M.Sc. (Physics) curriculum

Semester- wise structure of the programme

First Semester

Sl.No.	Course Name	L	T	P	Credits
1	Classical Mechanics	3	1	0	4
2	Electronics	3	1	0	4
3	Mathematical Physics-I	3	1	0	4
4	Quantum Mechanics-I	3	1	0	4
5	Computational Methods in Physics	3	0	0	3
6	Computational Methods in Physics Laboratory	0	0	2	1
7	Electronics Laboratory	0	0	9	4
	Total Credits				24

Second Semester

Sl.No.	Course Name	L	T	P	Credit
1	Thermodynamics and Statistical Mechanics	3	1	0	4
2	Quantum Mechanics-II	3	1	0	4
3	Mathematical Physics-II	3	1	0	4
4	Condensed Matter Physics-I	3	1	0	4
5	Electrodynamics-I	3	1	0	4
6	General Physics Laboratory	0	0	9	4
	Total Credits				24

Third Semester

Sl.No.	Course Name	L	T	P	Credit
1	Atomic and Molecular Physics	3	1	0	4
2	Nuclear and Particle Physics	3	1	0	4
3	Condensed Matter Physics-II	3	1	0	4
4	Electrodynamics-II	3	1	0	4
5	Advanced Statistical Mechanics	3	1	0	4
6	Master’s Project (Part I)	0	0	2	2
	Total Credits				22

Fourth Semester

Sl.No.	Course Name	L	T	P	Credit
1	Program Elective-I	3	0	0	3
2	Program Elective-II	3	0	0	3
3	Open Elective -I	3	0	0	3
4	Open Elective- II	3	0	0	3
5	Solid State Material Characterization Laboratory	0	0	9	4
6	Master’s Project (Part II)	--	--	--	6
	Total Credits				22

Possible Program Elective Courses

Sl.No.	Course Name	L	T	P	Credit
1	Introduction to Quantum Field Theory	3	0	0	3
2	Introduction to Quantum Many-Body Theory	3	0	0	3
3	Introduction to Special and General Relativity	3	0	0	3
4	Physical Cosmology	3	0	0	3
5	Phase Transitions in Materials	3	0	0	3
6	Introduction to Material Science and Engineering	3	0	0	3
7	Experimental Techniques for Material Characterization	3	0	0	3
8	Applied Optics	3	0	0	3
9	Group Theory	3	0	0	3
10	Advanced Computational Physics	3	0	0	3

Possible Open Elective Courses from the Department of Physics

Sl.No.	Course Name	L	T	P	Credit
1	Organic Electronics and Optoelectronics	3	0	0	3
2	Medical Physics	3	0	0	3
3	Renewable Energy: Science & Engineering	3	0	0	3
4	Nonlinear dynamics and Chaos	3	0	0	3
5	Quantum Computing and Quantum Information	3	0	0	3
6	Introduction to Molecular Modelling and Simulation	3	0	0	3

Course Information File (CIF) of core courses of the proposed M.Sc. Curriculum

Classical Mechanics

Programme: M.Sc. (Physics).	Year: 1st	Semester : 1
Course : Core	Credits : 4	Hours (LTP): 40+12+0

Course Context and Overview (100 words):

Students will learn to use the Lagrangian and Hamiltonian formulations of Classical Mechanics. This is a standard course which is the bedrock of Physics.

Prerequisites Courses: None

Course outcomes(COs):

On completion of this course, the students will have the ability to:
CO1 Use mathematical and physical principles to describe the laws governing classical mechanics.
C02 Use the Lagrangian formulation to describe and understand the dynamics of particles.
C03 Use the Hamiltonian formulation to describe and understand the dynamics of particles
C04 Use the Lagrangian and Hamiltonian formulations to describe and understand the Central Force problem
C05 Acquire and use the knowledge of the Special Theory of Relativity and Four Vectors

Course Topics:

Units	Lectures
Introduction, Mechanics of a Particle, Mechanics of a System of Particles, Degrees of freedom, generalized coordinates and velocities. Lagrangian action principle, Techniques of the Calculus of Variations, Euler-Lagrange equations. Constraints. Applications of the Lagrangian formalism. Generalized momenta, Hamiltonian, Hamilton's equations of motion. Legendre transform, relation to	14

Lagrangian formalism. Phase space, Phase trajectories. Applications to systems with one and two degrees of freedom. Conservation of linear momentum, energy and angular momentum.	
Central force problem, Kepler problem, bound and scattering motions. Scattering in a central potential, Rutherford formula, scattering cross section. Noninertial frames of reference and pseudoforces: centrifugal Coriolis and Euler forces.Elements of rigid-body dynamics. Euler angles. The symmetric top. Small oscillations Normal mode analysis. Normal modes of a harmonic chain.	12
Elementary ideas on general dynamical systems: conservative versus dissipative systems. Hamiltonian systems and Liouville's theorem. Canonical transformations, Poisson brackets. Action-angle variables. Non-integrable systems and elements of chaotic motion.	10
Special relativity: Internal frames. Principle and postulate of relativity. Lorentz transformations.Length contraction, time dilation and the Doppler effect. Velocity addition formula. Four- vector notation. Energy-momentum four-vector for a particle. Relativistic invariance of physical laws.	4

In addition to the lecture hours mentioned there will also be tutorials.

Textbook references (IEEE format):

Text Book:

Classical Mechanics by H. Goldstein, C. Poole and J. Safko

Reference books:

The Classical Theory of Fields by L. Landau and E. Lifshitz.
Introduction to Dynamics, Percival and D. Richards, Cambridge University Press (1987) [Chapters 4, 5, 6, 7 in particular. also parts of Chapter 1-3, 9, 10].
Special Theory of Relativity, D. Rindler, Oxford University Press (1982).

Electronics

Programme: M.Sc. Physics. **Year**: 1^{st} **Semester** : Ist
Course : core **Credits** : 4 **Hours (LTP):** 40+12+0

Course Context and Overview (100 words):

The objective of the course is to provide students with an in-depth understanding of fundamental principles of electronics devices and their applications.

Prerequisites Courses: None

B.Sc, (PCM or PEM group), B.Tech (ECE, CSE)

Course outcomes(COs):

On completion of this course, the students will have the ability to:
CO1 : Should be able to get knowledge about the fundaments of semiconductors and devices and their applications in different electronic devices and circuits.
CO2 : Fundamental knowledge of amplifies, feedback systems and oscillators
CO3 Should able to get understanding about the concept of operational amplifier and its various applications in different applications
CO4: Should be able to analyze the digital Electronics to be used in electronics
CO5 : Basic information about Communication electronics

Unit 1 Electronic devices (10 L)

Advanced electronic Devices: Brief introduction of Semiconductors Schottky Diodes, Semiconductor diodes, Zener diodes, tunnel diodes and their applications, BJT Transistors and its operation and characteristics, biasing and stabilization, Transistor hybrid model, Analysis of a transistor amplifier circuit using h-parameter, characteristics of Junction Field effect transistors, biasing of JFETs, Idea of metal oxide semiconductor JFETs and applications, Optoelectronic diodes, LED and solar cells, Power supplies (including rectifier and filter circuits) and regulators.

Unit 2 Feedback amplifiers and Oscillators (8 L)

Classification of amplifiers, Concept of feedback, General characteristics of negative and positive feedback, Oscillator principle, Barkhausen criterion, Colpitt's and Hartley oscillators, RC oscillator, Wein Bridge Oscillaltor, RC phase shift oscillator, Multivibrators, astable, monostable and bistable multivibrator, Square, triangle wave generators and pulse generators

Unit 3 Operational Amplifiers (6 L)
Differential amplifier - circuit configurations - dual input, balanced output differential amplifier, DC analysis, CMRR-constant current bias level translator. Block diagram of OP-Amp and analysis. inverting and non-inverting amplifiers, Op-Amp with negative feedback, voltage series feedback, effect of feed back on closed loop gain, input resistance, bandwidth and output offset voltage, voltage follower. Practical Op-Amp, input offset voltage-input bias current-input offset current, total output offset voltage, Integrator and differentiator using Op-AMP.

Unit 4 Digital Electronics (8 L)

Basic logic gates, Boolean algebra, combinational logic gates, digital comparators, Flip flops, shift registers, counters, Analog to digital converters and vice-versa, Adder (half and full), substractor (half and full), multiplexer/demultiplexer, decoder and end-coders, SR, JK master slave filp flop, synchronous, asynchronous counters, serial to parallel vice-versa, universal shift registors, ring counter. Priority Encoders, Decoder / Drivers for display devices, Seven Segment display device. ROM, Programmable Logic Array, Introduction of Microprocessors and microcontrollers

Unit 5 communication (8 L)

Fundamental of communication Electronics, Analog communication (AM, FM, PM), AM and AM transmitters, Demodulation fundamentals and circuits, Radio Receivers, digital communication, Concept of Transmission lines, Optical communication, Radar and microwave communications.

Text books

1. J. Millman and C.C. Hallkias, *Integrated Electronics*. Tata McGraw Hill.
2. Robert L., Boylsted and Louis Nashelsky, *Electronic Devices and Circuits*. PHI, New Delhi
3. A.P. Malvino and Donald P. Leach, *Digital Principle and Applications*, Tata McGraw Hill Company, New Delhi, 1993.
4. Ramakanth, A. Gayakwad *OP-AMP and Linear Integrated Circuits*, PHI, Second Edition 1991.
5. G. Kennedy and B. Davis *Electronic communications*:, Tata McGraw Hill

Reference books

1. Theodore F. Bogart, *Electronic Devices and Circuits*
2. Manuel Cardona and Peter Y. Yu, Springerlink Charles M. Gillmore, *Fundamentals of Semiconductors, Microprocessors: Principles and applications*, Tata McGraw Hill Publishing
3. William D. Stanley, *Operational Amplifiers with Linear Integrated Circuits.*

Mathematical Physics-I

Programme: M.Sc. (Physics) Year: 1st year Semester : 1st semester
Course : Core Course Credits : 4 Hours (LTP): 40+12+0

Course Context and Overview:
Importance of mathematics in the formulation of physics is well known. This course introduces the students to some of the basic and most frequently used mathematical tools in physics. These tools find applications in almost all areas of physics from classical mechanics to electrodynamics to quantum mechanics.

Prerequisite Courses:
Basic knowledge of calculus, coordinate geometry, complex numbers etc.

Course outcomes(COs):

On completion of this course
CO1: Students will acquire an understanding of the concept of linear vector spaces and they should be in a position to use the concept and techniques in various areas of physics like quantum mechanics.
CO2: Students will have an understanding of generalized (curvilinear) coordinate systems and tensors and they should be able to use the tensorial concepts to solve problems in various areas of physics like electrodynamics. This will also be a first step towards the more advanced topics like General Relativity.
CO3: Students will be able to use Fourier series as a basic tool of analysis in almost all branches of physics.
CO4: Students would have an appreciation for the most commonly occurring ordinary differential equations in physics and the methods for solving them.
CO5: Students would be able to understand how various special functions arise in different physical problems and use their knowledge to analyze these problems using special functions.

Course Topics:

Topics	Lectures+Tutorials
Linear vector spaces: Definition, bra-ket notation, scalar product, orthogonal vectors, dual vectors, Cauchy-Schwartz inequality, real and complex vector spaces, metric spaces and norm/length of a vector, triangle inequality, linear operators and their algebra, left and right inverse of a linear operator, adjoint of an operator, Hermitian or self-	13+3

adjoint operators, unitary operators, projection operator, linear independence of vectors, basis and span, components of a vector, eigenvalues and eigenvectors, Kronecker delta, Gram-Schmidt orthogonalization theorem, N-dimensional vector space, Representation of vectors and linear operators – matrices, matrix algebra, determinant of a matrix, inverse of a matrix, change of basis in N-dimensional vector space, similarity transformation, orthogonal bases, representation of adjoint operators, notion of transpose, representation of Hermitian and unitary operators, Application to real vector space: Cartesian coordinates, Orthogonal matrices, symmetric and anti-symmetric matrices, trace of a matrix, eigenvalues and eigenvectors of matrices, spectrum and spectral radius, linear independence of eigenvectors, eigenvalues and eigenvectors of similar matrices, matrix diagonalization, simultaneous diagonalization of Hermitian matrices, Cayley-Hamilton theorem.	
Introduction to Tensor analysis: Scalars, vectors, Concept of tensors, covariant and contravariant (components of) tensors, mixed tensors, rank of a tensor, tensors in a real vector space, Cartesian and non-Cartesian tensors, algebra of tensors, symmetric and anti-symmetric tensors, changing the rank of tensors – direct product, contraction, pseudo tensors, metric tensor – raising and lowering indices of the components of tensors.	4+1
Fourier series: Periodic functions, definition of Fourier series, Dirichlet conditions, sine and cosine as eigenfunctions of a linear, self-adjoint (differential) operator, Complete orthonormal set (only definition), Euler formula for Fourier coefficients, Fourier series expansion for periodic functions with arbitrary period, Complex form of Fourier series, Even and odd functions and symmetry properties, Half range expansion, integration and differentiation of Fourier series, Gibb's phenomena, Expression of Fourier coefficients as consequence of minimization of mean square error between the function and its representation as a trigonometric series, completeness of sine and cosine functions, convergence of Fourier series.	4+2
Ordinary differential equations: Classification of differential equations, order of a differential equation, degree of a differential equation, homogeneous and inhomogeneous differential equations, notion of solution of a differential equation, initial/boundary value problem, general solution and particular solution, singular solution, linear homogeneous and inhomogeneous ordinary differential equations and principle of superposition. **First order ordinary differential equations:** separable equations, exact differential equations, non-exact equations and integrating factor, Bernoulli equation, Existence and uniqueness of solution of first order initial value problem.	3+1
Second order ordinary differential equations: homogeneous equations with constant coefficient, Euler-Cauchy equation (a homogeneous equation with variable coefficients), existence and	3+1

uniqueness of solution of homogeneous initial value problem, solution of non-homogeneous equation using method of undetermined coefficient and solution by variation of parameters, Power series and Frobenius methods for solving ordinary differential equations, notion of regular or nonessential singular point and essential singular point, Fuchs theorem.	
Sturm-Liouville theory, Green's function	3+1
Special functions: Legendre, Bessel, Laguerre and Hermite functions. Differential equation approach and generating function approach, recurrence relation, orthogonality, related functions Neumann functions or Bessel functions of the second kind, associated Legendre functions etc.	10+3

Textbooks:

1. G.B. Arfken and H.J. Weber, *Mathematical Methods for Physicists* (Elsevier; 7th Ed. 2012).
2. E. Kreyszig, *Advanced Engineering Mathematics* (Wiley; 10th edition, 2015).

Additional References:

1. P. Dennery and A. Krzywicki, *Mathematics for Physicists*, (Dover Publications Inc.; New edition, 1996). (Especially for Linear spaces and tensor analysis).
2. J. Mathews and R.L. Walker, *Mathematical Methods of Physics*, (Pearson Addison-Wesley; 2nd edition, 1971).

Additional Resources (NPTEL, MIT Video Lectures, Web resources etc.):

1. Video lectures on *Selected topics in Mathematical Physics* by Prof. V. Balakrishnan (IIT Madras) available at http://nptel.ac.in/courses/115106086/

Quantum Mechanics I

Programme: M.Sc. (Physics) Year: 1st Year Semester : 1st semester
Course : Core Credits : 4 Hours (LTP): 40+12+0

Course Context and Overview (100 words):
Quantum mechanics has become an indispensable ingredient in understanding physics of atomic and subatomic particles. Thus, it helps in getting a grasp on subjects such as atomic physics, nuclear physics and quantum optics. The course tries to give a flavor of the vast topic of quantum mechanics and hopefully motivate students in advancing themselves in further understanding of this subject.

Prerequisites Courses:
None

Course outcomes (COs):

On completion of this course, the students will have the ability to:	
CO1:	Apply principles of quantum mechanics to calculate observables on known wave functions.
CO2:	Solve time-dependent and time-independent Schrodinger equation for simple potentials.
CO3:	Learn quantization of angular momentum and spin and its application to Hydrogen Atom problem.
CO4:	Apply techniques like time-independent perturbation theory and WKB methods to solve problems related Atomic and Molecular problems.
CO5:	Apply the of knowledge of Quantum Mechanics to further study other topics in theoretical physics.

Course Topics:

Topics	**Lecture Hours**
UNIT 1: Basic principles of quantum mechanics	6

1. Probabilities and probability amplitudes	
2. Linear vector spaces. Bra and ket vectors.	
3. Completeness, orthonormality, basis sets, change of basis	
4. Eigenstates and eigenvalues	
5. Position and momentum representations	
6. Wavefunctions, probability densities, probability current	
7. Schrodinger equation	
8. Expectation values	
9. Generalized uncertainty relation.	
UNIT 2: One dimensional potential problems	2
1. Particle in a box	
2. Potential barriers.	
3. Tunnelling	
UNIT 3: Linear harmonic oscillator:	7
1. Wavefunction approach	
2. Operator approach	
UNIT 4: Motion in three dimensions	15
1. Schrodinger Equation in Spherical Polar coordinates	
2. Hydrogen Atom	
3. Angular Momentum	
4. Spin	
UNIT 5: Time-independent perturbation theory	5
1. Non-degenerate and degenerate cases. Examples: a) Zeeman Effect b) Stark Effect	
UNIT 6: Semiclassical approximation	5
1. The WKB method	

Textbook references (IEEE format):

Text Book:

1. D. Griffiths, *Introduction to Quantum Mechanics*. Pearson Education, 2005.

2. A. Ghatak and S. Lokanathan, *Quantum Mechanics: Theory and Applications, ser. Fundamental Theories of Physics*. Springer Netherlands, 2004, no. v. 1.
3. R. Shankar, *Principles of Quantum Mechanics*. Springer, 1994.
4. J. J. Sakurai, *Modern Quantum Mechanics*. Pearson Education, 2006.

Reference books:

1. R. Feynman, R. Leighton, and M. Sands, *The Feynman Lectures on Physics*, ser. The Feynman Lectures on Physics. Pearson/Addison-Wesley, 1963, no. v. 3.
2. E. Merzbacher, *Quantum Mechanics*. Wiley, 1998.
3. V. Thankappan, *Quantum Mechanics*. J. Wiley, 1993.
4. P. Mathews and K. Venkatesan, *A Textbook of Quantum Mechanics*. McGraw-Hill Book Company, 1978.

Computational Methods in Physics

Programme: M. Sc. (Physics) | Year: 1st year | Semester: 1st semester
Course : Program Core | Credits : 3 | Hours (LTP): 40+0+0

Course Context and Overview (100 words):

Programming skills have become necessary in various fields of study not just Physics. This course teaches the basic concepts of programming techniques with emphasis on solving physics problems.

Prerequisites Courses:
None

Course outcomes(COs):

On completion of this course, the students will have the ability to:	
CO1:	Apply the knowledge of basic concepts of programming to any language of their choice
CO2:	Plot data (2D / 3D) derived from programming / experiments
CO3:	Find roots of equations
CO4:	Solve system of linear equations and
CO5:	Interpolate from given data
CO6:	Numerically perform differentiation and integration
CO7:	Solve Ordinary Differential Equations

Programming language to be taught: C

Course Topics:

Topics	**Lecture Hours**
UNIT I: Introduction to Computers / OS and Basic concepts of Programming	

1. Flow charts, Algorithms	16
2. Integer and floating point arithmetic, Precision, Variable types, Arithmetic statements, Input and output statements,	
3. Control statements, Executable and non-executable statements,	
4. Arrays	
5. Repetitive and logical structures, Subroutines and functions, Operation with files;	
UNIT II: Plotting softwares	2
1. Gnuplot, Grace, Origin **Examples:** a) Application of this in M. Sc. Laboratory Experiments b) Wave function in Quantum Tunnelling c) Radioactive Decay	
UNIT III: Root finding methods	3
1. Graphical Method	
2. Bracket Methods	
3. Open End Methods	
Examples: a) Finding roots of non-linear algebraic equations in Physics	
UNIT IV: System of Linear Equations	5
1. Gauss elimination Method with and without pivoting.	
2. LU Decomposition	
3. Gauss Seidel	
Examples: a) Coupled Harmonic Oscillator b) Heated rod problem	
UNIT V: Interpolation	4
1. Linear Interpolation	
2. Newton's interpolation technique	
3. Lagrange interpolation	
4. Pitfalls in interpolation	
5. Spline interpolation technique	
Examples: a) Application of this technique in M. Sc. Laboratory Experiments	
UNIT VI: **Differentiation & Integration**	3
1. Difference formulas for 1st order and 2nd order differentiation	
2. Trapezoidal rule	

3. Simpson's rule	
UNIT VII: Ordinary Differential Equations	7
1. Initial value problems	
a) Euler method / Heun’s Method / Runge-Kutta method of order four	
2. Boundary Value problem	
a) Shooting method	
b) Finite difference method	
Examples: a) Newton’s Law. b) Electrodynamics Problems. c) One dimensional time-independent Schrodinger’s Equation	

Textbook references:

Text Book:

1. E. Balagurusamy, *Programming in ANSI C*, McGraw Hill Education India Private Limited.
2. Y. Kanetkar, *Let us C*, BPB Publications, New Delhi 2016.
3. N. Giordano and H. Nakanishi, *Computational Physics*, Pearson/Prentice Hall, 2006.
4. P. DeVries and J. Hasbun, *A First Course in Computational Physics*, New Delhi: Jones & Bartlett Learning, 2011.

Reference books:

1. B. Gottfried, Schaum’s Outlines: *Programming in C*, Tata McGraw Hill Education Private Limited, New Delhi, 2011.
2. B. W. Kernighan, D. Ritchie, *The C Programming Language*, Pearson Education Singapore, 2015.
3. J. E. Hasbun, *Classical Mechanics with MATLAB Applications*, Jones & Bartlett Learning, New Delhi, 2012
4. S. C. Chapra, *Applied Numerical Methods with MATLAB for Engineers and Scientists*, Tata McGraw Hill Education Private Limited, New Delhi, 2012.

Additional Resources (NPTEL, MIT Video Lectures, Web resources etc.):

Thermodynamics and Statistical Mechanics

Programme: M.Sc. Year: 1st Semester: 2^{nd} semester
Course: Science Credits: 4 Hours (LTP): 40+12+0

Course Context and Overview (100 words):
The course is designed mainly for second semester M.Sc. physics students. This course reviews basic concepts of the thermodynamics and their application, postulates of statistical mechanics, statistical interpretation of thermodynamics, and theories of various ensembles (microcanonical, canonical and grand canonical ensembles). The course finally provides a flavor of how thermodynamics and statistical mechanics can be used to understand complex systems and related phenomena.

Prerequisites Courses:
Classical mechanics, elementary thermodynamics, basic quantum mechanics, and mathematical physics.

Course Outcomes (COs):
On completion of this course, students will have the ability to do:
CO1: Use the basic concept of thermodynamics to selected problems of physics and related field.
CO2: Acquire the knowledge of statistics and physical principles to describe kinetic theory of gases. Learn Boltzmann transport equation and its applications.
CO3: Use mathematical and physical principles to understand the classical statistical mechanics and learn about the statistical basis of thermodynamics.
CO4: Explain statistical physics and thermodynamics as logical consequences of the postulates of statistical mechanics.

Course Topics:

Topics	**Contact Hours (Including Tutorials)**
Unit 1: Basic concepts of thermodynamics Extensive and intensive variables, Laws of thermodynamics (includes Thermodynamic potentials, Entropy, the Maxwell relations, chemical potential), Applications of the thermodynamics to (a) ideal gas, (b) magnetic material, (c) dielectric material	**10(L) + 4(T)**
Unit 2: Kinetic theory of gases Key ideas of the kinetic theory, the mean free path, distribution of molecular velocities in an ideal gas, Maxwell-Boltzmann distribution law, experimental verification of the Maxwell's distribution law, Boltzmann Transport equation	**8(L) + 2(T)**

Unit 3: Formulation of the classical statistical mechanics **Part A:** Probability theory, Phase space and quantum states, macroscopic states and microscopic states, Liouville's theorem, the statistical basis of thermodynamics, classical ideal gas, entropy of mixing and the Gibbs paradox, equipartition theorem	**7(L) + 15(L) + 6(T)**
Part B: Elements of ensemble theory: Microcanonical ensemble, canonical ensemble, and grand canonical ensemble	

REFERENCES

This course does not follow a particular text book. The following are useful reference books:

1. K. Huang, *Statistical Mechanics* (John Wiley & Sons, 2003).
2. R. K. Pathria and P.D. Beale, *Statistical Mechanics* (Elsevier, Third edition, 2011).
3. D. Chowdhury and D. Stauffer, *Principles of Equilibrium Statistical Mechanics*, (Wiley-VCH, 2000).
4. L. D. Landau and E. M. Lifshitz, *Statistical Physics* (Part 1. 3rd ed. Pergamon Press, 1980)
5. Frederick Reif, ed. *Fundamentals of Statistical and Thermal Physics* (McGraw-Hill, 1965)
6. Richard Phillips Feynman, *Statistical Mechanics: A set of Lectures* (Westview Press, 1998)
7. M. W. Zemansky, *Heat and Thermodynamics* (McGraw-Hill Book Company Inc. 1968)
8. M. N. Saha and B. N. Srivastava *A treatise on Heat*: (Science Book Agency, 1967)
9. Carl S. Helrich *Modern Thermodynamics with Statistical Mechanics*, 2009, Springer.
10. , S. J. Blundell and K. M. Blundell, *Concepts in Thermal Physics*, 2nd Ed., 2012, Oxford University Press.

Additional Resources (NPTEL, MIT Video Lectures, Web resources etc.)

Quantum Mechanics-II

Programme: M.Sc. (Physics)	Year: 1st year	Semester : 2^{nd} semester
Course : Core Course	Credits : 4	Hours (LTP): 40+12+0

Course Context and Overview:
The Quantum Mechanics-2 course is intended to take forward the students' understanding of the topics covered in Quantum Mechanics-1 in the previous semester, as well as add further knowledge on the mathematical tools involved in Quantum Mechanics. It covers advanced topics regarding wave functions, ket spaces, perturbation theory and angular momentum, and provides an overview of microscopic systems of identical particles and scattering theory. Relativistic quantum mechanics and the sem-classical theory of radiation are also introduced.

Prerequisite Courses: Quantum Physics-I, Mathematical Physics

Course outcomes(COs):

On completion of this course
CO1: The students will understand the methods of angular momentum algebra, including eigenstates and addition of angular momenta, and will learn the technique of time-dependent perturbation theory. They will learn about wavefunction representations and equations of motion.
CO2: Students will get familiar with identical particle systems, the concepts of bosons and fermions, the symmetry of wavefunctions, and second quantization.
CO3: Students will learn the techniques of particle scattering theory and scattering cross-section calculations.
CO4: Students will understand the basic concepts of relativistic quantum mechanics and the semi-classical theory of radiation.

Course Topics and contact hours allotment:

Topics	Contact Hours
Wavefunctions and Eqns of Motion: Stern-Gerlach experiment. Wave functions in position and momentum representations. Schrodinger and Heisenberg pictures. Heisenberg equation of motion. Interaction picture.	6
Time-dependent Perturbation theory: Time-dependent perturbation theory. Transition probabilities. Sudden and adiabatic approximations. Fermi golden rule. The variational method: simple	7

examples.	
Addition of Angular Momenta: Angular momentum algebra. Eigenstates and eigenvalues of angular momentum. Addition of angular momenta, Clebsch-Gordon coefficients.	7
Identical particle Systems: Systems of identical particles. Symmetric and antisymmetric wavefunctions. Bosons and Fermions. Pauli's exclusion principle. Second quantization, occupation number representation.	7
Particle Scattering: Non-relativistic scattering theory. Scattering amplitude and cross- section. The integral equation for scattering. Born approximation. Partial wave analysis. The optical theorem.	7
Relativistic Quantum Mechanics: Elements of relativistic quantum mechanics. The Klein-Gordon equation. The Dirac equation. Semi-classical theory of radiation.	6

Textbook references (IEEE format):

Text Books:

1. J.J. Sakurai *Modern Quantum Mechanics*, Benjamin / Cummings (1985).
2. P.A.M. Dirac, *The Principles of Quantum Mechanics*, Oxford University Press (1991).

Reference Books:

1. L.D.Landau and E.M. Lifshitz, *Quantum Mechanics -Nonrelativistic Theory*, 3rd Edition, Pergamon (1981).
2. P.M. Mathews and K. Venkatesan, *A Textbook of Quantum Mechanics*, Tata McGraw-Hill (1977).
3. J. Bjorken and S. Drell*, Relativistic Quantum Mechanics*, McGraw-Hill (1965).
4. A. Messiah, *Quantum Mechanics*, Vols. 1 and 2, North Holland (1961).

Additional Resources (NPTEL, MIT Video Lectures, Web resources etc.):

Information of relevant videos and web resources will be given during the course.

Mathematical Physics-II

Programme: M.Sc. (Physics)	Year: 1st year	Semester : 2nd semester
Course : Core Course	Credits : 4	Hours (LTP): 40+12+0

Course Context and Overview:
Importance of mathematics in the formulation of physics is well known. This course introduces the students to some of the more advanced concepts used mathematical tools in physics. These tools find applications in almost all areas of physics like classical mechanics and quantum mechanics as well as in statistical mechanics and condensed matter physics.

Prerequisite Courses:
Mathematical Physics-I

Course outcomes(COs):

On completion of this course
CO1: Students would have a basic understanding of complex analysis as required in physics and should be able to use this knowledge to understand more advanced topics in quantum mechanics etc.
CO2: Students will be able to use integral transforms as a basic tool of analysis in almost all branches of physics.
CO3: Students would have an appreciation for the most commonly occurring partial differential equations in physics and the methods for solving them.
CO4: Students would acquire a basic understanding of the concepts of probability and statistics as used in physics and applied sciences. This should enable them to develop an appreciation for the analysis of experimental data.
CO5: Students would acquire a basic knowledge of elementary ideas of group theory. This will help them understand the language of more advanced topics in physics like gauge theories and crystallography.

Course Topics:

Topics	Lectures+Tutorials
Complex Analysis: Basic notions of set theory, neighborhood of a point, isolated point, accumulation point, interior point of a set, open set, closed set, region. Complex numbers and complex plane, Functions of complex argument, derivative of functions of complex variable, Cauchy-Riemann conditions, single valued and multivalued functions, analytic functions and domain of analyticity, entire function, regular	12+4

point, singular point isolated singular point, Examples of analytic functions, integration of functions of complex variables (contour integral), Darboux inequality, Cauchy's integral theorem, Cauchy's integral formula, derivatives of analytic functions, local behavior of analytic functions, Cauchy-Liouville theorem, Morera's theorem, Taylor series, Laurent series, zeros and isolated singular points of analytic functions – simple pole, meromorphic functions, isolated essential singularity, removable singularity, calculus of residues, application of residue theorem to evaluation of integrals, multivalued functions and Riemann surfaces, branch point and branch cut, evaluation of integrals involving multivalued functions.	
Integral Transforms: Definition, from Fourier series to Fourier transform, inverse Fourier transform, Properties of Fourier transform – linearity, transform of derivatives, integrals etc., convolution theorem, Parseval's relation, Transfer function, Laplace transform and its properties.	8+2
Partial differential equations: Classification of partial differential equations, characterstics, boundary conditions, Solution of partial differetial equations using separation of variables (examples of separation in Cartesian, spherical and cylindrical coordinates), solution using integral transform, solution by Green's function method.	8+2
Probability and statistics: Data representation, average, spread, experiments and outcome, Probability, random variables, probability distributions, mean and variance of a distribution, binomial, Poisson and normal distributions	6+2
Group Theory: Definition and general properties of groups, continuous groups, generators of continuous groups. Examples of SO(3) and SU(2).	6+2

Textbooks:

1. G.B. Arfken and H.J. Weber, *Mathematical Methods for Physicists* (Elsevier; 7th Ed. 2012).
2. E. Kreyszig, *Advanced Engineering Mathematics* (Wiley; 10th edition, 2015).

Additional References:

1. P. Dennery and A. Krzywicki, *Mathematics for Physicists*, (Dover Publications Inc.; New edition, 1996). (Especially for Complex Analysis).
2. J. Mathews and R.L. Walker, *Mathematical Methods of Physics*, (Pearson Addison-Wesley; 2nd edition, 1971).

Additional Resources (NPTEL, MIT Video Lectures, Web resources etc.):

1. Video lectures on Selected topics in Mathematical Physics by Prof. V. Balakrishnan (IIT Madras) available at http://nptel.ac.in/courses/115106086/

Condensed Matter Physics -I

Programme: M. Sc. **Year:** 1st **Semester:** 2nd

Course: Core course **Credits: 4** **Hours (LTP): 40+12+0**

Course overview:

Condensed matter physics is a branch of physics that deals with the physical properties of a large number of interacting particles. Such systems are omnipresent in our daily life. Examples include metallic utensils, semiconductors chip, LED screens and many more. Their studies are important for both scientific developments and for further progress of our daily life.

This course is designed for the first year M Sc. students to give an overview of introductory descriptions of condensed matter systems. Focus will be on giving exposer of various physical properties of different materials, their theoretical understanding and possible applications.

Prerequisites:

Basic Mathematical Physics and Thermodynamics.

Course Outcomes:

On completion of this course, the students will have the ability to:
CO1 : Understand symmetry based classification of condensed matter systems.
CO2 : Understand the basics of crystallography and the relation between crystal symmetry and macroscopic physical properties.
CO3 : Understand the phenomena of diffraction of waves by crystals.
CO4: Understand various kind of crystal bindings.
CO5 : Understand the basics of lattice dynamics and its consequences on various physical properties.
CO6: Understand various metallic behavior based on free electron model.
CO7: Understand the basics of semiconductors.

Following topics will be covered in this course:

Topics	Lecture Hours
UNIT – I Classification of condensed matter systems: Crystalline and Noncrystalline materials, Nanophase solids, Liquids, Liquid crystals and Glasses (symmetry based description).	1

UNIT – II Crystal symmetry and macroscopic physical properties: Bravais lattices, Primitive vectors, conventional unit cell, Wigner-Seitz cell, Symmetry operations; crystal systems, point groups, space groups and typical crystal structures. Their relation with various physical properties like pyroelectricity, ferroelectricity~~,~~ determination of elastic constants.	**7**
UNIT – III Diffraction of waves by crystals: X-rays, neutrons and electrons scattering, Reciprocal Lattice, Bragg's law and Lau's interpretation, Atomic and geometric structure factor, Explanation of experimental methods on the basis of Ewald construction, Principles of diffraction techniques, the concept of Brillouin zones.	**6**
UNIT – IV Crystal binding: Concept of bonding, understanding of interaction potential energy, Ionic crystals – covalent and metallic binding. Van der Waals binding - rare gas crystals and binding energies.	**4**
UNIT-V Lattice dynamics: Classical Theory of lattice vibration under harmonic approximation, Monoatomic and Diatomic lattices. Born-von Karman method. Phonon frequencies and density of states. Dispersion curves, inelastic neutron scattering., Lattice specific heat. Thermal expansion. Thermal conductivity. Normal and Umklapp processes.	**8**
UNIT-VI Free electron theory of metals: Nearly free electron approximation, Bloch functions, Formation of energy bands, Gaps at Brillouin zone boundaries. Electron states and classification into insulators, conductors and semimetals. Effective mass and concept of holes. Fermi surface. Cyclotron resonance. thermal and electrical transport properties, Electronic specific heat, Hall effect.	**10**
UNIT-VII Semiconductors: Carrier statistics in intrinsic and extrinsic semiconductors. Electrical conduction in semiconductors.	**4**

<u>Text Books</u>

1. Charles Kittel, *Introduction to Solid State Physics*, Wiley, 5th Edition (1976).
2. N.W. Ashcroft and N.D. Mermin, *Solid State Physics*, Saunders College Publishing (1976).
3. M. Ali. Omar, *Elementary Solid State Physics*, Pearson (2009).

<u>Reference Books</u>

1. Manijeh Razeghi, *Fundamentals of Solid State Engineering*, 3rd Edition, Springer (2009)

2. A.J. Dekker, *Solid State Physics*, Prentice Hall, (1957).
3. J.S. Blakemore, *Solid State Physics*, 2nd Edition, Cambridge University Press. (1974).
4. Harald Ebach and Hans Luth, *Solid-State Physics*, Springer International Student Edition, Narosa Pub. House, (1991).
5. Steven H. Simon, *The Oxford Solid State Basics*, Oxford(2013).
6. John Singleton, *Band Theory and Electronic Properties of Solid*, The Oxford Master Series in Physics(2001).

7. Martin T. Dove, *Structure and Dynamics, An Atomic View of Materials*, Oxford Master Series in Physics(2001).

Electrodynamics-I

Programme: M.Sc. (Physics)	Year: 1st	Semester : 2^{nd}
Course : Core Course	Credits : 4	Hours (LTP): 40+12+0

Course context and Overview:
Electromagnetic force is one of the four fundamental forces in nature and along with gravity it is the interaction which governs most of the phenomena on everyday scale. The theory, as enunciated by Maxwell in his equations, unified the apparently different fields of electricity, magnetism and light. This theory not only serves as a guide to build more advanced and sophisticated models of particle interactions but it also is at the foundation of a lot of technological advancements (electricity, communications etc.). Not only this, electrodynamics provided the theoretical motivation for the special theory of relativity. A sound understanding of electrodynamics is therefore necessary of physics majors and in this course we will try to cover the various aspects of this beautiful theory.

Prerequisite Courses:
Basic knowledge of classical mechanics, Mathematical Physics-I.

On completion of this course
CO1: The students will acquire an understanding of the concept of electric and magnetic fields along with techniques to calculate these fields (in various circumstances).
CO2: Students will also acquire an understanding of the very important concept of potential(s) which is useful in various areas of physics.
CO3: Students will learn to use Maxwell's equations in different situations. This is a basic prerequisite in various technological applications of electromagnetic fields (for instance, waveguides, antennas etc.).
CO4: After learning the relativistic formulation of electrodynamics, students would be able to use similar techniques in more advanced areas of physics like quantum field theory and particle physics.

Course Topics:

Topics	Lectures+Tutorials
Introduction: Particles versus fields, experimental motivation for electrodynamics, properties of electric charge, Scalar and vector fields, vector calculus, Helmholtz theorem.	2
Electrostatics: Coulomb's law, Electric field, electric potential, curl of electrostatic field, flux of electric field and Gauss law, Applications of Gauss's law, equilibrium in electrostatics.	2+1
Conductors: Basic properties, Induced charges, surface charge and force on conductor, boundary conditions for electrostatic fields. Limits on the validity of inverse square law.	2
Methods for solving electrostatic problem: Poisson equation and Laplace equation, properties of solution of Laplace equation, boundary conditions	8+3

and uniqueness theorems, Solution of Laplace equation, Solution of Poisson equation – Green's function method and method of images, two dimensional potential problems (method of complex analysis), electric dipole moment, multipole expansion, Capacitors, Work and Energy in Electrostatics, energy of a capacitor, electrostatic field energy.	
Electric field in matter: Dielectrics, Induced dipoles, atomic polarizability, polarization, linear dielectrics, electric susceptibility and dielectric constant, alignment of polar molecules, Electric Displacement-Gauss law in dielectrics, dielectric constant of gases, Clausius-Mossotti equation	5+1
Magnetostatics: Lorentz force law, steady currents, current density, continuity equation, Maxwell equations for magnetostatics, applications of Ampere's law, solving magnetostatic equations – magnetic vector potential, boundary conditions in magnetostatics, Biot-Savart law, magnetic dipole moment, multipole expansion for vector potential, torque on a magnetic dipole.	5+2
Magnetic field in matter: diamagnets, paramagnets, magnetization and magnetization or bound currents, Auxiliary field H-Amperes law in magnetized materials, ferromagnets.	3+1
Electromotive force- EMF, Motional EMF, Electromagnetic induction – Faraday's law, Induced electric field, mutual inductance and self inductance, energy in magnetic fields.	2
Maxwell's equations: Maxwell's correction of Ampere's law, Maxwell's equations in free space and in matter, boundary conditions on the fields, potential formulation of Maxwell's equations - scalar and vector potential, gauge transformations - Coulomb and Lorentz gauge.	2+1
Electromagnetic waves: plane and spherical waves in vacuum, Field energy and field momentum, conservation laws and Poynting's theorem, EM waves in dielectrics and conductors, wave polarization, reflection and refraction of waves at boundary between two media, Fresnel's law, index of refraction, wave dispersion and attenuation.	9+3

Text Books:

1. D.J. Griffiths, *Introduction to Electrodynamics* (Pearson Edu.; 4th edition, 2015).
2. J.D. Jackson, *Classical electrodynamics* (John Wiley; 3rd edition, 2007).

Additional References:

1. L.D. Landau and E.M. Lifshitz, *Classical Theory of Fields*, (BH; 4th edition, 1987).
2. W. K. H. Panofsky and M. Phillips, *Classical Electricity and Magnetism* (Addison-Wesley, 1962).
3. R.P. Feynman, R. Leighton and M. Sands, *Feynman Lectures on Physics* (Vol. 1 & 2): The New Millennium Edition (Pearson Education India, 1st edition, 2012).

Additional Resources (NPTEL, MIT Video Lectures, Web resources etc.):

1. Lecture notes are available from MIT open courseware. The link is https://ocw.mit.edu/courses/physics/

Atomic and Molecular Physics

Programme: M.Sc. Year: 2nd Semester : 3rd semester
Course : Core Course Credits : 4 Hours (LTP): 40+12+0

Course Context and Overview (100 words):
Atomic and molecular physics (AMP) is one of the canonical fields of physics. This course is developed by using quantum mechanics to provide the basic understanding for advanced courses in all branches of modern physics, physical chemistry and partially even biological and material sciences. AMP is highly productive in modern developments in experimental techniques especially spectroscopy. Few spectroscopic techniques will be discussed at appropriate places.

Prerequisites Courses:
First course on Quantum Mechanics

Topics	**Hours (Including Tutorials)**
UNIT 1: Spectra of one-electron atom Introduction to Spectroscopy and types of Spectra: Bohr Model for Hydrogen Atom, Bohr-Sommerfeld model of Hydrogen Atom, Sommerfeld's Relativistic Correction for energy levels of hydrogen atom, Fine Structure of Hydrogen Atom Magnetic Dipole Moments, Stern-Gerlach Experiment, Electron Spin, Spin-orbit interaction, Vector Atom Model, Spectroscopic terms Solution of Dirac equation in a central field; Relativistic correction to the energy of one electron atom. Fine structure of spectral lines; Selection rules; Lamb shift.	**10**
UNIT 2: Spectra of multi electron atoms: (An Introduction) Pauli's exclusion principle, Central-field and Hartree approximations field approximation; angular momentum, L-S and J-J coupling, Helium Spectra, Alkali Spectra,	**10**
UNIT 3: Interaction of atoms with electric and magnetic field (Hyper fine structure) Zeeman effect, Paschen-back effect, Stark effect, Hyperfine structure and isotope shift, Hyperfine splitting of spectral lines, selection rules, width of spectrum, X-ray spectra,	**10**
UNIT 4: Molecular Spectra Quantum mechanics of Molecules, Born-Oppenheimer approximation, Frank- Condon principle, rotational, vibrational, Electronic, and Raman	**15**

spectra of diatomic molecules, Selection rules, Nuclear Magnetic Resonance (NMR), Electron Spin Resonance (ESR),	
<u>UNIT 5: Lasers</u> Laser; Spontaneous and stimulated emission, Einstein A & B coefficients, Optical pumping, population inversion, rate equation, Modes of resonators and coherence length, Types of the lasers	**7**

Text Book

1. B.H.Bransden and C.J. Joachain, *Physics of Atoms and Molecules*, 2nd edition, Pearson Education, (2003).
2. G. Herzberg, *Atomic Spectra and Atomic Structure*, Dover Publications, (2003).
3. C. N. Banwell and E.M. McCash, *Fundamentals of Molecular Spectroscopy*, Forth Edition, McGrawHill (2016)
4. K. Thyagarajan and A.K. Ghatak, Lasers, *Theory and Applications*, 2nd edition, Springer US, (2011)
5. Gordon W. F. Drake, ed , Springer handbook of atomic, Molecular, and optical physics Springer(2006).
6. H.E. White, Introduction to Atomic Spectra, McGraw-Hill, (1934)

Reference Book

1. H.A.Bethe and R.W. Jackiw, *Intermediate Quantum Mechanics*, 3rd edition, Addison-Wesley, 1997.
2. L.L.Landau and E.M.Lifshitz , *Quantum Mechanics-non-relativistic theory*, Pergamon(1965).
3. R. Eisberg and R. Resnick, *Quantum Physics of Atoms, Molecules*, Solids, Nuclei, and particles, 2nd Edition Wiley (2006)
4. W. Demtroder , Laser Spectroscopy, 3rd Ed., Springer, (2003)

Online resources (NPTEL, MIT)

Nuclear and Particle Physics

Programme: M.Sc. (Physics) Year: 2nd year Semester : 3rd
Course : Core Course Credits : 4 Hours (LTP): 40+12+0

Course Context and Overview:
The Nuclear and Particle Physics course is intended to give the student a strong basis for understanding the smallest constituents of the universe. The properties of the atomic nucleus are discussed in terms of the forces involved, with models to explain the same. Radioactive decay and methods of dating are discussed. The course touches upon fission and fusion as sources of nuclear energy and power. A basic flavor of particle physics is given, with a description of the fundamental forces in nature, the particle zoo, conservation laws in particle reactions, the Standard Model and neutrino physics. Finally particle accelerators and detectors are explained at both a basic level and in terms of current facilities across the world.

Prerequisite Courses:

Quantum Physics-I and II, Mathematical Physics

Course Topics and contact hours allotment:

Topics	Contact Hours
Overview of nuclear properties and nuclear forces: Nuclear radius, nuclear mass and binding energy, angular momentum, charge distribution, spin and parity. Nucleon-nucleon-force, deuteron, pi-meson exchange model, Yukawa hypothesis. Nuclear models – liquid drop model, single-particle shell model, validity and limitations, spin-orbit interactions, collective model, nuclear rotation and vibration.	8
Radioactive decays and nuclear reactions: General properties, radioactive dating, Alpha, Beta and Gamma decay. Nuclear reactions, conservation laws, cross-sections, Coulomb scattering, nuclear scattering. Compound nuclei and direct reactions.	8
Nuclear power and reactors: Nuclear fission and fusion, nuclear power, mechanism and types of nuclear reactors, present-day reactors and their uses. Other applications of nuclear technology – nuclear medicine, agriculture, industrial and commercial applications.	8
Overview of elementary particle theory: The four fundamental forces. Parity non-conservation in weak interaction. Elementary particles - mesons and baryons, leptons and quarks. Quark model of elementary	8

particles, strong isospin, strange quark, Gell-Mann- Okubo mass relation, Gellmann Nishijima formula, colour charge. C, P and T invariance. Application of symmetry arguments to particle reactions. The Standard Model of Particle Physics. Neutrino Physics. Cosmic rays.	
Particle accelerators and detectors: Linear accelerators, cyclotrons, synchrotrons, basic particle detectors, modern complex detectors. The Linear Hadron Collider as a probe for fundamental Physics. Current neutrino detectors. Latest theories and results.	8

Textbook references (IEEE format):

Text Books:

1. A. Beiser, S. Mahajan, S. Rai Choudhury – *Concepts of Modern Physics*.

2. K. Krane – *Introductory Nuclear Physics*

Reference Books:

1. W.E. Burcham – *Nuclear and Particle Physics*.
2. S.S.M. Wong – *Introductory Nuclear Physics*.
3. A. Das, T. Ferbel – *Introduction to Nuclear and Particle Physics*.

Additional Resources (NPTEL, MIT Video Lectures, Web resources etc.):

Information of relevant videos and web resources will be given during the course.

Condensed Matter Physics-II

Programme: M. Sc. **Year:** 2^{nd} **Semester:** 3^{rd}
Course: Core course **Credits:** 4 **Hours (LTP):** 40+12+0

Course Context and overview:

Condensed matter physics is a branch of physics that deals with the physical properties of a large number of interacting particles. Such systems are omnipresent in our daily life. Examples include metallic utensils, semiconductors chip, LED screens and many more. Their studies are important for both scientific developments and for further progress of our daily life.

This course is designed for final year M Sc. Students and is a continuation of previously taught course Condensed Matter Physics - I.

Prerequisites: Condensed Matter – I and Statistical Mechanics-I

Course Outcomes:

On completion of this course, the students will have the ability to:
CO1 : Understand theoretical descriptions of various optical properties of solids.
CO2 : Understand dielectric properties of materials.
CO3 : Understand the fundamentals of magnetic behavior of various materials.
CO4: Understand various kind of defects present in the solids and their consequences.
CO5 : Understand the basics of superconductors.

Course Topics

Topics	**Lecture Hours**
UNIT – I Optical properties of solids: General view of optical properties of solids, definition of absorption, transmission reflection coefficient. Classical theory of optical properties of solids, Quantum theory**;** Band to band absorption, Luminescence, excitons, polarons.	**8**
UNIT – II Dielectric properties of insulators: Introduction to dielectric materials, Internal electric field in a dielectric. Clausius-Mossotti and Lorentz-Lorenz equations. Electronic, ionic and orientational polarization, static dielectric constant of gasses and solids - Dielectric dispersion and loss, relaxation time, Debye equations, Cole-Cole distributions, Ferroelectrics: types and models of ferroelectric transition.	**8**
UNIT – III Magnetic properties of solids: Diamagnetic susceptibility. Classical and Quantum theory of paramagnetism, Pauli paramagnrtism. Transition metal ions and rare earth ions in solids. Crystal field effect and	**8**

orbital quenching. Ferromagnetic and anti-ferromagnetic ordering. Curie-Weiss theory, Heisenberg exchange interaction , Curie and Neel temperatures. Domain walls.	
UNIT – IV Defects in a crystal: Classification of defects**,** Point defects, vacancies, concept of statistical vacancies, Frenkel and Schottky defects. Colour centres, Formation enthalpies. Diffusion in solids , Fick's 1st and 2nd law of diffusion to understand doping of atoms in a solid solution. Extended defects: dislocations, models of screw and edge dislocations. Burgers vector.	**7**
UNIT-V Superconductivity: experimental and theoretical aspects, new materials and models. [Phenomenological description of superconductivity – occurrence of superconductivity, destruction of superconductivity by magnetic field, Meissner effect; Type-I and Type-II superconductors; superconductivity from thermodynamics perspective; heat capacity, entropy and isotope effect; outline of Landau theory, outlines of BCS theory, Flux quantization; a.c. and d.c. Josephson effect; high TC superconductors (information only).	**9**

<u>Text Books</u>

1. Charles Kittel, *Introduction to Solid State Physics*, Wiley, 5th Edition (1976).
2. N.W. Ashcroft and N.D. Mermin, *Solid State Physics*, Saunders College Publishing (1976).
3. M. Ali. Omar, Elementary *Solid State Physics*, Pearson (2009).

<u>Reference Books</u>

1. Mark Fox, Optical Properties of Solids, 2nd Edition, (Oxford Master Series in Physics).

2. A.J. Dekker, *Solid State Physics*, Prentice Hall, (1957).
3. J.S. Blakemore, *Solid State Physics*, 2nd Edition, Cambridge University Press. (1974).
4. Harald Ebach and Hans Luth, *Solid-State Physics*, Springer International Student Edition, Narosa Pub. House, (1991).
5. Steven H. Simon, *The Oxford Solid State Basics*, Oxford(2013).
6. John Singleton, *Band Theory and Electronic Properties of Solid*, The Oxford Master Series in Physics(2001).
7. Martin T. Dove, *Structure and Dynamics, An Atomic View of Materials*, Oxford Master Series in Physics(2001).

Electrodynamics-II

Programme: M.Sc. (Physics)	Year: 2nd	Semester: 3rd
Course : Core Course	Credits : 4	Hours (LTP): 40+12+0

Course context and overview:
Electromagnetic force is one of the four fundamental forces in nature and along with gravity it is the interaction which governs most of the phenomena on everyday scale. The theory, as enunciated by Maxwell in his equations, unified the apparently different fields of electricity, magnetism and light. This theory not only serves as a guide to build more advanced and sophisticated models of particle interactions but it also is at the foundation of a lot of technological advancements (electricity, communications etc.). Not only this, electrodynamics provided the theoretical motivation for the special theory of relativity. A sound understanding of electrodynamics is therefore necessary of physics majors and in this course we will try to cover the various aspects of this beautiful theory.

Prerequisite Courses:
Mathematical Physics I and II, Electrodynamics-I

On completion of this course
CO1: The students will acquire an understanding of the concept of electric and magnetic fields along with techniques to calculate these fields (in various circumstances).
CO2: Students will also acquire an understanding of the very important concept of potential(s) which is useful in various areas of physics.
CO3: Students will learn to use Maxwell's equations in different situations. This is a basic prerequisite in various technological applications of electromagnetic fields (for instance, waveguides, antennas etc.).
CO4: After learning the relativistic formulation of electrodynamics, students would be able to use similar techniques in more advanced areas of physics like quantum field theory and particle physics.

Course Topics:

Topics	Lectures+Tutorials
Wave guides and transmission line: Rectangular waveguide, cut-off frequency, modes of the rectangular waveguide, energy flow and attenuation in waveguides, coaxial transmission line**.**	3+1
Resonant cavities: Cavity Modes, power losses in a cavity, Q of a cavity, Earth and ionosphere as a resonant cavity.	2+1
Solutions of Maxwell’s equations in the presence of sources: Retarded potentials, Jefimenko’s equations for the fields.	3+1
Radiation: Electric and magnetic dipole radiation, example of center fed linear antenna, multipole expansion of retarded potentials.	5+2

Radiation by moving charges: Lienard-Wiechert potentials and fields for a point charge, Potential for a charge moving with constant velocity – the Lorentz formula, Power radiated by an arbitrarily moving charge – the Larmor formula.	5+1
Electrodynamics and relativity: Non-invariance of Maxwell equations under Galilean transformation, Lorentz formula as a motivation for Lorentz transformation, Michelson-Morley experiment and special relativity, recapitulation of important results of special relativity, magnetism as a relativistic phenomena (change of frame), electrodynamics in relativistic notation – four vectors and four potential, Lorentz transormation of the fields, the electromagnetic field tensor, electrodynamics in tensor notation, Lagrangian for the electromagnetic field.	10+3
Dynamics of relativistic particles: Motion in uniform, static magnetic field, motion in combined, uniform, static electric and magnetic fields, motio in nonuniform, static magnetic fields.	2+1
Scattering: Scattering at long wavelengths by (induced) dipoles, scattering by a collection of scatterers, Rayleigh scattering and the Blue sky, polarization of radiation by scattering, scattering in the short wavelength limit, scattering by free charges (Thomson scattering).	5+2
Bremsstrahlung and synchrotron radiation: Radiation emitted during collisions, Bremsstrahlung in Coulomb collisions, Radiation emitted by a relativistic charged particle in circular motion (qualitative treatment of synchrotron radiation).	5+2

Text Books:

1. D.J. Griffiths, *Introduction to Electrodynamics* (Pearson Edu.; 4th edition, 2015).
2. J.D. Jackson, *Classical electrodynamics* (John Wiley; 3rd edition, 2007).

Additional References:

1. L.D. Landau and E.M. Lifshitz, *Classical Theory of Fields*, (BH; 4th edition, 1987).
2. W. K. H. Panofsky and M. Phillips, *Classical Electricity and Magnetism* (Addison-Wesley, 1962).
3. R.P. Feynman, R. Leighton and M. Sands, *Feynman Lectures on Physics* (Vol. 1 & 2): The New Millennium Edition (Pearson Education India, 1st edition, 2012).

Additional Resources (NPTEL, MIT Video Lectures, Web resources etc.):

1. Lecture notes are available from MIT open courseware. The link is https://ocw.mit.edu/courses/physics/

Advanced Statistical Mechanics

Programme: M.Sc. Year: 2nd Semester: 3^{rd}
Course: Science Credits: 4 Hours (LTP): 40+12+0

Course Context and Overview (100 words):

This course is designed mainly for the third semester M.Sc. physics students. This course introduces various analytical methods of statistical mechanics and then uses them to develop the Bose-Einstein statistics, and Fermi-Dirac statistics. The course helps to develop concepts in various approximate methods used for studying the interacting systems in statistical mechanics, theory of phase transition, Ising model and fluctuations. The course introduces various sophisticated analytical techniques of statistical mechanics and then uses them to understand the complex physical systems. At the end of the course selected advanced topics of statistical mechanics will be discussed that includes thermodynamic fluctuations, diffusion, Brownian motion, the fluctuation-dissipation theorem and random walk.

Prerequisites Courses:

Classical mechanics, elementary thermodynamics, basic quantum mechanics, mathematical physics, statistical mechanics -I.

Course Outcomes (COs):

On completion of this course, students will have the ability to do:
CO1: Get an opportunity to develop their critical thinking and problem-solving skills related to equilibrium quantum statistical mechanics.
CO2: Use the sophisticated analytical techniques to study the interacting systems.
CO3: Use the basic concepts of statistical mechanics and thermodynamics to understand the theory of phase transitions.
CO4: Acquire a knowledge of developing analytical modelling for complex systems.
CO5: Learn and use the basic concepts of fluctuations and nonequilibrium processes.

Course Topics	**Contact Hours (Including Tutorials)**
Unit 1: Formulation of the quantum statistical mechanics Quantum mechanical ensemble theory: the density matrix, systems of identical, indistinguishable particles, spin, symmetry of wavefunctions, bosons, Pauli's exclusion principle, fermions, statistics of the various ensembles, Fermi systems,	**15(L) + 4(T)**

Bose systems, Blackbody radiation and Planck's distribution law, B-E condensation, Einstein model of lattice vibrations.	
Unit 2: Statistical mechanics of interacting systems: Approximate Methods Classical cluster expansion, virial expansion of the equation of state, evaluation of the virial coefficients	**6(L) + 2(T)**
Unit 3: Theory of Phase Transitions Phase diagrams, Phase equilibria, critical point, phase transitions, Landau's phenomenological theories	**5(L) + 1(T)**
Unit 4: The Ising model Definition of the Ising model, spontaneous magnetization, the one-dimensional Ising model	**4(L) + 1(T)**
Unit 5: Fluctuations Thermodynamic fluctuations, Principle of detailed balance, irreversible process, Diffusion equation, Brownian motion, the fluctuation-dissipation theorem, random walk.	**10(L) + 4(T)**

REFERENCES

This course does not follow a particular text. The following are useful reference books:

1. K. Huang, *Statistical Mechanics* (John Wiley & Sons, 2003)
2. R. K. Pathria, *Statistical Mechanics* (Pergamon Press, 1972)
3. D. Chowdhury and D. Stauffer, *Principles of Equilibrium Statistical Mechanics*, (Wiley-VCH, 2000).
4. L. D. Landau and E. M. Lifshitz, *Statistical Physics* (Part 1. 3rd ed. Pergamon Press, 1980)
5. Frederick Reif, ed. *Fundamentals of Statistical and Thermal Physics* (McGraw-Hill, 1965)
6. Richard Phillips Feynman, *Statistical Mechanics: A set of Lectures* (Westview Press, 1998)
7. Kadanoff, *Statistical Mechanics*, World Scientific.

Additional Resources (NPTEL, MIT Video Lectures, Web resources etc.)

Electronics Laboratory

Programme: M. Sc. (Physics)	Year: 1st	Semester: 1st
Course: Program Core	Credits: 4	Hours: 9 hrs. per week

List of experiments:

1. Design and study of single and two stage R-C coupled amplifiers (Frequency response and bandwidth)
2. Design and study of negative feedback amplifier (Voltage gain, frequency response and bandwidth)
3. Design and study of full wave rectifier (no filter, C-filter, L filter and □-filter)
4. Design and study of Op-Amp based inverting and non-inverting amplifier with frequency response
5. Study of basic configuration of OPAMP (IC-741), simple mathematical operations and its use as comparator and Schmitt trigger
6. Differentiator and Integrator using OPAMP (IC-741)
7. Design of low pass, high pass and band pass filters using OPAMP (IC-741)
8. Phase shift oscillator using OPAMP (IC-741)
9. Design and study of astable and monostable multivibrators using IC 555
10. Design and study of Hartley and colpitt Oscillators (wave forms and determination of frequency).
11. Design and study of Wien Bridge oscillators using OPAMP (IC-741)
12. Design and study of Clipping and Clamping circuits

Computational Methods in Physics Laboratory

Programme: M. Sc. (Physics)	Year: 1st	Semester: 1st
Course: Program Core	Credits: 1	Hours: 2 hours per week

List of Assignments:

Part A: Basics of Programming

1. Read and write data
2. Find mean, mode median
3. Find prime number and factorize a number
4. Sorting
5. Find value of series term by term specified by accuracy
6. Matrix operations
7. Plotting

Part B: Numerical Analysis

Problems related to

1. Root finding methods
2. System of linear equations
3. Interpolation
4. Differentiation & Integration
5. Ordinary Differential Equations

General Physics Laboratory

Programme: M. Sc. (Physics)	Year: 1^{st}	Semester: 2^{nd}
Course: Program Core	Credits: 4	Hours: 9 hrs. per week

List of experiments:

1. Basics of data analysis
2. Measurement of Planck's Constant by Photo-Electric Effect.
3. Determination of bandgap of a semiconductor by four probe method
4. Study of Hall Effect with variation of temperature
5. Performance evaluation of a GM Counter
6. Measurement of Electrochemical equivalent of Copper and Hydrogen.
7. To determine the mode numbers, electronic tuning range and electronic tuning sensitivity of microwave modes using microwave test bench
8. To study the splitting of spectral lines in the presence of a static magnetic field (Zeeman Effect)
9. Measurement of parameters of Optical Fibre
10. Frank Hertz experiment to verify the discrete nature of electronic state in the atom
11. To study the rotation of the polarization vector of plane polarized light in a magnetic field and measure the Verdet constant (Faraday Effect)

Solid State Material Characterization Laboratory

Programme: M. Sc. (Physics)	Year: 2^{nd}	Semester: 4^{th}
Course: Program Core	Credits: 4	Hours: 9 per week

List of experiments:

1. Understanding the principle of X-Ray diffractometer and study of the structure of a powder sample
2. Understanding of the principle of absorption and luminescence.
3. Determination of optical band gap of a given material using absorption and the emission spectra.
4. Measurement of charge carrier mobility and conductivity of a given material in dark and under illumination.
5. Measurement of dielectric constant and loss in a material.
6. Understanding the principle of electron diffraction and microscopy.
7. Study of a solar cells (J-V characteristics under illumination, IPCE Spectra, calculation of short circuit current from IPCE Spectra)
8. Understanding the principle of cyclic voltammetry.