UNIVERSITY OF RAJASTHAN

JAIPUR

SYLLABUS

M.SC. (PHYSICS)

Semester Scheme

I & II Semester 2017-2018
III & IV Semester 2018-2019

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University of Rajasthan, Jaipur

M.Sc. Physics Syllabus

Semester Scheme 2017-19

Contents:

1. Eligibility:

A candidate who has secured more than 55% or CGPA of 3.5 in the UGC Seven Point scale [45% or CGPA 2.5 in the UGC Seven Point Scale for SC/ST/Non-creamy layer OBC] or equivalent in the Bachelor degree in Science or Engineering or Technology shall be eligible for admission to First Semester of a Master of Science course. The admission shall be based on Entrance Examination as per syllabus to be notified by URATPG based on B.Sc. Physics Syllabus of University of Rajasthan. The M.Sc. Physics course in affiliated college will also be based on this syllabus and Semester System, Choice Based Credit System and Grade System as per Ord. 199F.

2. Scheme of Examination:

(1) Each theory paper EoSE shall carry 100 marks The EoSE will be of 3 hours duration. Part 'A' of theory paper shall contain 10 Short Answer Questions of 20 marks, based on knowledge, understanding and

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applications of the topics/texts covered in the syllabus. Each question will carry one mark for correct answer.

(2) Part "B" of paper will consisting of Four questions with internal choice (except in cases where a different scheme is specifically specified in the syllabus) of 20 mark each. The limit of answer will be five pages.

(3) Each Laboratory EoSE will be of four/six hour durations and involve laboratory experiments/exercises, and viva-voce examination with weightage in ratio of 75:25.

4. Course Structure:

The details of the courses with code, title and the credits assign are as given below.

Abbreviations Used

Course Category

CCC: Compulsory Core Course

ECC: Elective Core Course

OEC: Open Elective Course

SC: Supportive Course

SSC: Self Study Course

SEM: Seminar

PRJ: Project Work

RP: Research Publication

Contact Hours

L: Lecture

T: Tutorial

P: Practical or Other

S: Self Study

The medium of instruction and examination shall be English only.

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First Semester

S. No.	Subject Code	Course Title	Course Category	Credit	Contact Hours Per week			EoSE Duration (Hrs.)	
					L	T	P	Thy	P
1.	PHY 701	Classical Mechanics	CCC	**4**	4	0	0	3	0
2.	PHY 702	Quantum Mechanics	CCC	**4**	4	0	0	3	0
3.	PHY 704	Classical Electrodynamics - I	CCC	**4**	4	0	0	3	0
4.		Theory Elective -1	ECC	**4**	4	0	0	3	0
5.		Theory Elective -2	ECC	**4**	4	0	0	3	0
7.		Theory Elective -3	ECC	**4**	4	0	0	3	0
8.	PHY 711	General Physics Lab (Six Experiments)	CCC	**6**	0	0	9	0	6
9		Elective Laboratory Work	ECC	**6**	0	0	9	0	6

Departments will offer minimum three and maximum five theory elective courses for the semester based on options submitted by students and availability of Faculty to teach the course.

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Second Semester

S. No.	Subject Code	Course Title	Course Category	Credit	Contact Hours Per week			EoSE Duration (Hrs.)	
					L	T	P	Thy	P
1.	PHY 802	Atomic and Molecular Physics	CCC	**4**	4	0	0	3	0
2.	PHY 804	Classical Electrodynamics - II	CCC	**4**	4	0	0	3	0
3.	PHY 805	Mathematical Methods in Physics	CCC	**4**	4	0	0	3	0
4.		Theory Elective -1	ECC	**4**	4	0	0	3	0
5.		Theory Elective -2	ECC	**4**	4	0	0	3	0
7.		Theory Elective -3	ECC	**4**	4	0	0	3	0
8.	PHY 811	General Physics Lab (Six Experiments)	CCC	**6**	0	0	9	0	6
9		Elective Laboratory Work	ECC	6	0	0	9	0	6

Departments will offer minimum three and maximum five theory elective courses for the semester based on options submitted by students and availability of Faculty to teach the course.

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Third Semester

S. No.	Subject Code	Course Title	Course Category	Credit	Contact Hours Per week			EoSE Duration (Hrs.)	
					L	T	P	Thy	P
1.	PHY 901	Advance Quantum Mechanics	CCC	4	4	0	0	3	0
2.	PHY 902	Statistical and Solid State Physics	CCC	4	4	0	0	3	0
3.	PHY 903	Nuclear Physics -I	CCC	4	4	0	0	3	0
4.		Elective -1	ECC	4	4	0	0	3	0
5.		Elective -2	ECC	4	4	0	0	3	0
7.		Elective -3	ECC	4	4	0	0	3	0
8.	PHY 911	Advance Physics Lab (Six Experiments)	CCC	6	0	0	9	0	6
9		Elective Laboratory Work/Project Wok	ECC/ PRJ	6 6	0 0	0 0	9	0	6

Departments will offer minimum three and maximum five theory elective courses for the semester based on options submitted by students and availability of Faculty to teach the course.

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Fourth Semester

S. No.	Subject Code	Course Title	Course Category	Credit	Contact Hours Per week			EoSE Duration (Hrs.)	
					L	T	P	Thy	P
1.	PHY X01	Introduction to Quantum Field Theory	CCC	**4**	4	0	0	3	0
2.	PHY X02	Solid State Physics	CCC	**4**	4	0	0	3	0
3.	PHY X03	Nuclear Physics -II	CCC	**4**	4	0	0	3	0
4.		Elective -1	ECC	**4**	4	0	0	3	0
5.		Elective -2	ECC	**4**	4	0	0	3	0
7.		Elective -3	ECC	**4**	4	0	0	3	0
8.	PHY X11	Advance Physics Lab (Six Experiments)	CCC	**6**	0	0	9	0	6
9		Elective Laboratory Work/Project Wok	ECC/ PRJ	**6** **6**	0 0	0 0	9	0	6

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Theory Elective Courses:

Specialization Clusters

A. AC: Astrophysics and Cosmology
B. CMP: Condensed Matter Physics
C. HEP: High Energy Physics
D. EC: Electronic Communications
E. ES: Energy Studies
F. PP: Plasma Physics
G. ON: Advance Physics Open Electives
H. GN: GENERAL
I. TP: Thermal Physics
J. CP: Computational Physics
K. RP: Reactor Physics
L. HP: Health Physics
M. LP: Laser Physics

Elective Course Code	Specialization	Paper Title	Prerequisite	Semester In which course will be available
PHY H01	GEN	Electronics	-	I
PHY H02	GEN	Programming in C	-	I

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PHY H04	GEN	Numerical methods	-	II/III/IV
PHY A01	AC	Astrophysics -I	-	I/II/III
PHY A02	AC	Astrophysics -II	-	II/III/IV
PHY A03	AC	General Theory of Relativity		All
PHY A04	AC	Cosmology		All
PHY A05	AC	Quantum Gravity and Quantum Cosmology	PHY A03 & PHY A04	III/IV
PHY A06	AC	Precision Tests in Astrophysics and Cosmology	PHY A03 & PHY A04	III/IV
PHY B01	CMP	Condensed Matter Physics -I	-	I/II/III
PHY B02	CMP	Condensed Matter Physics -II	-	II/III/IV
PHY C01	HEP	High Energy Physics -I	-	I/II/III
PHY C02	HEP	High Energy Physics -II	-	II/III/IV
PHY C03	HEP	High Energy Physics -III	PHY C01	II/III/IV
PHY C04	HEP	Renormalization	PHY C02	III/IV

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PHY C05	HEP	Supersymmetry	PHY C02	III/IV
PHY C06	HEP	Physics Beyond Standard Model	PHY C02	III/IV
PHY D01	EC	Electronics and Communications -I	-	I/II/III
PHY D02	EC	Electronics and Communications -II	-	II/III/IV
PHY DO3	EC	Microwave Electronics	-	II/III/IV
PHY D04	EC	Satellite Communication and Remote Sensing	-	II/III/IV
PHY E01	ES	Energy Studies -I	-	I/II/III
PHY E02	ES	Energy Studies -II	-	II/III/IV
PHY F01	PP	Plasma Physics -I	-	I/II/III
PHY F02	PP	Plasma Physics -II	-	II/III/IV
PHY G01	NT	Nanotechnology -I	-	I/II/III
PHY G02	NT	Nanotechnology -II	-	II/III/IV
PHY I01	TP	Thermal Physics-I		I/II/III

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PHY I02	TP	Thermal Physics -II		II/III/IV
PHY J01	CP	Computational Physics -I		I/II/III
PHY J02	CP	Computational Physics -II		II/III/IV
PHY K01	RP	Reactor Physics -I		I/II/III
PHY K02	RP	Reactor Physics -II		II/III/IV
PHY L01	HP	Health Physics -I		I/II/III
PHY L02	HP	Health Physics -II		II/III/IV
PHY M01	LP	Laser -I		I/II/III
PHY M02	LP	Laser -II		II/III/IV

Elective Core Courses Lab. Work will be based on Lab. Work of above papers wherever applicable.

The medium of instruction and examination shall be English only.

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5. Course Details

PHY 701: CLASSICAL MECHANICS

1. Constraints, holonomic and non-holonomic constraints, D'Alembert's Principle and Lagrange's Equation, velocity dependent potentials, simple applications of Lagrangian formulation. Hamilton Principle, Calculus of Variations, Derivation of Lagrange's equation from Hamilton's principle. Extension of Hamilton's Principle for non-conservative and non-holonomic systems, Method of Lagrange's multipliers, Conservation theorems and Symmetry Properties, Noether's theorem. Conservation of energy, linear momentum and angular momentum as a consequence of homogeneity of time and space and isotropy of space.
2. Generalized momentum, Legendre transformation and the Hamilton's Equations of Motion, simple applications of Hamiltonian formulation, cyclic coordinates, Routh's procedure, Hamiltonian Formulation of Relativistic Mechanics, Derivation of Hamilton's canonical Equation from Hamilton's variational principle. The principle of least action.
3. Canonical transformation, integral invariant of poincare: Lagrange's and Poisson brackets as canonical invariants, equation of motion in Poisson bracket formulation. Infinitesimal contact transformation and generators of symmetry, Liouvilee's theorem, Hamilton-Jacobi equation and its application.
4. Action angle variable adiabatic invariance of action variable: The Kepler problem in action angle variables, theory of small oscillation in Lagrangian formulation, normal coordinates and its applications. Orthogonal transformation, Euler's theorem, Eigenvalues of the inertia tensor, Euler equations, force free motion of a rigid body.

Reference Books:

(1) Goldstein - Classical Mechanics

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(2) Landau and Lifshitz - Classical Mechanics

(3) A. Raychoudhary - Classical Mechanics

PHY 702: QUANTUM MECHANICS

1. (a) States, Amplitude and Operators: States of a quantum mechanical system, representation of quantum-mechanical states, properties of quantum mechanical amplitude, operators and change of a state, a complete set of basis states, products of linear operators, language of quantum mechanics, postulates, essential definitions and commutation relations.

   (b) **Observables and Description of Quantum system:** Process of measurement, expectation values, time dependence of quantum mechanical amplitude, observable with no classical analogue, spin dependence of quantum mechanical amplitude on position, the wave function, super position of amplitudes, identical particles.
2. **Hamiltonian matrix and the time evolution of Quantum mechanical States:** Permittivity of the Hamiltonian matrix, time independent perturbation of an arbitrary system, simple matrix examples of time independent perturbation, energy given states of a two state system, diagonalizing of energy matrix, time independent perturbation of two state system the perturbative solution: Weak field and Strong field cases, general description of two state system,Pauli matrices, Ammonia molecule as an example of two state system.
3. **Transition between stationary States**: Transitions in a two state system, time dependent perturbations - The Golden Rule, Phase space, emission and absorption of radiation, induced dipole transition and spontaneous emission of radiation energy width of a quasi stationary state. The co-ordinate Representation: Compatible observables, quantum

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conditions and uncertainty relation, Coordinate representation of operators, position, momentum and angular momentum, time dependence of expectation values, The Ehernfest Theorem, the time evolution of wave function, the schroodinger equation, energy quantization, periodic potential as an example.

4. Symmetries and Angular Momentum:

1. Compatible observables and constants of motion, symmetry transformation and conservation laws, invariance under spaceand time translations and space rotation and conservation of momentum, energy and angular momentum.
2. Angular momentum operators and their Eigenvalues, matrix representations of the angular momentum operators and their eigenstates, coordinate representations of the orbital angular momentum operators and their eigen state (Spherical Harmonics), composition of angular momenta, Clebsch-Gordon Coefficients tensor operators and Wigner Expart theorem, c commutation relations, of J_X, J_y,J_Z with reduced tensor operator, matrix elements of vector operators, time reversal invariance and vanishing of static electric dipole moment of stationary state.

Reference Books:

1. Ashok Das and A.C. Melissions: Quantum Mechanics - A modern approach (Gordon and Breach Science Publishers).
2. P.A.M. Dirac, Quantum Mechanics.
3. E. Merzbecher: Quantum Mechanics, Second Edition (John Wiley and sons)
4. L.P. Landau and E.M. Lifshitz, Quantum Mechanics - Relativistic theory (Pergamon Press)
5. A. Ghatak and S. Lokanathan: Quantum Mechanics - Theory and Applications, Third Edition (Mac. Millan, India Ltd.

PHY 704: CLASSICAL ELECTRODYNAMICS –I
(Same as 801)

1. **Electrostatics:** Electric field, Gauss Law, Differential form of Gaussian law. Another equation of electrostatics and the scalar potential, surface distribution of charges and dipoles and discontinuities in the electric field and potential, Poisson and Laplace equations, Green's Theorem, Uniqueness of the solution with the Dirichlet or Neumann boundary Conditions, Formal Solutions of electrostatic Boundary value problem with Green's function, Electrostatic potential energy and energy density, capacitance.

   Boundary Value Problems in Electrostatics: Methods 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 a 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 wit hemispheres at a different potentials, orthogonal functions and expansion.
2. **Multipoles, electrostatics of Macroscopic Media Dielectric:** Multipole expansion, multipole expansion of the energy of a charge distribution in an external field, Elementary treatment of electrostatics with permeable media. Boundary value problems with dielectrics. Molar polarizability and electric susceptibility. Models for molecular polarizability, electrostatic energy in dielectric media.
3. **Magnetostatics:** Introduction and definition. Biot and Savart Law, the differential equations of magnetostatics and Ampere's law. Vector potential and magnetic induction for a current loop. Magnetic fields of a localized current distribution, Magnetic moment, Force and torque on and energy of a localized current distribution in an external induction,

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Macroscopic equations, Boundary conditions on B and H Methods of solving Boundary value Problems in magnetostatics, Uniformly magnetized sphere, magnetized sphere in an external fields, permanent magnets, magnetic shielding, spherical shell of permeable material in an uniform field.

4. **Time varying fields, Maxwell's equations conservation laws:** Energy in a magnetic field, vector and scalar potentials, Gauge transformations, Lorentz gauge, coulomb gauge, Green function for the wave equation, Derivation of the equations of Macroscopic Electromagnetism, Poynting's Theorem and conservation of energy and momentum for a system of charged particles and EM fields. Conservation laws for macroscopic media. Electromagnetic field tensor, transformation of four potentials and four currents, tensor dissipation of Maxwell's equations.

Reference Books:

1. J.D. Jackson: Classical Electrodynamics
2. Panofsky & Phillip: Classical electrodynamics and magnetism
3. Griffith: Introduction to Electrodynamics
4. Landau & Lifshitz: Classical Theory of Electrodynamics
5. Landau & Lifshitz: Electrodynamics of continuous media

PHY 802: ATOMIC AND MOLECULAR PHYSICS

1. Gross structure of energy spectrum of hydrogen atom. Non degenerate first order perturbation method, relativistic correction to energy levels of an atom, atom in a weak uniform external electric field – first and second order Stark effect, calculation of the polarizability of the ground state of hydrogen atom and of an isotropic harmonic oscillator; degenerate stationary state perturbation theory, linear Stark effect for hydrogen atom levels, inclusion of spin orbit interaction and weak

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magnetic field, Zeeman effect, effect of strong magnetic field. Magnetic dipole interaction, hyperfine structure and Lamb shift (only qualitative description).

2. Indistinguishability and exchange symmetry, many particle wave functions and Pauli's exclusion principle, spectroscopic terms for atoms. The helium atom, Variational method and its use in calculation of ground state energy. Hydrogen molecule, Heitler London method for hydrogen molecule. WKB method for one dimensional problem, application to bound states (Bohr Sommerfeld quantization) and the barrier penetration.
3. **Spectroscopy (qualitative):** General features of the spectra of one and two electron system – singlet, doublet and triplet characters of emission spectra, general features of alkali spectra. Rotation and vibration band spectrum of a molecule, P,Q and R branches. Raman spectra for rotational and vibrational transitions, comparison with infrared spectra – application to learning about molecular symmetry. General features of electronic spectra, Frank and Condon's principle.
4. **Laser cooling and trapping of atoms:** The scattering force, slowing an atomic beam, chirp cooling, optical molasses technique, Doppler cooling limit, magneto optical trap. Introduction to the dipole force, theory of the dipole force, optical lattice. Sisyphus cooling technique – description and its limit. Atomic fountain. Magnetic trap (only qualitative description) for confining low temperature atoms produced by Laser cooling, Bose-Einstein condensation in trapped atomic vapours, the scattering length, Bose-Einstein condensate, coherence of Bose-Einstein Condensate, The Atom Laser.

Reference Books:

1. G. Banewell – Atomic and Molecular spectroscopy
2. Christopher J. Foot Atomic Physics, Oxford Master series, 2005

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3. G.K. Woodgate, Elementray Atomic Structure, Second Edition Clarendon Press, Oxford.
4. T.A. Littlefield - Atomic and Molecular Physics.
5. Eistaberg and Rasmic- Quantum Physics of Atoms. Molecules Solids and Nuclear Particles.
6. Ashok Das and A.C. Melfessions. Quantum Mechanics ; A Modem Approach (Gordon and Breach Science Publishers).
7. White - Atomic Spectra.
8. Herzberg- Molecular spectra.

PHY 804: CLASSICAL ELECTRODYNAMICS –II
(Same as H03)

1. **Plane Electromagnetic Waves and Wave Equation:** Plane wave in a nonconducting medium. Frequency dispersion characteristics of dielectrics, conductors and plasma, waves in a conducting o dissipative medium, superposition of waves in one dimension, group velocity, casualty connection between D and E. Kramers-Kroning relation.
2. **Magnetohydrodynamics and Plasma Physics:** Introduction and definitions, MHD equations, Magnetic diffusion. viscosity and pressure, Pinch effect, instabilities in pinched plasma column, Magnetohydrodynamics waves. Plasma oscillations, short wave length limit of plasma oscillations and Debye shielding distance.
3. **Covariant Form of Electrodynamic Equations:** Mathematical properties of the space-time special relativity, Invariance of electric charge covariance of electrodynamics. Transformation of electromagnetic field.

   Radiation by moving charges: Lienard-Wiechert Potential for a point charge, Total power radiated by an accelerated charge: Larmour's formula and its relativistic generalization, Angular distribution of radiation emitted by an accelerated charge, Radiation emitted by a charge in arbitrary extremely relativistic motion. Distribution in frequency and angle of energy radiated by accelerated charges, Thomson scattering and radiation, Scattering by quasifree charges, coherent and incoherent scattering, Cherenkov radiation.

4. **Radiation damping, self fields of a particle, scattering and absorption of radiation by a bound system:** Introductory considerations, Radiative reaction force from conservation of energy, Abraham Lorentz evaluation of the self force, difficulties with Abraham Lorentz model, Integro-differential equation of motion including radiation damping, Line Breadth and level shift of an oscillator, Scattering and absorption of radiation by an oscillator, Energy transfer to a harmonically bound charge.

Reference Books:

1. Classical Electrodynamics: Jackson
2. Classical Electricity and Magnetism: Panofsky and Philips.
3. Introduction to Electrodynamics: Griffiths.
4. Classical Theory of Field: Landan and Lifshitz.
5. Electrodynamics of Continuous Media: Landau and Lifshitz.

PHY 805: MATHEMATICAL METHOD IN PHYSICS

(Same as 703)

1. **Coordinates Transformation in N - dimensional space:** Contravariant and covariant tensor, Jacobian. Relative tensor, pseudo tensors (Example: charge density, angular momentum) Algebra of tensors, Metric tensor, Associated tensors, Riemann space (Example: Euclidean space and 4D Minkowski space), Christoffel symbols, transformation of Christoffel symbols, covariant differentiation, Ricci's theorem, divergence, Curl and

Laplacian tensor form, Stress and strain tensors, Hook's law in tensor form. Lorentz covariance of Maxwell equation, Klein Gordon and Dirac Equation, Test of covariance of Schrödinger equation.

2. **Group of Transformation:** (Example: Symmetry transformation of square) Generators of a finite group, Normal subgroup, Direct product of groups, Isomorphism and Homomorphism. Representation theorem of finite groups, Invariants subspace and reducible representations, irreducible representation, crystallographic point groups, Irreducible representation of C_{4V}. Translation group and the reciprocal lattice.
3. **Fourier Transforms:** Development of the Fourier integral from the Fourier Series, Fourier and inverse Fourier transform: Simple Applications: Finite wave train, Wave train with Gaussian amplitude, Fourier transform of derivatives, solution of wave equation as an application. Convolution theorem. Intensity in terms of spectral density for quasi monochromic EM Waves, Momentum representation, Application of Fourier transform to diffraction theory: diffraction pattern of one and two slits.
4. **Laplace transforms and their properties:** Laplace transform of derivatives and integrals. derivatives and integral of Laplace transform. Convolution theorem. Impulsive function, Application of Laplace transform in solving linear, differential equations with constant coefficient with variable coefficient and linear partial differential equation.

Reference books:

1. Mathematical Methods for Physicists: George Arfken (Academic Press)
2. Applied Mathematics for Engineers and Physicists: L. A. Pipe (McGraw Hill)
3. Mathematical Methods - Potter and Goldberg (Prentice Hall of India)

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4. Elements of Group Theory for Physicists: A.W. Joshi (Wiley Eastern Ltd.)
5. Vector Analysis (Schaum Series) (McGraw Hill)

PHY 901: ADVANCED QUANTUM MECHANICS

1. **Scattering (non-relativistic):** Differential and total scattering cross section, transformation from CM frame to Lab frame, solution of scattering problem by the method of partial wave analysis, expansion of a plane wave into a spherical wave and scattering amplitude, the optical theorem, Applications-scattering from a delta potential, square well potential and the hard sphere scattering of identical particles, energy dependence an resonance scattering. Breit-Wigner formula, quasi stationary states.

   The Lippman-Schwinger equation and the Green's functions approach for scattering problem, Born approximation and its validity for scattering problem, Coulomb scattering problem under first Born approximation in elastic scattering.
2. **Relativistic Formulation ad Dirac Equation:** Attempt for relativistic formulation of quantum theory, The Klein-Gordon equation, Probability density and probability current density, solution free particle K.G. equation in momentum representation, interpretation of negative probability density and negative energy solutions.

   Dirac equation for a free particle, properties of Dirac matrices and algebra of gamma matrices, non-relativistic correspondence of the Pauli equation (inclusive of electromagnetic interaction). Solution of the free particle Dirac equation, orthogonality and completeness relations for Dirac spinors, interpretation of negative energy solution and hole theory.
3. **Symmetries of Dirac Equation:** Lorentz covariance of Dirac equation, proof of covariance and derivation of Lorentz boost and rotation matrices

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4. **The Quantum Theory of Radiation**: Classical radiation field, transversality condition, Fourier decomposition and radiation oscillators, Quantization of radiation oscillator, creation, annihilation and number operators, photon states, photon as a quantum mechanical excitations of the radiation field, fluctuations and the uncertainty relation, validity of the classical description, matrix element for emission and absorption, spontaneous emission in the dipole approximation, Rayleigh scattering. Thomson scattering and the Raman Effect, Radiation damping and Resonance fluorescence.

Reference Books:

1. Ashok Das and A.C. Milissiones: Quantum mechanics - A Modern Approach (Garden and Breach Science Publishers).
2. Eugen Merzbacher: Quantum Mechanics, Second Edition (John Wiley and Sons).
3. Bjorken and Drell: Relativistic Quantum Mechanics (McGraw Hill).
4. J.J. Sakurai: Advanced Quantum Mechanics (John Wiley)

PHY 902: STATISTICAL AND SOLID STATE PHYSICS

1. Basic Principles, Canonical and Grand Canonical ensembles:

Concept of statistical distribution, phase space, density of states Liouville's theorem, systems and ensemble, entropy in statistical mechanics Connection between thermodynamic and statistical quantities micro canonical ensemble, equation of state, specific hear and entropy of a perfect gas, using microcanonical ensemble.

Canonical ensemble, thermodynamic functions for the canonical ensemble, calculation of means values, energy fluctuation in a gas, grand canonical ensemble, thermodynamic functions for the grand canonical ensemble, density fluctuations.

2. **Partition functions and Statistics**: Partition functions and properties, partition function for an ideal gas and calculation of thermodynamic quantities, Gibbs Paradox, validity of classical approximation, determination of translational, rotational vibration contributions to the partition function of an ideal diatomic gas. Specific heat of a diatomic gas, ortho and para hydrogen.

   Identical particles and symmetry requirement, difficulties with Maxwell-Boltzmann statistics, quantum distribution functions, Bose Einstein and Fermi-Dirac statistics and Planck's formula, Bose Einstein condensation, liquid He4 as a Boson system, quantization of harmonic oscillator and creation and annihilation of phonon operators, quantization of fermion operators.

3. **Theory of Metals:** Fermi-Dirac distribution function, density of states, temperature dependence of Fermi energy, specific heat, use of Fermi-Dirac statistics in the calculation of thermal conductivity and electrical conduction band. Drude theory of light. absorption in metals.

4. **Band Theory**: Block theorem, Kronig Penny model, effective mass of electrons, Winger-Seqtz approximation. NFE model, tight binding method and calculation of density for a band in simple cubic lattice, pseudo potential method.

Reference Books :

1. Huag: Statistical Mechanics

2. Reif: Fundamentals of Statistical and Thermodynamical Physics.
3. Rice: Statistical mechanics and Thermal Physics.
4. Kittle: Elementary statistical mechanics.
5. Kittle: Introduction to solid state physics.
6. Palteros: Solid State Physics.
7. Levy: Solid State Physics.

PHY 903: NUCLEAR PHYSICS - I

1. **Two Nucleon system and Nuclear forces:** General nature of the force between nucleons, saturation of nuclear forces, charge independence and spin dependence, General forms of two nucleon interaction, Central, noncentral and velocity dependent potential, Analysis of the ground state (3S1) of deuteron using a square well potential, range-depth relationship, excited states of deuteron, Discussion of the ground state of deutron under noncentral force, calculation of the electric quadrupole and magnetic dipole moments and the D-state admixture.
2. **Nucleon-Nucleon Scatterign and Potentials**: partial wave analysis of the neutron-proton scattering at low energy assuming central potential with square well shape, concept of the scattering length, coherent scattering of neutrons by protons in (ortho and para), hydrogen molecule; conclusions of these analyses regarding scattering lengths, range and depth of the potential; the effective range theory (in neutron-proton scattering) and the shape independence of nuclear potential: the effective range theory (in neutron-proton scattering) and the shape independence of nuclear potential; A qualitative discussion of proton-proton scattering at low energy; General features of two-body scatterign at high energy effect of exchange forces. Phenomenological Hamada-Johnston ahard core potential ad Reid hard core and soft core potentials; Main features of the One Boson Exchange Potentials (OBEP) no derivation.

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3. **Interaction of radiation and charged particle with matter (Not derivation):** Law of absorption and attenuation coefficient photoelectric effect, Compton, scattering, pair production; Klein-Nishina cross sections for polarized and unpolarized radiation angular distribution of scattered photon and electrons, Energy loss of charged particles due to ionization, Bremstrahlung; energy target and projectile dependence of all three processes, Range-energy curves; Straggling.
4. **Experimental Techniques:** Gas filled counters; Scintillation counter; Cerenkov counters; Solid state detectors; Surface barrier detectors; Electronic circuits used with typical nuclear detector; Multiwire proportion chambers; Nuclear emulsions, techniques of measurement and analysis of tracks; Proton synchrotron; Linear accelerators; Acceleration of heavy ions.

Reference Books

1. J.M. Bhatt and V.E. Weisskipf: Theoretical Nuclear Physics.
2. L.R.B. Elton: Introductory Nuclear Theory (ELBS Publicatio, London, 1959).
3. B.K. Agarwal: Nuclear Physics (Lokbharti Publication Allahabad. 1989).
4. R.R. Roy and B.P. Nigam: Nuclear Physics (Willey -Easter, 1979).
5. M.A. Preston & R.K. Bhaduri: Structure of the Nucleus (Addition-Wesley, 1975).
6. R.M. Singru: Introductory Experimental Nuclear Physics.
7. England: Techniques on Nuclear Structure (Vol I).
8. R.D. Evans: The Atomic Nucleus (Mc Graw Hills, 1955)
9. H. Enge: Introduction Nuclear Physics (Additon-Wesley, 1970).
10. W.E. Burcham: Elements of Nuclear Physics (ELBS. Longma. 1988)
11. B.L. Cohen: Concept of Nuclear Phsyics (Tata McGraw Hills, 1988).
12. E. Segre: Nuclei and Particles (Benjamin, 1977).
13. I. Kaplan: Nuclear Physics (Addison Wesley. 1963).

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14. D. Halliday: Introductory Nuclear Physics (Wiley, 1955).
15. Harvey: Introduction of Nuclear Physics and Chemistry.

PHY X01: INTRODUCTORY QUANTUM FIELD THEORY

1. Scalar and Vector fields, Classical Lagrangian field theory, Euler Lagrange's equation, Lagrangian density for electromagnetic field. Occupation number representation for simple harmonic oscillator, linear array of coupled oscillators, second quantization of identical bosons, second quantization of the real Klein-Gordon Field and Complex Klein-Gordon field, the meson propagator.
2. The occupation number representation for fermions, second quantization of the Dirac field, the fermion propagator, the em interaction and gauge invariance, covariant quantization of the free electromagnetic field, the photon propagator.
3. S-matrix, the S-matrix expansion, Wick's theorem, Diagrammatic representation in configuration space, the momentum representation, Feynman diagrams of basic processes, Feynman rules of QED.
4. **Applications of S-matrix formalism:** The Coulomb scattering, Bhabha scattering, Moller scattering, and Compton scattering.

Reference Books:

1. Quantum Field Theory by F. Mandal & G. Shaw (Honh-Wiley).
2. Relativistic Quantum Mechanics by J.D. Bjorken & S. Drell (McGraw Hill Book Co.).
3. Advanced Quantum Mechanics by J.J. Sakaurai.
4. Element of Advanced Quantum Theory by J.M. Ziman. (Cambridge University Press).

PHY X02: SOLID STATE PHYSICS

1. **Lattice Dynamics and Optical Properties of Solids:** Interatomic forces and lattice dynamics and simple metals, ionic and covalent crystals. Optical phonons and dielectric constants. Inelastic neutron scattering, Mossbauer effect, Debye-Waller factor, Anharmonicity, thermal expansion and thermal conductivity. Interaction of electrons and phonons with photons. Direct and indirect transitions Absorption in insulators, Polaritions, one-phonon absorption, optical properties of metals, skin effect and anomalous skin effect.
2. **Semiconductors:** Law of mass action, calculation of impurity conductivity, ellipsoidal energy surfaces in Si and Ge, Hall effect, recombination mechanism, optical transitions and Schockely-Read theory, excitions, photoconductivity, photo-luminescence. Points line, planar and bulk defects, colour centres, F-centre and aggregate centres in alkali halides.
3. **Magnetism:** Larmor diamagnetism. Paramagnetism. Curie Langevin and Quantum theories. Susceptibility of rate earth and transition metals. Ferromagnetism: Domian theory, Weiss molecular field and exchange, spin waves: dispersion relation and its experimental determination by inelastic neutrons scattering, heat capacity. Nuclear Magnetic resonance: Conditions of resonance, Bloch equations. NMR-experiment and characteristics of an absorption line.
4. **Superconductivity:**

   (a) Experimental Results: Meissner effect, heat capacity, microwave and infrared properties, isotope effect, flux quantization, ultrasonic attenuation, density of states, nuclear spin relaxation, Giaver and AC and DC Josephson tunnelings.

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(b) Cooper pairs and derivation of BCS Hamiltonian, results of BCS Theory (no derviation).

Reference Books :

1. Kittle: Introduction to Solid State Physics, 5th Edition (John Wiley).
2. Levy: Solid State Physics.
3. Patterson: Solid State Physics.
4. Mckelvy: Solid State and Semi-conductor Physics.

PHY X03: NUCLEAR PHYSICS - II

1. **Nuclear Shell Model:** Single particle and collective motions in nuclei : Assumptions and justification of the shell model, average shell potential, spin orbit coupling; single particle wave functions and level sequence; magic numbers; shell model predictions for ground state parity; angular momentum, magnetic dipole and electric quadrupole moments; and their comparison with experimental data; configuration mixing; single particle transition probability according to the shell model; selection rules; approximate estimates for the transition probability and Weisskopf units; Nuclear isomerism.
2. **Collective Nuclear Models:** Collective variable to describe the cooperative modes of nuclear motion; Parameterization of nuclear surface; A brief description of the collective model Hamiltonian (in the quadratic approximation); Vibrational modes of a spherical nucleus, Collective modes of a deformed even-even nucleus and moments of inertia; Collective spectra and electromagnetic transition in even nuclei and comparison with experimental data; Nilsson model for the single particle states in deformed nuclei.
3. **Nuclear Gamma and Beta decay**: Electric and magnetic multipole moments and gamma decay probabilities in nuclear system (no

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derivations) Reduced transition probability, Selection rules; Internal conversion and zero-zero transition.

General characteristics of weak interaction; nuclear beta decay and lepton caputre; electron energy spectrum and Fermi-Kurie plot; Fermi theory of beta decay (parity conserved selection rules Fermi and Gamow-Teller) for allowed transitions; ft-values; General interaction hamiltonian for beta decay with parity conserving and non conserving terms; Forbidden transitions; Experimental verification of parity violation; The V-A interaction and experimental verification.

4. Nuclear Reaction s: Theories of Nuclear Reactions; Partial wave analysis of reaction Cross section; Compound nucleus formatin and breakup; Resonance scattering and reaction-Breit-Wigner dispersion formula for s-waves (1 = 0), continuum cross section; Statistical theory of nuclear reactions, evaporation probability and cross section for specific reactions; The optical model, Stripping and pick-up reactions and their simple theoretical description (Butler theory) using plane wave Born approximation (PWBA) Shortcomings of PWBA Nuclear structure studies with deuteron stripping (d, p) reactions.

Reference Books :

1. M.A. Preston and R.K. Bhaduri: Structure of Nucleus, Addision Wesley, 1975.
2. R.R. Roy and B.P. Nigam: Nuclear Physics, Wiley-Eastern. 1979.
3. L.R.B. Elton: Introductory Nuclear Theory, ELeBS Pub. London, 1959.
4. B.K. Agrawal: Nuclear Physics. Lokbharati Publt., Allahabad 1989.
5. M.K. Pal:Nuclear Structure, Affiliated East-West Press, 1982.
6. J.B. Blatt and V.F. Weisskopf: Theoretical. Nuclear Physics.
7. H Enge: Introduction to Nuclear Physics, Addison - Wesley, 1970.
8. B.L. Cohen: Concept of Nuclear Physics, Tata McGraw Hill, 1988.
9. W.E. Burchema: Element of Nuclear Physics, ELBS, Longman, 1988.

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10. R.D. Evans: The Atomic Nucleus, Mc Graw Hill, 1955.

11. E. Segre: Nuclei and Particles, Benjamin, 1977.

12. I. Kaplan: Nuclear Physics, Addison Wesley, 1963.

13. W.M. Gibson: The Physics of Nuclear Reactions, Pergamon Press, 1980.

14. G. de Beneditti: Nuclear Interactions. Wiley, 1955.

PHY 711 / PHY 811 General Physics Lab Experiments

1. Study following wave shaping circuits using discrete components

    a) High pass and Low pass filters

    b) Clipping circuits

    c) Clamping circuit

2. Study various flip- flop circuits and design counters to the base 16 up and down counter and an up counter to the base 10/9/7 using flip –flops.

3. Design and study single stage RC coupled transistor amplifier with lower half power frequency 500 HZ and gain 20.

4. Study following quantities in relation to thermal bias stability of a given transistor amplifier circuits

    a) Variation of Ico with temperature

    b) Variation of Ic with temperature

    c) Variation of S with temperature

    d) Distortion of ac signal with temp.

5. Design and study any two of the following circuits using IC 555 timer.

    a). Mono stable oscillator (pulse width W as 0.25 ms)

    b). A stable oscillator (freq. 300 HZ and duty cycle 75%)

    c). Ramp generator (slope =10V/ms)

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d). Voltage controlled oscillator.

6. Design and study RC phase shift oscillator of freq. 1.5 KHZ using op-amp 741
7. Design and study Wein bridge oscillator freq. 2KHZ using op-amp 741
8. Study analogue to digital/digital to analogue conversion.
9. Design and study a stable multivibrator of freq. 3KHZ & 1KHZ both in symmetric and asymmetric mode
10. Study following application of op-amp 741
    i) Unit gain buffer
    ii) Adder
    iii) Subtractor
    iv) Integrator
    v) Differentiator
    vi) Comparator
11. Study following characteristics of op-amp 741
    i) Inverting mode operation
    ii) Non converting mode operation
    iii) Input impedance
    iv) output impedance
    iv) input off set current
12. To study the coupled oscillator, frequency response with mass variation.
    i) Amplitude response with frequency
    ii) Phase lag between driven and driver.

PHY 911 / PHY X11 Advance Physics Laboratory Work

PART- A Nuclear Physics

1. To determine half-life of a radio isotope using GM counter.
2. To study absorption of particles and determine range using at least two sources.

3. To study characteristics of a GM counter and to study statistical nature of radioactive decay.
4. To study spectrum of beta- particles using Gamma ray spectrometer.
5. To calibrate a scintillation spectrometer and determine energy of g-rays from an unknown source.
6. (a) To study variation of energy resolution for a Nai (Tp) detector.

   (b) To determine attenuation coefficient (u) for rays from a given sources.
7. To study Compton scattering of gamma rays and verify the energy shift formula.

PART- B: Solid State Physics

1. To study temperature variation of resistivity for a semi-conductor and to obtain band gap using four probe method.
2. To study Hall Effect and to determine hall coefficient.
3. To study the variation of rigidity of a given specimen as a function of the temperature.
4. To study the dynamics o a lattice using electrical analog.
5. To study ESR and determine g-factor for a given spectrum.
6. To determine ultrasonic velocity and to obtain compressibility for a given liquid.
7. Study the characteristics of a given Klystron and calculate the mode number, E. F.S. and transit time.
8. Study the simulated L.C.R. Transmission line (audio frequency) and to find out the value fora Zo experimentally from the graph.
9. Study the radiation pattern of a given Pyramidal horn by plotting it on a Polar graph paper. Find the half power beam width and calculate its gain.
10. Find the dielectric constant of a given solid (Teflon) for three different lengths by using slotted section.
11. Find the dielectric constant of a given liquid (organic) using slotted

section of X-band.

12. Verification of Bragg's law using microwaves.

Theory Elective Courses

Cluster GN: GENERAL

PHY H01: ELECTRONICS

1. **Operational Amplifiers:** Differential amplifier - circuit configurations - dual input, balanced output differential amplifier, DC analysis, inverting and non-inverting inputs, CMRR-constant current bias level translator. Block diagram of typical OP-Amp analysis. Open loop configuration, inverting and non-inverting amplifiers, Op-Amp with negative feedback, voltage series feedback, effect of feedback 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, CMRR frequency response. DC and AC amplifier. Integrator and differentiator.
2. **Oscillators and wave shaping Circuits:** Oscillator Principle, Frequency stability response, the phase shift oscillator, Wein bridge oscillator, LC tunable oscillators, Multivibrators- Monostable, astable and bistable, Comparators, Square wave and triangle wave generation, clamping and clipping circuits.
3. **Digital Electronics:** Combinational logic: Standard representations for logic functions. Karnaugh Map Representation of logical functions Simplification of logical functions using K-Map, Minimization of Logical functions specified in Minterms / Maxterms or truth table, Don't care conditions. Adder (half and full), Subtractor (half and full), comparator, Multiplexers and their uses. Demultiplexer / Decoders and their uses. BCD

arithmatics, Parity generators / Checkers, Code Converters, Priority Encoders, Decoder / Drivers for display devices, Seven Segment display device. ROM, Programmable Logic Array. Basic concepts about fabrication and characteristics of integrated circuits.

4. **Sequential Logic:** Flip-Flops: one - bit memory, RS, JK, JK master slave, T and D type flip flops, shift resisters - synchronous and asynchronous counters, cascade counters, Binary counter, Decade counter. A/D and D/A conversion- Basic principles, circuitry and simple applications. Voltage regulators - fixed regulators, adjustable voltage regulators, switching regulators. Basic idea of IC 555 and its applications as multivibrator and sqaure wave generator. Opto-electronic Devices: Photo diode, Phototransistor, Light emitting Diode and their applications

Text and Reference Books:

1. "Electronic Devices and Circuit Theory" by Robert Boylested and Louis Nashdsky, PHI, New Delhi - 110001, 1991.
2. "OP-AMP and Linear Integrated Circuits" by Ramakanth, A. Gayakwad, PHI, Second Edition 1991.
3. "Digital Principle and Applications" by A.P. Malvino and Donald P. Leach, Tata McGraw Hill Company, New Delhi, 1993.

PHY H02: Computer Programming

1. **Basic concepts of programming languages:** Programming domains, language evaluation criterion and language categories. Describing Syntax and Semantics, formal methods of describing syntax, recursive descent parsing, attribute grammars, dynamic semantics. Names, Variables, Binding, Type checking, Scope and lifetime.
2. Data types, array types, record types, union types, set types and pointer types, arithmetic expressions, type conversions, relational and

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Boolean expressions, assignment statements, mixed mode assignment, Statement level control structures, compound statements, selection statement, iterative statements, unconditional branching, guarded commands. fundamentals of sub-program, design issues, parameter passing methods, overloaded subprograms, generic subprograms, separate and independent compilation, design issues for functions, accessing nonlocal environment, user defined overloaded operators, implementing subprograms, blocks, implementing dynamic scooping.

3. **Programming in C:** Character set, variables and constants, keywords, Instructions, assignment statements, arithmetic expression, comment statements, simple input and output, Boolean expressions, Relational operators, logical operators, control structures, decision control structure, loop control structure, case control structure, functions, subroutines, scope and lifetime of identifiers, parameter passing mechanism,
4. Arrays and strings, structures, array of structures, Unions of structures, operations on bits, usage of enumerated data types. Bit-fields, Pointers to Function, Function returning Pointers.

Recommended reference books:

2. Robert W. Sebesta: Concepts of Programming Language, Addison Wesley, Pearson Education Asia, 1999.
3. Deitel and Deitel: How to Program C, Addison Wesley, Pearson Education Asia, 1999.
4. Bryon Gottfried, Programming with C, McGraw Hill International.

PHY H 04: NUMERICAL METHODS

(Same as 803)

1. **Errors in Numerical Analysis:** Source of Errors, Round off error, Computer Arithmetic, Error Analysis, Condition and stability, Approximation, Functional and Error analysis, the method of Undetermined Coefficients. Use of interpolation formula, Iterated interpolation, Inverse interpolation, Hermite interpolation and Spline interpolation, Solution of Linear equations: Direct and Iterative methods, Calculation of eigen values and eigen vectors for symmetric matrices.
2. **Solution of Nonlinear equation**: Bisection method, Newton's method, modified Newton's method, method of Iteration, Newton's method and method of iteration for a system of causation Newtons' method for the case of complex roots. Integration of a function. Trapezoiddal and Simpson's rules. Gaussian quadrature formula, Singular integrals, Double integration.
3. **Integration of Ordinary differential equation:** Predictor-corrector methods, Runga-Kutta method. Simultaneous and Higher order equations. Numerical Integration and Differentiation of Data, Least-Squares Approximations, Fast Fourier Transform.
4. Elementary probability theory, random variables, binomial, Poisson and normal distributions.

Reference books:

1. A Ralston and P. Rabinowitz: A First Course in Numerical Analysis, McGraw Hill (1985).
2. S.S. Sastry: Introductory Methods of Numerical Analysis, Prentice-Hall of India (1979).

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Cluster AC: Astrophysics and Cosmology

PHY A01: ASTROPHYSICS – I

1. Astronomy fundamentals, Black body radiation, Radiation mechanism, Flux density and luminosity, basics of Radiative transfer and Radiative processes, Magnitudes, Motions and Distances of Stars: Absolute stellar magnitude and distance modulus, Bolometric and radiometric magnitudes, Colour-index and luminosities of stars,
2. Stellar positions and motions, Velocity dispersion, Statistical and moving cluster parallax, Extinction, Stellar temperature, Effective temperature, Brightness temperature, Color temperature, Kinetic temperature, Excitation temperature, Ionization temperature, Spectral Classification of stars, Utility of stellar spectrum, stellar atmospheres.
3. Overview of the major contents of the universe, Sun and stars, stellar interiors, HR diagram, nuclear energy generation, neutrino astronomy, white dwarfs and neutron stars, plasma processes, compact objects, shape, size and contents of our galaxy
4. Basics of stellar dynamics, normal and active galaxies, gravitational wave astronomy, Newtonian cosmology, microwave background, early universe.

Reference Books:

1. Theoretical Astrophysics, Vols.1-3, Padmanabhan, T., Cambridge University Press, 2005.
2. An Introduction to Modern Astrophysics: B.W. Carrol & D.A. Ostlie
3. Astrophysical Concepts : M.Harwit
4. An Introduction to Astrophysics : Baidyanath Basu
5. Astronomical Physics : Stars and Galaxies : K.D.Abhayankar
6. The Sun : An Introduction : M.Stix
7. Stellar Atmospheres : D.Mihalas
8. An Introduction to the Study of Stellar Structures : S.Chandrasekhar
9. Spherical Astronomy : W.M.Smart

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PHY A02: ASTROPHYSICS – II

1. Coordinate systems, precession, time, heliocentric corrections; methods of observation, resolution, sensitivity, noise, quantum efficiency, spectral response, Johnson noise, signal to noise ratio, background, aberrations, 2.
2. Telescopes at different wavelengths, detectors at different wavelengths, imaging, spectroscopy, polarimetry, calibration, atmospheric effects at different wavelengths, active/adaptive optics, interferometry, speckle interferometry, aperture synthesis, methods of data reduction,
3. Fourier transforms, calibrations; neutrino astronomy, gravitational wave astronomy. Numerical techniques in physics and astrophysics, errors and error propagation, numerical integration and interpolation, random numbers, astrostatistics, probability distributions, hypothesis testing, sampling methods,
4. Multivariate analysis, regression, time-series analysis, data reduction, error analysis, numerical solutions of algebraic, ordinary differential and partial differential equations.

Reference Books:

1. Roy, A.E., & Clarke, D., Astronomy Principles and Practice, 4th ed., Institute of Physics, 2003.
2. Kitchin, C.R.: Astrophysical Techniques, 4th ed., Institute of Physics, 2003.
3. Smart, W.M., Spherical Astronomy, 6th ed., Cambridge University Press, 1977.
4. Press, W.H., et al., Numerical Recipes in C, Cambridge University Press, 1992.
5. Babu G. J. & Fiegelson, E. D., Astrostatistics, Chapman and Hall, 1996.
6. Saha S. K., Diffraction-limited imaging with large and moderate telescopes, World Scientific, New Jersey, 2007

PHYSICS A03: General Theory of Relativity

1. Principle of equivalence. Metric formulation and tensor nature of gravitational field. Geodesic motion in curved space-time. Gradient, divergence, curl, and curvature and torsion in General Relativity.
2. Bianchi identity and curvature tensor. Einstein's field equation and gravitation. Schwarzchild metric and solutions of Einstein's equation.
3. Three crucial tests of Einstein's theory of gravitation. Killing vectors. Theory of gravitational waves.

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4. Singularities of Schwarzchild metric and Penrose diagrams. Ray-Chaudhary equation.

Reference Books:

1. S. Weinberg: Gravitation and Cosmology.
2. S. Carroll: General Relativity.

PHYSICS A04: Cosmology

1. Einstein's model of Universe. De-Sitter Universe. Friedman-Robertson-Walker-Lemaitre model of the Universe. Big-Bang and the Physics of the early Universe.
2. Particle and the Nucleo-synthesis in the early Universe. Various phase transitions and time-line of the Universe.
3. Inflationary cosmology and generation of density perturbations.
4. Alternative cosmologies: Quasi-Steady State Theory of the Universe.

PHY A05: Quantum Gravity and Quantum Cosmology

1. The need for a theory of Quantum Gravity and Quantum Cosmology. Physics at short distance. Big-Bang and Physics at Planck scale: Planck length, Planck time, Planck mass, and Planck energy.
2. Black-Hole Physics and Hawking radiations. Unification of Gravity with other fundamental interactions.
3. Overview of diverse approaches to Quantum Gravity: Geometrodynamics; Loop Quantum Gravity and Loop Quantum Cosmology;
4. Quantum Gravity in Super-String Theory.

PHY A06: Precision Tests in Astrophysics and Cosmology

1. Recent experimental results on Cosmic Microwave Background Radiations. Results of WMAP experiments and COBE experiments.
2. The experimental evidence of dark matter and dark energy.
3. Gravitational Wave detectors. Super-Novae as standard candles
4. Precision experiments in Astrophysics and Cosmology.

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Cluster CMP: Condensed Matter Physics

PHY B01: Condensed Matter Physics-I

1. **Phase transformation and alloys:** Equilibrium transformation of first and second order, equilibrium diagrams, phase rule, interpretation of phase diagrams, substitutional solid solutions, Vegard's law, intermediate phases, Hume-Rothery rules, interstitial phases (carbides, nitrides, hydrides, borides). Martensitic transitions.
2. **High temperature superconductors and GMR/CMR materials**: High temperature superconductors, normal state properties (structural phase transition) of cuprates, phase separation and charge distribution into CuO2 planes, striped phase, phase diagram, pseudogap, dependence of T_c on crystal structure, effect of impurities .GMR/CMR materials, Ruddlesden-Popper series of perovskites. Onset of ferromagnetism and metallic conduction. Double exchange.
3. **Novel organic materials:** Special carbon solids, fullerenes and tubules, formation and characterization of fullerenes and tubules. Single wall and multi-wall carbon tubules. Electronic properties of tubules. Carbon nanotubule based electronic devices. Polymers – amorphous polymers, glass transition temperature, effect of molecular architecture on glass transition temperature, free volume theory for glass transition, conducting polymers, optical band gap of polymers, electrical conduction in conducting polymers, mechanical and thermal properties of polymers, polymer blends and composites.
4. **Structural characterization and electron structure determination:** Basic theory of X-ray diffraction, indexing of Debye-Scherrer patterns from powder samples, examples from some cubic and non-cubic symmetries. Neutron diffraction -- basic interactions, cross section, scattering length and structure factor. Basic principles of X-ray absorption spectroscopy, photo emission and positron annihilation techniques. Qualitative discussion of experimental arrangement and of typical results for both simple as well as transition metals.

Books

1. Andrei Mourachkine: Room temperature superconductivity, Cambridge International Science Publishing.
2. C N R Rao: Colossal magnetoresistance, charge ordering and related properties of managanese oxide, Woprld Scientific, 1998

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3. Polymer Physics by Ulf W. Gedde, Chapmann & Hall, 2001.
4. Introduction to Polymer Physics by David. I. Bower.
5. Polymer Science by J.R. Fried.

PHY B02: Condensed Matter Physics-II

1. **Disordered systems:** Substitutional, positional and topographical disorder, short and long range order, glass transition, glass forming ability, nucleation and growth processes. Anderson model for random system and electron localization, mobility and hopping conduction. Metglasses, models for structure of metal glasses. Structure factor for binary metallic glasses and its relationship with radial distribution function. Discussion of electric, magnetic and mechanical properties of glassy systems. Point defects: shallow impurity states in semiconductors. Localized lattice vibrational states in solids. Vacancies, interstitials and colour centres in ionic crystals.
2. **Nanomaterials:** Free electron theory (qualitative idea), variation of density of states with energy, variation of density of state and band gap with size of crystal. Electron confinement in infinitely deep square well, confinement in two and one dimensional well, idea of quantum well structure , tunneling through potential barrier, quantum dots, quantum wires.Different methods of preparation of nanomaterials. Sol-gel and chemical co-precipitation method, effect of temperature on the size of the particles. Bottom up: cluster beam evaporation, ion beam deposition, top down: ball milling. DC and RF sputtering.
3. **Films and surfaces**: Study of surface topography by multiple beam interferometry, conditions for accurate determination of step height and film thicknesses (Fizeau fringes). Electrical conductivity of thin films, difference of behaviour of thin films from bulk material, Boltzman transport equation for a thin film (for diffuse scattering), expression for electrical conductivity for thin film. Enhancement of magnetic anisotropy due to surface pinning
4. **Experimental techniques:** Basic ideas of the techniques of field emission, scanning tunnelling and atomic force microscopy, scanning electron microscopy, transmission electron microscopy, X-ray diffraction line broadening, small angle X-ray scattering and small angle neutron scattering.

Books

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1. Tolansky: Multiple beam interferometry
2. Heavens: Thin films
3. Chopra: Physics of thin films
4. Quantum dot heterostructures: D. Bimerg, M. Grundmann and N.N. Ledenstov, John Wiley & Sons, 1998
5. Nano particles and nano structured films – preparation, characterization and applications, Ed. J.H. Fendler, John Wiley & Sons, 1998.
6. Physics of low dimensional semiconductors: John H. Davies, Cambridge Univ. Press, 1997
7. Physics of semiconductor nano structures: K.P. Jain, Narosa, 1997
8. Nanostructures and nanomaterials: synthesis properties and applications by Guozhong Cao, P\Impertial College Press, 2004
9. Fundamentals of Nanoelectronics by George W. Hanson, Pearson Education, 2009.
10. Nanotechnology: Principles and practices by Sulabha Kulkarni, Capital Publishing Company, 2009.
11. Handbook of Nanostructured materials and nanotechnology

Cluster HEP: High Energy Physics

PHY C01: High Energy Physics I

1. Elementary particles and the fundamental forces. Quarks and leptons. The mediators of the electromagnetic, weak and strong interactions. Interaction of particles with matter; particle acceleration, and detection techniques. Symmetries and conservation laws.
2. Bound states. Discoveries and observations in experimental particle physics and relation to theoretical developments. Symmetries, group theory, The gourp SU92), Finite Symmetry Group:P and C, SU(2) of Isospin, The group SU(3)
3. Quark and Antiquark states: Mesons. Three quark states: Baryon, color factors, Asymptotic freedom. Charged and neutral weak interactions. Electroweak unification
4. Decay rates. Cross sections. Feynman diagrams Introduction to Feynman integrals. The Dirac equation. Feynman rules for quantum electrodynamics (no derivation). Moller scattering, trace theorems and properties of gamma matrices, helicity representation at high energies, the electron propagator, the photon propagator

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Recommended books

1. Francis Halzen and Allan D. Martin, **Quarks and Leptons: An Introductory Course in Modern Particle Physics,** John Wiley and Sons
2. B.R. Martin and G. Shaw, **Particle Physics,** 2nd edition, J. Wiley and Sons (1997).
3. **The Review of Particle Physics,** (Particle Data Group
4. David Griffiths, **Introduction to Elementary Particles**
5. Byron Roe **Particle Physics at the New Millennium**
6. Donald Perkin, **Introduction to high energy physics**).
7. Martin and Shaw, **Particle Physics**

PHY C02: High Energy Physics II

1. **Structure of Hadrons:** form factors, e-p scattering, inelastic e-p scattering, Bjorken scaling, Partons, gluons, deep inelastic scattering, evolution equations for parton densities.
2. **QCD:** Electron positron annihilation into hadrons, heavy qwuark production, three jet events, QCD corrections, Perturbative QCD, Drell-Yan process
3. **Weak Interactions:** Parity violation, V-A form of weak interaction, Nuclear beta decay, muon decay, pion decay, charged curre nt neutrino electron scattering, neutrino quark scattering, weak neutral currents, the Cabibo angle, weak mixing angles, CP invariance.
4. **Gauge Symmetries**: U(1) Local gauge invariance and QED, Non-abelian gauge invariance and QCD, massive gauge bosons, spontaneous breakdown of symmetry, the Higgs mechanism.

Recommended books

1. Francis Halzen and Allan D. Martin, **Quarks and Leptons: An Introductory Course in Modern Particle Physics,** John Wiley and Sons
2. B.R. Martin and G. Shaw, **Particle Physics,** 2nd edition, J. Wiley and Sons (1997).
3. **The Review of Particle Physics**, (Particle Data Group
4. David Griffiths, **Introduction to Elementary Particles**
5. Byron Roe **Particle Physics at the New Millennium**
6. Donald Perkin, **Introduction to high energy physics**).
7. Martin and Shaw, **Particle Physics**

PHY C02: High Energy Physics III

1. Local gauge invariance and Yang-Mills fields, Lagrangian of the Spontaneous symmetry breaking and the Higgs mechanism, The Weinberg-Salam model and beyond.
2. Unified models of weak and electromagnetic interactions Standard Model, flavor group, flavor-changing neutral currents. Weak isospin.
3. Quark and lepton mixing. CP violation. Neutrino oscillations.CKM quark mixing matrix, GIM mechanism, rare processes, neutrino masses, seesaw mechanism
4. QCD confinement and chiral symmetry breaking, instantons, strong CP problem

Recommended books

1. Francis Halzen and Allan D. Martin, **Quarks and Leptons: An Introductory Course in Modern Particle Physics,** John Wiley and Sons
2. B.R. Martin and G. Shaw, **Particle Physics**, 2nd edition, J. Wiley and Sons (1997).
3. Particle Data Group, **The Review of Particle Physics,**
4. David Griffiths, **Introduction to Elementary Particles**
5. Byron Roe **Particle Physics at the New Millennium**
6. Donald Perkin, **Introduction to high energy physics**).
7. Martin and Shaw, **Particle Physics**

PHY C04: Renormalization

1. Theory of renormalization. The renormalization group and applications to the theory of phase transitions.
2. Renormalization of Yang-Mills theories.
3. Applications of the renormalization group of quantum chromodynamics.
4. Perturbation theory anomalies. Applications to particle phenomenology.

PHY C05: Supersymmetry

1. Grand unification, gauge coupling unification, proton decay;
2. Naturalness and the hierarchy problem; technicolor;
3. The supersymmetric Standard Model, supersymmetric unification,
4. SUSY dark matter, SUSY flavor problem

PHY C06: Physics Beyond the Standard Model

1. Introduction to general relativity and Curvature, energy-momentum tensor, Einstein field equations.
2. Evolution of the Universe based on the theory of general relativity.
3. Test of the models and the nature of dark matter and dark energy.
4. TeV scale gravity; the cosmological constant problem, Large extra dimensions.

Cluster EC: Electronics and Communication

PHY - D01: Electronics and Communication I

1. **Waveguides and components:**
   Field distribution in rectangular waveguide in TE and TM modes, Phase velocity, Group velocity, Characteristics impedance, wall current, Cavity resonators and their excitation techniques, Scattering matrix for Microwave Tees and hybrid junction directional coupler, Construction and working of precision attenuator and phase shifter.
2. **Solid State MW Devices**:
   Avalanche Transit Time Devices: Read diode, Negative resistance of an avalanching p-n junction diode, Transferred Electron Devices: Gunn effect, two valley model, High field domains, Different modes for microwave generation
   Parametric Devices: Varactor, Nonlinear reactance and Manley- Rowe power relations, Parametric Up-converter amplifier and its Noise properties

3. **Conventional microwave sources and Antennas:**
   Construction and working of two cavity Klystron and Reflex klystron and their efficiency.
   Magnetron and its operating characteristics, Hull cut-off condition.
   Traveling wave tubes: Construction and working and Introduction to Gyratron
   Antenna parameters, Huygen source, Electromagnetic horn antenna. Introduction to microstrip patch antennas and array antennas
4. **Measurements techniques:**

Microwave Measurements: Power, frequency, attenuation and VSWR measurements, Return loss measurement, Concept of Smith chart and its use in impedance measurement, Microwave antenna measurement, measurement of dielectric properties of a solid materials using wave guide method.

Measurement devices: Digital voltmeter- ramp type and integrating type, Bolometers, Power Meter, VNA

Reference Books:

1. Foundations for Microwave Engineering: R.E. Collins, Mc. Graw Hills
2. Solid State Electronic Devices: B. Streetman and S.K. Banerjee, PHI
3. Microwave Devices and Circuits: L.S.Y. Liao, PHI
4. Antenna Theory and Design: C.A. Balanis, John Wiley & Sons
5. Basic Microwave Techniques and Laboratory Manual: M. L. Sisodia, G. S. Raghuvanshi. New Age International, Jan 1, 1987

PHY- D02: Electronics and Communication II

1. Power Electronics:

Characteristic of power diodes, power transistor, TRIAC, DIAC. SCR: Construction and its characteristics, simple firing circuit using UJTs. Controlled rectifiers: Single and Three phase half wave and full wave controlled rectifiers. Commutation Circuits: Line commutation and different commutation circuits, Inverters: Single phase Tapped and Bridge inverter circuits, Basic chopper circuits, 2 and 4 quadrant choppers. Principle of operation of cycloconverter.

2. MW Propagation

Microwave propagation in ferrites, Faraday rotation, Microwave devices employing Faraday rotation: Gyrator, Isolator and Circulator.

Microwave communication: LOS microwave system, derivation of communication range, OTH microwave systems, derivation of field strength of troposphere waves. Introduction to satellite and mobile communication, RADAR.

3. Communication Electronics:

Introduction to signals: Size, classification, signal operations, unit signal functions, ortogonality, correlation, trignometric Fourier series, exponential fourier series.

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Analysis and transmission of signals, Aperiodic signal representation by fourier integral, fourier transforms of unit functions, scaling property, time shifting property, frequency shifting property, bandwidth,

4. **Modulation and demodulation**:

Amplitude modulation: Double-sideband suppressed carrier (DSBSC) modulation and demodulation, Generation of DSBSC waves, coherent detection of DSBSC waves, SSB amplitude modulation and demodulation, Generation and detection of SSB waves. Vestigial sideband modulation. Frequency division multiplexing (FDM).

Angle Modulation: Concept of instantaeous frequency, generalized concept os angle modulation, bandwidths, Wide-band FM, generation of FM waves, Demodulators, Fm receiver.

Reference Books:

PHY D03: Microwave Electronics and Applications

1. **CIRCUIT THEORY OF WAVE GUIDES:** Power Transmission in Wave Guides, Equivalent Voltages and Currents, Impedance Description of Wave Guide Elements and Circuits, Foster's Reaction Theorem, One Port Circuits, N-Ports Circuits, Scattering Matrix Formulation, Excitation and Coupling of Wave Guides, Dielectric Loaded Wave Guides, Surface Wave Guides.
2. **ANTAENNAS:** Familiarity with Different Types of Antennas, Radiation Properties, Strip-Lines and Microstrip Lines, Strip-Line Characteristics, Strip-Line Components, Microstrip Antennas, Radiation Properties of Microstrip Antennas.
3. **APPLICATIONS OF MICROWAVES:**Applications of Microwave in RADAR, Satellite Communication, Mobile Communication, Microwave Heating,
4. **FERRITES** Microwave Propagation in Ferrites, Nano Ferrites, Synthesis of Nano Ferrites, Dielectric Properties of Ferrites, Ferrites as a Microwave Absorbers.

PHY D04: Satellite Communications and Remote Sensing

1. Principle of Satellite Communication:General and Technical characteristics, Active and Passive satellites, Modem and Codec.mmunication Satellite Link Design:General link design equation, Atmospheric and Ionospheric effect on link design, Earth station

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parameters.

2. Satellite Analog Communication: Baseband analog signal, FDM techniques, S/N and C/N ratio in FM in satellite link. Digital Satellite transmission: Advantages, Elements of digital satellite communication, Digital base band signal, Digital modulation Techniques, Digital link Design, TDM, TDMA, some applications of satellite communications.
3. Concept and Foundations of Remote Sensing: Electromagnetic Radiation (EMR), interaction of EMR with atmosphere and earth surface, Application area of remote Sensing. Characteristics of Remote Sensing Platform & Sensors: Ground, Air & Space platforms, Return Beam Vidicon, Multi-spectral Scanner, Brief idea of Digital Image Processing.
4. Microwave Remote Sensing Tools: Radar Remote Sensing, Microwave Sensing, Lidar (Single and double ended system), (Radar & Lidar): Data Characteristics. Earth Resource Satellites: Brief description of Landsat and Indian remote sensing satellites (IRS) Satellites.

Reference Books:

1. Satellite Communication: D.C. Agrawal and A. K. Maini.
2. Satellite Communication: T. Pratt and C. W. Bostiern.
3. Satellite Communication System: M. Richharia.
4. Introduction of Remote Sensing: J.B. Campbell.
5. Manual of Remote Sensing Vol I & II: (Ed. R.N. Colwell).

Cluster ES: Energy Studies

PHY E01: ENERGY STUDIES –I

1. **Solar Energy:** Fundamentals of photovoltaic Energy Conversion Physics and Material Properties Basic to Photovoltaic Energy Conversion: Optical properties o Solids. Direct and indirect transition semiconductors, interrelationship between absorption coefficients and band gap recombination of carriers.
2. Types of Solar Cells, p-n junction solar cell, Transport Equation, Current Density, Open circuit voltage and short circuit current, Brief descriptions of single crystal silicon and amorphous silicon solar cells, elementary ideas of advanced solar cells e.g.

Tandem Solar Cells. solid Liquid Junction Solar Cells, Nature of Semiconductor, Electrolyte Junction, Principles of Photoelectrochemcial solar Cells.

3. **Hydrogen Energy**: Relevance in depletion of fossil fuels and environmental considerations.

   Hydrogen Production: Solar Hydrogen through Photo electrolysis and Photocatalytic process. Physics and material characteristics for production of Solar Hydrogen.

   Storage of Hydrogen: Brief discussion of various storage processes, special features of solid state hydrogen storage materials, structuraland electronic characteristics of storage materials. New Storage Modes.

4. **Safety and Utilisation of Hydrogen**: Various factors relevant to safety, use of Hydrogen as Fuel, Use in Vehicular transport, Hydrogen for Electricity Generation, Fuel Cells, Elementary concepts of other Hydrogen Based devices such as Air Conditioners and Hydride Batteries.

   Other Renewabel Clean Energies : Elements of Solar Thermal Energy, Wind Energy and Ocean Thermal Energy Conversion.

Text and Reference Books

1. Fonash: Solar Cell Devices - Physics.
2. Fahrenbruch & Bube: Fundamentals of Solar Cells Photovoltatic Solar Energy.
3. Chandra: Photoelectrochemical Solar Cells.
4. Winter & Nitch (Eds.): Hydrogen as an Energy Carrier Technologies System Economy.

PHY E02: ENERGY STUDIES –II

1. **Heat conduction:** Differential equation of heat conduction. Initial and boundary conditions. Methods of solving heat conduction problems : separation of variable method for one dimension, The Greens' functions method, Integral transform method for finite and infinite ranges. Problems with and without internal heat generation. Numerical analysis of transient and periodic state of heat conduction Measurement techniques for thermal conductivity and their comparative study (static and dynamic), Guarded hot plate method, Thermal probe, parallel wire.

2. **Convective and Radiative Heat Transfer**: Theory of convective heat transfer, Laminar and turbulent flow, Boundary layer theor. Heat transfer in duct. heat exchangers : basic thermal sign methods. Theory of heat pipes, Design considerations.

Applications of heat pipes. Direct and diffused thermal radiation. Radiative properties of real surfaces. Radiation exchange between surfaces. Atmospheric attenuation, solar radiation measurements solar radiation geometry.

3. **Solar Energy collectors**: Flat Plate solare energy collectors. Selective absorber surfaces. Transparent plates. Collector energy losses. Thermal analysis of collectors. Air heating collectors. Collector performance testing. Concentrating collectors. Thermal analysis of concentrating collectors. Tracking requirements.
4. **Thermal Energy Storage and Solar Thermal Devices**: Storage of solar energy. Water storage. Stratification fo water storage, Packed bed storage. Phase change storage. Solar pond. Chemical storage. Solar space conditioning- Energy requirements in buildings, Passive system architecture, Performance and design; coiling processes. Vapor compression refrigeration cycle, Absorption refrigeration cycel, Performance of solar absorption air conditioning. Solar energy process economics.

References :

1. Heat Condution: M. Necati Ozisik-John Wiley & Sons.
2. Hand Book of Heat transfer Application: Edited by Warren M. Rohsenow, James P. Harnou and Fjup N. Ganic.
3. Conduction of Heat in Solids: H.S., Carslas and J.C. Jsegar, Oxford Clarendon Press 1959.
4. Heat and Mass Transfer: A Luikov, Mir Publichers Moscow.
5. Thermal conductivity of Solids: J.E. Parrot and Audrey D. Stuckers : Pion Limited, London.
6. Solar energy Thermal Processs: Dluffie and Backman. Wiley & Sons. New York.
7. Solar Energy Engg.: Jui Sheng Haieh,Prentic Hall, New Jersey.
8. Solar Energy: S.P, Tata McGraw Hill, New Delhi.

Cluster PP: Plasma Physics

PHY F01: PLASMA PHYSICS-I

1. Basic properties and occurrence. Definition of plasma. Criterla for plasma behaviour, Plasma oscillation. Quasi-neutrality and Debye Shielding. The plasma parameter. natural occurrence of plasma. Astrophysical plasmas. Plasma in Magnetiosphere and ionosphere. Plasma production and diagnostics. Thermal ionization. Saha equation. Brief discussion of methods of laboratory plasma production. Steady stage glow

discharge, microwave breakdown and induction discharge, Double Plasma Machine. Elementary ideas about plasma diagnostics. Electrostatic and magnetic probes.

2. Charged particle motion and drifts, Guiding centre motion of a charges particle. Motion in (i) uniform electric and magnetic field (i) gravitational and magnetic fields. Motion in non-uniform magnetic field (i) grad B perpendicular to B, grad B drift and curvature drift (ii) grade B parallel to B and principle of magnetic mirror. Motion in non-uniform electric field for small Larmour radius. Time varying electric field and polarization drift. Time varying magnetic field adiabatic invariance of magnetic moment.
3. Plasma fluid equations fluid equations; Conventive, Two fluid and single fluid equations. Fluid drifts perpendicular to B diamagnetic drift.
   Diffusion and Resistivity: Collision and diffusion parameters. Decay of a plasma by diffusion, ambipolar diffusion. Diffusion across magnetic field. Collision in fully ionized plasma. Plasma resistivity Diffusion in fully ionized plasmas. Solution of Diffusion equation.
4. **Equilibrium and stability**: Hydromagnetic equilibriu. Concept of magnetic pressure. Equilibrium of a cylindrical pinch. The Benner pinch. Diffusion of magnetic field into a plasma. Classification instabilities. Two stream instability. The gravitational instability Resistive drift waves.

Referennces :

1. F.F. Chen: An Introduction to Plasma Physics (Plenum Press) 1977.
2. R.C. Davidson: Methods in Non-linear Plasma Theory (Academy Press) 1972.
3. W.B. Kunkel: Plasma Physics in Theory and Application (Mc Graw Hill) 1966
4. J.A. Bittencoms: Fundamentals of Plasma Physics (Pergamons Press. 1986.

PHY F02: PLASMA PHYSICS-II

1. **Waves in plasma**: Electron plasma waves. Ion Waves, Electrostatic electron oscillations perpendicular to B, upper hybrid oscillations. Electrostatic ion waves perpendicular to B, ion cyclotron waves, Lower hybrid oscillations. Electromagnetic waves in field free plasma. Electromagnetic waves perpendicular to B. Cut offs and resonances. Electromagnetic waves parallel to magnetic field, Hydromagnetic waves. Magnetosonic waves.
2. Kinetic Theory, Boltzmann and Vlasov Equation, Derivation of multifulid equations, Vlasov equation. Linearization of Valsove Maxwell equations High Frequency

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plasma waves, Landau damping, A Physical derivation of Landau damping, Low frequency ion acoustic waves, Ion Landau damping.

3. **Non-linear effects**: Non-linear effects in plasmas. The Sagdeov potential, Derivation of KdV equation for ion acoustic waves. Soliton solution in one dimension. Elementary ideas about the pondermotive force and parametric instability. Oscillating two stream instability, Non-linear Landau damping.
4. **Controlled thermonuclear fusion and other plasma applications:** Potentials and problems of controlled thermonuclear fusin. Ignition temperature and Lawson criteria. Magnetic confinement. Simple discussion of Tokomak, stellarators, multipoles and Z pinch. Idea about inertial confinement and laser fusion. Methods of plasma heating and problems of fusion. Basic principle and working of MHD power generator, Plasma applications in industry, Plasma torches.

References:

1. F.F. Chen: An Introduction to Plasma Physics (Plenum Press) 1974.
2. R.C. Davidson: Methods in Non-linear Plasma Theory (Academic Press) 1972.
3. J.A. Bittencomt: Fundamentals of Plasma Physics (Pergamon Press) 1988
4. C. Uberoi: Introduction to Unmagnetized Plasma (Prentice Hall) 1988.

Cluster NT: Nanotechnology

PHY G 01: Nanotechnology-I

1. Generic Methodologies for Nanotechnology

Introduction and classification, What is nanotechnology? Classification of nanostructures: Nanoscale architecture; The free electron model and energy bands, Crystalline solids, Periodicity of crystal lattices, Electronic conduction; Effects of the nanometer length scale, Changes to the system total energy, Changes to the system structure, How nanoscale dimensions affect properties.

2. Nanodimensional Materials

0D, 1D, 2D structures, Size Effects, Fraction of Surface Atoms, specific Surface Energy and Surface Stress, Effect on the Lattice Parameter, Phonon Density of States, the General Methods available for the Synthesis of Nanostrutures, precipitative, reactive, hydrothermal/ solvothermal methods, suitability of such methods for scaling, potential Uses

3. Physical and Chemical Methods of Nanostructured Materials

Thermal evaporation, Pulsed Laser Deposition (PLD), DC/RF Magnetron Sputtering, Molecular Beam Epitaxy (MBE), Inert Gas Condensation Technique (IGCT),
Ball Milling, Electro-deposition, Spray Pyrolysis, Sol-Gel Process: Self assembly, Metal Nanocrystals by Reduction. Solvothermal Synthesis, Photochemical Synthesis, Sonochemical Routes, Reverse Micelles and Micro emulsions, Combustion Method, Template Process, Chemical Vapor Deposition (CVD), Metal Oxide Chemical Vapor Deposition (MOCVD)

4. Specific Features of Nanoscale Growth

Thermodynamics of Phase Transitions, triggering the Phase Transition, fundamentals of nucleation growth, Controlling Nucleation & Growth, Size Control of the Nanometric State, Aggregation, Stability of Colloidal, Dispersions, Spontaneous Condensation of Nanoparticles: Homogeneous Nucleation, Spinodal decomposition, Other undesirable Post-Condensation Effects, Nanoparticles' morphology

References:

1. C. N. R. Rao, A. Mu¨ller, A. K. Cheetham, The Chemistry of Nanomaterials :Synthesis, Properties and Applications, Volume 1, Wiley-VCH, Verlag GmbH, Germany (2004).
2. C. Bre´chignac P. Houdy M. Lahmani, Nanomaterials and Nanochemistry, Springer Berlin Heidelberg, Germany (2006).
3. Guozhong Cao, Nanostructures & Nanomaterials Synthesis, Properties G;Z: Applications, World Scientific Publishing Private, Ltd., Singapore (2004).
4. Zhong Lin Wang, Characterization Of Nanophase Materials, Wiley-VCH, Verlag GmbH, Germany (2004).
5. Carl C. Koch, Nanostructured Materials: Processing, Properties and Potential Applications, Noyes Publications, William Andrew Publishing Norwich, New York. U.S.A (2002).

PHY G02: Nanotechnology-II

1. Nanoscale Properties - I

Magnetism: Magnetic Moment in clusters or Nanoparticles, Magnetic Order, coercivity, Magnetocrystalline Anisotropy, thermal activation and Superparamagnetic effects.

Electronics and Optoelectronics: Quantum Confinement of Super lattices and Quantum Wells, Doping of a Nanoparticles, Excitonic Binding and Recombination Energies, Capacitance in a Nanoparticle.

2. Nanoscale properties - II

Diffusion in Nanocrystalline Materials: Diffusion In Grain Boundaries Of Metals, Nanocrystalline Ceramics, Correlation Between Diffusion and Crystallite Growth, Other properties: brief overview of optical properties, mechanical properties including superplasticity phenomena, reactivity of nanoparticles.

3. Characterization Methods

X-ray diffraction: Debye-Scherer formula, dislocation density, micro strain. Synchrotron Radiation: Principle and Applications. Dynamic Light Scattering (DLS), Electron microscopes: Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM), Atomic Force Microscope (AFM), Scanning Tunneling Microscope (STM), X-ray Photoelectron Spectroscopy (XPS) – Working Principle, Instrumentation and Applications.

4. Nanotechnology in energy conservation and storage

Nanotechnology for sustainable energy: Energy conversion process, indirect and direct energy conversion, Materials for light emitting diodes, batteries, advanced turbines, catalytic reactors, capacitors, fuel cells.

Energy challenges, development and implementation of renewable energy technologies, nanotechnology enabled renewable energy technologies, Energy transport, conversion and storage: Nano, micro, and poly crystalline and amorphous Si for solar cells, Nano-micro Si-composite structure, various techniques of Si deposition.

References:

1. Guozhong Cao, Nanostructures & Nanomaterials Synthesis, Properties G;Z: Applications, World Scientific Publishing Private, Ltd., Singapore (2004).
2. Zhong Lin Wang, Characterization Of Nanophase Materials, Wiley-VCH, Verlag GmbH, Germany (2004).
3. J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, (1986).
4. Martin A Green, Solar cells: Operating principles, technology and system applications, Prentice Hall Inc, Englewood Cliffs, NJ, USA, (1981).

Cluster TP: Thermal Physics

PHY I01: THERMAL PHYSICS-I

1. **Heat Conduction Fundamentals**: The significance of heat conduction; Heat flux; Fourier's law for heat conduction; Heat conduction equation in different orthogonal coordinate systems; Boundary conditions; dimensionless heat conduction parameters; Homogeneous and non-homogeneous heat conduction problems; Conduction heat transfer in solids, fluids and complex materials.
2. **Methods of solution of heat conduction problems**: The use of Green's function in the solution of non-homogeneous, time dependent heat-conduction problems; Application of Laplace transform in the solution of time dependent heat-conduction problems; one dimensional composite medium; generalized orthogonal expansion technique for homogeneous heat conduction problems; Eigen values and Eigen functions.
3. **Approximate Analytical Methods**: The Integral method–basic concepts and applications; The variational Principles: Basic concepts, variational form of one dimensional steady state heat conduction equation; The Ritz method: steady state heat conduction problem for a solid cylinder; The Galerkin method: construction of φ_j functions, Boundary conditions, steady state heat conduction problem for a rectangular region with heat generation at a constant rate.
4. **Numerical methods for conduction heat transfer**: Finite difference approximation of derivatives through Taylor's series; Finite difference representation of steady state heat and time dependent conduction problems; errors involved in numerical solutions; Accuracy of solutions: Optimum step size; Method of choosing optimum step size; Applications of Finite difference methods to time dependent heat conduction problems.
5. **Conduction heat transfer in anisotropic medium**: Heat flux for anisotropic solids; Heat conduction equation for anisotropic solids; Boundary conditions; Thermal resistivity coefficients; Transformation of axis and conductivity coefficients; Geometrical interpretation of conductivity coefficients; The symmetry of crystals; One dimensional steady state and time dependent heat conduction in anisotropic solids; Heat conduction in orthotropic medium.

Reference Books:

1. Heat conduction by M. N. Ozisik; John Wiley & Sons.
2. Thermal conductivity of solids by J. E. Parrott and A. D. Stuckes; Pion Limited.
3. Introduction to ceramics by Kingery, Bowen and Uhlmann, John Wiley & Sons (Second edn.).
4. Heat transfer in cold climates by Virgil J. Lunardini, Van Nostrand Reinhold Company (VNR).

PHY I02:THERMAL PHYSICS-II

1. **Structures and Thermal properties of Ceramics:** Atomic bonding in solids; Crystal structures; Oxide and Silicate structures; Structure of oxide glasses; Density and thermal expansion of crystals and glasses; Thermal conduction processes; Phonon conductivity of single phase crystalline ceramics; Phonon conductivity of single-phase glasses; Photon conductivity; conductivity of multiphase ceramics
2. **Thermal properties of Complex materials**: A preview of complex materials and their structures; thermal properties of complex materials like polymer composites and metallic/non-metallic foams; Anisotropy effects; Morphology effects; Phase interaction effects; The local and global scale or size effects; Nano-scale size effects and multi-scale modeling; Scale effect in temporal domain; Other complexities and bi-modular behaviors; Structural effects, biometrics and meta-materials
3. **Thermal conduction in nano-fluids**: Fundamentals of nano-fluids; Effect of particle material, particle size and shape; Effect of base fluid and particle volume fraction; Theoretical considerations: Effect of temperature and Brownian motion of nano-particles; Liquid layering around nano-particles; Clustering of nano-particles; Ballistic phonon transport in nano-particles.
4. **Thermal properties of Permafrost**: Distribution of permafrost; origin and existence of permafrost; geophysical processes involved in energy transfer; geophysical conditions affecting permafrost; surface energy balance; thermal regime of permafrost; steady state and transient relations; ground temperatures; thermal conductivity, specific heat, thermal diffusivity of soils.
5. **Techniques for measurement of thermal properties**: Guarded hot plate method for low thermal conductivity materials, Basic design considerations; Point source, line source and parallel wire methods for the measurement of thermal conductivity of

solids, fluids and porous materials. Transient plain heat source for low to high thermal conductivity materials. Errors involved in these methods and their comparative study.

Reference Books:

1. Introduction to ceramics by Kingery, Bowen and Uhlmann, John Wiley & Sons (Second edn.).
2. Heat transfer in cold climates by Virgil J. Lunardini, Van Nostrand Reinhold Company (VNR)
3. Thermal conductivity of solids by J. E. Parrott and A. D. Stuckes; Pion Limited.

Cluster CP: Computational Physics

PHY J01: Computational Physics – I

Errors & Uncertainties in Computations, Monte Carlo Methods, Random Numbers, Probability distribution functions, Improved Monte Carlo Integration, Random walks and the Metropolis algorithm, Monte Carlo methods in statistical physics

Reference :

1. Computational Physics – M. Jensen
2. Computational Physics – Steven E. koonin
3. A Survey of Computational Physics – Rubin H. Landau, Manuel Jose Paez, C. Bordeianu

PHY J02: Computational Physics – II

Quantum Monte Carlo Methods- Variational Monte carlo for quantum mechanical systems, Simulation of molecular systems, Many body systems

Simulating matter with molecular dynamics, Molecular dynamics, verlet and velocity-verlet algorithm, 1-D implementation, Trajectory analysis

Reference :

1. Computational Physics – M. Jensen
2. Computational Physics – Steven E. koonin
3. A Survey of Computational Physics – Rubin H. Landau, Manuel Jose Paez, C. Bordeianu

Cluster RP: Reactor Physics

.PHY K01: Reactor Physics - I

Nuclear Reactions and Radiations - Radioactivity, Interaction of Alpha and Beta Particles with Matter, Interaction of Gamma rays with matter, Interaction of neutron with matter, Cross Sections for neutron reactions, Variation of Cross for neutron Reactions, Variation of cross sections with neutron Energy, The Fission Process

Neutron Transport behaviour-Neutron Transport Concept, Neutron Diffusion theory, Diffusion in multiplying systems, the slowing down of neutrons, slowing down in infinite media

Reference :

1. Nuclear Reactor Engineering (Reactor Design and Basics) – Samuel Glasstone & Alxander Sessonske.
2. Introduction to Nuclear Engineering – John R. Lamarsh
3. Fundamentals of Nuclear Reactor Physics – Elmer E. Lewis
4. Neutron Physics – K. H. Becuts, K. Wirtz.

PHY K02 Reactor Physics – II

Nuclear Design Basics – Multigroup Diffusion Theory, Fuel Depletion Calculations, The Neutron transport equation and its approximation

Reactor Kinetics and Control- Reactor Kinetics, Fission Product Poisoning, Effect of temperature on reactivity, Reactor stability Analysis, General features of Reactor Physics.

Reference :

1. Nuclear Reactor Engineering (Reactor Design and Basics) – Samuel Glasstone & Alxander Sessonske.
2. Introduction to Nuclear Engineering – John R. Lamarsh
3. Fundamentals of Nuclear Reactor Physics – Elmer E. Lewis
4. Neutron Physics – K. H. Becuts, K. Wirtz.

Cluster HP: Health Physics

PHY- L01: Health Physics-I

1. **Radiation sources:**

Radaition, types of radiation-ionizind and non-ionizing,radiations sources: naturally occuring radiation, define backgrounds radiation, machine source radiation: X-ray, linear accelarator, cyclotron. Generation of radiation sources: alpha, beta, gamma, x-rays, neutron, Interaction of radiation with matter-photo electric, compton, pair-production, concept of half life, average life, decay constant, transformation mechanism, transformation kinetics, seqular and transient equlibrium,

2. **Radiation Dosimetry:**

Radiation quantities: KERMA, fluence, realtion of KERMA with photon fluence and neutron fluence, Radaition dose, unit, absorbed dose, equivenet dose, whole body dose, exposure: defination, unit, relation between exposure to energy fluence, exposure rate, internal and external exposure, exposure measurment-free air chamber, air wall chamber, exposure-dose relation ship, absorbed dose measurement (bragg-gray principle), gamma dose calculation, beta dose calculation, skin dose calculation-surface dose, submersion dose, volume dose, ICRP methodology, effective dose, comitted dose.

3. **Dosimetry and calibration :**

Defination, calibration types, classification of caliberation laboratories, Absolute cavity ion chamber, calibration of ion chamber using X-rays/gamma rays, calibration of photon beams with exposure-calibrated ion chamber, calibration of photon beams in phantom. calibration of electron beams in phantom.

4. **Biological Effects of Ionizing Radiations & Risk Models:**

Biological basis for radiaion safety, effect of radiation, deterministic and stochastic effetes, chronical exposure and acute exposure, radiation syndroms, lethal dose,treatment of acute exposure, genetic effect of radiation, risk coeffiecient, qualityt factor, radaition weighting factor, radiaion weighted dose. Radiation protection methods: Decay, delay , shielding and time, medical treatment.

References:

1. Introduction to health Physics, Herman cember and Thomas E. Johnson, 4th edition.
2. Interaction to radiological physics and radiation dosimetry, Frank Herbert Attix,WILEY_VCH verlag Gmbh &Co KGaA

3. AERB SAFETY GUIDE NO.AERB/SG/G-8

4. Atomic Energy (Radiation Protection) Rules, 2004

5. Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1981 CRP report

PHY-L02: Health Physics-II

1. **Standards, Regulations and safety**

Regulaory bodies: ICRP, AERB, NRC, IAEA ,NEA and their comparision, philosopy of radiation safety, dose limitation systems-AERB and ICRP, ICRP basic radiation safety criteria, dose coeffiecient, annual limit of intake (ALI)-ICRP, and AERB, regulation on radian practices, radiation safety procedure,ICRP-30 and 60 criteria, lung model, ICRP-66 human respiratory tract model, Derived air concentration (DAC), uptake calculation, internal radiation safety and external radaiton safety, Atomic Energy (Radiation Protection) Rules, 2004, Annual reprot of AERB.

2. **Health Physics Instrumentation:**

Radiation detectors, Gasfilled detectors: GM tube detector, ion chamber, proportional counter, BF3 detector, scintilation detectors: Nai, CsI, semiconductor detectors, Dose measuring instruments and devices: personnel monitoring, pocket dosimeters, TLD dosimeter, film badge dosimeters, neutron dosimeters, electronic dosimeters, Survey meters, MDA of instruments, relibility of instruments, calibration of instruments, calibration facility in India, contamination monitor, criteria for choosing monitors, survey meters, dosimeters. Non-ionizing radiation safety.

3. **Radioactive waste management :**

Radiactive waste, classification of waste-halif life, activity, handling of radiactive source and waste, transportation of waste, TREM card, safe disposal of radiactive waste, clasification of waste disposal sites, monitoring of radiactive disposal site.

4. **Radiation Emmergency:**

Radiation emergency defination, its classification, measurable quatities in emergency, declaration, termination, radiation emergency reporting authorities, formats, handling procedures, interventionalevel, averted dose, emergency instruments, radiation safety in emergency, contamination, controll on contamination spread.

References:

1. Introduction to health Physics, Herman cember and Thomas E. Johnson, 4th edition.
2. Interaction to radiological physics and radiation dosimetry, Frank Herbert Attix, WILEY_VCH verlag Gmbh &Co KGaA.
3. AERB SAFETY GUIDE NO.AERB/SG/G-8.
4. Atomic Energy (Radiation Protection) Rules, 2004
5. Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987

ICRP reports.

6. Nuclear Reactor Engineering (Reactor Design and Basics) – Samuel Glasstone & Alxander Sessonske.

Cluster LP: Laser Physics

PHY M01: LASER-I

1. Interaction of radiation with matter : Absorption, spontaneous and stimulated emission, Einstein's Coefficients, population inversion, metastable states, gain, absorption coefficient, stimulated cross section, threshold condition. Two level system (Ammonia maser-Physical separation of excited species from those in ground state). Three and Four level system. Rate equations for three and four level system, threshold pump power, relative merits and de-merits of three and four level system.
2. Optical resonators : Resonator configurations, Stability of resonators, Characteristics of Gaussian beam, Transverse and longitudinal modes, mode selection techniques (at least two techniques in each case), losses in a resonator, Hardware design-laser support structure, mirror mounts, optical coating etc.
3. Gas and dye lasers: excitation in gas discharge, collisions of 1st and 2nd kind, electron impact excitation-its cross section, different types of gas lasers : He-Ne, N2, CO2, Metal vapour lasers, Excimer and chemical laser, dye laser.
4. Laser Parameters and their measurement : Near field and Far field regimes, Internal and external parameters in the near and far field, Detectors and their operational mechanism including specific properties like rise time, spectal response etc.

Text Books

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1. *Principles of lasers,* Fourth edition-by Orazio Svelto

2. (Plenum Publishing Corporation, New York, USAISBN 0-306-454748-2).

3. *Solid state laser engineering,* first and second edition,

4. walter Koechner *Springer series in Optical Sciences,* (Springer-Verlag, New York, USA ISBN).

5. *Principles of Laser and their applications,* Callen, O'shea, Rhodes

6. *Laser parameters,* Heard *Reference Books :*

7. *Masers,* A. G. Siegman.

8. *Gas lasers,* Garret.

9. *Maser Handbook,* vol. 1-4, F. T. Arecchi, E. O. Schul Dubois, (North Holland).

PHY M02: LASER-II

1. Optically pumped laser systems, Optical sources projection geometries, power supply Q-switches-pulse reflection mode, Multiple-pulsing in slow Q-switches. Mode locking. Ruby laser, Nd: YAG laser, Nd:glass, Amplifiers for these lasers, their characteristics, semiconductor lasers, color center laser.
2. Pulse transmission mode Q-switching, Mode locking-active and passive techniques Passive mode locking using dye cell, Distributed Feedback Lasers (and its importance for shoprt pulse generation)
3. Non-linear optics: interaction of radiation with matter, optical susceptibility, propagation of E-M radiation in a medium/non linear medium, S.H. generation, T.H. generation, wave mixing optical parametric oscillation, non linear materials.
4. Laser applications: (i) Holography, (ii) Optical communications/optical fiber (iii) Laser spectroscopy, (iv) Material processing welding cutting etc. (v) Medical applications, (vi) Doppler free two photon absorption, (viii) Isotope separation.

Text Books :

1. *Laser in Industry,* S.S. Charschan, (Vol Nostrand), 1972.

2. *Solid State Laser Engineering,* Walter Koechner, (Springer-Verlag), 1976.

3. *Applied non-linear optics,* Fzernik and J. Midwinte, (John Wiley), 1973.

4. *Laser Handbook,* Vol.1-4, F.T. Arechi, E.O. Schul Dobois, (North Holland), 1973.

5. *Application of lasers,* John F. ready.

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Propagation of Electromagnetic Waves in Nonlinear medium, Self Focusing, Phase matching condition, Fiber Lasers, Stimulated Raman Scattering and Raman Lasers, CARS, Saturation and Two photon Absorptions.

Novel Applications of Laser:

Cooling and Trapping of Atoms, Principles of Doppler and Polarization Gradient Cooling, Qualitative Description of Ion Traps, Optical Traps and Magneto-Optical Traps, Evaporative Cooling and Bose Condensation.

Spectroscopic Techniques:

Laser as a source of radiation and its characteristics, Laser fluorescence and absorption spectroscopy, Multiphoton ionization and separation of isotopes.

Reference Books:

1. Spectroscopy Volume 1, 2 and 3: B.P. Straughan and S. Walker.
2. Laser Spectroscopy and Instrumentation : W. Demtroder.
3. Principles of Lasers : O. Svelto.
4. Laser Cooling and Trapping : P.N. Ghosh.
5. Frontiers in Atomic, Molecular and Optical Physics : S.P. Sengupta.

Laboratory Elective Courses

PHY Y11/ PHY Y22 : Spectroscopy Lab

1. To determine the Rydberg constant using Hydrogen discharge tube and spectrometer.
2. To determine optical band gap of cds thin films using ocean optical spectrometer.
3. To verify the validity of Hartmann's formula using constant deviation prism for unknown material
5. To determine the magnetostriction of unknown material using Michaelson interferometer.
6. To determine the dissociation energy of iodine using the concave grating on Ronald's mounting
7. To study the diffraction pattern of LASER light using
   i. single slit
   ii. multi- slit
8. To study the Zeman splitting of Neon light using constant deviation prism and CCD camera .
9. To study the Raman spectra of C-H bands using Raman spectrometer
10. Fabry parot interferometer .
11. Study of Eliptically polarised light by Babinet Compensartor .
12. Verification of Cauchey's Dispersion relation.

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PHY Y12/Y22: Computational Physics Programming in C

Write program in C Programming Languages based on course of PHY 105 and PHY H02 involving computations relevant to Physics.

PHY Y13: Computational Astrophysics and Cosmology

Computational work based on curriculum of elective papers of Cluster AP: Astrophysics and Cosmology.

PHY Y14: Condensed Matter Physics Laboratory

Laboratory work based on curriculum of elective papers of Cluster CMP: Condensed Matter Physics.

PHY Y15: Computational High Energy Physics

Computational work based on curriculum of elective papers of Cluster HEP: High Energy Physics.

PHY Y16: Microwave Electronics Laboratory Work

Laboratory work based on curriculum of elective papers of Cluster EC: Electronics and Communication.

PHY Y17: Energy Studies Laboratory Work

Laboratory work based on curriculum of elective papers of Cluster ES: Energy Studies.

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