Principle

Unit-II

Conservation theorems and symmetry properties, Hamiltonian formalism, Hamiltons equations, Routh's procedure for cyclic coordinates, conservation laws Canonical transformations, Poisson brackets and Poisson theorems, Hamilton-Jacobi Theory

Unit-III

Central force motion, reduction to one body problem, equations of motions and first integrals, classification of orbits for inverse square central forces. Two body collisions, Rutherford scattering in laboratory and center-of-mass frames.

Unit-IV

Rigid body dynamics, Euler's angles, Euler's theorem, moment of inertia tensor, eigen values and principal axis transformation, non-inertial frames and Pseudo forces, Periodic motion: small oscillations, normal modes.

Reference books:

1. Classical Mechanics: H. Goldstein, C. Poole and J.Safko, Pearson Education Asia, New Delhi, Third Edition, 2002.
2. Classical Mechanics: N.C.Rana and P.S.Joag, Tata McGraw Hill, New Delhi, 2015.
3. Classical Mechanics : J. C. Upadhyaya, Himalaya Publishing House Pvt. Ltd, Bangalore, Second edition, 2017
4. Classical Mechanics, B.D.Gupta and Satya Prakash, Keder Nath Publishers, Meerut, Revised Edition, 2015.
5. Classical Mechanics: John R. Taylor
6. Introduction to Classical Mechanics With Problems and Solutions: David Morin

Paper 9 (Core 6) Quantum Mechanics – I (MPH3T09)

Course Outcomes (COs):
On completion of the course students will be able to,

- Introduce postulates and working principles of quantum mechanics.
- Familiarity with operator and matrix formalism of quantum mechanics.
- Solve Schrodinger equation for simple systems.
- Formulate the Heisenberg & Dirac formulation of quantum mechanics.
- Learn angular momentum operator, spin and be able to add angular momenta.

Unit- I

Time dependent and time-independent Schrodinger equation, continuity equation, wave packet, admissible wave functions, stationary states.

Formalism of wave mechanics, expectation values, quantum mechanical operators for position and momentum in the coordinate representation, Construction of quantum mechanical operators for other dynamical variables from those of position and momentum, Ehrenfest's theorem, momentum eigen functions in the coordinate representation, box normalization and Dirac delta function.

Coordinate and momentum representations, Schrodinger equation in momentum representation,

Unit-II

Brief revision of linear vector spaces, inner or scalar product, Schwarz inequality, state vectors, general formalism of operator mechanics vector, operator algebra, commutation relations, eigen values and eigen vectors, Hermitian operators degeneracy, orthogonality eigenvectors of Hermitian operators, noncommutativity of two operators and uncertainty in the simultaneous measurements of the corresponding dynamical variables, the fundamental expansion postulate, representation of state vector, Dirac's bra-ket notations. Matrix representation of operators, change of basis, unitary transformations, quantum dynamics, Schrodinger, Heisenberg and interaction picture.

Unit-III

Solution of Schrodinger equation for simple problems, 1-D Square well, step and barrier potentials, 1-D harmonic oscillator, zero point energy. harmonic oscillator problem by operator method.

Angular momentum operator, commutation relations, expression for L^2 operator in spherical polar coordinates, Role of L^2 operators in central force problem, eigen value problem for L^2, separation of Schrodinger equation in radial and angular parts, solution of radial equation for hydrogen atom, 3-d square well potential, parity of wave function, parity operator.

Unit-IV

Generalized angular momentum, raising and lowering operators, matrices for J^2, Jx, Jy, Jzoperators, Pauli spin matrices, Addition of angular momenta, Clebich-Gordon Co-efficient, spin angular momentum, spin momentum functions.

Reference Books:

1. Quantum mechanics: E. Merzbacher
2. Quantum mechanics: L.I.Schiff
3. Quantum mechanics: Mathews and Venkatesan
4. Quantum mechanics: Ghatak and Loknathan
5. Quantum mechanics: B.Craseman and J.D.Powell
6. Modern quantum mechanics: J.J.Sakurai
7. Quantum theory: D. Bohm
8. Quantum Mechanics: 500 problems with Solutions: Aruldhas (PHI)

Paper 10 (Core 7) Electrodynamics (MPH3T10)

Course Outcomes (COs):
On completion of the course students will be able to,
- Provide basic understanding of the concepts of electricity, magnetism and electromagnetic waves.
- Describe EM waves in vacuum as well as matter to solve the difficult problems of electrodynamics.
- Analyse and apply the laws of electromagnetism and Maxwell's equations.
- Understand the basics of electrostatics and magnetostatics to solve the electric and magnetic fields problems for different configurations.
- Describe relativistic electrodynamics to understand the magnetism as a relativistic phenomenon.

Unit-1

EM Waves: Scalar and Vector Waves, Plane waves, spherical waves, phase and group velocities and wave packets, Electromagnetic plane waves, harmonic plane waves, elliptic linear and circular polarization, Stokes parameters

EM Waves in vacuum: Maxwell's equations, the electromagnetic (EM) wave equation and its, energy and momentum in EM Waves.

EM Waves in matter: Propagation in linear non-conducting media, Reflection and Transmission at normal incidence, Reflection and Transmission at oblique incidence, Reflection and Transmission at a conducting surface

Unit II:

Absorption and Dispersion: EM waves in conductors, Reflection at a conducting surface, The frequency dependence of permittivity.

Guided Waves: Wave Guides, TE, TM, TEM modes in a rectangular and cylindrical wave guide, Resonant Cavities, Dielectric waveguides, coaxial transmission line.

Unit III:

Potentials: Scalar and Vector potentials, Gauge transformations, Coulomb Gauge and Lorentz Gauge, Retarded Potentials, Lienard-Wiechert Potentials, the fields of a moving point charge.

Radiation: Electric dipole radiation, Magnetic dipole radiation, Radiation from an arbitrary source, Power radiated by a point charge, radiation reaction.

Unit IV:

The special theory of relativity: Einstein's postulates, the geometry of relativity, the Lorentz transformations, the structure of space-time.

Relativistic Mechanics: proper time and proper velocity, relativistic energy and momentum, relativistic kinematics, relativistic dynamics.

Relativistic Electrodynamics: Magnetism as a relativistic phenomenon, how the fields transform, the field tensor, Electrodynamics in tensor notation, the 4-vector potential.

Reference Books:

1. Introduction to Electrodynamics - David J. Griffiths.
2. Electricity & Magnetism – B.Ghosh.
3. Electromagnetic Theory and Electrodynamics - Satya Prakash
4. Electromagnetism: With Solved Problems - Hiqmet Kamberaj
5. Fundamentals of Electromagnetic Theory, John R.Reitz, Frederick J Milford and Robert W.Christy
6. Classical Electrodynamics – J.D. Jackson

Paper 11 (Elective - 3 A) Materials Science (MPH3T11A)

Course Outcomes (COs):
On completion of the course students will be able to,

- Review of principle of thermodynamics and understand the fundamental concepts of phase rule and phase diagram.
- Understand the kinetics of phase transformation, homogeneous and heterogeneous nucleation and growth of particles.
- Explain the concept of equilibrium and nonequilibrium processing of materials and their importance.
- Describe the various physical and chemical route of materials synthesis.
- Understand the metallic and non-metallic, ceramic and other materials processing and heat treatment methodologies.

Unit-I
Review of general principles of thermodynamics: Entropy. Internal energy. Free energy. Chemical potential. Entropy of mixing. Free energy of ideal and regular solid solutions. Phase rule. Types of phase diagrams. Study of Fe-C, Cu-Ni, Cu-Zn, CaO-SiO_2 systems.

Unit–II
Phase Transformations: Kinetics of phase transformations. Homogeneous and heterogeneous nucleation and growth. Continuous and discontinuous reactions. Precipitation, spinodal and eutectoidal transformation. Heat treatment of steels and Al-alloys. Solidification and Casting. Zone refining. Single crystal growth techniques.

Unit-III
Concept of Synthesis: Concept of equilibrium and nonequilibrium processing and their importance in materials science.
Synthesis of materials: Physical method – cluster beam evaporation, Ion beam deposition, Gas evaporation, Ball milling, Solvated metal atom dispersion–thermal decomposition.
Chemical method – Hydrothermal, combustion, bath deposition, colloidal route, and micellar approach.

Unit-IV
Processing of materials: Metallic and nonmetallic, Ceramics and other materials. Only basic elements of powder technologies, calcination, compaction, sintering methodologies: Conventional heating, Microwave, Electric discharge vitrification reactions, with different example, phenomenon of particle coalescence, porosity. Quenching: concept, glass formation.

Reference books:

1. Phase Equilibria, Phase Diagrams and Phase Transformations: Their Thermodynamic Basis, Cambridge University Press; 2 edition: Mats Hillert
2. Materials Science: V. Raghvan
3. Chemical approaches to the synthesis of inorganic materials: C.N.R. Rao
4. Materials Science & Engineering–An Introduction: W.D. Callister.

Paper 11 (Elective - 3 B) Basic Nanoscience and Nanotechnology (MPH3T11B)

Course Outcomes (COs): On completion of the course students will be able to,

- Explain the term Nanoscience and Nanotechnology and quantum confinement, zero, one and two-dimension nano structures.
- Identify the various techniques to investigate the different properties such as optical, structural and morphology of nanoparticles.
- Acquire knowledge of basic approaches like Bottom up and Top down to synthesize inorganic colloidal nanoparticles and their self-assembly in solution and surfaces.
- Apply their acquired knowledge in research level to synthesis by various techniques and characterize the nanomaterials by microscopic and spectroscopic techniques.
- Understand the techniques of preparation of special nanomaterials and the properties of nanomaterials for future applications.

Unit I: Introduction to Nanoscience:

Particle size verses surface area, Free electron theory (qualitative idea) and its features, Quantum confinement (quantum wells, wires, dots), Density of states for zero, one, two and three, dimensional materials, Size dependence properties, Blue Shift in absorption spectra of nanomaterials, Increase in band gap of semiconducting nanomaterials, Determination of particle size, Blue Shift in emission spectra of nanomaterials, Increase in width of XRD peaks of nanoparticles.

Unit II: Nanomaterials Synthesis:

Physical methods: High energy ball milling, Physical vapour deposition, Laser ablation, Laser pyrolysis, Electric arc deposition, Sputter deposition, Photolithography.

Chemical methods: Chemical vapour deposition, Synthesis of metal & semiconductor nanoparticles by colloidal route, Langmuir-Blodgett method, Microemulsions, Sol-gel method, Chemical bath deposition.

Unit III: Nanomaterials Characterizations:

X-ray diffraction, UV-VIS spectroscopy, Photoluminescence spectroscopy, Raman spectroscopy, Transmission Electron Microscopy, Scanning Electron Microscopy, Scanning Tunnelling Microscopy, Atomic Force Microscopy, Vibration Sample Magnetometer.

Unit IV: Special Nanomaterials and Properties:

Special Nanomaterials: Carbon nanotubes, Porous silicon, Aerogels, Core shell structures. Self-assembled nanomaterials.

Properties of nanomaterials: Mechanical, Electrical, Thermal and Magnetic properties.

Reference books:

1. Nanotechnology: Principles & Practicals, Sulbha K. Kulkarni, Capital Publishing Co. New Delhi.
2. Nanostructures & Nanomaterials Synthesis, Properties & Applications. Guozhong Cao, Imperials College Press London.
3. Nanomaterials: Synthesis, Properties & Applications. Edited by A.S. Edelstein & R.C.Commorata. Institute of Physics Publishing, Bristol & Philadelphia.
4. Introduction to Nanotechnology. C.P. Poole Jr. and F. J.Owens, Wiley Student Edition.
5. Nano: The Essentials. T. Pradeep, McGraw Hill Education.
6. Handbook of Nanostructures: Materials and Nanotechnology. H. S. Nalwa Vol 1-5, Academic Press, Bostan..
7. Nanoscience and Technology: Novel Structure and Phenomena. Ping and Sheng
8. Hand Book of Nanotechnology, Bhushan

Semester III Practical (Lab 1)

Practical: Elective - Materials Science (MPH3P05A)

List of Practical

1. Crystal structure determination by powder diffraction.
2. Study of microstructures of metal alloys.
3. Dislocation in alkali halide crystals.
4. Crystal growth from slow cooling of the melt.
5. Thermal analysis of binary alloy.
6. Differential thermal analysis of $BaTiO_3$-$PbTiO_3$ solid solution.
7. To study electrochemical method of corrosion control.
8. Dielectric behaviour of $LiNbO_3$ and $BaTiO_3$ in crystals and ceramics.
9. Electrical conductivity of ionic solids.
10. To test hardness of a material by Brinell hardness tester.
11. Photo elasticity study.
12. Multiple beam interferromentric study of surfaces.
13. Thermal conductivity of bad conductor. 14. Thermal expansion coefficient of metals.
15. Study of transport property in solid electrolytes.
16. Verification Nernst law/Oxygen sensor.
17. Determination of Thermoelectricity Power.

Practical: Elective – Basic Nanoscience and Nanotechnology (MPH3P05B)

List of Practical

1. Synthesis of metal oxide nanoparticles by wet chemical method.
2. Deposition of thin films by spray pyrolysis technique.
3. Synthesis of inorganic nanomaterials by combustion method.
4. Synthesis of nanomaterials by sol-gel method.
5. Synthesis of conducting polymer nanofibres by chemical oxidation method.
6. Study of optical absorption of nanoparticles.
7. Determination of particle size of nanomaterials from x-ray diffraction.
8. Study of photoluminescence of well known luminescent nanoparticles.
9. Deposition of thin films by spin coating method.
10. Thermoluminescence study of nanomaterials.
11. Deposition of thin films by dip coating technique.
12. Study of particle size effect on luminescence.
13. Electrical characterization of nanostructured materials.
14. Synthesis of metal oxide nanoparticles by hydro-thermal method.
15. Deposition of thin film in vacuum.
16. Electrical resistivity of nanomaterials using four probe method
17. Photoluminescence study of prepared red/blue/green luminescent nanomaterials.
18. Characterization of nanomaterials using SEM/TEM.

Project/Dissertation (MRP3P01)

<u>Project Work Guidelines for the Students, Supervisors and Examiners</u>

Every student is required to carry out a project work in semester III & IV in lieu of Practical. The project can be of following types. (i) Experimental Project Work; (ii) Field Based Project Work; (iii) Review writing based Project Work.

Experimental Project Work OR Field Based Project Work:

Student can carry out Experimental / Field based Project Work on a related research topic of the subject /course. It must be an original work and must indicate some degree of experimental work / Field work. On the basis of this work, student must submit the Project Report (typed and properly bound) in two copies at least one month prior to commencement of the final Examination of Semester III & IV. The project report shall comprise of Introduction, Review of literature, Material and Methods, Results, Discussion, Summary, Conclusion and References along with the declaration by the candidate that the work is original and not submitted to any University or Organization for award of the degree and certificate by the supervisor and forwarded through Head / Course-coordinator.

Review writing based Project Work.

Student can carry out review writing based Project Work on a related topic of the subject / course. It must be a review of topic based on research publications. Student shall refer peer reviewed original research publications and based on findings, write a summary of the same. The pattern of review writing shall be based on reputed reviews published in a standard, peer reviewed journals. On the basis of this work, student must submit the Project Report (typed and properly bound) in two copies at least one month prior to commencement of the final Examination of Semester III & IV. The project report shall comprise of Abstract, Introduction, detailed review, Discussion, Summary, Conclusion and References along with the declaration by the candidate that the work is original and not submitted to any University or Organization for award of the degree and certificate by the supervisor and forwarded through Head / Course-coordinator.

The **supervisor** shall be able to guide not more than 11 (Eleven) students in the given examination. The supervisor shall declare in the project of every student which he / she is guiding stating that he / she has not guided more than 11 students in the given examination.

The supervisors for the Project Work shall be either (i) a person who is full time university PG recognized faculty member in the relevant subject or (ii) a person appointed in PG on contractual / contributory basis, having NET / SET and approved by the University in the relevant subject and having 3 years teaching experience as contractual / contributory at PG level, or (iii) University approved Ex-Faculty members in the relevant subject

The Project Work will carry total 100 marks and will be evaluated by both external and internal examiners. The examiners will evaluate the Experimental Project Work taking into account the coverage of subject matter, arrangement and presentation, references, etc.

For written Project work its Presentation: 40 Marks – Evaluated jointly by External & Internal

For Viva-Voce: 10 Marks – Evaluated by External examiner,

Internal Assessment: 50 Marks – Evaluated by Internal examiner.

Semester - IV

Paper 12 (Core 8) Nuclear and Particle Physics (MPH4T12)

Course Outcomes (COs):
On completion of the course students will be able to,

- Explain the nuclear structure and properties, nuclear forces and two body problems.
- Discuss the stability and properties of different nuclei by various nuclear models.
- Describe radioactive α, β, γ -decay of nuclei by their respective quantum mechanical theories, Conservation laws and various nuclear reactions.
- Know various nuclear radiation detectors and particle accelerators.
- Discuss the Elementary particles as the building blocks of matter and interacting fields. Describe Quark Hypothesis, Quark structures of Mesons and Baryons.

UNIT - 1

Nuclear structure and properties: size, radii, shape, charge radius, spin, parity, nuclear & atomic mass, binding energy, electric and magnetic moment of nuclei, isospin.

Nuclear forces and two body problems: Ground state of deuteron, Wave equation of deuteron & its solution, Excited states of deuteron, Normalization of the deuteron wave function, radius of deuteron, Low energy neutron-proton scattering, Scattering length, Spin dependence of n-p interaction, Charge independence and charge symmetry.

UNIT - 2

Nuclear Models: Liquid drop model, Bethe- Weizsacker formula, Applications of the Semi-empirical binding energy formula, Nuclear shell structure, Single particle states in nuclei, Applications of extreme single particle shell model, Collective model.

Radioactivity: Alpha particles and Geiger-Nuttall law, Beta particles & Fermi theory of allowed beta decay, Allowed & forbidden transitions, selections rules in beta decay, Gamma decay & Radiative transitions in nuclei, Nuclear isomerism & Internal conversion.

UNIT - 3

Nuclear reactions: Types of nuclear reactions, Conservation laws, Compound nucleus hypothesis, Direct reactions, Nuclear fission & its Bohr-Wheeler theory, Nuclear fusion & Thermonuclear reaction, Power & Nuclear reactors in India.

Nuclear radiation detectors: Proportional counter, Geiger-Muller counter, Scintillation detector, Semiconductor detectors, Cherenkov detector.

Particle accelerators: Linear accelerators, Van de Graaff, Cyclotron, Betatron, Ion beam accelerators, Accelerators in India.

UNIT - 4

Elementary Particles: Fundamental Interactions in nature, Classification of elementary particles, Conservation laws, Resonance particles, Symmetry Classification of Elementary particles, Quark Hypothesis, Quark structures of Mesons and Baryons, Quantum Chromodynamics, Charmed quark, Beauty & Truth, Unification of weak and Electromagnetic Interaction, Higgs boson.

Reference books:

1. Introductory Nuclear Physics, Kenneth S Krane, Wiley, New York ,1988.
2. Nuclear and Particle Physics: Brian Martin.
3. Atomic and Nuclear Physics: S.N. Ghoshal.
4. Introduction to Particle Physics: D. Griffiths.
5. Introduction to Nuclear Physics: F. A. Enge, Addison Wesley (1975)
6. Introductory Nuclear Physics: Burcham

Paper 13 (Core 9) Quantum Mechanics - II (MPH4T13)

Course Outcomes (COs):
On completion of the course students will be able to,

- Discuss the time independent perturbation theory and its application (Zeeman and Stark effect).
- Explain the time dependent perturbation theory and semi-classical theory of radiations and its applications.
- Describe the ground state of helium atom using WKB approximation.
- Analyse and apply the central field approximation for system of identical particles and system of non-interacting particles, Born-Oppenheimer approximation.
- Understand Klein- Gordon equation, Dirac's relativistic equation, Field quantization of the non-relativistic Schrodinger equation.

Unit - I
Time independent perturbation theory, first order perturbation theory applied to non-degenerate states, second order perturbation extension to degenerate state, Application of perturbation theory to the ground state energy, He atom (calculation given in Pauling and Wilson) Normal and anomalous Zeeman effect, First order Stark effect in the ground and first excited states of H atom and second order Stark effect of H atom, an-harmonic oscillator.
Unit - II
Time dependent perturbation theory, transition rate, Fermi Golden rule, constant perturbation harmonic in time, radiative transitions, absorption and induced emission, atomic radiation, dipole approximation, Einstein's atomic radiation, Einstein's A and B coefficients and their calculations. Approximation methods: W. K. B. method and its application to barrier penetration. Variational principle and its application to simple cases like ground state of He atom
Unit - III
System of identical particles, exchange and transposition operators, totally symmetric and antisymmetric wave function and their expressions for a system of non-interacting particles, statistics of systems of identical particles. Born-Oppenheimer approximation.
Scattering theory, scattering cross-section in laboratory and centre of mass system, scattering by a central potential, Partial wave method, phase shifts and their importance, scattering by a square well potential and a perfectly rigid sphere, resonance scattering.
Unit - IV
Relativistic wave equation, the Klein-Gordon equation and initial difficulties in interpreting its solutions, Dirac's relativistic equation, Dirac's matrices, explanation of the spin of the electron, equation for an electron in an electromagnetic field and explanation of the magnetic moment due to the electron spin, spin-orbit interaction, solution for hydrogen atom in Dirac's theory, negative energy states and their qualitative explanations.

References Books:

1. E. Merzbacher, Quantum Mechanics (Wiley and Sons-Toppon)
2. J. L. Powell and B. Crasemann, Quantum mechanics (B I Publications)
3. L. I. Schiff, Quantum Mechanics (McGraw-Hill)
4. Quantum Mechanics: Aruldhas
5. Pauling and Wilson, Introduction to Quantum Mechanics
6. A.K. Ghatak and Lokanathan, Quantum Mechanics (Macmillan, India)
7. Quantum Mechanics: 500 problems with Solutions: Aruldhas (PHI)

Paper 14 (Core 10) Solid State Physics (MPH4T14)

Course Outcomes (COs):
Upon completion of the course students will be able to,

- Understand the basics of free electron theory and band theory.
- Understand lattice vibrations of linear monoatomic and diatomic chains, dispersion relations, acoustic and optical phonons.
- Describe Dulong and Petit's law, Einstein and Debye models, T^3 law, etc theories of lattice specific heat.
- Explain electrical conductivity, Hall effect and magnetic properties of solids.
- Describe type I and II superconductors, elements of BCS theory, and elementary of high temperature superconductor and applications.

Unit - I

Free Electron Theory**:** Electrons moving in one and three dimensional potential wells, quantum state and degeneracy, density of states, electrical and thermal conductivity of metals, relaxation time and mean free path, the electrical resistivity of metals, thermonic emission. Seebeck effect, thermoelectric power.

Band Theory: Bloch theorem, the Kronig- Penney model, construction of Brillouin zones, extended and reduced zone schemes, effective mass of an electron, tight binding approximation. Fermi surface.

Unit - II

Lattice Dynamics: Energy of atomic motions, adiabatic principle, harmonic approximation, cyclic boundary condition. Lattice vibrations of linear monoatomic and diatomic chains. Dispersion relations, acoustic and optical phonons. Theories of lattice specific heat, Dulong and Petit's law, Einstein and Debye models, T3 law, Born procedure, anharmonicity and thermal expansion.

Unit - III

Semiconductors: Free carrier concentration in semiconductors, Fermi level and carrier concentration in semiconductors, effect of temperature on mobility, electrical conductivity of semiconductors, Hall effect in conductors and semiconductors.

Magnetic Properties: Quantum theory of paramagnetism, magnetism of iron group and rare earth ions, exchange interactions. Pauli paramagnetic susceptibility

Unit – IV

Superconductivity: Type I and II super conductors, Meissner effect, isotope effect, microwave and infrared properties. Elements of BCS theory, tunnelling Josephson effect. Ginzsburg-Landau theory and application to Josephson effect: d-c Josephson effect, a-c Josephson effect. Vortices and type I & type II superconductors, high temperature superconductor (elementary).

Reference books:

1. C. Kittle: Introduction to Solid State Physics (2nd and 4th Edition).
2. A. J. Dekker: Solid State Physics.
3. Kubo and Nagamiya : Solid State Physics.
4. Feynman Lectures: Vol. III.
5. Board and Huano : Dynamical Theory of Crystal Lattice.
6. N. W. Ashcroft and D. Mermin: Solid State Physics.

Paper 15 (Elective - 4A) Properties of Materials (MPH4T15A)

Course Outcomes (COs):
On completion of the course students will be able to,

- Understand the mechanical response and mechanical properties of materials.
- Explain the corrosion and degradation of materials and strategies of corrosion prevention.
- Get the knowledge of laws of diffusion, types of diffusion and methods of determining diffusion coefficients.
- Impart knowledge of Solid State Ionics.
- Describe silver ion conductors, cation conductors, oxygen ion conductors, halide ion conductors, proton conductors and electronic conductors with ionic transport.

Unit-I

Mechanical response of Materials: Elasticity, model of elastic response, inelasticity, viscoelasticity, stress –strain curves, concept of various mechanical properties such as hardness, yield strength, toughness, ductility, yield toughness, ductility, brittleness, stiffness, young modulus, shear modulus, shear strength, Frenkel model, Peierls -Nabarro relation, Plastic deformation

Unit-II

Corrosion and degradation of materials: Electrochemical considerations – Corrosion Rates- Prediction of corrosion rates- -Passivity- Forms of corrosion – Corrosion prevention- Oxidation- Corrosion of Ceramic Materials- Degradation of Polymers

Unit-III

Laws of diffusion. Solution of Fick's diffusion equation under simple boundary conditions. Types of diffusion. Diffusion and concentration gradient. Compositional dependence of diffusion. Diffusion in metals and alloys, Methods of determining diffusion coefficients. Diffusion in ionic solids. Diffusion and conductivity.

Unit-IV

Solid State Ionics: Types of Ionic Solids-Fast Ionics Solids-Point Defect Type-Sub Lattice type – Fast Ionic materials – alkali metal ion conductors - β aluminas- Silver ion conductors- Cation conductors- Oxygen ion conductors – Halide ion conductors – Proton conductors –Electronic conductors with ionic transport.

Reference Books:

1. Martin Eden Glicksman, Diffusion in Solids: Field Theory, Solid-State Principles, and Applications,Wiley-Interscience;1edition
2. A.R. West, Solid State Chemistry.
3. S. Chandra, Superionic Solids.
4. Principles of Electronic Ceramics, L.L.HenchandJ.K. West, (John Wiley & Sons, NewYork,1990).
5. Materials Science &Engineering–An Introduction, by W.D. CALLISTER

Paper 15 (Elective - 4 B) Applied Nanoscience and Nanotechnology (MPH4T15B)

Course Outcomes (COs): On completion of the course students will be able to,

- Understand accurate description of optical properties of material and basics of non-linear optics at nanoscale.
- Understand the basic magnetic parameters, the magneto-transport in nanoscale systems and gain the basic mechanisms for tuning the magnetic properties.
- Implicate the basic knowledge of Nano-CMOS to design the circuit and physical design for the single electron transistor.
- Know the meaning of composite materials and preparation techniques.
- Analyse the essential data on nanoscale materials dispersed in, or chemically bonded with metal/ceramic/polymer matrix.

Unit – I:

Nanophotonic: Fundamentals of photonics and photonic devices, Lasers, CFLs, LEDs, OLEDs, wallpaper lighting, Display devices, fabrication of photonic crystal structure (1D, 2D, 3D), optics in nano sized quantum wells and wires (periodic nanostructures), negative refractive index, microwave induced transport. Nano-scale photonic devices, couplers, waveguides. liquid crystals and their applications at the nanoscale.

Unit – II:

Nanomagnetic: Basics of Ferromagnetism, Nanostructure magnetism, effect of bulk nanostructuring of magnetic properties, Giant magneto resistance (GMR), Anisotropic magneto resistance (AMR) and Colossal magneto resistance (CMR), Magnetic multilayered thin films, superparamagnetism and ferromagnetism in semiconducting quantum dots, effect of grain size, ferrofluids, spintronics.

Unit – III:

Nanoelectronics: CMOS Scaling, Limits to Scaling, Nanoscale MOSFETs, System Integration, Interconnects; Nanowire Field Effect Transistors, FINFETs, Vertical MOSFETs, Nanosensors, Micro-/nano-electromechanical systems, Tunneling Devices, Single Electron Transistors.

Unit – IV:

Nanocomposites: Classification of nanocomposites, Metallic, ceramic and polymer nanocomposites, Tribology of polymeric nanocomposites, Optimizing nanofiller performance in polymers, Preparation techniques, Graphene/Fullerene/Carbon nanotube (CNT) polymer nanocomposites and their applications.

Reference books:

1. H.S.Nalwa; Hand book of Nanostructure materials and nanotechnology
2. C.P.Poole Jr., F.J.Owens; Introduction to Nanotechnology, John Wiley and sons
3. C. Furetta; Hand book of thermoluminescence; World Scientific Publ.
4. S.W.S. McKEEVER; Thermoluminescence in solids; Cambridge Univ. Press.
5. Alex Ryer; Light measurement hand book; Int. light Publ.
6. M.J.Weber; Inorganic Phosphors; The CRC Press.
7. T.J.Deming; Nanotechnology; Springer Verrlag
8. Gusev; Nanocrystalline Materials
9. C. Delerue, M.Lannoo; Nanostructures theory and Modelling
10. Fausto, Fiorillo ; Measurement and Characterization of Magnetic materials
11. Bhushan; Hand Book of Nanotechnology
12. Janos H., Fendler; Nanoparticles and Nanostructured Films
13. T.Pradip; Nano: The Essentials

Project/Dissertation (MRP4P02)

<u>Project Work Guidelines for the Students, Supervisors and Examiners</u>

Every student is required to carry out a project work in semester III & IV in lieu of Practical. The project can be of following types. (i) Experimental Project Work; (ii) Field Based Project Work; (iii) Review writing based Project Work.

Experimental Project Work OR Field Based Project Work:

Student can carry out Experimental / Field based Project Work on a related research topic of the subject /course. It must be an original work and must indicate some degree of experimental work / Field work. On the basis of this work, student must submit the Project Report (typed and properly bound) in two copies at least one month prior to commencement of the final Examination of Semester IV. The project report shall comprise of Introduction, Review of literature, Material and Methods, Results, Discussion, Summary, Conclusion and References along with the declaration by the candidate that the work is original and not submitted to any University or Organization for award of the degree and certificate by the supervisor and forwarded through Head / Course-coordinator.

Review writing based Project Work.

Student can carry out review writing based Project Work on a related topic of the subject / course. It must be a review of topic based on research publications. Student shall refer peer reviewed original research publications and based on findings, write a summary of the same. The pattern of review writing shall be based on reputed reviews published in a standard, peer reviewed journals. On the basis of this work, student must submit the Project Report (typed and properly bound) in two copies at least one month prior to commencement of the final Examination of Semester IV. The project report shall comprise of Abstract, Introduction, detailed review, Discussion, Summary, Conclusion and References along with the declaration by the candidate that the work is original and not submitted to any University or Organization for award of the degree and certificate by the supervisor and forwarded through Head / Course-coordinator.

The **supervisor** shall be able to guide not more than 11 (Eleven) students in the given examination. The supervisor shall declare in the project of every student which he / she is guiding stating that he / she has not guided more than 11 students in the given examination.

The supervisors for the Project Work shall be either (i) a person who is full time university PG recognized faculty member in the relevant subject or (ii) a person appointed in PG on contractual / contributory basis, having NET / SET and approved by the University in the relevant subject and having 3 years teaching experience as contractual / contributory at PG level, or (iii) University approved Ex-Faculty members in the relevant subject

The Project Work will carry total 100 marks and will be evaluated by both external and internal examiners. The examiners will evaluate the Experimental Project Work taking into account the coverage of subject matter, arrangement and presentation, references, etc.

For written Project work its Presentation: 40 Marks – Evaluated jointly by External & Internal
For Viva-Voce: 10 Marks – Evaluated by External examiner,
Internal Assessment: 50 Marks – Evaluated by Internal examiner.