UNIVERSITY OF RAJASTHAN
JAIPUR

SYLLABUS

M.Sc. PHYSICS

Semester Scheme

I/II Semester Examination 2019-20
III/IV Semester Examination 2020-21
University of Rajasthan, Jaipur
M.Sc. Physics Syllabus
Semester Scheme 2019-20

Contents:
1. Eligibility
2. Scheme of Examination
3. Semester Structure
4. Course Details

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 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 marks each. The limit of answer will be five pages.

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(3) Each Laboratory FoSE 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

<table>
<thead>
<tr>
<th>S. No.</th>
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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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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.
## Third Semester

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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

<table>
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<tr>
<th>S. No.</th>
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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

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<tr>
<th>Elective Course Code</th>
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<td>Programming in C</td>
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<td>PHY H04</td>
<td>GEN</td>
<td>Numerical methods</td>
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<td>II/III/IV</td>
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<td>AC</td>
<td>Astrophysics -I</td>
<td>-</td>
<td>I/II/III</td>
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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.
5. Course Details

**PHY 701: CLASSICAL MECHANICS**


**Reference Books:**

1. Goldstein - Classical Mechanics
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, production 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, superposition of amplitudes, identical particles.

2. Hamiltonian matrix and the time evolution of Quantum mechanical States:
Substitivity 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 conditions and uncertainty relation, Coordinate representation of operators, position, momentum and angular momentum, time dependence of expectation values, The Ehrenfest Theorem, the time evolution of wave function, the Schrödinger equation, energy quantization, periodic potential as an example.

4. Symmetries and Angular Momentum:

- Compatible observables and constants of motion, symmetry transformation and conservation laws, invariance under space and time translations and space rotation and conservation of momentum, energy and angular momentum.

- Angular momentum operators and their Eigen values, matrix representations of the angular momentum operators and their eigen states, 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
Reference Books:
2. P.A.M. Dirac, Quantum Mechanics.

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 with hemispheres at a different potentials, orthogonal functions and expansion.


3. Magnetostatics: Introduction and definition, Biot and Savart Law, the differential
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 & Phillips: 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 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.


Reference Books:
1. G. Banewell – Atomic and Molecular spectroscopy
2. Christopher J. Foot – Atomic Physics, Oxford Master series, 2005
8. Herzberg- Molecular spectra.


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.


Reference Books:

1. Classical Electrodynamics: Jackson
3. Introduction to Electrodynamics: Griffiths.
PHY 805: MATHEMATICAL METHOD IN PHYSICS
(Same as 703)


Reference books:
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.


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 for Dirac spinors. Projection operators involving four momentum and spin, Parity (P), charge conjugation (C), time reversal (T) and CPT operators for Dirac spinors. Bilinear covariants and their transformations, behaviour under Lorentz transformation, P,C,T and CPT, expectation values of coordinate and velocity involving only positive energy solutions and the associated problems, inclusion of negative energy solution. Zitterbewegung, Klein paradox.

Reference Books:
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 heat 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.

   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.


Reference Books:
1. Huang: Statistical Mechanics
2. Reif: Fundamentals of Statistical and Thermodynamical 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 deuteron under noncentral force, calculation of the electric quadrupole and magnetic dipole moments and the D-state admixture.

2. Nucleon-Nucleon Scattering 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 scattering; two-electron effect of exchange forces; exchange
Hamada-Jensen; two-electron potential at Reid hard core potential; valence
Main features of exchange self-interchange potentials (OR) in particular.

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; Bremsstrahlung; 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


**PHY X01: INTRODUCTORY QUANTUM FIELD THEORY**

1. Scalar and Vector fields, Classical Lagrangian field theory, Euler Lagrange's equation,
Lagrangian density of electromagnetic field. Occupation number representation of the free fields and the interaction of coupled oscillators. Second quantization of an identical boson. Second quantization of the real Klein-Gordon field and the meson propagator.

2. The occupation number representation for fermions, second quantization of the Dirac field, the fermion propagator, the electromagnetic field, 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.


Reference Books:

1. Quantum Field Theory by F. Mandal & G. Shaw (Honh-Wiley).

PHY X02: SOLID STATE PHYSICS


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, excitons, photoconductivity, photoluminescence. Points line, planar and bulk defects, colour centres, F-centre and
3. **Magnetism**

- Paramagnetism
- Ferromagnetism
- Curie-Weiss law and other theories
- Susceptibility of rare earths and transition metals
- Ferromagnetism
- Heisenberg model
- Weiss molecular field and exchange
- Spin waves
- Dispersion relations
- Experimental determination by neutron scattering
- Heat capacity
- Nuclear magnetic resonance
- Conditions of resonance
- Bloch equations
- NMR-experiment
- 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, Giaever and AC and DC Josephson tunnelings.

   (b) Cooper pairs and derivation of BCS Hamiltonian. Results of BCS Theory (no derivation).

**Reference Books**:


**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 nuclear collective properties and magnetic transition in even-parity comparison with experimental data. Atomic model for the single particle shell deformed nuclei.

3. Nuclear Gamma and Beta decay: Electric and magnetic multipole moments and gamma decay probabilities in nuclear system (no derivations). Reduced transition probability, selection rules, internal conversion and zero-zero transition.

General characteristics of weak interaction; nuclear beta decay and lepton capture, electron energy spectrum and Fermi-Kurie plot; Fermi theory of beta decay (parity conserved selection rules Fermi and Gamow-Teller) for allowed transitions; \( \beta \)-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 theories: Theories of Nuclear Reactions; Partial wave analysis of reaction Cross section; Compound nucleus formation and breakup; Resonance scattering and reaction-Breit-Wigner dispersion formula for s-waves \((l = 0)\), 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:

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 I_c with temperature
   b) Variation of I_c 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)
   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
iv) Integrator
v) Differentiator
vi) Comparator

11. Study following characteristics of op-amp 741:
   i) Inverting mode operation
   ii) Non inverting mode operation
   iii) Input impedance
   iv) Output impedance
   v) Input offset 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 (Tl) detector.
   (b) To determine attenuation coefficient (μ) 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 of a lattice using electrical analog.
5. To study LSR 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 Klosterman and calculate the mode number, f, k, S, and transit time.
8. Study the simulated L.C.R Transmission line (audio frequency) and to find out the value for a 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


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...


Text and Reference Books:

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 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

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subprograms, separate and independent compilation, design issues for functions, accessing non-local environment, over defined overloaded operators, implementing subprograms, blocks, implementing dynamic scoping.

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 structures, loop control structures, case control structure, functions, subroutines, scope and lifetime of identifiers, parameter passing mechanism.


Recommended reference books:


PHY H 04: NUMERICAL METHODS

(Same as 803)


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 Newton's method for the case of complex roots. Integration of a
function: Trapezoidal and Simpson's rules, Gaussian quadrature formula, Simplicial integrals, Double integration.


4. Elementary probability theory, random variables, binomial, Poisson and normal distributions.

Reference books:


Cluster AC: Astrophysics and Cosmology

PHY 301: 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.


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:
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. 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.

Reference Books:
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.
   Schwarzschild metric and solutions of Einstein's equation.
3. Three crucial tests of Einstein's theory of gravitation. Killing vectors. Theory of
gravitational waves.

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

PHYSICS A04: Cosmology
   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.

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.


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.

Cluster CMP: Condensed Matter Physics

PHY B01: Condensed Matter Physics-I


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.


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 attenuation cross section, scattering factor and structure factor. Basic principles of X-ray diffraction spectroscopy, photo electron and positron annihilation techniques. Qualitative discussion of experimental arrangement and of typical results for both simple and transition metals.

Books
4. Introduction to Polymer Physics by David I. Bower.
5. Polymer Science by J.R. Fried.

PHY B02: Condensed Matter Physics-II


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.

conditions for accurate determination of step height and film thickness by X-ray methods.

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

1. Tolansky: Multiple beam interferometry
2. Heavens: Thin films
3. Chopra: Physics of thin films
8. Nanostructures and nanomaterials: synthesis properties and applications by Guozhong Cao, Pimperial College Press, 2004
11. Handbook of Nanostructured materials and nanotechnology

Cluster HEP: High Energy Physics

PHY C01: High Energy Physics I


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2. QCD: Electron positron annihilation into hadrons, heavy quark 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 current 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


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

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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
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

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
4. David Griffiths, Introduction to Elementary Particles
5. Byron Roe Particle Physics at the New Millennium
7. Martin and Shaw, Particle Physics

PHY C04: Renormalization

1. Theory of renormalization. The renormalization group and applications to the theory of phase transitions.

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3. Applications of the renormalization group of quantum chromodynamics.

**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 – D11: 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, Field distribution in cylindrical waveguide, Attenuation in a waveguide and mode excitation techniques.

2. Waveguide components
   Cavity resonators and their Q factor, their excitation techniques. Scattering matrix for Microwave Tees and hybrid junction, directional coupler, Construction and working of precision attenuator, directional coupler and precision phase shifter.

3. Conventional microwave sources:
4. Solid State MW Devices:
   Apocalypse Transit Time Devices: Read diode, Negative resistance of an avalanching pn junction diode.
   Transferred Electron Devices: Gunn effect, two valley model, High field domains. Different modes for microwave generation

Reference Books:
3. Microwave Devices and Circuits: L.S.Y. Liao, PHI

PHY-D12: Electronics and Communication II

1. Power Electronics:

2. MW Propagation
   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. Measurements techniques:

4. Antennas

Reference Books:
1. Antenna Theory and Design C.A. Balanis, John Wiley & Sons
2. Power Electronic circuit, design & applications. M.H. Rashid, Pearson

PHY D13: Electronics and Communication III

1. Communication Electronics:
Introduction to signals: Size, classification, signal operations, unit signal functions, orthogonality, correlation, trignometric Fourier series, exponential fourier series. 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

2. Modulation and demodulation:
3. Concept and Foundations of Remote Sensing:
Electromagnetic Radiation: E.M.R. interaction of E.M.R. with atmosphere and earth surface

4. Microwave Remote Sensing Tools:
Radar Remote Sensing, Microwave Sensing, Lidar (Single and double ended system).

Reference Books:
1. Introduction of Remote Sensing, J.B. Campbell

Cluster ES: Energy Studies

PHY E01: ENERGY STUDIES -I


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 Photoelectrochemical solar Cells.

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


Text and Reference Books


**PHY E02: ENERGY STUDIES -II**


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References:


Cluster PP: Plasma Physics

PHY F01: PLASMA PHYSICS-I


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

References:

PHY F02: PLASMA PHYSICS-II


4. Controlled thermonuclear fusion and other plasma applications: Potentials and
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. Nanoscale Materials

   Improved micro-scale 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 Nanostructures, precipitative, reactive, hydrothermal/solvothermal methods, suitability of such methods for scaling, potential Uses

3. Physical and Chemical Methods of Nanostructured Materials


References:

4. Specific Features of Nanoscale Growth

Thermodynamics of Phase Transitions, triggering the Phase Transition Fundamentals of nucleation growth, Contrasting 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:


PHYG02: 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


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3. Characterization Methods


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:

Cluster TP: Thermal Physics

PHY 101: 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 problems: 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 \( \varphi \) 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:

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.).
1. Structures and Thermal properties of Ceramics: Atomic bonding in single crystal structures; Oxide and Silicate structures; Structure of oxide glasses; Deformation 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 P. Koonin

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

Cluster RP: Reactor Physics

PHY K01: Reactor Physics - I


dr. Registrar
University of Rajasthan
Jaipur
Reference:

1. Nuclear Reactor Engineering (Reactor Design and Basics) - Samuel Glasstone & Alexander Sessonske.
2. Introduction to Nuclear Engineering - John R. Lamarsh.

PHY K02 Reactor Physics – II


Reference:

1. Nuclear Reactor Engineering (Reactor Design and Basics) - Samuel Glasstone & Alexander Sessonske.
2. Introduction to Nuclear Engineering - John R. Lamarsh.

Cluster HP: Health Physics

PHY- L01: Health Physics-I

1. Radiation sources:


2. Radiation Dosimetry:

Radiation quantities: KERMA, fluence, relation of KERMA with photon fluence and neutron fluence. Radiation dose, unit, absorbed dose, equivalent dose, whole body dose, exposure: definition, unit, relation between exposure to energy fluence, exposure rate, internal and external exposure, exposure measurement-free air chamber, air wall chamber, exposure-dose relationship, absorbed dose.
3. Dosimetry and calibration:

Definition, calibration types, classification of calibration laboratories, Absolute cavity 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:


References:

1. Introduction to health Physics, Herman chamber 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/SQ/G-8

4. Atomic Energy (Radiation Protection) Rules, 2004


PHY-L02: Health Physics-II

1. Standards, Regulations and safety


2. Health Physics Instrumentation:
3. Radioactive waste management:

Radioactive waste, classification of waste-half life, activity, handling of radioactive source and waste, transportation of waste, TREM card, safe disposal of radioactive waste, classification of waste disposal sites, monitoring of radioactive disposal site.

4. Radiation Emergency:

Radiation emergency definition, its classification, measurable quantities in emergency, declaration, termination, radiation emergency reporting authorities, formats, handling procedures, intervention level, averted dose, emergency instruments, radiation safety in emergency, contamination, control 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/4-8.

4. Atomic Energy (Radiation Protection) Rules, 2004


ICRP reports.


Cluster LP: Laser Physics

PIHY M01: LASER-I

1. Interaction of radiation with matter: Absorption, spontaneous and stimulated emission.
Einstein's Coefficient: population inversion, metastable states, gain coefficient coefficient stimulated cross section, threshold condition. Two level system: resonance, 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 demerits 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.


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, spectral response etc.

**Text Books:**

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

**PHY M02: LASER-II**


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


Text Books:

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.
4. To determine the magnetostriction of unknown material using Michaelson interferometer.
5. To determine the dissociation energy of iodine using the concave grating on Ronald's mounting.
6. To study the diffraction pattern of LASER light using
   i. single slit
   ii. multi-slit
7. To study the Zeman splitting of Neon light using constant deviation prism and CCD camera.
8. To study the Raman spectra of C-H bands using Raman spectrometer.
9. Fabry parot Interferometer.
10. Study of Elliptically polarized light by Babinet Compensator.
11. Verification of Cauchey's Dispersion relation.

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PHY Y12/PHY22: Computational Physics Programming in C
Write program in C Programming Languages based on course of PHY 105 and PHY 110 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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