Program structure for M.Sc. Physics- 2 years (All Semesters)

Semester I	Semester II	Semester III	Semester IV
CLASSICAL MECHANICS [**CU:4,** L-4, P-0] {CC}	CLASSICAL ELECTRODYNAMICS [**CU:4,** L-4, P-0] {CC}	NUCLEAR PHYSICS [**CU:4,** L-4, P-0] {CC}	ASTRO/NANO/RADIATIO PHYSICS/ADVANCED MATHEMATICAL [**CU:4,** L-4, P-0]
STATISTICAL MECHANICS (P [**CU:4,** L-4, P-0] {CC}	ADVANCED MATHEMATICAL METHODS [CU:4, L-4, P-0] {CC}	PARTICLE PHYSICS [**CU:4,** L-4, P-0] {CC}	ADVANCED PARTICLE PHYSICS [**CU:4,** L-4, P-0] {CC}
QUANTUM MECHANICS [**CU:4,** L-4, P-0] {CC}	Research Methodology [**CU:4**, L-4, P-0]	CONDENSED MATTER PHYSICS-II [**CU:4,** L-4, P-0]	ADVANCED NUCLEAR PHYSICS [**CU:4,** L-4, P-0] {CC}
ELECTRONICS [**CU:4,** L-4, P-0] {CC}	COMPUTATIONAL PHYSICS [**CU:4,** L-2, P-2]	ATOMIC AND MOLECULAR PHYSICS [**CU:4,** L-4, P-0]	ARTIFICIAL INTELLIGEN AND MACHINE LEARNING/BIOPHYSIC MEDICAL PHYSICS/MOO
PHYSICS LABORATORY [**CU:4,** L-0, P-4] {SEC}	QUANTUM FIELD THEORY [**CU:4**, L-4, P-0]	RESEARCH BASED COURSE [**CU:8**] {NTCC}	RESEARCH BASED COURSE [**CU:8**] {NTCC}
NUMERICAL METHODS AND ANALYSIS [**CU:4,** L-2, P-2]	PHYSICS LABORATORY [**CU:4,** L-0, P-4] {SEC}		
VAC [**CU:2,** L-2, P-0] {CC}	VAC [**CU:2,** L-2, P-0] {CC}		
MOOC-I	MOOC-II	MOOC-III	MOOC-IV
26Cr	**26 Cr**	**24Cr**	**24Cr**
Total Credits: 100			

MOOC COURSES:

Code	Title	Credits
MOOC-I	Physics of Renewables Systems	4
MOOC-II	Relativity - A gentle introduction	3
MOOC-III	Nanophotonics, Plasmonics & Metamaterials	3
MOOC-IV	Introduction to Quantum Field Theory	3

Semester-I

S.	Course Title	Course title	Course type	Credit	Credit unit

No.				L	T	P	
1.	PHY601	Classical Mechanics	Core Courses	4	0	0	4
2.	PHY602	Quantum Mechanics	Core Courses	4	0	0	4
3	PHY603	Statistical Mechanics	Core Courses	4	0	0	4
		Electronics	DSE	4	0	0	4
4.	PHY604	Physics Laboratory	DSE Laboratory	0	0	4	4
5.	PHY605	Numerical methods and analysis	DSE	2	0	2	2+2
6.	VAC	Behavioural Science	Value Added Course	1	0	0	1
7.		Foreign Business Language		1	0	0	1

Course Title: Classical Mechanics

L	T	P	Total Credits

4	0	0	4

Course Outcomes

CO1	Learning the knowledge of Newtonian physics from a single particle to a system of particles, generalized coordinates and D'Alembert's Principle and the Lagrangian formulations of classical mechanics, applications in appropriate physical problems
CO2	Learn about the Hamilton's Principle, variational principle, cyclic coordinates and Hamilton's equations
CO3	Understand the Canonical variables. Legendre transformation, Poisson and Lagrange brackets and their properties.
CO4	Learning of rigid body dynamics and small oscillations based normal modes and frequencies for different examples

Course Content

Unit-1-Lagrangian Formulation	**Lectures: 20**
Mechanics of a system of particles; constraints of motion, generalized coordinates, D'Alembert's Principle and Lagrange's velocity - dependent forces and the dissipation function, Applications of Lagrangian formulation	
Unit-2- Hamilton's Principles & Equations	**Lectures: 16**
Calculus of variations, Hamilton's principle, Lagrange's equation from Hamilton's principle, extension to nonholonomic systems, advantages of variational principle formulation, symmetry properties of space and time and conservation theorems. Legendre Transformation, Hamilton's equations of motion, Cyclic-co-ordinates, Hamilton's equations from variational principle, Principle of least action	
Unit-3- Canonical Transformation:	**Lectures: 20**
Canonical transformation and its examples, Poisson's brackets, Equations of motion, Angular momentum, Poisson's Bracket relations, infinitesimal canonical transformation, Conservation Theorems. Hamilton-Jacobi equations for principal and characteristic functions, Harmonic oscillator problem, Action-angle variables for systems with one-degree of freedom.	
Unit-4- Rigid Body Dynamics and Small Oscillation	**Lectures: 16**

Independent co-ordinates of rigid body, orthogonal transformations, Eulerian Angles and Euler's theorem, infinitesimal rotation, Rate of change of a vector, Coriolis force, angular momentum and kinetic energy of a rigid body, the inertia tensor, principal axis transformation, Euler equations of motion, Torque free motion of rigid body, motion of a symmetrical top. Eigen value equation, Free vibrations, Normal Coordinates, Vibrations of a triatomic molecule.

Text/Reference Books

AUTHOR	TITLE	Publisher	Year of publication	ISBN
H. Goldstein	Classical Mechanics	Pearson Education	2014	9781292038933
G.R. Fowles and G.L. Cassiday	Analytical Mechanics,	Cengage Learnings	2004	9788131501115
L.D. Landau and E.M. Lifshitz	Mechanics	Pergamon	1976	0750628960
N. C. Rana and P. S. Jaog	Classical Mechanics	McGraw-Hill,	1991	9780074603154

Course Title: PHY601 (Quantum Mechanics)

L	T	P	Total Credits
4	0	0	4

Course Contents/syllabus:

	Time(h)
Unit-I-Linear Vector Space	**16**
Linear vector spaces, Inner product, norm, Schwarz inequality, linear operators, eigenvalue and eigenvector, adjoint of a linear operator, Hermitian or self-adjoint operators and their properties, unitary operators, ortho-normal basis –discrete and continuous. Dirac's bra and ket notation, commutators, Simultaneous eigenvectors	
Unit-II-Matrix Mechanics & Angular Momentum	**20**
Postulates of quantum mechanics, uncertainty relation. Harmonic oscillator in matrix mechanics, Time development of states and operators, Heisenberg and Schroedinger representations, Exchange operator and identical particles. Density Matrix and Mixed Ensemble. Commutation relations of angular momentum operators. Eigenvalues, eigenvectors. Ladder operators and their matrix representations. Orbital angular momentum operator, Spin angular momentum and Pauli matrices. General angular momentum & its representation. Clebsch-Gordan coefficients. Wigner - Eckart theorem	
Unit III: Perturbation and Scattering Theory	**20**
Non-Degenerate and degenerate perturbation theory and its applications, Variational method with applications to the ground states of harmonic oscillator and other sample systems. General expression for the	

probability of transition from one state to another, constant and harmonic perturbations, Fermi's golden rule and its application to radiative transition in atoms, Selection rules for emission and absorption of light. Cross-section and scattering amplitude, partial wave analysis, Low energy scattering, Green's functions in scattering theory, Born approximation and its application to Yukawa potential and other simple potentials. Optical theorem, Scattering of identical particles.	
Unit IV: Introduction to Relativistic Quantum Mechanics	**16**
Quantum mechanics of many particle systems. The need for QFT (relativity, many-body and interactions), Klein-Gordon equation, Dirac equation and its plane wave solutions, significance of negative energy solutions, spin angular momentum of the Dirac particle.	

Text / Reference Books:

AUTHOR	TITLE	Publisher	Year of publication	ISBN
P.M. Mathews K. Venkatesan	A Text book of Quantum Mechanics: 2nd edition	Tata McGraw Hill, New Delhi	2004	978-0070146174
J.L. Powell and B. Crasemann	Quantum Mechanics	Narosa, New Delhi	1995	978-0201059205
J.J. Sakurai	Modern Quantum Mechanics	Addison Wesley	2004	978-0201539295
E. Merzbacher	Quantum Mechanics	John Wiley, Singapore	2004	978-0471887027
M.P. Khanna	Quantum Mechanics	Har Anand, New Delhi	2006	978-8124113684

R. Shankar	Principles of Quantum Mechanics: 3rd Ed.	Springer	2008	978-1475705768

Course Title: Statistical Physics

L	T	P	Total Credits
4	0	0	4

Course Outcomes

CO1	Ability to understand fundamentals of thermodynamics and revision of laws of thermodynamics
CO2	Knowledge of statistical ensemble, probability distributions, partition function and classification of ensemble theory on the basis of thermodynamic quantities
CO3	Implementation of quantum concepts on Statistical mechanics.
CO4	Understanding of phase transition concepts/rules and their implementation to describe spin interactions and Ising model
CO5	Learning of Brownian motion and random walk problems.

Course Contents

Unit-1- Review of Thermodynamics	**Lectures: 12**
Laws of thermodynamics, macroscopic and microscopic states, contact between statistics and thermodynamics, classical ideal gas, Gibbs paradox and its solution.	
Unit-2- Classical Ensemble Theory	**Lectures: 24**
Phase space and Liouville's theorem, the microcanonical ensemble theory and its application to ideal gas of monatomic particles, Boltzmann relation for entropy, The	

canonical ensemble and its thermodynamics, partition function, classical ideal gas in canonical ensemble theory, energy fluctuations, equipartition and virial theorems, a system of quantum harmonic oscillators as canonical ensemble, statistics of paramagnetism; The grand canonical ensemble and significance of statistical quantities, classical ideal gas in grand canonical ensemble theory.	
Unit-3- Quantum Statistical Mechanics	**Lectures: 18**
Indistinguishable particles in quantum mechanics. Bosons and Fermions. Bose-Einstein statistics, ideal Bose gas, photons, Bose-Einstein condensation. BoseEinstein condensation, discussion of gas of photons (the radiation fields) and phonons (the Debye field), Fermi-Dirac statistics, Fermi energy, ideal Fermi gas. discussion of heat capacity of a free-electron gas at low temperatures.	
Unit-4- Phase Transitions and Fluctuations	**Lectures: 18**
First- and second-order phase transitions, Interacting spin systems. The Ising model. Exact solution of Ising model in 1-dimension, mean-field solution in higher dimensions. Diamagnetic, Paramagnetic and ferromagnetic phases. Thermodynamic fluctuations, random walk and Brownian motion, introduction to nonequilibrium processes, diffusion equation	

Text/Reference Books

AUTHOR	TITLE	Publisher	Year of publication	ISBN
C. Kittel	Elementary Statistical Physics	Dover Publications	2004	978-0486435145
R.K. Pathria	Statistical Mechanics	Elsevier	2021	9351073971

F. Reif,	Statistical Physics	Tata McGraw-Hill	2008	978-0070048621
K. Huang	Statistical Mechanics	Wiley	2023	9354247736

Course Title: PHY603 (Electronics)

L	T	P	Total Credits
4	0	0	4

Course Contents/syllabus:

	Time (h)
Unit I: Circuit Analysis	**16**
Thevenin and Norton theorems, Mesh and Node analysis. Admittance, impedance, scattering and hybrid matrices for two and three port networks and their cascade & parallel combinations. Laplace Transforms.	
Unit II: Physics of Semiconductor Devices	**20**
Energy band diagrams, Direct and indirect semiconductors, Metal-semiconductor junctions, Semiconductor junctions p-n junction, Zener diode, Schottky diode, switching diodes, Tunnel diode, LEDs, Solar cell, Photoconductors, Photodiodes, Semiconductor laser, JFET and MOSFET, Liquid crystal displays, UJT, Gunn diode, IMPATT devices, pn devices and applications	
Unit III: Analog Circuits and its Applications	**18**

Differential amplifiers, common mode rejection ratio, Transfer characteristics, OPAMP configurations, open loop and close loop gain, inverting, non-inverting and differential amplifier, Basic characteristics with detailed internal circuit of IC Opamp, slew rate, Comparators with hysteresis, Window comparator, wave generators, Summing amplifier, Analogue computation, Logarithmic and antilogarithmic amplifiers. Current-to-voltage and Voltage-to-current converter, Voltage regulation circuits, Precision rectifiers, Instrumentation amplifiers, True RMS voltage measurements. 555 timer based circuits.	
Unit IV: Oscillators and Filter	**18**
Phase shift oscillator, Wien-bridge oscillator, Sample and hold circuits, Phase Locking Loop basics and applications. Lock-in-detector, box-car integrator. Sallen and Key configuration and Multifeedback configuration, Low Pass, High Pass, Band Pass and Band Reject active filters, Delay equalizers.	

Text / Reference Books:

AUTHOR	TITLE	Publisher	Year of publication	ISBN
W.D. Stanley	Network Analysis with Applications	Pearson	2003	978-0130602466
Chua, Desoer and Kuh	Linear and Non-linear Circuits	Tata McGraw	1987	978-9339220686
S.M. Sze	Semiconductor Devices Physics and Technology	John Wiley	2002	978-8126556755
J. Millman C. C. Halkias and S. Jit	Electronic Devices and Circuits, 4th Ed.	McGraw-Hill	2015	978-9339219543

Boylested and Nashelsky	Electronic Devices and Circuits Theory, 10th ed	Pearson Education,	2009	978-9332542600
Ben Streetman, Sanjay Banerjee	Solid State Electronic Devices: 6th Edition	Prentice Hall India	2005	978-0131497269

Course Title: PHY604 (Physics Labortary)

L	T	P	Total Credits
0	0	4	4

Lab/ Practical details:

List of Experiments -with basic instructions

- To study the characteristics of a regulated power supply and voltage multiplier circuits.
- To study the characteristics of a PN junction with varying temperature & the capacitance of the junction.
- To study the characteristics of a LED and determine activation energy.
- To study the frequency response of an operational amplifier & to use operational amplifier for different mathematical operations
- To study the power dissipation in the SSB and DSB side bands of AM wave. To study the demodulation of AM wave.
- To study various aspects of frequency modulation and demodulation.
- To study Hartley and Wien-Bridge oscillators.
- FET/MOSFET characteristics, biasing and its applications as an amplifier..
- UJT characteristics and its application as relaxation oscillator or triggering of triac.
- To study logic gates and flip flop circuits using on a bread-board.
- To design (i) Low pass filter (ii) High pass filter (iii) All-pass filter (iv) Band pass filter (v) Band-reject passive filter.
- Use of timer IC 555 in astable & monostable modes and applications involving relays, LDR.
- To design a rectangular/triangular waveform generator using Comparators and IC8038.
- Hybrid parameters of a transistor and design an amplifier. Determination of k/e ratio.

- To determine Planck’s constant using photocell.
- To determine the electric charge of an electron using Millikan drop experiment

Text / Reference Books:

AUTHOR	TITLE	Publisher	Year of publication	ISBN
Flint, B L and Worsnop, H T	Advanced practical physics for students	Asia Publishing	1971	978-0423738902
J. Millman & C. C. Halkias	Electronic Devices and Circuits	McGraw-Hill	4th Ed., 2015	9780137246830

Course Title: (Numerical Methods and Analysis)

L	T	P	Total Credits
2	0	2	4

Course Contents/syllabus:

	Time(h)
Unit I: Introduction	**9**
Introduction to computational physics, Need of computational physics, Computer hardware, basic computer architecture, hierarchical memory, cache, latency and bandwidth, Moores law, power bottleneck, Software: compiled (Fortran, C) vs. interpreted languages (MATLAB, python); software management	
Unit II: Errors and Precision	**9**
Error analysis for round-off and truncation errors. Elements of Numerical Integration, Error estimates of Trapezoidal rule, Simpson midpoint and 3/8	

rules, Integer representation; floating-point representation, Machine precision, error calculation	
Unit III: Interpolation	**9**
Composite Numerical Integration. Gaussian Quadrature using interpolating polynomials, special polynomials like Legendre polynomials, Multidimensional integrals - Two and three dimensional integration. Interpolation – Introduction, Polynomial interpolation; Lagrange Interpolatiion polynomial; Cubic Spline Interpolation, Neville's algorithm	
Unit IV: Data Analysis	**9**
Modeling of Data, Maximum Likelihood Estimator; Pearson chi square; Least Squares method – both without and with errors in dependent variable; Parameter estimations and errors; General Linear Least square.	

Text / Reference Books:

AUTHOR	TITLE	Publisher	Year of publication	ISBN
S. Sastry	Introductory Methods of Numerical Analysis	PHI Learning Pvt. Ltd.	5th edition, 2012	9788120345928
R.C. Verma	Computational Physics: An Introduction	New Age International	1st ed., 2005	9788122416596
Atkinson, K E	Elementary Numerical analysis	Wiley India	3rd edition, 2003	9780471433378
Humming, R W	Numerical methods for scientists and engineers	Dover Publications	2nd edition, 1987	9780486652412
Walker, Darren	Computational Physics	Mercury Learning and Information	Revised edition, 2016	9781942270737

Numerical Methods and Analysis Laboratory-I	

Objectives: The major objective of this course is intended to be an Introduction to a programming Language (C/C++) as well as application for general mathematical problems**.**

- Introduction to Linux and Computer Programming Language (C/C++)
- Introduction to Graphics (Gnuplot etc.)s.
- Data and Statements : Data Types. Constants and Variables. Mathematical, Relational, Logical and Bitwise Operators. Expressions and Statements. Block, Local and Global variables. Auto, Static and External Variables
- I/O Statements : printf, scanf, getc, getch, getchar, getche, etc. Streams: cin and cout.
- Control Statements : If-statement. If-else Statement. Nested if Structure. Else-if Statement
- Unconditional and Conditional Looping. While Loop. Do-while Loop. For Loop. Break and Continue Statements.
- Loops.
- Arrays and Structures : One and Two Dimensional Arrays. Idea of Structures.
- Functions and Classes: Standard Library Functions, User-defined Functions. Void Functions and Functions returning Values,
- Classes, Objects, Idea of Strings and Pointer
- C++ program of matrix multiplication.
- C++ Programs on Random number generation and tests of randomness.
- C++ program to find reverse of number by defining functions outside class.
- C++ Program to calculate Volume of Cube using constructor and destructor.
- C++ program for various Mathematical Operations using Switch case.
- C++ Programs on Measurement of central moment, correlation coefficients using classes.
- C++ Programs on Least squares fitting for linear and general equations.
- C++ Programs on Numerical Differentiation
- C++ Programs on Interpolation – Lagrange interpolating polynomial Lagrange interpolation.

- C++ Programs on Cubic spline interpolation.
- C++ Programs on Root Finding (Bisection, Secant and Newton-Raphson Methods)

Semester-II

S. No.	Course Code	Course title	Course type	Credit			Credit unit
				L	T	P	
1.		Advanced Mathematical Methods	Core Courses	4	0	0	4
2.		Classical Electrodynamics	Core Courses	4	0	0	4
3		Quantum Field Theory	DSE Courses	4	0	0	4
4.		Physics Laboratory	DSE Laboratory	0	0	4	4
5.		Computational Physics	DSE	2	0	2	2+2

6.		Research Methodology	DSE Courses	4	0	0	4
7.		Behavioural Science	Value Added Course	1	0	0	1
8.		Foreign Business Language		1	0	0	1

Course Title: Advanced Mathematical Methods

L	T	P	Total Credits
4	0	0	4

Course Outcomes

CO1	Acquire knowledge of methods to solve partial differential equations specifically variable separation method with the examples of important partial differential equations in Physics
CO2	Learn the Fourier analysis of periodic functions and their applications in physical problems, understand the Fourier, Laplace transform and their applications
CO3	Learn about the special functions Bessel, Legendre, Hermite and Laguerre, their differential equations and their applications in various physical problems
CO4	Learn about the properties of complex functions such as analyticity, and evaluating integrals using Cauchy's Integral formula and series (Taylor and Laurent) expansion

Course Content

Unit-1-Integral Transformations	**Lectures: 22**
Fourier series, Dirichlet conditions. General properties. Convolution and correlation, Advantages and applications, Gibbs phenomenon. Fourier transforms, Development of the Fourier integral, Inversion theorem, Fourier transforms of derivatives; Momentum representation. Laplace transforms, Laplace transforms of derivatives, Properties of Laplace transform, Inverse Laplace transformation. Applications	
Unit-2- Complex Variables	**Lectures: 14**
Cauchy-Riemann conditions, analyticity, Cauchy-Goursat theorem, Cauchy's Integral formula, branch points and branch cuts, multivalued functions, Taylor and Laurent expansion, singularities and convergence, calculus of residues, evaluation of definite integrals, Dispersion relation.	
Unit-3- Group Theory	**Lectures: 20**
Multiplication table, conjugate elements and classes, Abstract groups: subgroups, classes, cosets, factor groups, normal subgroups, direct product of groups; Examples,	

Homomorphism & isomorphism. Representations: reducible and irreducible, unitary representations, Schur's lemma and orthogonality theorems, characters of representation, direct product of representations. Introduction to continuous groups: Lie groups, rotation and unitary groups. Representation of SO(3), SU(2), SU(3) and SO(3,1)	
Unit-4- Theory of Probability and Statistics	**Lectures: 16**
Introduction to probability theory, Random Variables, Binomial, Poisson and Normal Distributions. Central Limit Theorem, Hypothesis Testing and Data Analysis in Statistics	

Text / Reference Books:

AUTHOR	TITLE	Publisher	Year of publication	ISBN
G.B. Arfken	Mathematical Methods for Physicists	Elsevier	2012	9381269556
George F. Simmons,	Differential Equations	McGraw Hill.	2007	978-8173193293
A.S.Fokas & M.J.Ablowitz	Complex Variables	Cambridge Univ. Press	2011	978-0521534291
K.F Riley, M.P. Hobson and S. J. Bence	Mathematical Methods for Physics and Engineers	Cambridge University Press	2006	978-0521890670

Course Title: PHY602 (Classical Electrodynamics)

L	T	P	Total Credits
4	0	0	4

Course Contents/syllabus:

	Time (h)
Unit I: Electrostatics & Boundary Value Problems	**18**
Gauss's law, Poisson and Laplace equation, Green's theorem, Dirichlet and Neuman boundary conditions, Formal solution of electrostatic boundary value problems with Green function, Electrostatic potential energy and energy density. Method of Images , Point Charge in the Presence of a Grounded Conducting Sphere, Point Charge in the Presence of a Charged, Insulated, Conducting Sphere, Point Charge Near a Conducting Sphere at Fixed Potential , Conducting Sphere in a Uniform Electric Field by Method of Images, Green Function for the Sphere; General Solution for the Potential , Conducting Sphere with Hemispheres at Different Potentials, Separation of Variables; Laplace Equation in Rectangular coordinates, Laplace Equation in Spherical Coordinates, Legendre Equation and Legendre Polynomials, Boundary-Value Problems with Azimuthal Symmetry. Multipole Expansion, Multipole Expansion of the Energy of a Charge Distribution in an External Field, Elementary Treatment of Electrostatics with Ponderable Media, Boundary-Value Problems with Dielectrics, Electrostatic energy in dielectric media	
Unit II: Magnetostatics	**18**
Biot and Savart Law, Ampere's Law, Vector potential, Magnetic Fields of a Localized Current Distribution, Magnetic Moment , Force and Torque on and Energy of a Localized Current Distribution in an External Magnetic Induction, Singularity in dipole field, Fermi-contact term, Macroscopic Equations, Boundary Conditions on B and H, Methods of Solving Boundary-	

Value Problems in Magnetostatics, Uniformly Magnetized Sphere, Magnetized Sphere in an External Field; Permanent Magnets, Magnetic Shielding, Spherical Shell of Permeable Material in a Uniform Field.	
Unit III: Maxwell's Equations & waveguides	**18**
Maxwell's Displacement Current; Maxwell Equations, Vector and Scalar Potentials, Gauge Transformations, Lorenz Gauge, Coulomb Gauge, Hertz potential. Cylindrical Cavities and Waveguides, Waveguides, Modes in a Rectangular Waveguide, Energy Flow and Attenuation in Waveguides, Coaxial cable, Resonant Cavities, Power Losses in a Cavity; Q of a Cavity , Earth and Ionosphere as a Resonant Cavity: Schumann Resonances, Multimode Propagation in Optical Fibers, Modes in Dielectric Waveguides.	
Unit IV: Electromagnetic Waves	**18**
Green Functions for the Wave Equation, plane waves in free space and isotropic dielectrics, waves in conducting media, skin depth, Plane waves in a non conducting medium, Reflection and Refraction of Electromagnetic Waves at a Plane Interface Between two Dielectrics, Fresnel's amplitude relations, Reflection and Transmission coefficients, polarization by reflection, Brewster's angle, Total internal reflection, Stoke's parameters, Waves in rarefied plasma (ionosphere) and cold magneto-plasma, Frequency Dispersion Characteristics of Dielectrics, Conductors, and Plasmas, Simplified Model of Propagation in the Ionosphere and Magnetosphere. Fields at the Surface of and within a Conductor,	

Text / Reference Books:

AUTHOR	TITLE	Publisher	Year of publication	ISBN
D.J. Griffiths	Introduction to Electrodynamics, 4th ed.	Prentice Hall India, New Delhi	2012	978-1108822909
A.Z. Capri and P.V. Panat	Introduction to Electrodynamics	Narosa Publishing House	2010	978-8173193293

L. D. Landau E. M. Lifshitz L. P. Pitaevskii	Electrodynamics of Continuous Media	Oxford	2005	978-8181477934
John David Jackson	Classical Electrodynamics,3rd Ed	Wiley	1998	978-0471309321
S. P. Puri	Classical Electrodynamics	Narosa	2011	978-8184875843

Course Title: Research Methodology

L	T	P	Total Credits
4	0	0	4

Course Outcomes

CO1	Ability to understand the basic characteristics of research and importance of various techniques while performing research.
CO2	Understand the types of data and measurement methods.
CO3	To develop numerical methods aided by technology to solve algebraic equations, calculate derivatives and integrals, curve fitting and optimization techniques
CO4	Understanding the role of hypothesis formulation in research.

Course Content

Unit I: Introduction	Lectures: 18

Research meaning and significance, Characteristics of scientific Research Type of research: pure, applied, analytical, exploratory, descriptive, surveys, Case-study Conceptual or theoretical models Research process Limitations of Social science research Role of computer technology in research.	
Unit II: Data: Types and Measurement	**Lectures: 18**
Data information and statistics Data types Qualitative and Quantitative; Cross and Time series Scales of measurement :nominal, ordinal, interval, ratio Sources of data: Primary and secondary Census and sample survey-criterion of good sample, choice of sample, probability and non-probability sampling methods, sampling and non-sampling errors.	
Unit III: Numerical Techniques in Defence Research	**Lectures: 18**
Introduction to defence related numerical data, solution of non-linear equations, solution of linear systems. Introduction and polynomial approximation, curve fitting, Numerical applications & integrations, numerical optimization. Matrices and types of linear systems, direct elimination methods, conditioning and stability of solutions, Simulation for Computer Graphics, Modelling techniques.	
Unit IV: Hypothesis: Nature and Role in Research	**Lectures: 18**
Definition of a Hypothesis Role of Hypothesis Types of Hypothesis Criteria of Good Hypothesis Null and Alternative Hypothesis, parameter and statistic, Type- I and type ii errors, Level of significance, Critical region	

Text/Reference Books:

AUTHOR	TITLE	Publisher	Year of publication	ISBN
Kothari R.C	Research Methodology, Methods and Techniques.	New Age International Publishers	2008	9389802555

O.R.Krishnaswamy, House, 1993	Methodology of Research In Social Sciences	Himalya publishing	1993	9350975696
P.V. Young	Scientific Social Survey and Research,	Prentice Hall of India Ltd,	1984	8120300858
S.S. Sastry.	Introductory Methods of Numerical Analysis	Prentice Hall India Learning Private Limited Pvt. Ltd	2009	9788120345928

Course Title: Computational Physics

L	T	P	Total Credits
2	0	2	4

Course Outcomes

CO1	Review of C++ programming including arrays, pointers and functions
CO2	Learning of various methods to find the roots of equations

CO3	Understanding of Gauss elimination methods to solve linear algebraic equations
CO4	Understanding the differential equation to solve complex physics equations like heat equation and wave equation

Course Content

Unit-1-Review of C++ Programming	**Lectures: 9**
Data types, C programming syntax for Input/Output, Control statements: if, if-else and nested-if statements. Looping: while, for do while loops, Functions: Call by values and by references, Arrays and structures: one dimensional two-dimensional arrays, Pointers, Idea of string and structures	
Unit-2-Roots of Equations	**Lectures:9**
Real roots of single variable function; iterative approach; qualitative behavior of the function; Closed domain methods (bracketing): Bisection; False position method; Open domain methods: Newton-Raphson, Secant method; Muller's method; Complications; Roots of polynomials; Roots of non-linear equations.	
Unit-3-Linear Algebraic Equations	**Lectures: 9**
Introduction, Augmented Matrix, Gaussian Elimination with Backward substitution, Pivoting strategies – partial and complete, Gauss Jordan Elimination Method, Operation Counts, Tridiagonal Systems of Linear Equations, Inverse of a matrix, LU Decomposition	
Unit-4- Differential Equations	**Lectures: 9**
Numerical Differentiation, Partial differential equations – elliptic equations; boundary conditions; Finite Difference method; Forward and Backward difference methods, Few examples: Heat equations, Wave equations; Introduction to Finite Element method	

Computational Programming Laboratory	

Objectives: The major objective of this course is intended to be an Introduction to a programming Language (C/C++) as well as application for general mathematical problems**.**

- C++ Programs on Cubic spline interpolation.
- C++ Programs on Root Finding (Bisection, Secant and Newton-Raphson Methods)
- C++ Programs to solve First & Second Order differential Equations including Simultaneous Equations (Euler & Runge Kutta)
- C++ Programs on Numerical Integration (Trapezoidal, Simpson and Quadrature methods).
- C++ Programs on Numerical Differentiation
- C++ Programs on Solution of algebraic equations using Gauss elimination with back substitution.
- C++ Programs on Implementing random walk problem in 1-, 2- and 3-dimensions.
- To study graphically the motion of falling spherical body under various effects of medium using Euler method i.e. viscous drag, buoyancy and air drag.
- To study graphically the EM oscillations in a LCR circuit using Runge-Kutta Method

	• To study the motion of an artificial satellite. • To obtain the energy eigenvalues of a quantum oscillator using the Runge-Kutta method • To study the motion of a charged particle in: (a) Uniform electric field, (b) Uniform Magnetic field, (c) in combined uniform electric and magnetic fields. • To study phase trajectory of a Chaotic Pendulum. • To study the motion of 1-D harmonic oscillator (without and with damping effects). • To study graphically the path of a projectile with and without air drag using FN method. • To study convection in fluids using Lorenz system • Use Monte Carlo techniques to simulate phenomenon of Nuclear Radioactivity.

Text/Reference Books:

AUTHOR	TITLE	Publisher	Year of publication	ISBN
Nicholas J. Giordano and Hisao Nakanishi	Computational Physics	Prentice Hall,India	2005	0131469908

R.C. Verma	Computational Physics: An Introduction	New Age International Publishers	1999	9393159169
Richard L. Burden, J. Douglas Faires, Annette M. Burden	Numerical Analysis	Cengage Learning	2016	9788131516546
Binder, Kurt, Heermann, Dieter	Monte Carlo Simulation in Statistical Physics: An Introduction	Springer	2010	3030107574

Course Title: Physics Laboratory-II

L	T	P	Total Credits
0	0	4	4

Objective: The main objective of this laboratory is to understand the basic concepts of electronics physics through standard set of experiments. Students are expected to perform at least 08 experiments in each semester. In addition, performance of the and the continuous evaluation process allows each and every student to correlate these experiments with the corresponding theory.

- To study the characteristic of J-H curve using ferromagnetic standards.

- To determine the Hall coefficient for a given semi-conductor
- To study temperature-dependence of conductivity of a given semiconductor crystal using four probe method.
- To determine dipole moment of an organic molecule, Acetone
- Tracking of the Ferromagnetic-paramagnetic transition in Nickel through electrical resistivity.
- Temperature dependence of a ceramic capacitor - Verification of Curie-Weiss law for the electrical susceptibility of a ferroelectric material.
- To determine the velocity of ultrasonic waves using interferometer as a function of temperature.
- To study the lattice dynamics using LC analog kit.
- To study the characteristics and dead time of a GM Counter
- To study Poisson and Gaussian distributions using a GM Counter.
- To determine the gamma-ray absorption coefficient for different elements.
- To study the alpha spectrum from natural sources Th and U.
- To calibrate the given gamma-ray spectrometer and determine its energy resolution
- To study polarization by reflection - Determination of Brewester's angle.
- To study the Magnetorestriction effect using Michelson interferometer.
- To measure numerical aperture and propagation loss and bending losses for optical fibre as function of bending angle and at various wavelengths

Text/Reference Books:

AUTHOR	TITLE	Publisher	Year of publication	ISBN
B. L. Flint and H.T. Worsnop	Advanced Practical Physics for students	Asia Publishing House	1971	B097NDTRKR
W.R. Leo 1987.	Techniques for Nuclear and Particle Physics Experiments:	Springer Verlag	1987	978-3540572800

G. F. Knoll (John Wiley & Sons, Inc. 3rd Ed.)	Radiation Detection and Measurement	John Wiley & Sons, Inc	2000	9780470131480

Course Title: Quantum Field Theory

L	T	P	Total Credits
4	0	0	4

Course Outcomes

CO1	Have the knowledge of the founding principles of relativistic quantum mechanics, Klein-Gordon equation, Dirac equation
CO2	Implementation of Lagrangian and Hamiltonina on scalar fields.
CO3	Understand the basic Feynman rules and its applications
CO4	Significance of decay rates in Field theory

CO5	Understanding the different order of processes and calculation of matrix elements and cross sections.

Course Content

֍	**Unit-1-Dirac Equation**	**Lectures: 15**
	The nonrelativistic limit of Dirac equation, Electron in electromagnetic fields, spin magnetic moment , spin-orbit interaction, Dirac equation for a particle in a central field, fine structure of hydrogen atom, Lambshift	
֍	**Unit-2- Quantum Field Theory**	**Lectures: 15**
	Resume of Lagrangian and Hamiltonian formalism of a classical field, Noether theorem. Quantization of real scalar field, complex scalar field, Dirac field and e.m. field, Covariant perturbation theory, Wick's Theorem, Smatrix, Feynman rules, Feynman diagrams and their applications	
֍	**Unit-3- Yukawa Field Theory**	**Lectures: 15**
	Yukawa field theory, calculation of scattering cross sections, decay rates, with examples.	
֍	**Unit-4- Yukawa Field Theory & QED**	**Lectures: 15**
	Quantum Electrodynamics, calculation of matrix elements - for first order and second order processes	

Text/Reference Books:

AUTHOR	TITLE	Publisher	Year of publication	ISBN
M. E. Peskin & D.V. Schroeder	An Introduction to Quantum Field Theory	Westview Press)	1995	978-0367320560
L. H. Ryder	Quantum Field Theory	Cambridge University Press	1996	978-0521478144
A. Das (), 2008	Lectures on Quantum Field Theory	World Scientific	2008	978-9811220869
A. Lahiri & P. Pal	A first book of Quantum Field Theory	Narosa Publishers	2005	8173196540

VALUE-ADDED COURSES

Course Title: Individual, Society and Nation (Behavioural Sciences)

List of Professional Skill Development Activities (PSDA):

- Project on Understanding Diversity
- Term Paper on Patriotism among Youth

Course Learning Outcomes: On completion of the course:

- To recognize individual differences
- To manage individual differences
- To develop patriotic feelings
- To recognized their self in relation to society & nation

Course Contents/syllabus:

	Time (h)
Unit-1- Individual differences & Personality	**4 H**
● Personality: Definition& Relevance ● Importance of nature & nurture in Personality Develop ● Importance and Recognition of Individual differences in Pe ● Accepting and Managing Individual differences Intuition, Ju Perception & Sensation (MBTI) BIG5 Factors	
Unit-2- Managing Diversity	**4 H**
● Defining Diversity ● Affirmation Action and Managing Diversity ● Increasing Diversity in Work Force ● Barriers and Challenges in Managing Diversity	
Unit-3- Socialization, Patriotism and National Pride	**4 H**
● Nature of Socialization ● Social Interaction ● Interaction of Socialization Process ● Contributions to Society and Nation ● Sense of pride and patriotism ● Importance of discipline and hard work ● Integrity and accountability	
Unit-4- Human Rights, Values and Ethics	**4 H**
● Meaning and Importance of human rights ● Human rights awareness ● Values and Ethics- Learning based on project work on Scriptures like- Ramayana, Mahabharata, Gita etc.	

Text / Reference Books:

AUTHOR	TITLE	Publisher	Year of publication	ISBN
Department of English, Univ. of Delhi	The Individual & Society	Pearson Education	2010	978-8131704172

Umang Malhotra	Individual, Society, and the World	Universe	2004	978-0595662401
Tonja R. Conerly & Kathleen Holmes	Introduction to Sociology 3e	Openstax	2015	9781711493978
Daksh Tyagi	“A Nation of Idiots”	Every Protest	2019	978-8194275015

Course Title: French Grammar (INL-101)

L	T	Total Credit Units
1	0	1

Course Learning Outcomes: At the end of the course, the student shall be able to:

- Understand information; Express in his own words; Paraphrase; Interpret and translate.
- Apply information in a new way in a practical context
- Analyze and break-down information to create new ideas
- Evaluate and express opinion in a given context

Course Contents/syllabus:

	Teaching Hours
Unit-I : My family and my house	**4 H**
Descriptors/Topics • Talk about your family members • Usage of possessive adjectives • Describe your house/apartment • Prepositions of location • Negation	
Unit-II- Lifestyle	**4 H**
Descriptors/Topics • Talk about your hobbies and pastimes • Usage of appropriate articles : definite and contracted	

● Talk about your daily routine ● Usage of pronominal verbs	
Unit-III- In the city	**4 H**
Descriptors/Topics ● Filling up a simple form ● Ask for personal information ● Usage of interrogative adjectives ● Give directions about a place ● Ordinal numbers ● Usage of demonstrative adjectives	
Unit-IV- Week-end	**4 H**
Descriptors/Topics ● Talk about your week-end plans ● Usage of disjunctive pronouns ● Usage of Near Future tense ● Talk about weather ● Write a simple post card	

Text / Reference Books:

Author	Title	Publisher	Year of Publication	ISBN No
Christine Andant, Catherine Metton, Annabelle Nachon, Fabienne Nugue,	A Propos - A1, Livre de l'élève et Cahier d'exercices.	Langers International Pvt. Ltd.	2010	978-9380809069
Collins Dictionaries	Easy Learning French Complete Grammar, Verbs and Vocabulary	Collins	2016	978-0008141721

Nikita Desai, Samapita Dey Sarkar	Apprenons La Grammaire Ensemble - French	Langers International Pvt. Ltd.	2017	978-8193002681

Course Title: German Grammar (INL-102)

L	T	Total Credit Units
1	0	1

Course Outcome:

At the end of the course, the student shall be able to:

- Understand information; Express in his own words; Paraphrase; Interpret and translate.
- Apply information in a new way in a practical context
- Analyze and break-down information to create new ideas
- Evaluate and express opinion in a given context

Course Contents/syllabus:

	Teaching Hours
Module I: Time (Uhrzeit); People and the World: Land, Nationalität und Sprache	**4 H**
• Introduction of time • Read text related to time and teach the students the time expressions • Exercises related to Time • Adverbs of time and time related prepositions • Vocabulary: Countries, Nationalities, and their languages • Negation: “nicht/ kein” • Ja/Nein Fragen.	

● All the colors and color related vocabulary, adjectives, and opposites ● Exercises and comprehension for the same.	
Module II: Irregular verbs (unregelmässige Verben)	**4 H**
● Introduction to irregular verbs and their conjugation e.g. fahren, essen, lesen etc ● Read a text related to the eating habits of Germans ● Vocabulary: Obst, Gemüse, Kleiderstück with usage of irregular verbs ● Free time and hobbies ● Food and drinks	
Module III: Accusative case: articles and pronouns (Akkusativ Kasus: Artikel und Pronomen)	**4 H**
● Introduction to the concept of object (Akkusativ) ● Formation of sentences along with the translation and difference between nominative and accusative articles ● Usage of accusative Definite articles ● Usage of accusative Indefinite articles	
Module IV: Accusative case: possessive pronouns (Akkusativ Kasus: Possessivpronomen) Family and Relationship	**4 H**
● Accusative Personal Pronouns: - Revision of the nominative personal pronouns and introduction of accusative. Applicability of pronouns for both persons and things. ● Usage of accusative Personal Pronouns ● Introduction of accusative possessive pronouns ● Difference between nominative and accusative possessive pronouns ● usage of accusative possessive pronouns	

Text / Reference Books:

Author	Title	Publisher	Year	ISBN No
Dora Schulz, Heinz Griesbach	Deutsche Sprachlehre Fur Auslander	Max Hueber Verlag	1984	978-3190010066
Hartmut Aufderstrasse, Jutta Muller, Helmut Muller	Themen Aktuell: Glossar Deutsch	Max Hueber Verlag	2003	978-3190816903
Giorgio Motta	Wir Plus Grundkurs Deutsch fur Junge Lerner Book German Guide	Goyal Publishers	2011	9788183072120

Semester-III

S. No.	Subject	Theory Hours	Practical Hours	Total Credits
1	Nuclear Physics (Core)	4	0	4
2	Particle Physics (Core)	4	0	4
3	Atomic and Molecular(Core)	4	0	4
4	Condensed Matter physics	4	0	4
5	Research project			8

Course Title: Nuclear Physics

L	T	P	Total Credits
4	0	0	4

Course Outcomes

CO1	Become familiar with nuclear structure and its fundamental properties, effect of external magnetic field, NMR
CO2	Gains knowledge on radioactive decay and its application
CO3	Understanding of nuclear force and its implementation on nucleons.
CO4	Learning of characteristics of neutron and various kind of nuclear reactions

Course Contents

Unit-1-Nuclei Properties	Lectures: 16
Nuclear radii and measurements, nuclear binding energy (review), nuclear moments and systematic, wave-mechanical properties of nuclei, hyperfine structure, effect of external magnetic field, Nuclear magnetic resonance.	
Unit-2-Radioactive Decays	**Lectures: 20**
Review of barrier penetration of alpha decay & Geiger-Nuttal law. Beta decays, Fermi theory, Kurie plots and comparative half-lives, Allowed and forbidden transitions, Experimental evidence for Parity-violation in beta decay, Electron capture probabilities, Double beta decay, Neutrino,detection of neutrinos, measurement of the neutrino helicity. Multipolarity of gamma transitions, internal conversion process, transition rates, Production of nuclear orientation, angular distribution of gamma rays from oriented nuclei.	
Unit-3-Nuclear Forces	**Lectures: 18**
Evidence for saturation of nuclear density and binding energies (review), types of nuclear potential, Ground and excited states of deuteron, dipole and quadrupole moment of deuteron, n-p scattering at low energies, partial wave analysis, scattering length, spin-dependence of n-p scattering, effective-range theory, coherent and incoherent scattering, central and tensor forces, p-p scattering, exchange forces & single and triplet potentials, meson theory of nuclear forces	
Unit-4-Neutron Physics & Nuclear Reactions	**Lectures: 18**
Neutron production, slowing down power and moderating ratio, neutron detection. Nuclear reactions and cross-sections, Resonance, Breit–Wigner dispersion formula for l=0 and higher values, compound nucleus, Coulomb excitation, nuclear kinematics and radioactive nuclear beams	

Text / Reference Books:

Author	Title	Publisher	Year	ISBN No

K. Hyde	Basic Ideas and Concepts in Nuclear Physics	CRC Press	2004	0750309806
Herald Enge	Introduction to Nuclear Physics ;	Addison-Wesley	1971	0201018705
Irving Kaplan	Nuclear Physics	Narosa Publishers	2002	8185015899
R.R. Roy and B.P. Nigam	Theory of Nuclear Structure	New Age, New Delhi	2005	812243410

Course Title: Particle Physics

L	T	P	Total Credits
4	0	0	4

Course Outcomes

CO1	Classification of elementary particles on the basis of fundamental interactions and their properties, quantum numbers, various reactions and decay processes
CO2	Hadron-hadron interactions and its fundamentals
CO3	Implementation of relativity to understand the kinematics of the elementary particle
CO4	Learning of characteristics of weak interactions; beta decay and Fermi theory, parity violation

Course Content

Unit-1- Introduction to Particle Physics	**Lectures: 18**
Fermions and bosons, particles and antiparticles, quarks and leptons, interactions and fields in particle physics, classical and quantum pictures, Yukawa picture, types	

of interactions - electromagnetic, weak, strong and gravitational, units. Invariance in CCT422: classical mechanics and in quantum mechanics, Parity, Pion parity, Charge conjugation, Positronium decay. Time reversal invariance, CPT theorem.	
Unit-2-Hadron-Hadron Interactions	**Lectures: 18**
Cross section and decay rates, Pion spin, Isospin, Twonucleon system, Pion-nucleon system, Strangeness and Isospin, G-parity, Total and Elastic cross section, Particle production at high energy	
Unit-3-Relativistic Kinematics and Phase Space	**Lectures: 18**
Introduction to relativistic kinematics, particle reactions, Lorentz invariant phase space, two-body and three-body phase space, recursion relation, effective mass, dalitz, K-3 π-decay, τ-θ puzzle, dalitz plots for dissimilar particles, Breit-Wigner resonance formula, Mandelstam variables.	
Unit-4-Quark Model and Weak Interaction	**Lectures: 18**
The Baryon decuplet, quark spin and color, baryon octer, quark-antiquark combination. Classification of weak interactions, Fermi theory, Parity nonconservation in β-decay, experimental determination of parity violation, helicity of neutrino, K-decay, CP violation in K- decay and its experimental determination.	

Text / Reference Books:

Author	Title	Publisher	Year	ISBN No
Griffiths D.	Introduction to Elementary Particles	Wiley Press	2008	**9783527406012**
D.H. Perkins (), 4th ed. 2000	Introduction to High Energy Physics	Cambridge University	2000	0521138469
I.S. Hughes	Elementary Particles	Cambridge University Press	1991	B01FIX1JNA
R. P. Feynman and S. Weinberg	Elementary Particles and the	CambridgeUniversity Press	1999	0521658624

	Laws of Physics			

Course Title: Condensed Matter Physics

L	T	P	Total Credits
4	0	0	4

Course Outcomes

CO1	Knowledge of lattice vibrations, phonons and in depth of knowledge of Einstein and Debye theory of specific heat of solids
CO2	Understanding above the band theory of solids in the view of periodic potential and must be able to differentiate insulators, conductors and semiconductors.
CO3	Study and learn the transport properties of charge carriers under electric and magnetic fields
CO4	Secured an understanding about the dielectric and ferroelectric properties of materials
CO5	Understand the liquid crystals, classification, properties and their behaviour in electric and magnetic fields

Course Content

Unit-1-Lattice Dynamics	**Lectures: 18**
Lattice vibrations, adiabatic and harmonic approximation, vibrations of linear mono-atomic lattice, one-dimensional lattice with basis, models of three dimensional lattices, quantization of lattice vibrations, Einstein and Debye theories of specific heat, phonon density of states.	

Unit-2-Band theory of Solids	Lectures: 18
Periodic potential and Bloch's theorem, weak potential approximation, density of states in different dimensions, energy gaps, Fermi surface and Brillouin zones. Origin of energy bands and band gaps, effective mass, tight-binding approximation, Semiconductor Crystals, Band theory of pure and doped semiconductors.	
Unit-3-Transport Properties of Solids	**Lectures: 18**
Electronic transport from classical kinetic theory, Boltzmann transport equation, resistivity of metals and semiconductors, Fermi surfaces – determination, Landau levels, Quantum Hall effect- Integral quantum Hall effect and. Magnetoresistance	
Unit-4-Dielectric Properties of Solids	**Lectures: 18**
Dielectrics and ferroelectrics, macroscopic electric field, local field at an atom, dielectric constant and polarizability, Clausius-Mosotti relation, ferroelectricity, antiferroelectricity, piezoelectric crystals, ferroelasticity, electrostriction	
Superconductivity	
Basic phenomenology and experimental evidence, BCS pairing mechanism and nature of BCS ground state, Flux quantization, Vortex state of a Type II superconductors, Tunneling Experiments, High Tc superconductors and current work on superconductivity.	

Text / Reference Books:

Author	Title	Publisher	Year	ISBN No
J. Ziman	Principles of the Theory of Solids	University Press	1972	1107641349
C. Kittel	Introduction to Solid State Physics	Wiley, NewYork	2005	8126578432
P.M. Chaikin and T.C. Lubensky	Principles of Condensed Matter Physics	Cambridge University Press	1995	97881759602511
H. Ibach and H. Luth () 3rd. ed. 2002	Solid State Physics	Springer Berlin	2002	9783540585732

Course Title:Atomic and Molecular Physics

L	T	P	Total Credits
4	0	0	4

Course Outcomes

CO1	Students will learn the details of atomic and diatomic molecular (diatomic) structures in terms of quantum mechanical treatment elaborately beyond the basic models
CO2	It will give the descriptions of fine structure of atoms and rotational, vibrational and electronic energies of molecules manifesting in their respective spectroscopies Understand the basic Feynman rules and its applications
CO3	The details of these spectroscopies would serve as the fundamentals for various concerned experimental results
CO4	The basic principles of light coherence as laser with their types and variants will also be covered exposing the students to the important modern spectroscopic tool

Course Contents

	Unit I: Atomic Physics	**Lectures: 15**

	Fine structure of hydrogenic atoms, Mass correction, spin-orbit term, Darwin term. Intensity of fine structure lines. Effect of magnetic and electric fields: Zeeman, Paschen-Bach and Stark effects. The ground state of two-electron atoms – perturbation theory and variational methods. Many-electron atoms – Central Field Approximation-LS and jj coupling schemes, Lande interval rule. The Hartrec-Fock equations. The spectra of alkalis using quantum defect theory. Selection rules for electric and magnetic multipole radiation. Auger process.	
	Unit II: Molecular Structure	**Lectures: 15**
	Born-Oppenheimer approximation for diatomic molecules, rotation, vibration and electronic structure of diatomic molecules. Spectroscopic terms. Centrifugal distortion. Electronic structure-Molecular symmetry and the states. Molecular orbital and valence bond methods for H_2^+ and H2. Morse potential. Basic concepts of correlation diagrams for heteronuclear molecules	
	Unit III: Molecular Spectra	**Lectures: 15**
	Rotational spectra of diatomic molecules-rigid and non-rigid rotors, isotope effect, Vibrational spectra of diatomic molecules-harmonic and anharmonic vibrators, Intensity of spectral lines, dissociation energy, vibration-rotation spectra, Electronic spectra of diatomic molecules- vibrational structure of electronic transitions (coarse structure)-progressions and sequences. Rotational structure of electronic bands (Fine structure)-P,Q,R branches. Intensities in electronic bands-The Franck Condon	

	principle. The electron spin and Hund's cases. Raman Effect. Electron Spin Resonance. Nuclear Magnetic Resonance	
	Unit IV: Laser	**Lectures: 15**
	Life time of atomic and molecular states. Multilevel rate equations and saturation. Coherence and profile of spectral lines. Rabi frequency. Laser pumping and population inversion. He-Ne Laser, Solid State laser, Free-electron laser. Non-linear phenomenon. Harmonic generation. Liquid and gas lasers, semiconductor lasers	

Text / Reference Books:

Author	Title	Publisher	Year	ISBN No
Raj Kumar	Atomic & Molecular Spectra: Laser	Knrn	2012	**9380803303**
J Michael Hollas	Basic Atomic and Molecular Spectroscopy	Royal Society of Chemistry	2002	**9781107063884**
C.J. Foot ,, 2004	Atomic Physics	Oxford University	2004	9788175960251
B. H. Brensden and C. J. Jochain,; 2nd edition 2003	Physics of Atoms and Molecules	Pearson Education India	2003	0582356924

Semester – IV

S. No.	Subject		Theory Hours	Practical Hours	Total Credits
1	Advanced Nuclear Physics	Core	4	0	4
	Advanced Particle Physics	Core	4	0	4
2	Specialized Course (1 No.)		4	0	4
4	Research Work				8
5	Artificial Intelligence and Machine Learning	Allied Course	4	0	4

Course Title: Advanced Nuclear Physics

L	T	P	Total Credits
4	0	0	4

Course Outcomes

CO1	Understanding the concept of angular momentum and calculation of C.G and Racah Coefficients and their properties.
CO2	Knowledge of Shell model and implementation of learning to understand the properties of nucleus
CO3	Learning of Collective model and Nilsson model of nucleus to describe its kinematics

CO4	Classification of nuclear reactions.

Course Contents

Unit-1- Angular Momentum	**Lectures: 16**
Coupling of angular momenta, LS & jj coupling, spin-orbit coupling, C.G. and Racah coefficients, Wigner' 3j,6j and 9j symbols and properties	
Unit-2- Shell Model	**Lectures: 20**
Extreme particle model with square-well & harmonic oscillator potentials, shell model predictions, static electromagnetic moments of nuclei, seniority wave function, magnetic moment-Schmidt lines, Single particle model, Total spin 'J' for various configurations, electric quadrupole moment, configuration mixing, independent particle model, coefficient of fractional parentage, Two nucleon wavefunction, Matrix elements of one and two body operators, Correlation in nuclear matter.	
Unit-3- Collective Model	**Lectures: 18**
Rotation-D matrices and properties, Collective modes of motion, nuclear vibrations, isoscalar vibrations, Giant resonance, derivation of collective Hamiltonian and applications, Rotation and vibration of even-even nuclei, β and γ vibrations, Rotational-vibrational coupling, odd-mass nuclei - coupling of particle to even-even core, Nilsson model, Rotational motion at high spin, Kinematic and dynamic moment of inertia, Routhian and alignment plots.	
Unit-4- Compound Nucleus and Nuclear Reactions:	**Lectures: 18**
Statistical and Optical model for compound nucleus, Direct reactions, Kinematics and theory of stripping, pick up and reverse reactions, Fusion evaporation & transfer reactions and various models, Heavy-ion induced nuclear reactions at various energies.	

Text Books

- Basic Ideas and Concepts in Nuclear Physics : K. Hyde (Institute of Physics) 2004
- Introduction to Nuclear Physics ; Herald Enge (Addison-Wesley) 1971

Reference books:

- Nuclear Physics : Irving Kaplan (Narosa), 2002

- Nuclei and Particles : E. Segre (W.A. Benjamin Inc), 1965
- Theory of Nuclear Structure : R.R. Roy and B.P. Nigam (New Age, New Delhi) 2005.

Course Title: Advanced Particle Physics

L	T	P	Total Credits
4	0	0	4

Course Outcomes

CO1	Classification of scattering types in particle physics
CO2	Knowledge of symmetries, fields and groups to understand field theorems
CO3	Significance of field theories in describing the mathematical structure of Standard Model
CO4	Understanding the basic nature of quantum chromodynamics including confinement theory and asymptotic freedom to describe the particle behaviour at high energies.

Course Contents

Unit-1- Deep Inelastic Scattering	**Lectures: 16**
Types of scattering, elastic and inelastic scattering, Form factors of nucleons, Parton model, Deep inelastic scattering structure functions.	
Unit-2- Symmetries and Fields	**Lectures: 20**

Abelian and Non-Abelian groups, U(1), SO(2), SO(3), SU(2), SU(3) and Unitary groups. Lorentz group SO(1,3) and its representations. Dirac, Weyl and Majorana fermions. Approximate symmetries. Noether's theorem. Spontaneous breaking of symmetry and Goldstone theorem. Higgs mechanism. Abelian and Non-Abelian gauge fields. Lagrangian and gauge invariant coupling to matter fields. Elements of Quantization and Feynman rules	
Unit-3- Standard Model of Particle Physics	**Lectures: 18**
SU(3) x SU(2) x U(1) gauge theory, Coupling to Higgs and Matter fields of 3 generations. Gauge boson and fermion mass generation via spontaneous symmetry breaking, CKM matrix . Low energy Electroweak effective theory and the V-A 4-fermion interactions. Elementary electroweak scattering processes. Neutrino masses and Neutrino oscillations.	
Unit-4- Quantum Chromo-Dynamics	**Lectures: 18**
Asymptotic freedom and Infrared slavery, confinement hypothesis. Approximate flavor symmetries of the QCD Lagrangian: Chiral symmetry and it's breaking. Classification of hadrons by flavor symmetry: SU(2) and SU(3) multiplets of Mesons and Baryons	

Text Books

- Elementary Particles and the Laws of Physics: R. P. Feynman and S. Weinberg (CambridgeUniversity Press), 1999
- Introduction to Quarks and Partons : F.E. Close (Academic Press, London), 1979
- Gauge Theories of Weak, Strong and Electromagnetic Interactions: C. Quigg (AddisonWesley), 1994.

Reference books:

- Introduction to Elementary Particles: Griffiths D. (Wiley), 2008.
- Introduction to High Energy Physics : D.H. Perkins (Cambridge University Press), 4th ed. 2000.
- First Book of Quantum Field Theory , A. Lahiri and P. Pal , (Narosa, New Delhi), 2nd ed. 2007.

Course Title: Specialized Elective

L	T	P	Total Credits

4	0	0	4

Course Title: PHY605 (Radiation Physics and Technology)

Course Contents/syllabus:

	Time(h)
Unit I: Atomic and Nuclear Physics	**18**
Basic concept of atomic structure; characteristic X rays and production; concept of bremsstrahlung and auger electron, The composition of nucleus and its properties, mass number, isotopes of element, spin, binding energy, stable and unstable isotopes, law of radioactive decay, Mean life and half life, basic concept of alpha, beta and gamma decay, concept of cross section and kinematics of nuclear reactions, types of nuclear reaction, Fusion, fission.	
Unit II: Interaction of Radiation with Matter	**18**
Alpha, Beta, Gamma and Neutron and their sources, sealed and unsealed sources, Photoelectric effect, Compton Scattering, Pair Production, Linear and Mass Attenuation Coefficients, Interaction of Charged Particles, Heavy charged particles, Beth-Bloch Formula, Scaling laws, Mass Stopping Power, Range, Straggling, Channeling and Cherenkov radiation. Beta Particles Collision and Radiation loss (Bremsstrahlung), Interaction of Neutrons- Collision, slowing down and Moderation.	
Unit III: Radiation Detection	**18**
Basic idea of different units of activity, KERMA, exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, Annual Limit of Intake (ALI) and derive Air Concentration (DAC). Basic concept and working principle of gas detectors (Ionization Chambers, Proportional Counter, Multi-Wire Proportional Counters (MWPC) and Gieger Muller Counter), Scintillation Detectors (Inorganic and Organic Scintillators),	

Solid States Detectors and Neutron Detectors, Thermo luminescent Dosimetry. Biological effects of ionizing radiation, Operational limits and basics of radiation hazard evaluation and control: radiation protection standards, International Commission on Radiological Protection (ICRP) principles, justification, optimization, and limitation, introduction of safety and risk management of radiation. Nuclear waste and disposal management.	
Unit IV: Application of Nuclear Techniques	**18**
Application in medical science (e.g., MRI, PET, Projection Imaging Gamma Camera, radiation therapy), Archaeology, Art, Crime detection, Mining and oil. Industrial Uses: Tracing, Gauging, Material Modification, Brief idea about Accelerator driven Subcritical system (ADS) for waste management., Polymer cross-linking Sterlization	

Text / Reference Books:

AUTHOR	TITLE	Publisher	Year of publication	ISBN
K. Hyde	Basic Ideas and Concepts in Nuclear Physics	CRC Press	3rd edition, 2004	978-0750309806
Herald Enge	Introduction to Nuclear Physics	Addison Wesley Publishing	1966	978-0201018707
E. Segre	Nuclei and Particles	Basic Books	2nd edition,1977	978-0805386011
G. F. Knoll	Radiation Detection and Measurement	John Wiley & Sons, Inc	3rd Ed., 2000	978-0470131480

Course Title: PHY607 (Physics of Nanomaterials)

Course Contents/syllabus:

	Time(h)
Unit I: Introduction to Nano-Materials	**18**
Band structure, Failure of Classical Mechanics; Brief discussion of general ideas such as "Wave particle duality", Uncertainty principle, Superposition principle etc.; Solutions of Schrodinger Equation for 1-D and 3-D square wells and potential barriers, H-atom.	
Unit II: Properties of Nano-Structured Materials	**18**
Size and shape dependent properties, color, melting point, magnetism, density of states, conductivity and band gap, metal to insulator transition. Mechanical properties of nano-materials, Magnetic and electronic transport properties of nano-structured materials.	
Unit III: Optical Properties	**18**
Optical properties and radiative processes: General formulation absorption, emission and luminescence; Optical properties of heterostructures and nanostructures. Carrier transport in nanostructures: Coulomb blockade effect, scattering and tunneling of 1D particle; applications of tunneling, single electron transistors. Defects and impurities: Deep level and surface defects.	
Unit IV: Dielectric Properties	**18**
Coulomb interaction in nanostructures. Concept of dielectric constant for nanostructures and charging of nanostructure. Quasi-particles and excitons: Excitons in direct and indirect band gap semiconductor nanocrystals. Quantitative treatment of quasiparticles and excitons. Charging effects.	

Text / Reference Books:

AUTHOR	TITLE	Publisher	Year of publication	ISBN

C. P. Poole Jr. & F. J. Owens	Introduction to Nanotechnology	Wiley-Interscience	2003	978-0471079354
H. S. Nalwa	Nanostructured Materials and Nanotechnology	Academic Press	2002	978-0-12-513920-5
A. L. Rogach	Semiconductor Nanocrystal Quantum Dots	Springer Wien NY	2008	978-3-211-75237-1
D. Bimerg, M. Grundmann N.N Ledentsov	Quantum Dot Heterostructures	Wiley	1998	9780471973881
H.C. Hoch, H.G. Craighead L. Jelinski	Nanofabrication and Bio-system.	Cambridge Univ. Press	1996	9780521462648

Course Title: Astro Physics

Course Outcomes

CO1	Conceptual understanding of various basic principles involved in astronomy
CO2	Understanding of the structure of galaxies, interstellar dust and formation of molecular clouds.
CO3	Knowledge and learning of theoretical models that explain the origin of elements in the universe and nucleosynthesis processes.
CO4	Learn about relevant nuclear and astrophysical measurements and observations

Course Content

Unit I: Introduction	Lectures: 18
Basic concepts of celestial sphere, Co-ordinate systems; Alt-azimuth, Equatorial, Right Ascension, Ecliptic, Basic stellar properties; Luminosity, apparent and absolute magnitude, photo visual and photographic magnitude system, estimation of distance using parallax method and Cepheid variables, stellar masses in binary system. Spectral classification of stars, Origin of emission and absorption spectra, Doppler effect and its applications, Mass-Luminosity relation, free electron scattering and bound-free scattering, HR diagram. Basic concepts of astronomical observations in -rays, X-rays, UV, visible, infra-red, radio waves	
Unit II: Interstellar medium and molecular clouds	**Lectures: 18**
Structure of our galaxy, Globular clusters, velocity distribution of stars, origin of 21-cm radiation and interstellar gas, fine structure of Carbon, Origin of spiral arms and its basic features, Interstellar dust and theory of extinction of stellar light, molecules and molecular clouds, the galactic magnetic field, the active star forming molecular clouds.	
Unit III: Stellar evolution and nucleosynthesis	**Lectures: 18**
Origin of the solar system, Jean's criteria, Shedding excess of angular momentum and magnetic field, T Tauri phase, Quasi-hydrostatic equilibrium, Virial theorem, Radiative and convective heat transfer, the sun on the main sequence, rates of nuclear energy generation, the standard solar model, evolution of low, intermediate and high mass stars on HR diagram, late stage evolution of stars, red giant phase, white dwarf, supernova (type Ia, Ib/c, II), neutron star, black hole, stellar nucleosynthesis, hydrostatic and explosive nucleosynthesis, sprocess, r- process, the galactic chemical evolution.	
Unit IV: Cosmology	**Lectures: 18**
Simple extragalactic observations, Olber's paradox, Hubble's constant and its implications, the steady state universe, Evolution of the Big Bang, hadron era, lepton era, primordial nucleosynthesis, the radiation era, the matter era, time evolution of the future universe.spacecrafts and missions; Elements of hyperspectral imaging, SAR	

(Synthetic Aperture Radar), onboard optical, IR, UV, X-ray, γ-ray spectrometers and particle detectors

Text Books

- Physics of stellar evolution and cosmology: H.S. Goldberg and M.D. Scadron (Gordon and Breach), 1986.

Reference Books

- Theoretical Astrophysics (Vol. I, II, III) : T. Padmanabhan (Cambridge University Press), 2005.

Course Title: Advanced Electrodynamics and General Theory of Relativity

Course Outcomes

CO1	Understanding of radiations and its application to describe electromagnetic fields and potentials.
CO2	Learning the dynamics of charged particles from the relativistic view point
CO3	Concepts of four vectors and formulation of Maxwell's equations in the terms of covariant and contravariant vectors.
CO4	Detailed knowledge of relativistic physics and its implementation to understand Einstein's field equations, Riemann curvature and Ricci tensors.

Course Contents

Unit-1- Radiations	**Lectures: 20**
Fields and Radiation of a Localized Oscillating Source, Electric Dipole Fields and Radiation, Magnetic Dipole and Electric Quadrupole Fields, Center-Fed Linear Antenna, Multipole Expansion of the Electromagnetic Fields, Angular Distribution of Multipole Radiation. Sources of multipole radiation, mutipole radiations in atoms and nuclei. Lienard-Wiechert Potentials, Field of a charge in arbitrary motion and uniform motion, Radiated power from an accelerated charge at low velocities-Larmor-Power formula. Radiation from a charged particle with collinear velocity and acceleration. Radiation from a charged particle in a circular orbit, Radiation from anultra-relativistic	

particle, Radiation reaction. Line-width and level shift of an oscillator. Thomson scattering, Rayleigh scattering, absorption of radiation by bound electron.	
Unit-2- Charged Particle Dynamics in Electromagnetic Fields	**Lectures: 16**
Non-relativistic motion in uniform constant fields, Slowly varying magnetic field : Time varying magnetic field, space varying magnetic field, Adiabatic invariance of flux through an orbit, magnetic mirroring, Crossed electrostatic and magnetic fields and applications, Relativistic motion of a charged particle in electrostatic and magnetic fields.	
Unit-3- Covariant Formulation	**Lectures: 18**
Four vectors in Electrodynamics, 4-current density, 4-potential, covariant continuity equation, wave equation, covariance of Maxwell equations. Electromagnetic field tensor, transformation of EM fields. Invariants of the EM fields. Energy momentum tensor of the EM fields and the conservation laws. Lagrangian and Hamiltonian of a charged particle in an EM field	
Unit-4- Theory of Relativity	**Lectures: 18**
Lorentz transformation as orthogonal transformation in 4- dimension, relativistic equation of motion, applications of energy momentum conservation, particle disintegration, Motion of free particle in curvilinear coordinates : Variational Principle, Principle of equivalence, Riemann curvature tensor, Bianchi identities, Ricci tensor, Einstein field equations, Electromagnetic field in Riemann space time.	

Text Books

- Classical Electrodynamics : J.D. Jackson (New Age, New Delhi), 2009.
- Introduction to Electrodynamics : D.J. Griffiths (Prentice-Hall Learning), 2009

Reference books:

- Classical Electrodynamics: S.P. Puri (Narosa Publishing House) 2011..
- Classical Electromagnetic Radiation : J.B. Marion and M.A. Heald (Saunders college Publishing House), 3rd ed. 1995..
- An Introduction to General Relativity : S.K. Bose (Wiley Eastern Limited, New Delhi), 1980..
- Theory of Relativity : R.K. Patharia (Hindustan Pub., Delhi) 2nd ed., 1974