Rayat Shikshan Sanstha's

# Yashavantrao Chavan Institute of Science, Satara (Autonomous)

**Syllabus for M.Sc. Part – I**

1. **Title:** Physics

2. **Year of Implementation:** The syllabus will be implemented from June, 2020 onwards.

3. **Preamble**:

This syllabus is framed to give advanced knowledge of Physics to postgraduate students at first year of two years of M.Sc. degree course.

The goal of the syllabus is to make the study of Physics popular, interesting and encouraging to the students for higher studies including research.

The new syllabus is based on a basic and applied approach with vigor and depth. At the same time precaution is taken to make the syllabus comparable to the syllabi of other universities and the needs of industries and research.

The syllabus is prepared after discussion at length with number of faculty members of the subject and experts from industries and research fields.

The units of the syllabus are well defined, taking into consideration the level and capacity of students.

4. **General Objectives of the Course:**

1. The students are expected to understand the fundamentals, principles, physical concepts and recent developments in the subject area.
2. The practical course is framed in relevance with the theory courses to improve the understanding of the various concepts in physics.
3. The student can critically and independently asses and evaluate research methods and results.
4. To develop the power of appreciations, the achievements in Physics and role in nature and society.
5. To enhance student sense of enthusiasm for Physics and to involve them in an intellectually stimulating experience of learning in a supportive environment.
6. The candidate has the ability to develop and renew scientific independently, via courses or through Ph. D. studies in Physics.
7. The candidate can understand the roll of Physics in society and has background to consider ethical problems.

**5. Duration:**Two year full time.

**6. Pattern: S**emester examination.

**7. Medium of Instruction:** English.

## Structure of Course: Final M.Sc. – I Semester – I

| Sr. No. | Course Title | Theory | | | | Practical | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paper Code | No. of lectures Per week | Total Hours Per week | Credits | Paper Title & Code | No. of lectures per week | Total Hours Per week | Credits |
| 1 | Mathematical Methods in Physics | MPT 101 | 4 | 4 | 4 | **LAB I:** MPP 105 | 12 | 12 | 4 |
| 2 | Classical Mechanics | MPT 102 | 4 | 4 | 4 | | | | |
| 3 | Quantum Mechanics-I | MPT 103 | 4 | 4 | 4 | **LAB II:** + Project MPP 106 | 12 | 12 | 4 |
| 4 | Atomic and Molecular Physics | MPT 104 | 4 | 4 | 4 | | | | |
| **Total Credits Theory** | | | | | **16** | **Total Credits Practical** | | | **08** |

## Structureof Course:M.Sc. – I Semester – II

| Sr. No. | Course Title | Theory | | | | Practical | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paper Code | No. of lectures per week | Total Hours Per week | Credits | Paper Title & Code | No. of lectures per week | Total Hours Per week | Credits |
| 1 | Quantum Mechanics II | MPT 201 | 4 | 4 | 4 | **LAB III** MPP 205 | 12 | 12 | 4 |
| 2 | Statistical Mechanics | MPT 202 | 4 | 4 | 4 | | | | |
| 3 | Solid State Physics-I (Physical Properties of Solids ) | MPT 203 | 4 | 4 | 4 | **LAB IV** + Project MPP 206 | 12 | 12 | 4 |
| 4 | Condensed Matter Physics | MPT 204 | 4 | 4 | 4 | | | | |
| **Total Credits Theory** | | | | | **16** | **Total Credits Practical** | | | **08** |

## Structureof Course:M.Sc.II Semester- III

| Sr. No. | Course Title | Theory | | | | Practical | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paper Code | No. of lectures Perweek | Total Hours Per week | Credits | Paper Title Code | No. of lectures Per week | Total Hours Perweek | Credits |
| **Compulsory Papers** | | | | | | | | | |
| 1 | Experimental Techniques | MPT 301 | 4 | 4 | 4 | **SSP LAB I** MPP 305 | 12 | 12 | 4 |
| 2 | Electro-dynamics | MPT 302 | 4 | 4 | 4 | | | | |
| 3 | Solid State Physics- II (Semiconductor Physics) | MPT 303 | 4 | 4 | 4 | **SSP LAB II+** Project MPP 306 | 12 | 12 | 4 |
| **Elective Paper** | | | | | | | | | |
| 4 | i) Nanoscience and Nanotechnology<br>ii) Optoelectronics and Photonics | MPT 304A<br>MPT 304B | 4 | 4 | 4 | | | | |
| **Total Credits Theory** | | | | | **16** | **Total Credits Practical** | | | **08** |

## Structureof Course:M.Sc.-IISemester-IV

| Sr. No. | Paper Title | Theory | | | | Practical | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paper Code | No. of lectures Per week | Total Hours Per week | Credits | Paper Title& Code | No. of lectures Per week | Total Hours Per week | Credits |
| **Compulsory Papers** | | | | | | | | | |
| 1 | Nuclear and Particle Physics | MPT 401 | 4 | 4 | 4 | **LAB III** MPP 405 | 12 | 12 | 4 |
| 2 | Solid State Physics -III (Thin Solid Films: Deposition and Properties) | MPT 402 | 4 | 4 | 4 | | | | |
| 3 | Solid State Physics- IV (Energy Conversion and Storage Devices) | MPT 403 | 4 | 4 | 4 | **LAB IV** +Project MPP 406 | | | |
| **Elective Paper** | | | | | | | | | |
| 4 | i) Electronic Devices<br>ii) Laser Physics Special | MPT 404A<br>MPT 404B | 4 | 4 | 4 | | 12 | 12 | 4 |
| **Total Credits Theory** | | | | | **16** | **Total Credits Practical** | | | **08** |

**MPT: M:** M.Sc.**, P:** Physics**, T:** Theory **MPP: M:** M.Sc., **P:** Physics, **P:** Practical

## M.Sc. - I
## Semester-I
## Structure of Course: Final M.Sc. – I Semester – I

| Sr. No. | Course Title | Theory | | | | Practical | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paper Code | No. of lectures Per week | Total Hours Per week | Credits | Paper Title & Code | No. of lectures per week | Total Hours Per week | Credits |
| 1 | Mathematical Methods in Physics | MPT 101 | 4 | 4 | 4 | **LAB I:** MPP 105 | 12 | 12 | 4 |
| 2 | Classical Mechanics | MPT 102 | 4 | 4 | 4 | | | | |
| 3 | Quantum Mechanics-I | MPT 103 | 4 | 4 | 4 | **LAB II:** + Project MPP 106 | 12 | 12 | 4 |
| 4 | Atomic and Molecular Physics | MPT 104 | 4 | 4 | 4 | | | | |
| **Total Credits Theory** | | | | | **16** | **Total Credits Practical** | | | **08** |

## MPT 101: Paper-I Mathematical Methods in Physics (Credits: 4)

**Learning Objectives:**

**Students will able to:**

1. understand the laws of Matrices, eigen values and eigen vectors.
2. study complex algebra.
3. study singularities, Legendre, Hermite, Laguerre, Bessel's function and their applications.
4. study properties of Fourier Series and applications of Fourier Series.

**Unit I- Matrix Algebra and Eigen value Problems ( 15 )**

Matrix multiplication – Inner product, direct product, Diagonal matrices, trace, matrix Inversion, Gauss-Jordon Inversion theorem, problems, Eigenvalues and Eigenvectors, Properties of Eigenvalues and Eigenvectors, CaylyHamilton Theorem and applications, similar matrices and diagonalizable Matrices, Eigenvalues of some Special Complex Matrices, Quadratics forms, problems.

**Unit II- Complex Variables: ( 15 )**

Definition of Complex Numbers and variables, Equality of Complex variables, 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, problems

**Unit III: Calculus of Residues & Special function: (15)**

Singularities- Poles, Branch Points, Calculus of Residues-Residues Theorem, Taylor Series and Laurent's series, Special function (only definitions)- Legendre Hermite, Laguerre function, Generating function, Recurrence relations and Their differential equations, Orthogonality properties.

**Unit IV- Fourier- Series, Integral, and Transform: ( 15 )**

Definition, Evaluation of Coefficients of Fourier Series (Cosine and Sine Series), Dirichelet's Theorem, Graphical representation of a square wave function, Extension of interval, Complex form of Fourier Series, Properties of Fourier Series (Conversions, Integration, Differentiation, Parseval's Theorem). Fourier Integral- exponential form, Applications of Fourier Series analysis in Physics (Square wave, Full wave rectifier, Expansion of Raman Zeta function), Fourier transform, Inversion theorem, exponential transform Example: Full wave train, Uncertainty principle.

**Text Books:**

1. Arfken And Weber, Mathematical Methods For Physicists 6th Edition, Academic Press, 2005
2. Iyengar S R K, Jain R K , Mathematical Methods, Narosa, 2006
3. Rajput B S, Mathematical Physics, Pragati Prakashan (Meerat) 1999

**Reference Book:**

1. Riley K F, Hobson M P and Bence S J, Mathematical Methods for Physics and Engineering, Cup, 1997
2. Introduction to mathematical physics, Balsubramanyam
3. Mathematical Methods of physical science, M. L. Bose

**Learning Outcomes :**

**Unit – I** :

1. Student should able to define Inner product, direct product, Diagonal matrices, trace, matrix Inversion
2. Student should able to understand Gauss-Jordon Inversion theorem.
3. Students should able to define Eigenvalues and Eigenvectors
4. Student should able to understand Theorem and applications of matrices.

**Unit – II** :

1. Understanding of Complex Algebra, Conjugate Complex Numbers and their sum ,Difference, Product and quotient.
2. Student should able to define Complex Numbers and variables, Equality of Complex variables
3. Student should able to understand Cauchy Theorem.

**Unit – III** :

1. Understanding of Calculus of Residues-Residues Theorem.
2. Student should able to understand Pole Expansion of Meromorphic Functions, Product expansion of entire Functions, problems.
3. Student should able to define Bessel’s function of first kind.

**Unit – IV** :

1. Student should able to understand Dirichelet’s Theorem.
2. Understanding of Fourier Series and its complex form, integral form and exponential form.
3. Student should able to understand Fourier transform, Inversion theorem.

*******

**MPT 102: Paper-II Classical Mechanics (Credits: 4)**

**Learning Objectives:**

**Students will able to:**

1. understand the laws of rotational motion, two body central force and Rutherford scattering.
2. study Lagrangian equation of motion, Jocobi integral, energy conservation and concept of symmetry.
3. study Lagrangian and Hamiltonian equations and applications.

4. study Canonical Transformation and Poisson Brackets.

**Unit1:Rotatioanl motion and central force problem (15)**

Inertial forces in rotating frames, Larmour precision, electromagnetic analogy of inertial forces, effect of coriolis force, Focoult's pendulum.

Two body central force ,equation of motion and first integral, Kepler's problem: Inverse-square law of force (It is essential to mention it here), central analysis of orbit, Rutherford scattering: Scattering formulae, Different scattering cross section

**Unit 2:Lagrangian formulation (15)**

Introduction, generalized coordinates Lagrangian equation of motion, Applications of Lagrange's Equation, properties of kinetic energy function, theorem on total energy, generalized momenta, cyclic coordinates, integral of motion, Jocobi integral and energy conservation , concept of symmetry, invariance under Galilean transformation, velocity dependent potential.

**Unit 3: Hamilton's formulation and Variational Principle (15)**

Hamilton's function and Hamilton's equation of motion, configuration space, Lagrangian and Hamiltonian of relativistic particles and light rays, Variational Principle, Euler's equation, applications of Variational Principle,

**Unit 4: Canonical Transformation and Poisson Brackets (15)**

Generating function, condition for conical transformation and problems.

Definition of Poisson Brackets, Identities, Poisson theorem, Jacobi-Poisson Brackets, Jacobi Identity, Invariance of Poisson Brackets under conical transformation.

**Reference Books :**

1.Classical Mechanics– H Goldstein 2$^{ND}$ Edition (Addison Wesley 1980)

2.Classical Mechanics –N C Rana and P S Joag 2013 (Tata McGraw Hill 1991)

3.Classical Mechanics– R G Takwale and P S Puranik (Tata McGraw Hill 1991)

4.Classical Mechanics– J.C Upadhyaya, Himalaya Publishing House.

**Learning Outcomes :**

**Unit – I** :

1. Student should able to define Inertial forces, Larmour precision, carioles for forces
2. Student should able to understand Focoult's pendulum, two body central force.
3. Students should able to understand Kepler's laws
4. Student should able to understand Rutherford scattering: Scattering formulae, Different scattering Cross-section.

**Unit – II** :

1. Understanding of inertial Lagrangian equation of motion.

2. Student should able to understand generalized momenta, cyclic coordinates
3. Student should able to understand Jocobi integral and energy conservation , concept of symmetry, invariance under Galilean transformation.

**Unit – III** :

1. Student should able to understand Hamilton's function and Hamilton's equation of motion,
2. Understanding of configuration space, phase space and state space ,
3. Student should able to understand Variational Principle, Euler's equation.
4. Student should able to understand Brachistrochrone problem.

**Unit – IV** :

1. Student should able to define Generating function.
2. Student should able to define Poisson Brackets, Identities, Poisson theorem, Jacobi- Poisson Brackets, Jacobi Identity.
3. Student should able to understand concept Invariance of Poisson Brackets.

*******

**MPT 103: Paper –III Quantum Mechanics – I (Credits: 4)**

**Learning Objectives:**

**Students will able to:**

1. understand ket and bra spaces, inner products, operators and uncertainty relations.
2. study Schrödinger wave equation and commutation relations.
3. study Eigen values and Eigen functions of $L^2$ and $L_z$ operators, Ladder operators , Paulli theory of spins.
4. understand perturbation theory, Eigen values and Eigen functions.

**Unit I: Fundamental Concepts and Formalism** **(15)**

Why Q.M? Revision; Inadequacy of classical mechanics; sequential Stern Gerlach experiment, analogy with polarization of light, ket and bra spaces and inner products, operators, the associative axiom, base kets and matrix representations, measurements, observables and the uncertainty relations.

**Unit II: Quantum Dynamics** **(15)**

Time evolution operator and Schrödinger equation, the Schrödinger, Heisenberg, Interaction picture and comparison of time evolution in all pictures, simple harmonic oscillator, commutation relations (problems). Schrödinger wave equation - one dimensional problems, well and barriers, General formalism of wave mechanics

**Unit III: Angular Momentum (15)**

Eigen values and Eigen functions of $L^2$ and $L_z$ operators, Ladder operators $L_+$ and $L_-$ , Paulli Theory of spins (Paulli's Matrices ), angular momentum as a generator of infinitesimal rotations, Matrix representation of Jin|jm> basis. Addition of angular momenta, Computation of Clebsch-Gordon Coefficients in simple cases ($J_1= \frac{1}{2}$; $J_2= \frac{1}{4}$ )

**Unit IV: Time Independent Perturbation Theory (15)**

Introduction of perturbation theory, Eigen value of energy and Eigen function in the first order approximation in case of a system with non degenerate & degenerate energy levels. First order Stark Effect (Ground state and First Excited state of H atom)

**Reference Books:**


1. Modern Quantum Mechanics, 30th Edition by J.J. Sakurai
2. Introduction to Quantum Mechanics by A .C. Philips Wiley publications
3. Quantum Mechanics -Theory and Applications by Ghatak & Lokhanthan
4. Introduction to Quantum Mechanics by David J Griffith
5. Quantum Mechanics concept and application by N Zettili (Taylor and Francis)
6. Introduction to Quantum mechanics by Venkatesan and Mathews TMH
7. Quantum Mechanics by L. I Schiff, (McGraw-Hill)


**Learning outcomes:**

**Unit – I**:

1. Student should able to define and understand ket and bra spaces and inner products, operators
2. Student should able to understand kets and matrix representations.
3. Students should able to understand wave function in position and momentum space.

**Unit – II** :

1. Understanding of Time evolution and Schrödinger equation.
2. Student should able to understand Schrödinger wave equation - one dimensional problems, well and barriers.
3. Student should able to understand Uncertainty relation of x and p states.

**Unit – III** :

1. Student should able to define and understand Eigen values and Eigen functions of $L^2$ and $L_z$ operators.
2. Understanding of Paulli Theory of spins.
3. Student should able to understand Computation of Clebsch-Gordon Coefficients in simple cases ( $J_1$=1/2; $J_2$=1/4 ).

4. Student should able to define Central forces.

**Unit – IV**:

1. Understanding of perturbation theory.
2. Student should able to understand Eigen value of energy and Eigen function in the first order approximation.

*******

**MPT 104: Paper-IV Atomic and Molecular Physics (Credits: 4)**

**Learning Objectives:**

**Students will able to:**

1. understand vector atom model and couplings.
2. study Zeeman Effect, Paschen-Back effect and Stark effect.
3. study classification of molecules, electronic and rotational spectra of diatomic molecules.
4. understand the vibrating diatomic molecule and harmonic oscillators.

**Unit I: Vector atom model for two valence electron system (15)**

Types of coupling- ll, ss, LS or Russel Sounder's coupling, Pauli Exclusion principle and terms arising from different states, coupling schemes for two valence electron system, Γ-factors for LS coupling, Lande interval rule, jj-coupling and Γ-factors for jj coupling, Selection rules for LS and jj coupling and intensity relations.

**Unit II: Zeeman Effect, Paschen-Back effect and Stark effect (15)**

The magnetic moment of the atom, Zeeman effect for two-electrons, Intensity rules for Zeeman effect, Paschen-Back effect for two-electrons, Stark effect of hydrogen, weak field stark effect in hydrogen, strong field Stark effect in hydrogen, origin of hyperfine structure of Hydrogen atom, relativistic corrections for energy levels of Hydrogen atom, Principles of Resonance spectroscopy (ESR and NMR)

**Unit III: Rotational Spectroscopy (15)**

Classification of molecules: Linear, symmetric tops, spherical tops, asymmetric tops

Rotational spectra: the rigid diatomic molecule, spectrum and selection rules of a rigid rotator, non-rigid rotator, energy spectrum and selection rules of a non-rigid rotator**,** techniques and instrumentations of microwave spectroscopy, chemical analysis by microwave spectroscopy.

**Unit IV: Vibrational and Electronic spectroscopy (15)**

The vibrating diatomic molecule: the energy spectrum and selection rules of diatomic molecule, the simple harmonic oscillator, energy spectrum and selection rules of simple harmonic oscillator, Morse function, the anharmonic oscillator, energy spectrum and selection rules of anharmonic oscillator, the diatomic vibrating-rotator, energy spectrum and selection rules of the diatomic vibrating-rotator, techniques and instrumentation of infra-red spectroscopy, chemical analysis by infra-red spectroscopy,

Born-Oppenheimer approximation, Electronic spectra of diatomic molecules, Franck Condon Principle, electronic structure of diatomic molecule, chemical analysis by electronic spectroscopy.

Raman spectroscopy.

**Reference books:**

1) Introduction to Atomic Spectra – H.E. White, McGraw Hill (1934).

2) Fundamentals of Molecular Spectroscopy, Edn. 3 – C.N. Banwell, Elaine M Maccash Tata McGraw Hill (1983).

3) Spectra of Diatomic Molecules, Vol. I – G. Herzberg, N.J.D. van Nostrand (1950).

4) Introduction to Molecular Spectroscopy – G.M. Barrow, McGraw Hill (1962).

5) Molecular Spectroscopy – J.M. Brown, Oxford University Press (1998).

6) Molecular Structure and spectroscopy-G. Aruldas EEE PHI(2010)

7) Atomic & Molecular Spectroscopy , Jaychand

**Learning outcomes :**

**Unit – I** :

1. Student should able to understand ll, ss, jj, LS or Russiel Sounder's coupling
2. Student should able to understand coupling schemes for two valence electron system.
3. Students should able to understand Selection rules for LS and jj coupling and intensity relations

**Unit – II**:

1. Understanding of Zeeman effect for two-electrons, Paschen-Back effect for two-electrons,
2. Student should able to understand Stark effect of hydrogen.
3. Student should able to understand origin of hyperfine structure.
4. Understanding of concept principles of Resonance spectroscopy (ESR and NMR)

**Unit – III**:

1. Student should able to understand electronic spectra and rotational of diatomic molecules chemical
2. Understanding of Classification of molecules Linear, symmetric tops, spherical tops, asymmetric tops
3. Student should able to understand instrumentations of microwave spectroscopy.

**Unit – IV** :

1. Student should able to understand vibrating diatomic molecule the simple harmonic oscillator,
2. Understanding of techniques and instrumentation of infra-red spectroscopy.
3. Student should able to understand chemical analysis by infra-red spectroscopy.

*******

## MPP 105: LAB I (Credits: 4)

**Learning Objectives:**

**Students will able to:**

1. Measure counts of radioactive radiation
2. Measure charge of an electron
3. Understanding of photo catalytic dye degradation
4. Measure intensity by Lux meter
5. Measure Hall coefficient
6. Understand concept of LVDT by measuring emf
7. Understand concept of neutron diffraction
8. Understand concept of FP Etalon
9. Understanding of XRD pattern
10. Measure lattice constant

**Experiments:**

1. Counting statistics G M Tube
2. ‘e’ by Millikan’s oil drop method
3. Photo catalytic dye degradation of given sample
4. Intensity measurement by Lux meter
5. Hall Effect
6. L.V.D.T.
7. Neutron Diffraction
8. Fabry-Parrot etalon
9. Crystal Structure (F.C.C. & B.C.C.)
10. Lattice Dynamics

**Learning outcomes:**

1. Student should able to measure counts of radioactive radiation
2. Student should able to measure charge of an electron
3. Student should able to understanding of photo catalytic dye degradation of sample.
4. Student should able to measure intensity by Lux meter
5. Student should able to measure Hall coefficient
6. Student should able to understand concept of LVDT by measuring emf
7. Student should able to understand concept of neutron diffraction

8. Student should able to understand concept of FP Etalon
9. Student should able to understanding of XRD pattern
10. Student should able to measure lattice constant

**MPP 106: LAB II +Project (Credits: 4)**

**Learning Objectives:**

**Students will able to:**

1. Understand concept of temperature transducer
2. Determine heat capacity
3. Understand concept of stair case ramp generator
4. Determine frequency response of negative feedback amplifier
5. Understand concept of astable multivibrator
6. Understand concept of monotable multivibrator
7. Determine Stefan's constant
8. Understand B-H curve
9. Determine thermal conductivity
10. Determine Planck's constant

**Experiments:**

1. Temperature Transducer
2. Heat Capacity
3. Staircase Ramp Generator
4. Negative Feedback Amplifier
5. Astable Multivibrators
6. Monostable Multivibrators
7. Stefan's Constant
8. B-H Curve
9. Thermal & electrical conductivity of copper
10. Planks Constant

**Learning outcomes:**

1. Student should able to understand concept of temperature transducer
2. Student should able to determine heat capacity
3. Student should able to understand concept of stair case ramp generator
4. Student should able to determine frequency response of negative feedback amplifier
5. Student should able to understand concept of Astable multivibrator
6. Student should able to understand concept of monotable multivibrator

7. Student should able to determine Stefan's constant

8. Student should able to understand B-H curve

9. Student should able to determine thermal conductivity

10. Student should able to determine Planck's constant

**********

**M.Sc. – I Semester II**

**Structure of Course:**

<table>
<tr><th rowspan="2">Sr. No.</th><th rowspan="2">Course Title</th><th colspan="4">Theory</th><th colspan="4">Practical</th></tr>
<tr><th>Paper Code</th><th>No. of lectures per week</th><th>Total Hours Per week</th><th>Credits</th><th>Paper Title & Code</th><th>No. of lectures per week</th><th>Total Hours Per week</th><th>Credits</th></tr>
<tr><td>1</td><td>Quantum Mechanics II</td><td>MPT 201</td><td>4</td><td>4</td><td>4</td><td rowspan="2">LAB III MPP 205</td><td rowspan="2">12</td><td rowspan="2">12</td><td rowspan="2">4</td></tr>
<tr><td>2</td><td>Statistical Mechanics</td><td>MPT 202</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td>3</td><td>Solid State Physics-I (Physical Properties of Solids )</td><td>MPT 203</td><td>4</td><td>4</td><td>4</td><td rowspan="2">LAB IV + Project MPP 206</td><td rowspan="2">12</td><td rowspan="2">12</td><td rowspan="2">4</td></tr>
<tr><td>4</td><td>Condensed Matter Physics</td><td>MPT 204</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td colspan="5">Total Credits Theory</td><td>16</td><td colspan="3">Total Credits Practical</td><td>08</td></tr>
</table>

**MPT 201: Paper-V Quantum Mechanics-II (Credits: 4)**

**Learning Objectives:**

**Students will able to:**

1. understand Time-dependent perturbation theory and degeneracy.
2. study basic principle of variation method, application to their ground state of Hydrogen atom, first excited state of harmonic oscillator, WKB method and its applications
3. Study scattering theory.
4. understand Semi classical theory of radiation and Selection rules.

**Unit I: Time dependent Perturbation (15)**

Time-dependent Perturbation Theory, Two State Problem, Transition probability for constant and harmonic perturbations, Fermi's Golden rule.

**Unit II: Approximation methods (15)**

Variational method: Basic principle, Application to their ground state of Hydrogen atom and first excited state of harmonic oscillator, WKB method and its applications.

**Unit III: Scattering Theory** **(15)**

Laboratory and centre of mass frames, scattering amplitude, differential scattering cross section and total scattering cross section : scattering by spherically symmetric potentials; Method of partial waves; Phase shift; Ramsauer-Townsend effect; scattering by a perfectly rigid sphere and by square well potential. The Born approximation, applications and validity of the Born approximation.

**Unit IV: Theory of Radiation** **(15)**

Semi classical theory of radiation; Transition probability for absorption and induced emission; Electric dipole and forbidden transitions, Selection rules. (Zettili pp. 586-596)

**Text and Reference Books:**

1. Modern Quantum Mechanics, 30$^{th}$ Edition by J.J. Sakurai
2. Introduction to Quantum Mechanics by A.C.Philips Wiley publications
3. Quantum Mechanics –Theory and Applications by Ghatak Lokhanthan
4. Introduction to Quantum Mechanics by David J Griffith
5. Quantum Mechanics concept and application by N Zettili, 2$^{nd}$ Edition (Taylor and Francis)
6. Introduction to Quantum mechanics by Venkatesan and Mathews TMH
7. Quantum Mechanics by L. I Schiff, (McGraw-Hill)

**Learning Outcomes:**

**Unit – I** :

1. Student should able to understand Time-dependent perturbation theory.
2. Student should able to understand Non degenerate case and applications
3. Students should able to understand Stark effect, Fermi's Golden rule.

**Unit – II** :

1. Understanding of Variational method.
2. Student should able to understand problem of Hydrogen atom.
3. Student should able to understand WKB method and its applications.

**Unit – III** :

1. Student should able to understand the Lippman-Schwinger Equation, Born Approximation,
2. Understanding of Optical Theorem.
3. Student should able to understand Low energy scattering and bound state, Resonance scattering, Scattering by hard sphere, Coulomb scattering.

**Unit – IV** :

1. Student should able to understand semi classical theory of radiation
2. Understanding of transition probability for absorption and induced emission;
3. Student should able to understand electric dipole and forbidden transitions, Selection rules.

*********

**MPT 202: Paper –VI Statistical Mechanics (Credits: 4)**

**Learning Objectives:**

**Students will able to:**

1. understand specification of state of system, postulate of equal priori probability. Thermodynamic laws and its applications.
2. study ensemble and its application to thermodynamic system.
3. Study MB, BE and FD distributions and free electron theory of metals.
4. understand first and second order phase transitions.

**Unit I: Introduction of Statistical Mechanics and thermodynamics (15)**

Specification of state of system, Macroscopic and microscopic states, phase space, μ space, Γ space, constraints on a system,(These points required needed to explain state of system) postulate of equal apriori probability. Fluctuations of physical quantities, Statistical Equilibrium, problems. (Problems are required to solve no. of Macroscopic and microscopic states in given system)

Thermodynamics -Thermodynamic Laws and its applications, Thermodynamic Functions–Entropy ,Internal energy, Helmholtz free energy, Gibbs free energy,(These are the Thermodynamic Functions & it is necessary to understand the concept ) Enthalpy, Connection between statistics and thermodynamics – Entropy in terms of microstates, change in entropy with volume and temperature.

**Unit II: Statistical Ensembles Theory (15)**

Micro canonical Ensemble– Micro canonical distribution, Entropy and specific heat of a perfect gas, Entropy and probability distribution.

Canonical Ensemble– Canonical Distribution, partition function, Calculation of free energy of an ideal gas, Thermodynamic Functions, Energy fluctuations, Applications of Canonical Ensemble.

Grand Canonical Ensemble– Grand Canonical distribution, Thermodynamic Functions, Number and Energy fluctuations.

**Unit III: Formulation of Quantum Statistics (15)**

Distinction between MB, BE and FD distributions, Quantum distribution functions – Boson and Fermion gas and their Boltzmann limit, Partition function. Ideal Bose gas, Bose Einstein Condensation, Photon gas, Liquid He4: Second Sound. Ideal Fermi gas: Weakly and strongly degenerate, (It is covered in solid state physics paper)

**Unit IV: Phase Transitions and Critical Phenomenon (15)**

Phase Transitions, Conditions for phase equilibrium, First order Phase Transition: Clausius - Clayperon equation, Second order phase transition, Ehrenfest equation (It is condition for Second order phasetransition), The critical indices.

**Text and Reference books:**

1. Statistical Mechanics Theory and Applications, S K Sinha, Tata McGraw-Hill, (1990).
2. Introduction to Statistical mechanics by Saxena and Gupta
3. Introduction to Statistical mechanics, B B Laud, Macmillan, N Delhi, (1981).
4. Statistical Mechanics by R K Pathria, Pergamon press (1972).
5. Fundamentals of Statistical and thermal Physics 1985 F Reif, McGraw-Hill (1965).
6. Statistical Physics, L D Landau and E M Lifshitz, Pergamon press (1958).
7. Statistical Mechanics by Kerson Huang.

**Learning Outcomes :**

**Unit – I** :

1. Student should able to define specification of state of system, Macroscopic and microscopic states, phase space.
2. Student should able to understand Fluctuations of physical quantities, Statistical Equilibrium.
3. Students should able to understand Thermodynamic Laws and its applications.
4. Student should able to define Entropy, Free energy, Internal Energy, Enthalpy.

**Unit – II**:

1. Understanding of distinction Micro canonical, Ensemble Canonical Ensemble and Grand Canonical
2. Student should able to understand Micro canonical distribution, Canonical Distribution and its applications
3. Student should able to understand Thermodynamic Functions, Number and Energy fluctuations

**Unit – III**:

1. Student should able to understand Distinction between MB, BE and FD distributions, Quantum,
2. Understanding of Boson and Fermion gas, Photon gas
3. Student should able to understand Bose Einstein Condensation

**Unit – IV**:

1. Student should able to understanding Phase Transitions, Conditions for phase equilibrium, First order Phase Transition, Second order phase transition.
2. Understanding of Clausius - Clayperon equation.
3. Student should able to understand the critical indices.

*******

## MPT203: Paper-VII Physical Properties of Solid (Credits:4)

**Learning Objectives:**

**Students will able to:**

1. Understand the Drude model and DC electrical conductivity.
2. Study Band theory of solid.
3. Understand Electronic levels in periodic potential.
4. Study Transport Properties of Metals likeSommerfeld theory of electrical conductivity, The mean free path in metals, Thermal scattering and thermal conductivity of metals.
5. Study magnetic properties of materials
6. Understand various theories of paramagnetism.

**Unit 1 : Theory of metals ` (15)**

Free electron gas model, basic assumptions ofDrude Model, Collision or relaxation times, Failures of the free electron model, Sommerfeld theory of metals,Free electron gas in one-dimensional box and three-dimensional box,Filling up of energy levels, density of electron states, density of available electron states and density of filled electron states, parameters of free electron gas at absolute zero: fermi energy, average kinetic energy of electron, average velocity of electron, effect of temperature on the parameters of free electron gas: fermi energy, average energy.

**Unit 2: Static and Transport Properties of Metals (15)**

Static properties: Electronic specific heat, Pauli spin paramagnetism, thermionic emission, the Schottky effect, field emission, the photoelectric effect.

Transport properties: the Boltzmann transport equation, electrical conductivity: definition and experimental features, Drude-Lorentz theory of electrical conductivity, Sommerfeld theory of electrical conductivity, Drift velocity, mean free path and relaxation time, electrical conductivity at low temperature, Matthiessen’s rule, Electronic Thermal conductivity, Wiedemann-Franz law, Hall effect.

**Unit 3: Lattice vibrations and thermal properties (15)**

Lattice vibration:- Phonon, elastic vibrations of one-dimensional homogenous line, Vibrations of monatomic lattices:derivation of dispersion relation, first Brillouin zone, group velocity, phase velocity, long wavelength limit, short wavelength limit, maximum frequency limit, many wavelengths correspond to single frequency, Vibrations of diatomic lattices:derivation of dispersion relation, optical and acoustic branch, same mass limit, infinite heavy mass limit, zero light mass limit, sublattice vibrations at first brillouin zone boundary, Quantization of lattice vibrations, Phonon momentum**.**

Thermal properties:- Lattice specific heat: classical theory (Dulong Petit law), Einstein theory (Quantum theory), Debye theory ($T^3$ law), Lattice thermal conductivity, phonon-phonon scattering-umklapp process, geometric scattering, Anharmonicity and Thermal expansion**.**

**Unit 4: Magnetic Properties of Materials (15)**

Introduction, Magnetic permeability, Magnetisation, Electric current in atoms-bohr magnetron, Electron spin and magnetic moment due to nuclear spin. Diamagnetism**,**Paramagnetism, Langevin's with experiment classical theory of paramagnetism, Weiss theory of paramagnetism, quantum theory of paramagnetism, Comparion of theory with experimental results. Ferromagnetism, Spontaneous Magnetisation in ferromagnetic materials, quantum theory of ferromagnetism. Magnetic resonance, Nuclear magnetic resonance (NMR), The resonance condition**,The structure of ferrite, The saturation magnetization,Elements of Neels theory.**

**Reference Books:**

1. Solid State Physics by N W Ashcroft and N D Mermin, HRW, International editions (1996) (Units 1 and 2)

2. Introduction to Solid State Physics by C Kittle (8th edition) John Willey Publication (1979) (Units 3 and 4)

3. Solid State Physics by A J Dekker (1986) Macmillan India Ltd

4. Solid State Physics by S O Pillai (7$^{th}$edition) New Age Iternational (P) Ltd. Publishers

5. Fundametals of Solid State Physics by B.S.Saxena,P.N.Saxena,R.C.Gupta and J. N. Mandal, Pragatiprakashan Meerut

**Learning Outcomes :**

**Unit – I** :

1. Student will able to understand Drude Theory of metals andBasic assumptions of Model, Collision or relaxation times, DC electrical conductivity

2. Students should able to understand ground state properties of electron gas.

3.Student will able to understand Band theory of solid.

4.Student will able to understand electronic levels and various method for calculation of electronic levels

4. Student will able to explain independent electron approximation, general features of valence band wave functions

**Unit – II** :

1. Understanding of features of the electrical conductivity of metals

2. Student will able to define steady state, Drift velocity and relaxation time

3. Student will able to understandSommerfeld theory of electrical conductivity, The mean free path in metals, Thermal scattering
4. Student will able to understand Dielectric properties of insulators. Macroscopic electrostatic Maxwell equations, Theory of Local Field, Theory of polarizability, Clausius- Mossottirelati

**Unit – III** :

1. Understanding of Vibrations of monatomic lattices: first Brillouin zone
2. Student will able to define group velocity, Long wavelength limt, Lattice with two atoms per primitive cell.
3. Student will able to understandQuantization of lattice vibrations, Phonon momentum
4. Student will able to understandTransverse optical modes in a plasma, Longitudinal Plasma oscillations, Plasmons,

**Unit – IV** :

1. Student willd able to understand Magnetic permeability, Magnetisation
2. Understanding of Paramagnetism and theories of paramagnetism
3. Student will able to understand Ferromagnetism, Spontaneous Magnetisation in ferromagnetic materials
4. Student will d able to understandThe structure of ferrite, The saturation magnetization, Elements of neels theory
5. Student will able to understand Meagnetic resonance and NMR

**********

**MPT 204: Paper-VIII Condensed matter Physics – I (Credits: 4)**

**Learning Objectives:**

**Students will able to:**

1. study crystal growth and imperfections in crystals.
2. study dielctricity, ferroelectricity and its consequences.
3. study ferromagnetism and Anti-ferromagnetism its applications.
4. understand semiconducting and Superconducting Properties of materials.

**Unit I: Crystal growth and Imperfections in crystals (15)**

Crystal growth:- Nucleation and growth- Homogeneous and heterogeneous nucleation- classification of crystal growth techniques - melt growth, Bridgman, Czochralski techniques.

Imperfections : Classification of imperfections- point defects - schottky and freckle defects- Expressions for equilibrium defect concentrations o Colour centers- Production of colour centresline defects- Dislocations- Edge and Screw dislocations- Burger Vector- Estimation of dislocation densities- Mechanism of creep- (Wahab pp. 150-190)

**Unit II: Dielectrics and Ferroelectrics (15)**

Dielectrics: Introduction, Dipole moment, various types of polarization, electronic, ionic and orientation polarization, Langevin's theory, Lorentz field, Local electric effect and its expression Clausius- Mosotti equation and Lorentz-Lorentz relation (Related to C-M relation), measurement of dielectric constant, Applications of dielectrics.

Ferroelectrics :Piezo, pyro and ferroelectric crystals, Spontaneous polarization, classification and properties of ferroelectrics, ferroelectric domains- oxygen ion displacement theory Application of ferroelectrics.

**Unit III: Ferromagnetism and Anti-ferromagnetism (15)**

Ferromagnetism: Introduction, Weiss molecular field theory-Temperature dependence of spontaneous magnetization, Heisenberg model, Hysteresis curve (property of Ferromagnetic materials), Exchange interaction, ferromagnetic domains- Magnetic bubbles, Bloch wall, Thickness and energy, ferromagnetic spin waves, Magnons- Dispersion relations.

Anti-ferromagnetism: Introduction, Two sub lattice model of anti-ferromagnetism, ferrimagnetism, ferrites, structure, Applications, Multi ferroics.

**Unit IV: Semiconducting and Superconducting Properties. (15)**

Semiconductors: Kronig Penny Model (revision and significance), Nearly free electron approximation, tight binding approximation, Derivation of width of band in SC, BCC & FCC structure, intrinsic semiconductor: band model, calculation of electron & hole concentration, electrical conductivity, extrinsic semiconductor: impurity states and band model,calculation of electron & hole concentration, electrical conductivity.

Superconductors: Critical temperature, Meissner effect, type-I, type-II superconductors, BCS Theory of superconductivity, flux quantization, Josephson Effects: ac and dc (Types of Josephson Effects), SQUID, high- Tc super conductivity.

**Reference Books:-**


1. Solid State Physics by N W Ashcroft and N D Mermin, HRW, International Ed. (1996)
2. Introduction to Solid State Physics by Puri and Babar S. Chand publication
3. Introduction to Solid State Physics by C Kittle (8th Ed.) John Willey Pub. (1979)
4. Solid State Physics, A.J. Dekker (1986) Macmillan India Ltd.
5. Crystal Growth from high temperature solutions D.Elwell and H.J Scheel, Academic press.

**Learning outcomes:**

**Unit – I**:

1. Student should able to understand concept of Crystal growth.
2. Student should able to understand melt growth, Bridgman, Czochralski techniques.
3. Students should able to imperfections- point defects and dislocations
4. Student should able to understand Experimental determination of point defects and dislocations

**Unit – II** :

1. Understanding of electronic , ionic and orientation polarization
2. Student should able to understand Langevin's theory and measurement of dielectric constant.
3. Student should able to understand Piezo, pyro- and ferroelectric crystals.
4. Understanding of oxygen ion displacement theory

**Unit – III**:

1. Student should able to understand Weiss molecular field theory of Ferromagnetism
2. Understanding of Temperature dependence of spontaneous magnetization
3. Student should able to understand two sub lattice model of anti- ferromagnetism.
4. Student should able to understand ferrimagnetisms and ferrites.

**Unit – IV**:

1. Student should able to define energy band gap in semiconductor.
2. Understanding of impurity levels in doped semiconductors.
3. Student should able to understand superconductors: Critical temperature, Meissner effect.
4. Student should able to understand BCS Theory of superconductivity.

*******

**M. Sc. – I, Semester – II**

**MPP 206: LAB III (Credits: 4)**

**Learning Objectives:**

Student will able to:

1. Measure Young's modulus
2. Measure thermal diffusivity of Brass
3. Know Concept of Fourier analysis of various waves
4. Understand concept of passive filters
5. Understand working of solar cell
6. Study of AC bridge
7. Measure mutual inductance
8. Understand concept of band gap

9. Understand concept of series and parallel resonant circuits

10. Calculate specific capacitance

**Experiments:**

**Group I**

1. Young's modulus
2. Thermal diffusivity of brass
3. Fourier analysis
4. Passive filters
5. Solar cell
6. A.C. bridges
7. Mutual inductance of coil
8. Band gap energy
9. Series & parallel resonant circuits
10. Specific capacitance calculation of given material

**Learning outcomes:**

Student should able to

1. measure Young's modulus.
2. measure thermal diffusivity of Brass
3. know Fourier analysis of various waves
4. understand concept of passive filters
5. understand working of solar cell
6. study of AC bridge
7. measure mutual inductance
8. calculate energy of band gap
9. understand concept of series and parallel resonant circuits
10. calculate specific capacitance

**M. Sc. – I Semester – II**

**MPP 207: LAB IV + Project (Credits: 4)**

**Learning Objectives:**

Student will able to:

1. Understand concept of LDR
2. Measure resistivity of sample
3. Measure thermo electric power
4. Understand ESR

5. Study XRD pattern
6. Determine Rydberg constant
7. Measure dissociation energy
8. Measure magnetic susceptibility
9. Differentiation using Python
10. Integration using Python

**Group II**

1. LDR
2. Resistivity by four Probe
3. Thermoelectric power
4. Electron Spin Resonance
5. Crystal structure of thin film
6. Rydberg constant
7. Dissociation energy of iodine molecule
8. Magnetic susceptibility of ferric chloride solution
9. Numerical differentiation using Python
10. Numerical integration using Python

**Learning outcomes:**

Student should able to

1. understand concept of LDR
2. measure resistivity of sample
3. measure thermo electric power
4. understand ESR
5. study XRD pattern
6. determine Rydberg constant
7. measure dissociation energy
8. measure magnetic susceptibility
9. obtain differentiation using Python
10. obtain integration using Python

*********