Rayat Shikshan Sanstha's

Sadguru Gadge Maharaj College, Karad

(Autonomous)

Revised Syllabus As per Maharashtra Gov. GR dated-20 April, 2023 for Implementing NEP-2020

M.Sc. I Syllabus w.e.f. 2023-24

NATIONAL EDUCATION POLICY (NEP-2020)

Syllabus For

M.Sc. Program

Physics

Syllabus to be implemented 2023-2024

Rayat Shikshan Sanstha's

Sadguru Gadge Maharaj College, Karad

(Autonomous)

Department of Physics

Structure and credit distribution for M. Sc. Program as per NEP -2020

Year	Level	SEM	Major		RM	OJT/FP	RP	Cum Cr.	Degree
			Mandatory	Elective					
I	6	I	MP (4) CM(4) P-Lab- I (4) P-Lab -II (2)	SSP-1 (4 credit)	RM-PH (4)			**22**	**PG Diploma (after 3 Yr Degree)**
	6	II	QM (4) CMP(4) P-Lab- III (4) P-Lab -IV (2)	SSP-2 (4 credit)		FP-PH (4)		**22**	
Cum. Cr. PG Diploma			**28**	**8**	**4**	**4**		**44**	
Exit option : PG Diploma (40-44 Credits) after three year UG Degree									
II	**6.5**	**III**	SM (4) AMP(4) P-Lab- V (4) P-Lab -VI (2)	SSP-3 (4 credit)			RP-PH (4)	**22**	**PG Degree after 3-Yr UG or PG Degree after 4 -Yr UG**
		IV	ED (4) NP(4) P-Lab- VII (4)	SSP- 4 (4 credit)			RP-PH (6)	**22**	
Cum. Cr. for 1 Yr PG Degree			**26**	**8**			**10**	**44**	
Cum. Cr. for 2 Yr PG			**54**	**16**	**4**	**4**	**10**	**88**	

Abbreviations: Yr: Year; Sem: Semester; OJT: On Job Training: Internship/Apprenticeship; FP: Field Projects; RM: Research Methodology; RP: Research Project; Cum. Cr.: Cumulative Credits; MP: Mathematical Physics; CM: Classical Mechanics; P-Lab- Practical Lab; QM: Quantum Physics; CMP: Condensed Matter Physics; SM: Statistical Mechanics; AMP: Atomic and Molecular Physics; ED: Electrodynamics; NP : Nuclear and Particle Physics; SSP: Solid State Physics.

M. Sc.- I

	Semester - I		
Sr.No	**Major**		Credit
	Mandatory	**Elective** (4 credit)	
1	Mathematical Physics (4 credit)	Solid State Physics-1	
2	Classical Mechanics (4 credit)		
3	Practical Lab - I (4 credit)		
4	Practical Lab - II (2 credit)		
5	Research Methodology (4 credit)		
	Credits 18	**4**	**22**
	Semester - II		
	Mandatory	**Elective** (4 credit)	
1	Quantum Mechanics (4 credit)	Solid State Physics-2	
2	Condensed Matter Physics (4 credit)		
3	Practical Lab - III (4 credit)		
4	Practical Lab - IV (2 credit)		
5	Field Project (4 credit)		
			22
	Credits 18	**4**	

M. Sc.- II

	Semester - III		
Sr.No	**Major**		Credit
	Mandatory	**Elective** (4 credit)	
1	Statistical Mechanics (4 credit)	Solid State Physics-3	
2	Atomic and Molecular Physics (4 credit)		
3	Practical Lab - V (4 credit)		
4	Practical Lab - VI (2 credit)		
5	Research Project (4 credit)		
	Credits 18	**4**	**22**
	Semester - IV		
	Mandatory	**Elective** (4 credit)	
1	Electrodynamics (4 credit)	Solid State Physics-4	
2	Nuclear and Particle Physics (4 credit)		
3	Practical Lab - VII (4 credit)		
4	Research Project (6 credit)		
5			
			22
	Credits 18	**4**	
		Total credit	**88**

M. Sc. - I
Semester-I

M.Sc. (Physics) NEP-Semester-I
Course Code: MJ-MPT23-101
Paper title: Mathematical Physics (MP)
Total Credits: 4-credits

Mathematical Physics

Unit - I: Vector Spaces and matrices (15)

Linear vector space (Rajput 123 – 126), Matrix multiplication – inner product, direct product, diagonal matrices, trace, matrix inversion, example of Gauss-Jordon inversion, problems (Rajput 735 – 45). eigen values and eigen vectors, properties of eigen values and eigen vectors, Cayley- Hamilton theorem and applications, similar matrices, and diagonalizable matrices, eigen values of some Special complex matrices, quadratics forms, problems.

Unit - II: Differential equations and Special functions (15)

Solution for first order differential equation, Bernulli equation, exact equation, second order linear differential equation with constant and variable coefficient, special functions (Hermite, Bessel, Laguerre, and Legendre functions) generating functions, recurrence relation (Rajput 510 –667)

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

Definition, evaluation of coefficients of Fourier series (Cosine and Sine Series), graphical representation of a square wave function, complex form of Fourier series, Fourier integral exponential form, applications of Fourier series analysis in physics (square wave, full wave rectifier, expansion of Raman Zeta function) (Rajput 527 – 561). Fourier transform, inversion theorem, exponential transform Example: full wave train, uncertainty principle [Arfken 931-946]. Dirac delta function, derivative of δ- function and Laplace Transform of δ- function (Rajput1467 – 1475).

Unit – IV: Complex Analysis (15)

Analytical functions, Cauchy-Riemann conditions, Cauchy’s theorem, Cauchy integral formula, derivatives of analytical functions, Taylor’s theorem, Laurent’s theorem, residues, evaluation of definite integrals (Rajput 404-499)

Reference book:

1) Rajput B. S., Mathematical Physics, Pragati Prakashan (Meerat) 1999
2) Iyengar S. R. K., Jain R. K., Mathematical Methods, Narosa, 2006
3) Arfken and Weber, Mathematical Methods for Physicists 6th Edition, Academic Press, 2005
4) Mathematical Physics, Binoy Bhattacharyya, New Central Book Agency (P) Limited, 2010
5) Complex Variables and Applications – J. W. Brown, R. V. Churchill – (7th Edition) - Mc-Graw Hill – Ch. 2 to 7.
6) Complex Variables –Seymour Lipschutz, John J. Schiller, Dennis Spellman, (2^{nd} Edition) Mc-Graw Hill – 2009.

M.Sc. (Physics) NEP -Semester-I
Course Code: MJ-MPT23-102
Paper title: Classical Mechanics (CM)
Total Credits: 4-credits

Classical Mechanics

Unit - I: Central Force Problem and Small oscillations: (15)
Two body problem, The equation of motion and first integrals, Equation of orbit, Kepler's laws, Kepler's problem, General analysis of orbits, Stability of orbits, Rutherford Scattering: Differential scattering cross–section, Rutherford Formulae for scattering, Virial theorem. Small oscillations: Potential energy and equilibrium-one dimensional oscillator, general theory of small oscillations.

Unit - II: Variational principle and Hamiltonian Dynamics: (15)
Variational principle, Deduction of canonical equations from Variational principle, Principle of least action with proof, Hamilton's principle, Hamiltonian, Generalized momentum & Conservation Theorems using cyclic coordinates, Hamilton's canonical equations of motion, Applications of Hamilton's equations of motion-1) Simple Pendulum 2) Compound Pendulum 3) Linear Harmonic Oscillator.

Unit - III: Canonical Transformations and Poisson's Brackets: (15)
Legendre transformations, Generating Functions, Illustrations of Canonical transformations, Condition for Canonical Transformation, Examples. Poisson's Brackets, Poisson's theorem, Properties of Poisson's Brackets, **Lagrange Bracket, Relation between Lagrange and Poisson's Brackets**, Hamilton's Canonical equations in terms of Poisson's Brackets, Hamilton–Jacobi Theory, Solution of harmonic oscillator problem by HJ Method, Problems.

Unit - IV: Special Theory of Relativity and Relativistic Mechanics: (15)
Special theory of relativity and its postulates, Galilean transformations, Lorentz transformations **relativistic kinematics** (Relativity of Mass, Length, Time), Minkowski Space, 4-Vectors, 4-Momentum, Lorentz Tensor, Addition of velocities, Mass-Energy relation, Force in relativistic mechanics, Lagrangian formulation of relativistic mechanics, Particle accelerating under constant force, Hamiltonian formulation of relativistic mechanics, Relativistic Doppler's Effect.

Reference Books:

1. Classical Mechanics, by H Goldstein (Addison Wesley 1980).
2. Classical Mechanics, by J. C. Upadhyaya (Himalaya Publishing House 2015).
3. Classical Mechanics, by N. C. Rana and P. S. Joag (Tata McGraw Hill 1991).
4. Introduction to Classical Mechanics, by R. G. Takwale and P. S. Puranik (Tata McGraw Hill 1999).
5. Classical Mechanics, by Gupta, Kumar, and Sharma (Pragati Prakashan 2000).

M.Sc. (Physics) NEP -Semester-I
Course Code: RM-MPT23-104
Paper title: Research Methodology (RM)
Total Credits: 4-credits

Research Methodology

Unit-I Research Methodology: (15)

a) Meaning of research, objectives of research, motivation in research, types of research, research approaches, significance of research, research methods versus research and scientific methodology, importance of knowing how research is done, research progress, criteria of good research.

b) Research design: meaning of research design, features of good design, important concepts of relating research design, different basic designs.

c) Method of data collection, types of data analysis; statistics in research, measure of central tendency, measure of dispersion; measure of asymmetry, measure of relationship, simple regression analysis, multiple correlation and regression, partial correlation.

Unit-II Literature Searching and Report Writing: (15)

a) Literature Searching: On-line searching, Database, SciFinder, Scopus, Science Direct, CA on CD, Searching research articles, Citation Index, Impact Factor, H-index etc,

b) Writing scientific report: Structure and components of research report, revision, and refining' writing project proposal, Paper writing for International Journals, submitting to editors. conference presentation, preparation of effective slides, pictures, graphs, and citation styles.

c) Thesis writing: the preliminary pages and the introduction, the literature review, methodology, the data analysis chapters, the conclusion

Unit III Vacuum (15)

Production of low pressures: rotary, diffusion, and sputter ion pumps; measurement of low pressure: McLeod, Pirani, thermocouple & Penning gauges; leak detection: simple methods of LD, palladium barrier and halogen leak detectors.

Unit IV Low Temperature and Microscopy Techniques (15)

Production of low temperatures: Adiabatic cooling, the Joule-Kelvin expansion, adiabatic demagnetization, 3 He cryostat, the dilution refrigerator, principle of Pomerunchuk cooling, principle of nuclear demagnetization; measurement of low temperatures. Optical microscopy, scanning electron microscopy, electron microprobe analysis, low energy electron diffraction.

Reference Books

1.Fundamentals of computers, Morley & Parkar, Cengage Learning Pvt. Ltd. New Delhi,
2.Research Methodology – Methods and Techniques, C. R. Kothari, Wiley Easter Ltd, New Delhi 1985.
3. Writing your thesis, Paul Oliver, Vistaar Publication, New Delhi
4. High vacuum techniques- J. Yarwood (Chapman & Hall) 1967
5. Vacuum technology- A. Roth (North-Holland Publishing Company, Amsterdam) 1982
6. Experimental techniques in low temperature physics – G. K. White (Oxford) 1968
7. Low temperature physics – L.C. Jackson

M. Sc. I (Physics) NEP- Semester I
Course Code: MJ-MPP23-101
Paper title: Physics LAB-I
Total Credits: 4-credits

Laboratory/ Practical Course-I

(Two experiments and certified journal- 4-credits)

1. Hall effect (Hall coefficient & carrier concentration of semiconductor).
2. Linear Variable Differential Transducer.
3. Crystal structure identification by Neutron diffraction pattern.
4. Wavelength of given source by using Fabry-Parrot etalon.
5. Crystal structure identification by X- ray diffraction pattern.
6. Structure identification of given samples (F.C.C.& B.C.C.)
7. Monatomic/ diatomic lattice vibrations using lattice dynamics kit.
8. Characteristic of Temperature Transducers (Thermocouple, Thermistor and IC sensor)
9. Specific heat capacity of given metals.
10. Staircase Ramp Generator using UJT
11. Negative feedback amplifier (with and without feedback)
12. Astable multivibrator
13. Monostable multivibrator.
14. Stefan’s constant.
15. Magnetic parameters of given sample using B-H curve kit
16. Thermal & electrical conductivity of copper.
17. Numerical, algebraic, and trigonometric problems using Mathematica.
18. Analysis of statistical data.
19. Numerical differentiation using Python.
20. Numerical integration using Python.
21. Physical density of material by using Archimedes’ Principle.

M. Sc. (Physics) NEP -Semester-I
Course Code: MJ-MPP23-102
Paper title: Physics LAB-II
Total Credits: 2-credits

Laboratory/ Practical Course-II

(Seminar & certified seminar report 1-credits +Tutorials on practical-1-credits)
Total Credits: 2-credits

Elective Paper

Sr. No.	Course Code	Paper Title
1	GE-MPT23-103	Semiconductor Physics (4 credits)

M.Sc. (Physics) NEP Semester-I
Course Code: GE-MPT23-103
Paper title: Semiconductor Physics
Total Credits: 4-credits

(Solid State Physics-1)
Semiconductor Physics

Unit I: Energy Bands and Charge Carriers in Semiconductors: (15)
Direct and Indirect semiconductors, variation of energy bands with alloy composition, Charge carriers in semiconductors: electrons and holes, effective mass, intrinsic and extrinsic materials, electrons and holes in quantum wells, The Fermi level, carrier concentration at equilibrium, temperature dependence, space charge neutrality, conductivity and mobility, Drift and resistance, effects of temperature and doping on mobility, the Hall effect.

Unit II: Excess Carriers in Semiconductors: (15)
Optical absorption, Luminescence: photoluminescence and electroluminescence, Direct recombination of electrons and holes, Indirect recombination and trapping, steady state carrier generation and Quasi Fermi levels, Diffusion processes, Diffusion and Drift of carriers, built-in fields, The continuity equation, steady state carrier injection, diffusion length,

Unit III: Junctions-I (15)
Fabrication of p-n junctions; Thermal oxidation, diffusion, CVD, Photolithography, etching, metallization, The contact potential, Space charge at a junction, qualitative description of current flow at a junction, reverse-bias breakdown, Capacitance of p-n junctions, Zener and Avalanche breakdown, rectifiers.

Unit IV: Junctions-II (15)
The tunnel diode, the Varactor diode, recombination, and generation in the transition region, ohmic losses, graded junctions, Schottky barriers, rectifying contacts, ohmic contacts, hetero-junctions, AlGaAs-GaAs hetero-junction.

References:
1. Solid state electronic devices by B. G. Streetman.
2. Physics of semiconductor devices by S. M. Sze.
3. Solid State and Semiconductor Physics by McKelvey.
4. Principles of Electronic Materials and Devices by S.O. Kasap

M. Sc. - I
Semester-II

M.Sc. (Physics) NEP-Semester-II
Course Code: MJ-MPT23-201
Paper title: Quantum Mechanics
Total Credits: 4-credits

Quantum Mechanics

Unit-I: Mathematical Tools of Quantum Mechanics (15)
Hilbert space and wave function, Dirac notations, Operators (General definitions, Hermitian adjoint operator, projection operators, uncertainty relation between two operators, functions of operators, inverse and unitary operators, eigenvalues and eigenvectors of an operator, parity Representation in continuous bases (Position representation, Momentum representation and connection between them), Matrix representation of orbital and spin angular momentum.

Unit-II: Variational Method and WKB Approximation (15)
The variational principle, Rayleigh-Ritz method, variational method for excited states, the Hellmann-Feynman theorem, ground state of harmonic oscillator, infinite square well, hydrogen atom, the WKB method, the connection formulas, validity of WKB method, barrier penetration, Alpha emission.

Unit-III: Perturbation Theory (15)
Time independent perturbation: basic concept, non-degenerate energy levels, Eigen value of energy and Eigen function in the first order approximation, Anharmonic oscillator: first order correction, first order correction to ground state of helium. The pictures of quantum mechanics (Schrodinger picture, Heisenberg picture and Interaction picture), Time dependent perturbation: Basic concept, Dyson series, First-order perturbation, transition probability, constant perturbation, harmonic perturbation, transition to continuum states (Fermi-Golden rule), semi-classical theory of radiation: absorption and emission of radiation, electric dipole approximation, Einstein's A and B coefficients.

Unit – IV: Scattering Theory (15)
Scattering cross-section, scattering amplitude, partial wave, scattering by central potential: partial wave analysis, optical theorem, scattering by hard sphere, scattering by square well, Breit-Wigner formula, scattering length, expression for phase shifts, integral equation, the Born approximation, scattering by screened Coulomb potential, scattering by Yukawa potential, validity of Born approximation.

Reference Books:

1) Quantum Mechanics: Concepts and Applications, Zettili Nouredine, John Wiley & Sons Ltd., Second Edition (2009).
2)Quantum Mechanics, Aruldhas G, Prentice Hall India Learning Private Lt., 2nd Edition (2009).
3) Introduction to Quantum Mechanics, David J. Griffiths, Pearson Education, 2nd Edition (2015).
4) Quantum Mechanics: Theory and Applications, Ajoy Ghatak and S. Lokanathan, Macmillan Publishers India, Fifth Edition (2004).
5) Modern Quantum Mechanics, J. J. Sakurai and Jim J. Napolitano, Pearson Education India, 2nd Edition, (2013).

M.Sc. (Physics) NEP-Semester-II
Course Code: MJ-MPT23-202
Paper title: Condensed Matter Physics
Total Credits: 4-credits

Condensed Matter Physics

Unit – I: Crystal Physics (15)

Crystalline state of solid, unit cell and Bravais lattice (2D and 3D), bonding of common crystal structure, direction, position, and orientation of planes in crystal, concept of reciprocal lattice, concept of Brillouin zones, closed packed structure, Fourier analysis of the basis (structure factor), Bragg's law, comparison of X-ray, electron and neutron diffraction method.

Unit - II: Crystal Defects (15)

Types of defects, Point defects-Vacancies, Interstitials, impurities, electronic, Line defects-Edge and screw dislocation, Schottky and Frenkel defect Expression for Schottky and Frenkel defects, equilibrium concentration of vacancies, color center, line defect, screw and edge dislocation, Berger's vector and circuit, role of dislocation in plastic deformation and crystal growth, observation of imperfection in the crystals. Frank-Read mechanism. Planer defects, Surface defects- Grain boundaries, Tilt boundaries, Twin boundaries, Effect of Imperfections.

Unit – III: Semiconducting and superconducting properties (15)

Semiconductor: Determination of Band gap energy, direct and indirect band gap, effective mass, intrinsic and extrinsic semiconductors, carrier concentration, Fermi level and conductivity for intrinsic and extrinsic semiconductor, impurity level in doped semiconductor, Hall Effect. Quantum Confinement.

Superconductor: Critical temperature, effect of magnetic field, Meissner effect, type-I and type-II superconductor, London equation, coherence length, Josephson effect (flux quantization), BCS theory, introduction of high Tc superconductor, SQUID, Cooper pairing in superconducting dots.

Unit – IV: Dielectrics and Magnetism (15)

Dielectrics: Polarization mechanism, dielectric constant, Lorenz cavity field, Clausius-Mossotti equation, ferroelectricity and piezoelectricity, type of ferroelectric and piezoelectric.

Magnetism: Classification of magnetic materials, Langevin theory of diamagnetism, paramagnetism and ferromagnetism, theory of diamagnetism- Heisenberg exchange interaction theory (ferro-antiferro and ferrimagnetism), Weiss theory of ferromagnetism. Comparison between dia, para and ferromagnetism, Super-paramagnetism.

Reference Books:

1. Introduction to Solid State Physics Kittel, 8thedn. JohnWiley & Sons. Inc., New York (2019).
2. Solid State Physics by A. J. Dekker, MacMillan India Ltd. (1986).
3. Solid State Physics-N. W. Ashcroft and N. D. Mermin, HRW International edn. (1976).
4. Solid State Physics–S. O. Pillai. New Age International Publication. -2002
4. Solid State Physics-H. C. Gupta-Vikas Publishing House, New Delhi-2002
5. Electronic Properties of Materials - R.E.Humel, 2ndedn.Springer International(1994)
6. Solid State Physics–J. S.Blakemore, 2ndedn. Cambridge University Press (1985)

M.Sc. (Physics) NEP -Semester-II
Course Code: MJ-MPP23-201
Paper title: Physics LAB-III
Total Credits: 4-credits

Laboratory/ Practical Course- III

1. Fourier analysis.
2. Transmission characteristics of passive filters.
3. I-V characteristics of solar cell.
4. A. C. bridges (Maxwell, Anderson and De-Sauty bridge)
5. Thermal diffusivity of brass.
6. Mutual inductance of given coil.
7. Series & parallel resonant LCR circuits.
8. Young's modulus of a beam by flexural vibration created by frequency generator.
9. 2D and 3D plots using Mathematica.
10. Band gap energy of semiconductor.
11. Resistivity of given semiconductor sample using four probe method.
12. Thermoelectric Power
13. Magnetic field variation as a function of resonance frequency using ESR.
14. Crystal structure of thin film by using given XRD data.
15. Rydberg constant.
16. Dissociation energy of iodine molecule.
17. Magnetic susceptibility of ferric chloride solution.
18. Plank's constant using photocell.
19. Numerical solutions of simple first order differential equation using Python (Euler and Runge Kutta 4^{th} order method)
20. Plotting simple functions using Python.
21. Plotting of simple graphs using origin software.
22. Crystallite size by Debye- Scherrer Formula ($D=0.9\lambda/\beta \cos\theta$).

M.Sc. (Physics)NEP- Semester-II
Course Code: MJ-MPP23-202
Paper title: Physics LAB-IV
Total Credits: 2-credits

Laboratory/ Practical Course- IV

(Seminar & certified seminar report 1-credits +Tutorials on practical-1-credits)
Total Credits: 2-credits

M.Sc. (Physics) NEP-Semester-II
Course Code: FP-MPT23-204
Paper title: Field Project
Total Credits: 4-credits

On Job Training/ Field Project

(Arrange on job training/Field project at CFC (4 credits) for all the students of university department and affiliated colleges running M. Sc. Physics)

Elective Paper

Sr. No.	Course Code	Paper Title
1	GE-MPT23-203	Semiconductor Devices (4 credits)

M.Sc. (Physics) NEP Semester-II
Course Code: GE-MPT23-203
Paper Title: Semiconductor Devices
Total Credits: 4-credits

(Solid State Physics-2)
Semiconductor Devices

Unit I: Transistors and Microwave Devices: **(15)**

Bipolar junction transistor (BJT), Frequency response and switching, of BJT, Base Narrowing, Ebers-Moll Model, Gummel–Poon Model, Kirk Effect, Field effect transistor (FET), JFET, MOSFET, MESFET, Tunnel diode, Transferred electron devices and Gunn diode, Avalanche transit time diode ~~and~~, IMPATT diode.

Unit II: Photonic Devices: **(15)**

Optical absorption, Radiative and non-radiative transitions, Light emitting diodes, Organic LED, Infrared LED, Photo detector, Photoconductor, Photodiode, Solar cells, Semiconductor Lasers.

Unit III: Memory Devices: **(15)**

Number system and its conversion to binary number, Semiconducting memories, Memory organization, Read and Write operation, expanding memory size, Classification and characteristics of memories, Static and dynamic RAM, Charge couple memory (CCD) devices, Magnetic, optical, ferroelectric, Spintronic and other memory based devices.

Unit IV: Other electronic Devices: **(15)**

Magneto-optic and acousto-optic effects, Material's properties related to get these effects, Piezoelectric, Electrostrictive and Magnetostrictive effects, Sensors, and actuator devices.

Reference Books:

1) Semiconductor devices: Physics and Technology 2nd Edition, S. M. Sze
2) Modern Digital Electronics, R. P. Jain
3) Introduction to Semiconductor devices by M. S. Tyagi
4) Optical electronics by Ajoy Ghatak and K. Thyagrajan, Cambridge University Press.

M. Sc. - II
(Semester-III)

M.Sc. (Physics) NEP Semester-III
Course Code: MJ-MPT23-301
Paper title: Statistical Mechanics
Total Credits: 4-credits

Statistical Mechanics

Unit I: Contact between Statistics and Thermodynamics: (15)

Fundamental postulate of equilibrium statistical mechanics, Basic concepts – Phase space, ensemble, a priori probability, Liouville's theorem (Revision). Fluctuations of physical quantities, Statistical Equilibrium, Thermodynamic Laws and their consequences (in brief), Thermodynamic Functions – Entropy, Free energy, Internal Energy, Enthalpy (definitions), Maxwell's Equations (only equations), Contact between statistics and thermodynamics – Entropy in terms of microstates, Gibb's paradox, Sackkur-Tetrode formula.

Unit II: Classical Statistical Mechanics: (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. Grand Canonical Ensemble– Grand Canonical distribution, Thermodynamic Functions,Number and Energy fluctuations.

Unit III: Quantum Statistical Mechanics: (15)

Quantum Statistics: Distinction between MB, BE and FD distributions, Quantum distribution functions –Bosons and Fermions and their distribution functions, Boltzmann limit of quantum gases, Partition function, Ideal Bose gas, Bose -Einstein Condensation, Specific heat of solids (Einstein and Debye models) Phonon gas, Liquid He4: Second Sound, Ideal Fermi gas: Weakly and strongly degenerate, Fermi temperature, Fermi velocity of a particle of a degenerate gas, Electron gas: Free electron theory ofmetals, Pauli paramagnetism, white dwarfs, *Brownian motion*: Einstein-Smoluchowski theory, Langevin theory, Approach to equilibrium: Fokker-Planck equation, the fluctuation-dissipation theorem.

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, The critical indices, Weakly Interacting Gases, Weiss Molecular theory of paramagnetism, The Ising Model of a Ferromagnetism

Reference books:

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

M.Sc. (Physics) NEP Semester-III
Course Code: MJ-MPT23-302
Paper title: Atomic & Molecular Physics
Total Credits: 4-credits

Atomic and Molecular Physics

Unit - I: Atomic Spectra **(**15)

Quantum states of an electron in an atom, electron spin, spectrum of helium and alkali atom. Relativistic corrections for energy levels of hydrogen atom, ll-coupling, ss-coupling, LS or Russell - Saunder's coupling; the Pauli exclusion principle, Coupling schemes for two electrons, Γ- factors for LS coupling, Lande interval rule, jj coupling, branching rules, selection rules, Intensity relations.

Unit - II: Effect of magnetic and electric field on atomic spectra **(**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, Inner shell vacancy, X-ray and Auger transitions, Compton effect.

Unit - III: Molecular spectra **(**15)

Molecular physics – covalent, ionic and Vander Waal's interaction, Classification of molecules: linear, symmetric tops, spherical tops, asymmetric tops; rotational spectra: the rigid diatomic molecule, the non-rigid rotator, spectrum of a non-rigid rotator, techniques and instrumentation of microwave spectroscopy, chemical analysis by microwave spectroscopy, the vibrating diatomic molecule: the energy of a diatomic molecule, the simple harmonic oscillator, the anharmonic oscillator, the diatomic vibrating-rotator, vibrational rotational spectra, techniques and instrumentation of infra-red spectroscopy, chemical analysis by infra-red spectroscopy.

Unit - IV: Electronic, Nuclear and Raman spectra **(**15)

Revision on electronic spectra of diatomic molecules, electron spins resonance, nuclear magnetic resonance, chemical shift. Frank-Condon principle, dissociation energy and dissociation products, rotational fine structure of electronic-vibration, transitions. Born-Oppenheimer approximation, separation of electronic and nuclear motions in molecules, band structures of molecular spectra. Raman spectra: Pure rotational Raman spectra, vibrational Raman spectra, polarization of light and Raman effect, techniques, and instrumentation of Raman spectroscopy.

Reference books:

1) Introduction to Atomic Spectra – H.E. White, Mac-Graw Hill (1934).
2) Fundamentals of Molecular Spectroscopy, 4th Edition. – C.N. Banwell, Tata MacGraw Hill (2008).
3) Molecular Structure and Spectroscopy, G. Aruldhas, PHI Learning Pvt. Ltd. Spectra of diatomic Molecules, Vol. I – G. Herzberg, N.J.D. van Nostrand (1950).
4) Spectroscopy, Vol. I, II and III – B.P. Straughan and S. Walker, Chapman, and Hall (1976).
5) Introduction to Molecular Spectroscopy – G.M. Barrow, McGraw Hill (1962).
6) Molecular Spectroscopy – J.M. Brown, Oxford University Press (1998).

M.Sc. (Physics) NEP Semester-III
Course Code: MJ-MPP23-301
Paper title: SOLID STATE PHYSICS LAB –V
Total Credits: 4-credits

Laboratory/ Practical Course-SSP-V
(Solid State Physics Lab –V)

List of Experiments
Group I:

[1] Thin film deposition by SILAR method
[2] Thin film deposition by electro-deposition method
[3] Thin film deposition by hydrothermal method
[4] Thin film deposition by reflux method
[5] Thin film deposition by dip-coating method
[6] Thin film deposition by CBD method
[7] Microwave assisted synthesis of thin film
[8] Thin film deposition by spray pyrolysis method

Group II:

[9] Rietveld method of structure refinement
[10] Calculation of XRD peak positions and intensities
[11] Thickness measurement of thin film by transmittance spectroscopy
[12] Electrical resistivity of thin film by 2 probe method
[13] Thermoelectric power of thin film
[14] Contact angle measurement of thin film
[15] Determination of band gap energy of thin film
[16] Measurement of dielectric constant

M.Sc. (Physics) NEP Semester-III
Course Code: MJ-MPP23-302
Paper title: SOLID STATE PHYSICS LAB –VI
Total Credits: 4-credits

Laboratory/ Practical Course-SSP-VI

(Seminar & certified seminar report 1-credits +Tutorials on practical-1-credits)
Total Credits: 2-credits

M.Sc. (Physics) NEP Semester-III
Course Code: RP-MPT23-304
Paper title: Solid State Physics Project Work - I
Total Credits: 4-credits

Solid State Physics Project Work - I (4 credits)

Elective Paper

Sr. No.	Course Code	Paper Title
1	GE-MPT23-303	Thin solid films: Deposition and properties (4 credits)

M.Sc. (Physics) NEP-Semester-III
Course Code: GE-MPT23-303
Paper title: Thin solid films: Deposition and properties
Total Credits: 4-credits

(Solid State Physics- 3)
Thin solid films: Deposition and properties

Unit 1: Physical methods of thin film deposition **(15)**

Vacuum deposition apparatus: Vacuum systems, substrate deposition technology, substrate materials, Thermal Evaporation methods: Resistive heating, Flash evaporation, Arc evaporation, laser evaporation, electron bombardment heating, Sputtering: sputtering variants, glow discharge sputtering, Magnetic field assisted (Triode) sputtering, RF Sputtering, Ion beam sputtering, sputtering of multi- component materials.

Unit 2: Chemical methods **(15)**

Chemical vapor deposition: Common CVD reactions, Methods of film preparation, laser CVD, Photochemical CVD, Plasma enhanced CVD, Chemical bath deposition, Electro deposition, Spray pyrolysis, successive ionic layer adsorption reaction method (SILAR) method, Sol-gel method, Hydrothermal method.

Unit 3: Nucleation growth processes and thickness measurement **(15)**

Condensation process, Langmuir-Frenkel theory of condensation, Theory of nucleation and growth process, Thickness measurements: Electrical methods, Microbalance monitors, mechanical method, radiation absorption and radiation emission methods, optical interference methods: photometric method, spectrometric method, interference fringes, X-ray interference fringes.

Unit 4: Properties and characterization of thin films **(15)**

Mechanical properties of thin films: Introduction to elasticity, plasticity, and mechanical behavior, Electrical and magnetic properties of thin films, Optical properties of thin films, Structural characterization: X-ray diffraction, Scanning electron microscopy, Transmission electron spectroscopy, chemical characterization: X-ray Energy Dispersive Analysis (EDX), X-ray photoelectron spectroscopy (XPS).

Reference Books

1. Thin Film Phenomena by K L Chopra McGraw -Hill Book Company, NY 1969
2. The Materials Science of Thin Films by Milton Ohring, Academic Press, (1992)
3. Properties of Thin Films by Joy George, Marcel, and Decker, (1992)
4. Physics of Thin Films by Ludmila Eckertová, Springer (1986)
5. Thin Film Technology by O S Heavens, Methuen young books (1970)
6. Solid State Physics by N.W. Ashcroft, N. D. Mermin, Harcourt College Publishers (1976)
7. Chemical Solution Deposition of Semiconductor Films by G. Hodes, Marcel Dekker Inc. (2002)

M. Sc. - II
Semester - IV

M.Sc. (Physics) NEP Semester-IV
Course Code: MJ-MPT23-401
Paper title: Electrodynamics
Total Credits: 4 - credits

Electrodynamics

Unit - I: Maxwell's Equations and E.M. Waves: (15)
Maxwell's Equations: microscopic and macroscopic forms (revision), Maxwell's equations in free space, dielectrics and conductors, conservation of the bound charge and current densities (Equation of Continuity and Displacement Current), E.M. wave equations in waveguide of the arbitrary cross section: TE and TM modes; Transmission lines and wave guides, rectangular and circular waveguides , dielectric waveguide, resonant cavity. Reflection and refraction, polarization, Fresnel's law, interference, coherence, and diffraction.

Unit - II: Time –Dependent Potentials and Fields: (15)
Scalar and vector potentials: coupled differential equations, Gauge transformations: Lorentz and Coulomb Gauges, Retarded Potentials, Lienard – Wiechert Potentials, Fields due to a charge in the arbitrary motion.

Unit - III: Radiation from Accelerated Charges and Radiation Reaction: (15)
Fields of charge in uniform motion, applications to linear and circular motions: cyclotron and Synchrotron radiations, Power radiated by point charge – Larmor's formula, Angular distribution of radiated power, Cerenkov radiation and Bremsstrahlung (qualitative treatments). Radiation Reaction: criteria for validity, Abraham –Lorentz formula, Physical basis of radiation reaction –self force.

Unit - IV: Electrodynamics and Relativity: (15)
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 Field Tensor, Relativistic Potential. Four vectors and Tensors: covariance of the equation of Physics, Transformation of Electric field, Lorentz transformation as orthogonal Transformation in Fourier dimensions, Proper time and light cone, Relativistic Particle- Kinematics and dynamics, Covariant Lorentz force.

Reference books:
1) Introduction to Electrodynamics – D. J. Griffiths (Prentices- Hall 2002 (3rd edn)
2) Foundation of E.M. Theory- J. R. Reitz, F.J. Milford & R.W. Christy (Narosa Publication House 3rd edition 1993)
3) Classical Electrodynamics – J. D. Jackson (Wiley Eastern 2nd edition)
4) Classical Electrodynamics –S. P. Puri (Tata McGraw Hill 1990)
5) Electromagnetics - Laud B. B. - New Age International Private Limited; 3rd edition

M.Sc. (Physics) NEP Semester-IV
Course Code: MJ-MPT23-402
Paper title: Nuclear and Particle Physics
Total Credits: 4 - credits

Nuclear and Particle Physics

Unit-I Nucleon-Nucleon Interaction: **(15)**
Nature of the nuclear forces, form of nucleon-nucleon potential, Deuteron problem: The theory of ground state of deuteron, excited states of deuteron, n-p scattering at low energies (cross-section, phase shift analysis, scattering length, n-p scattering for square well potential, effective range theory); p-p scattering at low energies (cross-section, experiment and results) ; exchange forces, tensor forces; high energy N-N scattering (qualitative discussion only of n-p and p-p scatterings), charge-independence and charge-symmetry of nuclear forces.

Unit-II Nuclear Models: **(15)**
Evidences for shell structure, single-particle shell model, its validity and limitations, collective model: collective vibration and collective rotation, single particle motion in a deformed potential

Unit-III Nuclear Reactions: **(15)**
Elementary ideas of alpha, beta and gamma decays and their classifications, characteristics, selection rules and basic theoretical understanding. Nuclear reactions, reaction mechanism, Compound nucleus reaction (origin of the compound nucleus hypothesis, discrete resonances, continuum states), optical model of particle-induced nuclear reaction and direct reactions (experimental characteristics, direct inelastic scattering, and transfer reactions). Fission and fusion, Fission, and heavy ion reactions.

Unit-IV Particle Physics: (15)
Classification of fundamental forces. Classification of Elementary particles and their quantum numbers (charge, spin, parity, isospin, strangeness, etc.). Gellman-Nishijima formula. Quark model, CPT invariance. Application of symmetry arguments to particle reactions, Parity non-conservation in weak interaction, Relativistic kinematics.

Reference Books:

1. Nuclear and Particle Physics- W.E. Burcham and M.Jobes, (Addison Wesley, Longman, England, 1995).
2. Introduction to Particle Physics- M.P. Khanna (Prentice Hall, India, 1999).
3. Concept of Nuclear Physics, B.L. Cohen, (Tata McGraw-Hill, 2005)
4. Nuclear Physics Principles and Applications, John Lilley, (John Wiley and Sons (Asia) 2001)
5. Nuclear physics – D. C. Tayal. (Himalaya Publishing House,1997)
6. Nuclear Physics- Iriving Kaplan (Narosa, Madras, 1989).
7. Introduction to High Energy Physics- Donald H.Perkins (Addison Wesley, Massachusetts, 1982).

M.Sc. (Physics) NEP Semester-IV
Course Code: MJ-MPP23-401
Paper title: SOLID STATE PHYSICS LAB –VII
Total Credits: 4-credits

Laboratory/ Practical Course-SSP-VII
(Solid State Physics Lab –VII)

List of Experiments:

Group I:

[1] Particle size analysis by dynamic light scattering

[2] Photo electrochemical Solar Cell

[3] Characteristics of phototransistor and LDR

[4] Spectral response of solar cell

[5] Gas sensing properties of thin film

[6] I-V characteristics of solar panel

[7] Analysis of EIS spectrum

[8] I-V characteristics and solar cell parameters

Group II:

[9] Analysis of FT-IR and FT-IR spectra

[10] Cyclic Voltammetry and electro-chromism

[11] Super capacitive behaviour of MnO_2 sample

[12] Specific area by BET method

[13] Analysis of PL spectrum and calculation of life time of defects

[14] Analysis of TG-DTA pattern

[15] Analysis of XAFs pattern

M.Sc. (Physics) NEP Semester-IV
Course Code: RP-MPT23-404
Paper title: Solid State Physics Project Work - II
Total Credits: 4-credits

Solid State Physics Project Work - II **(6 credits)**

Semester-IV
Elective Paper

Sr. No.	Course Code	Paper Title
1	GE-MPT23-403	Physical Properties of solids (4-credits)

M.Sc. (Physics) NEP Semester-IV
Paper Code: GE-MPT23-403
Paper title: Physical properties of solid
Total Credits: 4-credits

(Solid State Physics - 4)
Physical properties of Solids

Unit 1: Electronic Structure of Crystals (15)

Basic assumptions of Model, Collision or relaxation times, DC electrical conductivity, Failures of the free electron model, The tight-binding method, Linear combinations of atomic orbitals, Application to bands from s-Levels, General features of Tight-binding levels, Wannier functions, Other methods for calculating band structure, Independent electron approximation, general features of valence band wave functions, Cellular method, Muffin Tin potentials, Augmented plane wave (APW) method, Green's function (KKR) method, Orthogonalized Plane Wave (OPW) method Pseudo potentials.

Unit 2: Transport Properties of Metals (15)

Drift velocity and relaxation time, The Boltzmann transport relation, The Sommerfeld theory of metals of electrical conductivity, The mean free path in metals, Thermal scattering, The electrical conductivity at low temperature, The thermal conductivity of metals, Dielectric Properties of insulators, Macroscopic electrostatic Maxwell equations, Theory of Local Field, Theory of polarizability, Clausius- Mossotti relation, Long- wavelength optical modes in Ionic crystals.

Unit 3: Phonons, Plasmons, Polaritons, and Polarons (15)

Vibrations of monatomic lattices: first Brillion zone, group velocity, Long wavelength limit, Lattice with two atoms per primitive cell. Quantization of lattice vibrations, Phonon momentum Dielectric function of the electron gas, Plasma optics, Dispersion relation for Electromagnetic waves, Transverse optical modes in a plasma, Longitudinal Plasma oscillations, Plasmons, Polaritons, LST relations, Electron-electron interaction, Electron phonon interaction: Polarons.

Unit 4: Defects in crystals (15)

Thermodynamics of point defects, Schottky and Frenkel defects, annealing, electrical conductivity of ionic crystals, color centers, Polarons and exciton, dislocations, strength of crystals, crystal growth, stacking faults and grain boundaries.

Reference Books:

1. Solid State Physics by N W Ashcroft and N D Mermin, HRW, International editions (1996) (Units 1, 2 and 3)
2. Introduction to Solid State Physics by C Kittle (4th edition) John Willey Publication (1979) (Units 3)
3. Solid State Physics by A J Dekker ((1986) Macmillan India Ltd

Nature of Question Paper

Theory: Time -3 hours, **Marks**-80

Instructions: **1) Question No.1 is compulsory.**
2) Attempt any four questions from Q.2 to Q.7

Question 1: Answer in Short (8 short questions – each having -2 Marks) - 16 marks

Question 2: a) Long Answer question for - 12 marks
b) Short answer questions for - 4 marks

Question 3: a) Long Answer question for - 12 marks
b) Short answer questions for - 4 marks

Question 4: a) Long Answer question for - 12 marks
b) Short answer questions for - 4 marks

Question 5: a) Long Answer question for - 12 marks
b) Short answer questions for - 4 marks

Question 6: a) Long Answer question for - 12 marks
b) Short answer questions for - 4 marks

Question 7: a) Long Answer question for - 12 marks
b) Short answer questions for - 4 marks

Note: Equal weightage should be given to each unit.