Karmaveer Bhaurao Patil University, Satara

Syllabus for

M. Sc. I Physics

Under

Faculty of Science and Technology

(As per NEP 2020)

With effect from Academic Year 2024-2025

Syllabus for M.Sc. Part – I
Title: Physics
Year of Implementation: The syllabus will be implemented from Academic Year 2024-2025 onwards.

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.

Program Outcomes:

PO No.	**PO Statement** **After completing the Master of Science in Physics students will be able to-**
PO-1	Expertise in the subject
PO-2	Qualified to continue Ph.D. in his subject
PO-3	Eligible to research scholar abroad
PO-4	Qualified to appear for the examinations for jobs in government organizations, private industries, research laboratories, etc.
PO-5	Eligible to appear for jobs with minimum eligibility as science post graduate.

Program Specific Objectives:

1. The students are expected to know the core knowledge and recent developments in the Physics.
2. The practical course is designed in consequence with the theory courses to expand the understanding of the several concepts in Physics.
3. It is predicted to inspire and improve interest of the students in Physics
4. To grow the power of appreciations, the successes in science and part in society and nature.
5. To develop student sense in recent research areas.

Program Specific Outcomes:

PSO No.	PSO Statement
PSO-1	Understand the basics and advances of Physics
PSO-2	Study, plan and perform experiments in the labs to prove the ideas, values and theories learned in the classrooms
PSO-3	Improve scientific knowledge in Physics
PSO-4	Classify their area of attention in academic, research and development.
PSO-5	Perform job in various fields like science, engineering, education, banking, business and public service, etc. or be an entrepreneur with precision, analytical mind, innovative thinking, clarity of thought, expression, and systematic approach.

Duration: Two year full time.

Pattern: Semester examination.

Medium of Instruction: English.

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

Level	Semester	Course Code	Course Title	No. of hours Per Week	Credits
6	I	MPT 411	Mathematical Methods in Physics	4	4
		MPT 412	Classical Mechanics	4	4
		MPT 413	Quantum Mechanics-I	4	4
		MPT 414 E-I MPT 414 E-II DSE (Elective: Any one among two)	E-I: Atomic and Molecular Physics E-II: Optoelectronics and Photonics	2	2
		MPT415	Research Methodology	4	4
		MPP 416	Practical-I: LAB- I	4	2
		MPP 417	Practical-II: LAB- II	4	2
Total					**22**

Structure of Course: M.Sc. – I Semester – II

Level	Semester	Course Code	Course Title	No. of hours Per Week	Credits
6	II	MPT 421	Quantum Mechanics II	4	4
		MPT 422	Statistical Mechanics	4	4
		MPT 423	Solid State Physics-I (Physical Properties of Solids)	4	4
		MPT 424 E-I MPT 424 E-II DSE (Elective : Any one among two)	E-I: Condensed Matter Physics E-II: Laser Physics	2	2
		MPP 425	Research Projects	8	4
		MPP 426	Practical-III: LAB- III	4	2
		MPP 427	Practical-IV: LAB- IV	4	2
Total					**22**

SEMESTER I
MPT 411: MATHEMATICAL METHODS IN PHYSICS

Course Objectives: student should be able to:

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

Credits 4	**SEMESTER-I** **MPT 411: Mathematical Methods in Physics**	**No. of hours per unit**
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, Cayly Hamilton 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.	

Course Outcomes: After completion of syllabus, student will be able to:

1. define Inner product, direct product, Diagonal matrices, trace, matrix Inversion
2. perform Complex Algebra, Conjugate Complex Numbers and their sum, Difference, Product and quotient.
3. solve the complex Calculus problems of Residues-Residues Theorem.
4. analyse and apply Fourier transform and inversion theorem.

Reference Books:

1. Arfken and Weber, *Mathematical Methods For Physicists* (New York: Academic Press, 2005)

2. S R K Iyengar, R K Jain, *Mathematical Methods* (New Delhi: Narosa Publishing House, 2006)

3. B. S. Rajput, *Mathematical Physics*, (Meerat: Pragati Prakashan, 1999)

4. K F Riley, M P Hobson and S J Bence, *Mathematical Methods for Physics and Engineering* (Cambridge: Cambridge University Press, 1997)

5. M. L. Bose, *Mathematical Methods of physical science* (New Jersey: Wiley Publications, 1983)

MPT 412: Classical Mechanics

Course Objectives: student should be able to:

1. understand the laws of rotational motion, two body central force and Rutherford scattering.
2. learn Lagrangian equation of motion, Jocobi integral, energy conservation and concept of symmetry.
3. know Hamilton's formulation and Variational principle
4. study Canonical Transformation and Poisson Brackets

Credits 4	**SEMESTER-I** **MPT 412: Classical Mechanics**	**No. of hours per unit**
UNIT I	**Rotational 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, central analysis of orbit, Rutherford scattering: Scattering formulae, Different scattering cross section	
UNIT II	**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, Jacobi integral and energy conservation ,concept of symmetry, invariance under Galilean transformation, velocity dependent potential.	
UNIT III	**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, shortest distance problem , Brachistochrone problem, Geodesics of a Sphere.	
UNIT IV	**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 canonical transformation.	

Course Outcomes: After completion of syllabus, student will be able to:

1. define inertial forces, Larmour precision, carioles for forces

2. identify generalized coordinates, momenta, cyclic coordinates and utilize Lagrangian formulation
3. describe and apply Hamilton's formulation, variational Principle and Euler's equation.
4. utilize Poisson Brackets, Identities, Poisson theorem, Jacobi- Poisson Brackets, Jacobi Identity for canonical transformation

Reference Books:

1. H. Goldstein, *Classical mechanics* (Publisher , Narosa Pub. House:2001).
2. Narayan Rana, Pramod Joag, *Classical mechanics(*Publisher *.McGraw Hill Edu:*2017).
3. R Takwale, P Puranik, *Introduction to classical mechanics* (Publisher : McGraw Hill Edu.1st edition 2017).
4. J. C. Upadhyaya, *Classical Mechanics* (PublisherH :imalaya Publishing House 2022).

MPT 413: Quantum Mechanics- I

Course Objectives: student should be able to:

1. understand ket and bra spaces, inner products, operators and uncertainty relations.
2. learn Schrödinger wave equation and commutation relations.
3. study Eigen values and Eigen functions of L_2 and Lz operators, Ladder operators , Paulli theory of spins.
4. know perturbation theory, Eigen values and Eigen functions.

Credits 4	**SEMESTER-I** **MPT 413: Quantum Mechanics- I**	**No. of hours per unit**
UNIT I	**Fundamental Concepts and Formalism**	**(15)**
	Why Q.M? Revision; 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 L2 and Lz operators, Ladder operators L+ and L- , Paulli Theory of spins (Paulli's Matrices), angular momentum as a generator of infinitesimal rotations, Matrix representation of Jinljm> basis. Addition of angular momenta, Computation of Clebsch-Gordon Coefficients in simple cases (J1=1/2, J_2=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).	

Course outcomes: After completion of syllabus, student will be able to:

1. define ket and bra spaces and inner products and operators
2. solve Schrödinger wave equation - one dimensional problems, well and barriers.
3. compute Clebsch-Gordon Coefficients in simple cases (J1=1/2; J2=1/4).
4. find Eigen value of energy and Eigen function in the first order approximation.

Reference Books:

1. J. J. Sakurai, Jim Napolitano, *Modern Quantum Mechanics* (Publisher: Cambridge University Press; 3rd edition, 2020).
2. David J. Griffiths, Darrell F. Schroeter, *Introduction to Quantum Mechanics* (Publisher: Cambridge University Press; 3rd edition, 2018).
3. N Zettili, *Quantum Mechanics concept and application* (Publisher ; Wiley India Pvt. Ltd: 2nd edition, 2016).
4. P M Mathews, K Venkatesan, *A Textbook of Quantum Mechanics* (Publisher: McGraw Hill Education; 2nd edition, 2017).

MPT 414 E-I: Atomic and Molecular Physics

Course Objectives: student should be able to:

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

Credits 2	**SEMESTER-I** **MPT 414 E-I: Atomic and Molecular Physics**	**No. of hours per unit**
UNIT I	**Vector atom model for two valence electron system**	**(7)**
	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, -factors for LS coupling, Lande interval rule, jj-coupling and -factors for jj coupling, Selection rules for LS and jj coupling	
UNITII	**Zeeman Effect, Paschen-Back effect and Stark effect**	**(8)**
	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	
UNIT III	**Rotational Spectroscopy**	**(7)**

	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	
UNIT IV	**Vibrational spectroscopy**	**(8)**
	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	

Course outcomes: After completion of syllabus, student will be able to:

1. describe and use ll, ss, jj, LS or Russiel Sounder's coupling for solving numericals.
2. analyse Zeeman effect for two-electrons, Paschen-Back effect for two-electrons,
3. discuss and draw rotational of diatomic molecules chemical.
4. differentiate between rotational and vibrational spectroscopy.

References:

1. H. E. White, *Introduction to Atomic Spectra (*Publisher:McGraw Hill Edu., 2019*).*
2. Raj Kumar, *Atomic and Molecular Physics,* (Publisher: Campus Books International 2013).
3. S.N. Ghoshal, *Atomic Physics (Modern Physics)* (Publisher: S Chand & Company 2010).
4. S P Kuila, *Concepts of Atomic Physics* (Publisher:) New Central Book AgencyNCBA),1st Edition 2017).

MPT 414 E-II: Optoelectronics and Photonics

Course Objectives: student should be able to:

1. understand concepts of light emitting materials.
2. study different modulators and electro-optic devices.
3. know principle of optical fibers and their types.
4. learn second, third order non linear optical media and concepts of optical digital computer

Credits 2	**SEMESTER-I** **MPT 414 E-II: Optoelectronics and Photonics**	**No. of hours perunit**
UNIT I	**Optoelectronic devices**	**(7)**
	Photoconductivity, Light dependent resistor, photodiode, phototransistor, solar cell, metal semiconductor detector, Liquid crystal display, charged coupled devices, light emitting diode Laser diode: Spontaneous and stimulated emission, laser structures, time response of lasers, advanced	

	semiconductor laser structures, temperature dependence of laser output. PIN photodiode, Avalanche photodiode, Heterojunction photodiode,	
UNITII	**Optoelectronic modulators**	**(8)**
	Polarization of Light, Elliptical polarization, Optics of anisotropic media: The index ellipsoid, Birefringence, Optical activity, Electro-optic effect, Electro-optic modulators, Acousto-optic modulators, use of optoelectronic modulator, Kerr modulator- Kerr effect, Magneto-optic modulator – Faraday effect, Acousto-optic effect, Electro-optic Devices: Wave retarders, rotators and optical isolators	
UNIT III	**Fiber optics**	**(7)**
	Basic characteristics and ray propagation in an optical fibers, Step –index and graded-index fibers, Multipath dispersion, pulse dispersion, material dispersion, combined effect of multipath and maerial dispersion, rms pulse width. Modes In planar waveguides – TE modes of a symmetric step-index planar waveguide, power distribution and confinement factor, wave propagation in a cylindrical wave guide, single mode fiber and its characteristic parameters, dispersion and attenuation in SMF, Optical fiber cable and connections, Dispersion compensation mechanism	
UNIT IV	**Non-linear Optics**	**(8)**
	Non-linear optical media, second order non-linear optics-SHG, Three wave mixing. Third order non-linear optics, THG and self-phase modulation, Coupled wave theory of three-wave mixing. Four wave mixing and Optical Phase conjugation. Frequency conversion, Parametric Amplication and Oscillation.	

Course outcomes: After completion of syllabus, student will be able to:

1. describe concepts of photodiodes, LEDs based displays
2. explain electro-optic and magneto-optic phenomenon’s and devices based on it
3. analyse principle of optical fibers, analog and digital fiber optic communication system
4. utilize second, third order non linear optical media for the concepts of optical digital computer and optical switches.

References:

1. Jixiang Yan, Tsinghua University Press, *Optical Electronics: An Introduction* (De Gruyter Textbook, 2019).
2. Ajoy Ghatak, Optical Electronics (Publisher: **(Cambridge India, 2017**.
3. Tetsuzo Yoshimura, *Optical Electronics: Self-Organized Integration and Applications* (Publisher: **Pan Stanford Publishing Pte Ltd; 1**st edition, 2012).

MPT 415: Research Methodology

Course Objectives: student should be able to: -

1. understand fundamentals of research methods
2. learn design and measurement concepts of research
3. know data collection and analysis tools
4. get knowledge of scientific report writing

Credit 4	**SEMESTER-I** **MPT 415: Research Methodology**	**No. of hours per unit**
UNIT I	**Fundamentals of Research Methods**	**(15)**
	Definition of research, Research ethics and morality, Role and objectives of research, Applications and types of research, Research process and steps in it, Collecting and reviewing the literature, Conceptualization and Formulation of: research problem, identifying variables, constructing hypothesis and Synopsis.	
UNIT II	**Research Design and Measurement Concepts**	**(15)**
	Selecting and defining a research problem, Need for research design, Features of a good research design, Different research designs, Scales of measurements, Nominal, Ordinal, Internal and ratio scales, Errors in measurements, Validity and Reliability in measurement, Scale Construction Techniques.	
UNIT III	**Literature Searching**	**(15)**
	Search engines, database, science direct, Scifinder, Scopus, Web of science, INFLIBNET, Research Matrices: Citation index, H index, Impact factor, i10 index, etc. Plagiarism: introduction, types and awareness, detection tools	
UNIT IV	**Review Writing**	**(15)**
	Discussions, Conclusion, referencing and various formats for reference writing, Review writing, Use of Mandalay software, Bibliography, Thesis Writing, Formats of publications in research journals	

Learning outcomes: After completion of syllabus, student will be able to:

1. explain fundamental methods of research
2. evaluate, design and measure the concepts of research
3. differentiate different research matrices
4. write scientific report

Reference:

1. Kothari C.R., "*Research Methodology, Methods and Techniques*" (Second revised edition, New Age International Publication, 2004).
2. Saravanavel P., *"Research Methodology*" (Kitab Mahal, Sixteenth edition, 2007).
3. Ranjit Kumar, *"Research Methodology, a step-by-step guide for beginners*" (Pearson education Australia, Second edition 2005).
4. Mark Saunders, Philip Lewis, Adrain Thornhiu, "*Research Methods for Business Students"* (Pearson Education ltd, Seventh edition, 2016)

MPP 416: Practical I: LAB I

Course Objectives: student should be able to:

1. Determine conductivity
2. Understand concept of stair case ramp generator
3. Determine frequency response of negative feedback amplifier
4. Understand concept of astable multivibrator

Credits 2	SEMESTER-I	No. of hours
	MPP 416: LAB I	**(60)**
	1. Conductivity measurement 2. Staircase Ramp Generator 3. Negative Feedback Amplifier 4. Astable Multivibrators 5. Monostable Multivibrators 6. Stefan's Constant using dimmerstat 7. Planks Constant 8. Intensity measurement by Lux meter 9. Hall Effect 10. L.V.D.T. 11. Fabry-Parrot etalon 12. Lattice Dynamics 13. A.C. Bridges 14. Photocatalytic dye degradation of a given sample (2 days)	

Course outcomes: After completion of syllabus, student will be able to:

1. calculate the heat capacity value of given material
2. demonstrate the concept of stair case ramp generator using CRO
3. determine frequency response of negative feedback amplifier using CRO
4. illustrate the Astable multivibrator using IC 555

MPP 417: Practical II: LAB II

Course Objectives: student should be able to:

1. Determine Stefan's constant

2. Understand concept of Simpson's 1/3 Rule
3. Determine Numerical Integration using Runge–Kutta method
4. Understand concept Numerical differentiation using Newton Raphson method

Credits 2	**SEMESTER-I**	**No. of hours**
	MPP 417: LAB II	**(60)**
	1. Neutron Diffraction 2. Study and verify Simpson's 1/3 Rule for Numerical Integration 3. Study and verify Simpson's 3/8 Rule for Numerical Integration 4. Study and verify the trapezoidal Rule for Numerical Integration 5. Study and verify the Runge–Kutta method for Numerical Integration 6. Numerical differentiation using Bisection method 7. Numerical differentiation using Secant method 8. Numerical differentiation using Newton Raphson method 9. Crystal structure of thin film 10. B-H Curve 11. Temperature Transducer 12. Fourier analysis 13. Stefan's constant using Black body radiation 14. Michelson's Interferometer- Refractive index of glass plate using virtual lab 15. Verification of Beer-Lambert's law using virtual lab	

Course outcomes: After completion of syllabus, student will be able to:
1. calculate area using B-H Curve of given material
2. demonstrate the concept of Beer-Lambert's law
3. determine numerical integration using trapezoidal rule
4. illustrate neutron diffraction

SEMESTER II
MPT 421: QUANTUM MECHANICS-II

Course Objectives: student should be 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. learn scattering theory.
4. know Semi classical theory of radiation and Selection rules.

Credits 4	SEMESTER-II MPT 421: Quantum Mechanics-II	No. of hours perunit
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	

Course Outcomes: After completion of syllabus, student will be able to:

1. discuss Stark effect and Fermi's Golden rule.
2. solve the problems of hydrogen atom.
3. analyse Low energy scattering and bound state, Resonance scattering, Scattering by hard sphere, Coulomb scattering.
4. describe the electric dipole and forbidden transitions and selection rules.

Reference Books:

1. J. J. Sakurai, Jim Napolitano, *Modern Quantum Mechanics*, (Publisher: Cambridge University Press; 3rd edition, 2020).
2. David J. Griffiths, Darrell F. Schroeter, *Introduction to Quantum Mechanics*, (Publisher: Cambridge University Press; 3rd edition, 2018).
3. N Zettili, *Quantum Mechanics concept and application*, (Publisher ; Wiley India Pvt. Ltd: 2nd edition, 2016).
4. P M Mathews, K Venkatesan, *A Textbook of Quantum Mechanics*, (Publisher: McGraw Hill Education; 2nd edition, 2017).

MPT 422: Statistical Mechanics

Course Objectives: student should be 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. know MB, BE and FD distributions and free electron theory of metals.
4. learn first and second order phase transitions.

Credits 4	**SEMESTER-II** **MPT 422: Statistical Mechanics**	**No. of hours perunit**
UNIT I	**Introduction of Statistical Mechanics and thermodynamics**	**(15)**
	Specification of state of system, Macroscopic and microscopic states, phase space, Γ space, μ 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 Course)	

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 phase transition), The critical indices.	

Course Outcomes : After completion of syllabus, student will be able to:

1. define specification of state of system, Macroscopic and microscopic states, phase space.
2. distinguish between Micro canonical, Ensemble Canonical Ensemble and Grand Canonical
3. distinguish between MB, BE and FD distributions
4. discuss phase transitions, conditions for phase equilibrium, First order Phase Transition, Second order phase transition.

Reference books:

1. B. B. Laud, Fundamentals of Statistical Mechanics (New Age International Private Limited Publisher, 2020) 47-200.
2. L. D. Landau, Statistical Physics (Butterworth-Heinemann Publisher, 1996) 158-183.
3. F. Reif, Fundamentals of Statistical and Thermal Physics (Waveland Press Publisher, 2010) 48-60.
4. S. K. Sinha, Introduction to Statistical Mechanics (Narosa Publisher, 2009) 202-348.
5. A. K. Saxena, Introduction to Statistical Mechanics (New Delhi, Narosa Publishing House Pvt. Ltd. Publisher, 2016) 52-102.

MPT 423: Physical Properties of Solid

Course Objectives: student should be able to:

1. understand the Drude model and DC electrical conductivity.
2. study Transport Properties of Metals like Sommerfeld theory of electrical conductivity, The mean free path in metals, Thermal scattering and thermal conductivity of metals.
3. know Phonons, Plasmons, Polaritons, and Polarons
4. learn magnetic properties of materials

Credits 4	SEMESTER-II MPT 423: Physical Properties of Solid	No. of hours per
UNIT I	Theory of metals	(15)
	Basic assumptions of Drude Model, Collision or relaxation times, DC electrical conductivity, Ground state properties of electron gas, Sommerfeld theory of metals, Failures of the free electron model. Band theory of solid, Brillouin zones Electron Levels in a Periodic Potential : Introduction, The tight-binding method, Linear combinations of atomic orbitals, Application to bands from s-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, Pseudopotentials	
UNIT II	**Transport Properties of Metals**	**(15)**
	Some features of the electrical conductivity of metals, A simple model leading to a steady state, Drift velocity and relaxation time, The Boltzmann transport relation, The Sommerfeld theory 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 III	**Phonons, Plasmons, Polaritons, and Polarons**	**(15)**
	Vibrations of monatomic lattices: first Brillouin 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 IV	**Magnetic Properties of Materials**	**(15)**
	Introduction, Magnetic permeability, Magnetisation, Electric current in atoms-Bohr magnetron, Electron spin and magnetic moment due to nuclear spin, Langevin's with experiment classical theory of paramagnetism, Weiss theory of paramagnetism, quantum theory of paramagnetism, Comparison of theory with experimental results, 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	

Course Outcomes: After completion of syllabus, student will be able to:

1. describe Drude Theory of metals and Basic assumptions of Model, Collision or relaxation times, DC electrical conductivity
2. discuss steady state, Drift velocity and relaxation time
3. analyse Quantization of lattice vibrations, Phonon momentum
4. explain the structure of ferrite, the saturation magnetization and elements of Neels theory

Reference Books:

1. Ashcroft, Neil W., and N. David Mermin. 2003. *Solid state physics*.(Units 1pp. 1 to 304,II pp.534-643)
2. Kittel, Charles, and Paul McEuen. 2019. *Introduction to solid state physics*. Hoboken, NJ: John Wiley & Sons. (Units 3pp. 89-640)
3. Dekker, Adrianus J. 1981. *Solid State Physics*.(Units 1pp. 3-299, II pp. 395-397)
4. Pillai, S. O. 2018. *Solid state physics*.(Units 1pp.293-700, II pp. 427-485)
5. Saxena, B. S., R. C. Gupta, and P. N. Saxena. 1993. *Fundamentals of solid state physics*. Meerut:Pragati Prakashan.(Units IV pp.351-397)

MPT 424 E-I: Condensed Matter Physics – I

Course Objectives: student should be able to:

1. study crystal growth and imperfections in crystals.
2. understand dielectricity, ferroelectricity and its consequences.
3. learn ferromagnetism and Antiferromagnetism its applications.
4. know semiconducting and Superconducting Properties of materials.

Credits 2	SEMESTER-II MPT 424 E-I: Condensed matter Physics – I	No. of hours per unit
UNIT I	**Crystal growth and Imperfections in crystals**	(7)
	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 Colour centers- Production of colour centres- line defects- Dislocations- Edge and Screw dislocations- Burger Vector- Estimation of dislocation densities- Mechanism of creep	
UNITII	**Dielectrics**	(8)
	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.	
UNIT III	**Ferromagnetism**	(7)
	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.	

UNIT IV	Semiconducting Properties	(8)
	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.	

Course outcomes: After completion of syllabus, student will be able to:

1. discuss concept of crystal growth.
2. analyse Langevin's theory and measurement of dielectric constant.
3. describe two sub lattice model of anti- ferromagnetism.
4. explain BCS theory of superconductivity

Reference Books:-

1. Saxena and Gupta, Fundamentals of Solid State Physics (Meerut, Pragati Publications, 2016) 355-437.
2. M.A.Wahab, Solid State Physics (Narosa Publisher, 2009) 150-558.
3. C. Kittle, Introduction to Solid State Physics (Wiley Publisher, 1979) 257-482.
4. R. K.Puri and V. K. Babbar, Solid State Physics (S. Chand Publication, 2010) 88-122.
5. A. J. Dekker, Solid State Physics (Laxmi Publisher, 2008) 132-430.

MPT 424 E-II: Laser Physics

Course Objectives: student should be able to:

1. understand principles of lasing action.
2. study different types of resonators.
3. know switching phenomenon’s.
4. learn different laser systems

Credits 2	SEMESTER-II MPT 424 E-II: Laser Physics	No. of hours per unit
UNIT I	Basic Laser Principle and Laser System	(8)
	Summary of black body radiation, Quantum theory for evaluation of the transition rates and Einstein coefficients-allowed and forbidden levels-metastable state; population inversion; rate equations for three level and four level lasers, threshold of power calculation, various broadening mechanism, homogeneous and inhomogeneous broadening. **Basic Laser System**: Basic concept of construction of laser system, various pumping system, pumping cavities for solid state laser system, characteristics of host materials and doped	

	ions	
UNITII	**Optical beam propagation and Resonators**	**(7)**
	Paraxial ray analysis, wave analysis of beams and resonators, propagation and properties of Gaussian beam, Gaussian beam in lens like medium, ABCD law-Gaussian beam focusing **Resonators:** Stability of resonators-‘g’ parameter, various types of resonators, evaluation of beam waist of such combination, design aspect of resonator for various types of lasers, unstable resonator and their application	
UNIT III	**Q-switching and Ultrafast Phenomenon**	**(8)**
	Giant pulse theory, different Q-switching techniques: mechanical Q-switching, electrooptic Q-switching, acoustooptic Q-switching, dye Q-switching, Raman-Nath effect. Ultrafast Phenomenon: Principle of generation of ultrafast pulses (mode locking), basic concepts for measurement of fast processes, Streak technique, Stroboscopy, sampling technique, nonlinear optical methods for measuring ultrashort pulses	
UNIT IV	**Different laser systems**	**(7)**
	Gas Lasers: (i) Molecular gas lasers- CO_2 laser & N_2 (ii) ionic gas laser – Ar+ laser (iii) gas dynamic laser (iv) high pressure pulsed gas laser Solid State Laser: (i) Nd:YAG laser, (ii) Nd:Glass laser, comparison of performances (iii) Tunable solid state laser: Ti:sapphire laser; Alexandrite laser Chemical Laser: HF laser, HCl laser, COIL Excimer laser; Color centre laser; Free electron laser; semiconductor diode laser	

Course outcomes: After completion of syllabus, student will be able to:

1. utilize fundamental concepts related to pumping systems, metastable state, population inversion and stimulated emission.
2. design different aspects of resonator for various types of lasers
3. discuss Q switching and ultrafast phenomenon’s
4. explain lasing action in different types of lasers like CO_2, N_2, Nd:YAG etc.

References:

1. M. Singh, *Lasers: Theory*, *Principles and Applications (*Publisher: Vei; 1st edition,2012).
2. K.R. Nambiar, *Lasers: Principles*, *Types and Applications* (Publisher: New age publishers; 1st Edition, 2004).
3. William S. C. Chang, *Principles of Lasers and Optics* (Publisher: Cambridge University Press 2007).

MPT-425 Research Project

Credits 4	**MPT-425 Research Project**	**No. of hours 120**

MPP 426: Practical III: LAB III

Course Objectives: student should be able to:

1. Measure Young's modulus
2. Measure thermal and electrical conductivity of copper
3. Understand concept of passive filters
4. Understand concept of magnetic susceptibility

Credits 2	SEMESTER-II MPP 426: LAB III	No. of hours
	MPP 426: LAB III	(60)
	1. Young's modulus 2. To study the shape of the LASER beam: divergence angle, cross-section and to evaluate beam spot 3. Passive filters 4. Thermal and electrical conductivity of copper 5. Mutual inductance of coil 6. Band gap energy 7. Series and parallel resonant circuits 8. LDR 9. Resistivity by four Probe 10. To determine the diameter of lycopodium powder using LASER beam 11. Dissociation energy of iodine molecule 12. Rydberg constant 13. Magnetic susceptibility of ferric chloride solution 14. pH effects on absorption spectra: pKa determination by spectrophotometric method using virtual lab 15. Basics of Scanning Electron Microscopy: Secondary Electron and BSE imaging mode using virtual lab	

Course outcomes: After completion of syllabus, student will be able to:

1. measure Young's modulus.
2. measure Band gap energy of given material
3. demonstrate concept of passive filters
4. demonstrate working of Series and parallel resonant circuits

MPP 427: Practical IV: LAB IV

Course Objectives: student should be able to:

1. Measure Stark energy and Stark splitting using Scilab
2. Measure scattering angle of Rutherford scattering using Scilab
3. Understand concept of de Broglie wavelength of a particle using Python

4. Understand concept of radius of an electron's orbit in a hydrogen atom using Python

Credits 2	**SEMESTER-II** **MPP 427: LAB IV**	**No. of hours**
	MPP 427: LAB IV	**(60)**
	1. Calculate Zeeman energy and Zeeman splitting using Scilab 2. Calculate Stark energy and Stark splitting using Scilab 3. Calculate fine structure energy and Paschen Back splitting using Scilab 4. Calculate the resonance frequency of electron spin resonance using Scilab 5. The scattering angle of Rutherford scattering using Scilab 6. Calculate the energy levels of an electron in a hydrogen atom using Scilab 7. Calculate spin angular momentum using Scilab 8. Calculate the energy of a photon given its frequency using Python 9. Calculate the de Broglie wavelength of a particle using Python 10. Calculate the uncertainty in position given the uncertainty in momentum using Python 11. Calculate the energy levels of an electron in a hydrogen atom using Python 12. Calculate the wave function of a particle in a one-dimensional box using Python 13. Calculate the kinetic energy of ejected electrons using Python 14. Calculate the radius of an electron's orbit in a hydrogen atom using Python 15. Calculate the maximum number of electrons in a shell using Python	

Course outcomes: After completion of syllabus, student will be able to:

1. measure Zeeman energy and Zeeman splitting using Scilab
2. measure energy levels of an electron in a hydrogen atom using Python
3. demonstrate concept of kinetic energy of ejected electrons using Python
4. demonstrate concept of maximum number of electrons in a shell using Python

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