

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

Semester I

S N	Course Category	Name of Course	Course Code	Teaching Scheme (hrs.)			Total (Hrs)	Total Credit	Examination Scheme						
				(Th)	TU	P			Theory				Practical		
									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						
				(Th)	TU	P			Theory				Practical		
									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

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 their 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 Theorem, 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 silicon 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, MOSFET, 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 (TTL and CMOS gates).

Unit III

Digital integrated circuits- NAND and NOR gates building block, X-OR gate, simple combinational Circuits -Half and full adder, Flip-Flops, Multivibrators (using transistor) and sweep generator (using transistors, UJT and SCR). shift registers, counters, A/D and D/A converters, 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 Schmitt trigger, Butterworth 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, magnetron and Gunn diode), Cavity resonators. Standing wave detector.

Reference Books:

1. A. Malvino and D. J. Bates: Electronic Principles (Mc Graw Hill Education, India)
2. Boylestad & Nashysky, "Electronic Devices & Circuits", PHI
3. Millman, J. Halkias, "integrated electronics", Tata McGraw Hill
4. J. J. Cathey Schaum'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 Kuppaswamy 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, Akiya Kozawa
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-Eastern Limited, 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, Himalaya Publishing House
4. Instrumental Methods of Analysis by H.H. Willard, L.L. Merritt, J.A. Dean, CBS Publishers
5. Characterization of Materials, John B. Wachtman & Zwi. H. Kalman, Pub. Butterworth-Heinemann (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 Foucault 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 Bistable multivibrator.
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-Riemann 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 He⁴

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 resolving power of spectrographs, Photographic and other methods of detection, resolving power of detectors. 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 Feby 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.