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

# 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<br>(Choose any one)<br>1. Materials Science<br>2. Basic Nanoscience & Nanotechnology | MPH3T11 | 4 | - | - | 4 | 4 | 3 | 80 | 20 | 40 | - | - | - |
| 5 | LAB | Practical -1<br>(Electives) | MPH3P05 | - | - | 4 | 4 | 2 | 2-6* | - | - | - | 50 | 50 | 50 |
| 11 | RP | Research Project/<br>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

| 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 | 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<br>(Choose any one)<br>1.Properties of Materials<br>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<br>B. Experimental Techniques in Physics | MPH1T03 |
| II | Elective 2 | A. Spectroscopy<br>B. X-Rays | MPH2T07 |
| III | Elective 3 | A. Materials Science<br>B. Basic Nanoscience & Nanotechnology | MPH3T11 |
| IV | Elective 4 | A. Properties of Materials<br>B. Applied Nanoscience & Nanotechnology | MPH4T15 |

***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

# 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.