हिमाचल प्रदेश केंद्रीय विश्वविद्यालय
Central University of Himachal Pradesh
[Established under Central Universities Act 2009]
Department of Physics & Astronomical Science
School of Physical & Material Sciences

Syllabus contents for the M.Sc. Physics, 3rd Semester during Monsoon Semester (2020-21)

Condensed Matter Physics
PAS 408 A
Core Compulsory
4 Credit

Course Objectives:

The course aims to introduce students to the internal architecture of materials to explore phenomena happening in materials at atomistic length scales.

Unit 1:Crystal Structure and Reciprocal Lattice (10 hours)

1. Review of basic concepts in crystalline solids, periodic array of atoms
2. Lattice, basis and crystal structure, Unit cell, primitive lattice cell crystallographic planes and Miller indices.
3. Symmetry operations, the seven crystal systems and Bravais lattices, point and space groups,
4. Schoenflies and International notations. Illustration of some crystals such as NaCl, CsCl, Diamond structure, HCP and honeycomb lattice, Cubic ZnS, Perovskite structure.
5. Diffraction of waves by crystals, Bragg's law
6. Scattered wave amplitude, Fourier analysis, Reciprocal lattice vectors, diffraction condi- tions Laue equations.
7. Brillouin zones. Wigner-Seitz cell and Ewald's construction.
8. Structure factors and atomic form factors. Quasicrystals.
9. Experimental methods of crystal structure determination: Laue, rotating crystal and pow- der method,
10. Basics of electron and neutron diffraction by crystals.

Unit 2: Crystal Binding, Elastic Constants And Atomic Vibra- tions (12 hours)

1. Continuum model and analysis of elastic strains, Elastic compliance and stiffness constants
2. Elastic waves in cubic crystals: Longitudinal and transverse waves.
3. Different Types of binding forces for atoms in materials, cohesive energy
4. Lenard-Jones potential and crystals of inert gases
5. Ionic crystals and Madelung constant,
6. Covalent and metallic crystals, hydrogen bonding. Atomic and ionic radii. Bulk modulus.
7. Failures of static lattice approximation. Classical theory of Harmonic crystals: Harmonic and adiabatic approximations, Specific heat
8. Vibrations of 1D crystals with mono atomic basis
9. di and poly atomic basis Acoustical and optical phonon branches. Vibrations in 3D lattices.
10. Phonon momentum, inelastic scattering by phonons.
11. Quantum theory of Harmonic crystals: low and high temperature specific heat, Einstein and Debye models for phonon heat capacity.
12. Phonon density of states. Anharmonic crystal interaction, thermal expansion, thermal conductivity of phonon gas, Normal and Umklapp processes.

Unit 3: Electron Gas: Free Electron Gas And Electrons In Lat- tice (14 Hours)

1. Brief review of Drude model, Sommerfeld theory of metals, Fermi Dirac distribution func- tion and effect of temperature on FD distribution function
2. Free electron gas in three dimensions, electronic density of states. Fermi energy, momen- tum.
3. Heat capacity of electron gas, heavy fermions. Electrical conductivity and Ohm’s law.
4. Motion of electron in magnetic fields: Hall effect.
5. Thermal conductivity of metals and Wiedemann Franz law.
6. Failures of free electron theory, electron in periodic potential. Nearly free electron model: origin and magnitude of band gap, Bloch’s theorem.
7. Born-Von Karman boundary conditions. Wave equation of electrons in a periodic potential: crystal momentum, central equation
8. Kronig-Pennney model in reciprocal space,
9. Empty lattice approximation, approximate solution near zone boundary.
10. Density of states and van-Hove singularity.

11. Extended, periodic and reduced zone schemes. effective mass of electron and concept of holes
12. Tight binding method
13. Band structures of some materials (Cu, Si, GaAs, NaCl).
14. Fermi surfaces and their determination dHvA effect.

Unit 4: Superconductivity And Magnetism (12 Hours)

1. Superconductivity: Introduction; experimental facts, zero resistivity, critical temperature, critical B field and critical current.
2. Type-I and Type-II superconductors, vortex state. Basic properties of superconductors: Isotope effect, Specific heat, Meissner effect,
3. Thermodynamic properties; London equations
4. Basic elements of BCS theory, Flux quantisation in superconducting ring, High temperature superconductors.
5. Magnetism: Magnetization of matter and classification of magnetic materials. Diamag- netism and Langevin theory of diamagnetism.
6. Paramagnetism: Langevin theory and Curie law for Paramagnetism,
7. Weiss theory of Paramagnetism and Curie-Weiss law,
8. Pauli Paramagnetism. Quantum theory of Paramagnetism: Effective number of Bohr magneton, Brillouin function.
9. Ferromagnetism, ferromagnetic Curie temperature, exchange interaction, mean field ap- proximation.
10. Brief idea of Heisenberg model, magnons: Bloch T3/2 law.
11. Magnetic domains and domain theory, Bloch wall. Superparamagnetism.
12. Ferrimagnetism: Curie temperature and Susceptibility. Antiferromagnetism: Neel temper- ature.

Prescribed Textbooks:

1. Introduction to Solid State Physics, C. Kittel, Wiley 8th edition
2. Solid State Physics, N. W. Ashcroft and N.D. Mermin, Cengage Learning
3. Solid State Physics, S.O. Pillai, New Age International

Other Resources/Reference Books:

1. Solid State Physics, Guiseppe Grosso and GuiseppePastoriParravicini, Academic Press
2. Solid State Physics, A. J. Dekker, Prentice Hall
3. Understanding solids: The science of materials, Richard J. D. Tilley, John Wiley and Sons

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Nuclear and Particle Physics

PAS 409A

Core Compulsory

4 Credit

Course Objectives:

The main objectives of the course are to discuss the following:

Basic nuclear properties, Binding energy, Liquid drop model, Semi-empirical mass formula, Nature of the nuclear force, form of nucleon-nucleon potential, Deuteron problem, Nuclear reactions, reaction mechanisms, Nuclear Shell Model, Theories of Alpha, Beta and Gamma decays and their selection rules, Eightfold way and static Quark model of hadrons.

Unit 1: General Properties of Nucleus (6 hours)

1. Nuclear shapes and sizes: matter and charge distribution
2. Quantum properties: parity, spin and magnetic dipole moment
3. Mass spectroscopy, binding energy
4. Semi-empirical mass formula: Liquid drop model.

Unit 2: Nuclear Force and Two-Nucleon Interaction (6 hours)

1. Two-body bound state problem (deuteron)
2. Nucleon-nucleon scattering at low energies
3. Saturation of nuclear forces, charge-independence and charge-symmetry
4. Yukawa theory of Nuclear interaction

Unit 3: Nuclear Reactions (6 hours)

1. Nuclear reaction mechanisms
2. Compound nucleus reaction
3. Direct nuclear reactions and heavy ion reactions
4. Fusion and Fission

Unit 4: Nuclear Structure (8 hours)

1. Evidence of shell structure
2. Single particle shell model: Mean field approximation using Harmonic oscillator
3. Single particle shell model: Woods-Saxon potential and spin-orbit term
4. Its validity and limitations; Need for Collective description
5. Collective Model: Qualitative treatment to explain Vibrational and Rotational spectra

Unit 5: Nuclear Decay (6 hours)

1. Theory of α-decay, Geiger-Nuttel law, Viola-Seaborg empirical formula
2. Fermi theory of β-decay and selection rules
3. Theory of γ-decays and selection rules.

Unit 6: Nucleonic Structure (Ref 2) (8 hours)

1. Quarks and Leptons
2. Quarks : Basic building block of Hadrons
3. Iso-spin, Iso-spin of Anti-matter & charge conjugation
4. Strangeness and other quantum numbers
5. Static Quark model of Hadrons

Prescribed Textbooks (TB):

1. K.S. Krane: Introductory Nuclear Physics, John Wiley& Sons Ltd.
2. Samuel S.M. Wong, Introductory Nuclear Physics, Wiley-VCH

Suggested Extra Readings (RB):

1. B.R. Martin: Nuclear and Particle Physics, John Wiley & Sons Ltd.
2. H.A. Enge: Introduction to Nuclear Physics, Addison-Wesley (1971).
3. V.K. Mittel, R.C. Verma and S.C. Gupta: Nuclear & Particle Physics, PHD.
4. D.C. Tayal: Nuclear Physics, Himalaya Publishing House Pvt. Ltd (2008).
5. M.P. Khanna: ParticlePhysics, PHD.

Atomic, Molecular and Laser Physics

PAS 411A

Core Compulsory

4 Credit

Course Objectives:

The course is designed to, discuss various aspects of atomic,and molecular spectra,Understand about Lasers and their applications to non-linear optics

Unit 1: Interaction of Radiation with Matter (4 hours)

1. Classical Electrostatics of Molecules in Electric Fields
2. Quantum Theory of Molecules in Static Electric Fields
3. Classical Decription of Molecules in Time depended Fields
4. Time-dependent perturbation theory of radiation-matter interations
5. Selection rules for one-photon transitions

Unit 2: Atomic Spectra (6 hours)

1. Hydrogenlike Spectra, Spin—Orbit Coupling
2. Variational Principle, Hamiltonian for many electron system and Born-Oppenheimer Ap- proximation
3. Hartree Theory for He atom
4. Hartree-Fock method for excited state of He atom
5. Angular Momentum Coupling in Many-Electron Atoms
6. Many-Electron Atoms: Selection Rules and Spectra
7. The Zeeman Effect

Unit 3: Rotation and Vibrational Spectra in Diatomics (5 hours)

1. Diatomic Rotational Energy Levels and Spectroscopy
2. Vibrational Spectroscopy in Diatomics
3. Vibration—Rotation Spectra in Diatomics
4. Centrifugal Distortion
5. The Anharmonic Oscillator

Unit 4:Electronic Spectra in Diatomics (5 hours)

1. LCAO—MO Wave Functions in Diatomics
2. Molecular Orbital Theory of Hydrogen molecule
3. Electronic Spectra in Diatomics
4. Flouroscence Spectroscopy
5. NMR and ESR

Unit 5: Lasers (8 hours)

1. General Features and Properties
2. Methods of obtaining Population Inversion
3. Ray tracing in optical cavities; ABCD law;
4. Stability diagram; ray tracing in stable cavity;
5. Rate equations for two, three and four level laser systems;
6. Spatial and temporal coherence;
7. Longitudinal and transverse modes in laser cavities – concepts;
8. Q-Switching and Mode Locking

Unit 6: Types of Lasers (4 hours)

1. Solid-state lasers (Ruby, Nd-YAG)
2. Gas Lasers (He-Ne, CO2)
3. Semi-conductor lasers
4. Ion Lasers (Argon ion and Krypton ion)
5. Dye lasers

Unit 7: Laser Spectroscopy (8 hours)

1. Raman Spectroscopy
2. Photoluminiscense process
3. Non-linear Optics

Prescribed Textbooks:

1. Jeanne L. McHale, "Molecular Spectroscopy" First Edition, Pearson, 2009.
2. J. Michael Hollas, "Modern Spectroscopy" Fourth Edition, Wiley, 2013.
3. A. K. Ghatak and Thyagarajan, "Optical Electronics", Cambridge University Press, 1989.
4. AmnonYariv, :Quantum Electronics", John Wiley & sons, 1987.
5. Verdeyan, Laser Electronics, Prentice Hall, 199

Other Resources/Reference books:

1. Walter S. Struve, Fundamentals of Molecular Spectroscopy, John Whiley and Sons, 1989.
2. Michael R Muller, "Fundamentals of Quantum Chemistry: Molecular Spectroscopy and Modern Electronic Structure Computations", 1st Edition, Springer, 2001.
3. Elaine M. McCash, Colin N. Banwell, "Fundamentals of Molecular Spectroscopy", 5th Edition, Mc-Graw Hill Education, 2013.
4. G. Aruldhas, Molecular Structure and Spectroscopy, 2nd Edition, PHI Learning, 2009.
5. J Michael Hollas,Basic Atomic and Molecular Spectroscopy, Royal Society of Chemistry, 2002.
6. Straughan, B. P. and Walker, S. : Spectroscopy: (Vols. 1 - 3), Chapman and Hall (1976).
7. Chang, R. : Basic Principles of Spectroscopy, McGraw Hill (1971).
8. Characterization of Materials, E. N. Kaufmann, Wiley (2003).

Modern Physics Laboratory

PAS 423

Core Compulsory

2 Credit

Course Objectives:

The course is designed to perform experiments to go hand in hand with the theory courses on Condensed Matter Physics, Nuclear physics and Atomic, Molecular and Laser physics Experi- ments:

Lab 1: Four Probe Method

1. Measurement of resistivity of a semiconductor by four-probe method at different tempera- ture and determination of band gap.

Lab 2: Hall Effect

1. Determination of Hall coefficient of a given semiconductor and estimation of charge carrier concentration.

Lab 3: Experiments using Geiger-Muller Counter

1. Characterisation of GM tube
2. Nuclear counting statistics

Lab 4: Experiments using Gamma-ray spectrometer

Lab 5: Experiments using Alpha spectrometer

1. Prepare the radioactive source using electrolysis for thin film decomposition
2. Obtain the alpha spectrum and analyse

Lab 6: Zeeman Effect

1. Production and Analysis of linearly and circularly polarised light
2. Angular dependence of reflection and transmission
3. To explore Brewster's law and find Brewster angle

Lab 7: Michelson Interferometer

Lab 8: Electron Spin Resonance

Lab 9: Laser Beam Parameters

1. Determine the wavelength of laser
2. Determine the laser beam waist and beam spreading
3. Determine the coherence length of laser

Reference: Lab Manuals of CUHP.

Quantum Field Theory

PAS 426A

Core Open
4 Credit

Course Objectives:

Quantum field theory is the basis of modern theory of microscopic physics. This course provides us with a set of mathematical rules which when computed for physical processes give highly accurate results. Moreover, the formulation of these quantum field theories provides deep insights towards the mathematical, physical and philosophical foundations of the microscopic world. The plan of this course is to introduce the basics of field quantization. Students will learn the quantum theoretic descriptions of the electromagnetic, the weak and the strong forces and standard electroweak theory.

Unit 1: Theory of classical fields and symmetries (6 hours)

1. Why quantum field theory, creation and annihilation operators
2. relativistic notation and natural Unit s
3. Action principal and the Euler- Lagrange equations, Hamiltonian formalism, Noether the- orem

Unit 2: Quantisation of free fields (6 hours)

1. Scalar fields, field and its canonical quantization, ground state and Hamiltonian, Fock space
2. Complex scalar fields and propagator
3. Dirac fields, Hamiltonian, free particle solutions, projection operators
4. Lagrangian, Fourier decomposition and propagators

Unit 3: S-matrix, Cross- sections and decay rates (8 hours)

1. Evolution operator, S-matrix and Wick's theorem
2. Yukawa interaction, fermion scattering, Feynman amplitude and rules
3. Decay rates and scattering cross-sections
4. Four fermion interaction
5. Mandelstam variables

Unit 4: Quantum electrodynamics (8 hours)

1. Classical electromagnetic fields and quantization problems
2. Modified Lagrangian, propagator, Fourier decomposition, Feynman rules for photons
3. Local Gauge invariance and it's consequences: U(1), SU(2) and SU(3).
4. Interaction Hamiltonian, e-e scattering

Unit 5: Renormalization (4 hours)

1. Degree of divergence, Specific Example of QED
2. Self energy, vacuum polarization, Vertex function
3. Regularisation of self energy, modified Coulomb interaction
4. Running coupling constant, cancellation of infrared divergences

Unit 6: Non-Abelian gauge theories and Standard electroweak theory (8 hours)

1. Spontaneous symmetry breaking, Goldstone bosons, Higgs Mechanism
2. Yang-Mills theory of non-Abelian gauge fields
3. Interaction of gauge fields
4. Feynman rules, colour factors, QCD Lagrangian
5. Gauge group, Fermions in theory
6. Gauge boson decay
7. Scattering processes
8. Propagators, global symmetries of the model

Prescribed Text books:

1. A. Lahiri and P.B. Pal- A First Book of Quantum Field Theory 2ndedn.,Narosa Pub. (2004).
2. G. Sterman- An Introduction to Quantum Field Theory, Cambridge University Press (1993).

Prescribed Reference books:

1. F. Mandl and G. Shaw- Quantum Field Theory 2nd Edition, Wiley & Sons (2010).
2. Peskin and D. Schroeder- An Introduction to Quantum Field Theory, Levant Books (2005).
3. P. Ramond- Field Theory: A Modern Primer, Westview Press (1995).
4. S. Weinberg- Quantum field theory, Cambridge University Press (1998).

Astronomy and Astrophysics
PAS581
Elective Specialization
Credit:4

1 Astrophysical Processes:
Simple orbits, Kepler's laws, Flat rotation curve of galaxies and implications for dark matter, Role of gravity in different astrophysical systems; Radiative Process: Radiation theory and Larmor formula, Different radiative processes.

2 Stellar structure and Evolution:

Virial theorem, formation of stars, Hydrostatic Equilibrium, Integral theorems on pressure, den-density and temperature, Homologous Transformations, Polytropic gas spheres– Lane Emden Equa-tion and its solution, energy generation in stars, P-P and C-N cycles, Radiative and Convective transport of energy, equations of stellar structure and their solution, Evolution of stars of different masses, pre and post main sequence evolution.

3 Compact Objects:
Fate of massive objects, Degenerate electron and neutron gases, White-dwarfs–mass limit, mass-radius relation, neutron stars, pulsars and gamma-ray bursts.

4 Our Solar system, Planets, Dwarf planet, Astroid, Comet. Different types of binary system. Use of binary system to determine the stellar mass.

5 Telescopes and Instrumentation:

Different optical configurations for Astronomical telescopes, Mountings, Image formation, Diffrac-tion, Aberrations, plate scale and diffraction limits, telescopes for gamma ray, X-ray, UV, IR, mm and radio astronomy, Stellar photometry,-solid state, Photomultiplier tube and Charge-Coupled Device (CCD) based photometers, Spectroscopy and Polarimetry using CCD detectors. Sensitivity and dynamic range, Time resolution, Energy resolution, spatial resolution of the photon detector, Concept of grating and spectra and spectral resolution.

6 Observational Data:
Astronomical coordinates- Celestial Sphere, horizon, Equatorial, Ecliptic, and Galactic Systems of coordinates, Conversion from one system of coordinates to another, Magnitude Scale- Ap- parent and absolute magnitude, distance modulus. Determination of mass, luminosity, radius,temperature and distance of a star, Colour Index, Stellar classification- henry-draper and Modern M-K classification schemes, H-R diagram, H-R Diagram of clusters, empirical Mass-luminosity relation.

7 Variable stars : Photometry of variable stars, differential photometry, extinction coefficients, classes of variable stars, period-Mean density relationship, classical cepheids as distance indicators

8 Galaxies:

The milky way galaxy, Distribution of stars, Morphology, kinematics, Interstellar medium, galac-tic center. Classification of galaxies, Hubble sequence, Ellipticals, lentreculars and spiral galaxiesand their properties, distribution of light and mass in galaxies. Active galactic nuclei Quasars and Black holes.

9 Overview of the Universe and modern astronomy:

Qualitative description of astro-objects (from planets to large scale structures): length mass andtime scales, Evolution of structures in the universe; Red shift, Expansion of the universe and determination of Hubble’s constant. Thermal history of the Universe, Inter-galactic medium.Cosmology with Ly-alpha forest, 21-cm hydrogen line, cosmic radio sources, Quasar absorptionline.

References
1. Frank Shu, The physical universe
2. T. Padnabhan, Course of Theoretical Astrophysics- Volume I, II, III
3. B. W. Carroll and D. A. Ostlie, Introduction to Modern Astrophysics
4. M. Zeilik and S. A. Gregory. Introductory Astronomy and Astrophysics
5. S. L. Shapiro and S. A. Teukolsky, Black Holes, White Dwarfs and Neutron Stars
6. B. James and S. Tremaine, Galactic Dynamics
7. G. B. Rybicki and A. P. Lightman, Radiative Processes in Astrophysics
8. C. R. Kitchin, Telescopes and Techniques: An Introduction to Practical Astronomy
9. NPTL lectures on Astrophysics and cosmology

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Astronomy and Astrophysics Lab
PAS581L
Elective Specialization
Credit:2

Experiments:

To become familiar with the astronomical objects visible to naked eye in the night sky using the software Stellarium.
To become familiar with the Constellations in the night sky using the software Stellarium.
To identify some of the prominent spectral lines in the spectrum of our sun.
To get familiar with the spectra of different stars.
To identify the absorption line systems in QSOs optical spectra, using various alkali-doublets lines.

Some numerical methods/tools for tutorials:

1 Programming languages:
Like PYTHON, C++, FORTRAN, MATLAb etc, for numerical interpolation/extrapolation integration and plotting.
2 Practical Astronomy tools:
Spectroscopy using IRAF and usage of Archival Data
I. Images: Aladin, Datascope, SkyView, VODesktop, Data Discovery Tools, SDSS
II. Spectra: SDSS, Aladin, CASSIS, Datascope, SPLAT, Specview, VOServices, VOSpec
III. Catalogues: Aladin, Datascope, TOPCAT, VODesktop, SDSS
3 Photometry using DAOPHOT and DS9
4 Spectroscopy using IRAF and DS9
5 Virtual Observatory:

Unitary Symmetry in Quantum Physics
PAS 545
Elective Open
2 Credit

Course Objectives:

To study the role of symmetry in various aspects of quantum mechanics. How symmetry leads to conserved quantities (Noether theorem). Discrete symmetries, symmetries of the Schrodinger equation, symmetry and degeneracy of states will be discussed. Rotation symmetry, angular momentum and SO(3) group. Symmetries of the Dirac equation. Special Unit ary SU(2) and SU(3) symmetry and their relation with particle physics.

Unit -1: Symmetries and Conservation Laws (4 hours)

1. Symmetries in Classical Physics
2. Symmetries and their physical meaning-Noether Theorem
3. Time invariant equations of motion
4. Unitary translational operator
5. Symmetry and degeneracy of states
6. Discrete symmetries

Unit 2: Angular momentum and the Group SO(3) (4 hours)

1. Wigner theorem
2. Rotations in Euclidian space
3. Isotropy of Space

4. Infinitesimal and finite rotations
5. An isomorphism of the rotation group

Unit 3: Symmetries and Further Properties of the Dirac Equation- I(4 hours)

1. Active and Passive Transformations,
2. Transformations of Vectors
3. Invariance and Conservation Laws
4. The General Transformation
5. Rotations
6. Translations

Unit 4: Symmetries and Further Properties of the Dirac Equation- II (4 hours)

1. Spatial Reflection (Parity Transformation)
2. Charge Conjugation
3. Time Reversal (Motion Reversal)
4. Reversal of Motion in Classical Physics
5. Time Reversal in Quantum Mechanics
6. Time-Reversal Invariance of the Dirac Equation
7. Racah Time Reflection, Helicity, Zero-Mass Fermions

Unit 5: The SU(2) and SU(3) Symmetry (4 hours)

1. Group U(n) and SU(n)
2. Generators of U(n) and SU(n)
3. Linear independence of the generators
4. Lie algebra of SU(2) group, SU(3) group
5. The generators of SU(3)
6. Linear independence of the generators

Prescribed Textbooks:

1. Walter Greiner and Berndt Muller, Quantum Mechanics Symmetries, Springer
2. H. F. Jones, Groups, Representations and Physics, 2nd edition, Institute of Physics Pub- lishing
3. Franz Schwabl, Advanced Quantum Mechanics, Springer

Other Resources/References books:

1. M. Chaichian and R. Hagedorn, Symmetries in Quantum Mechanics, Institute of Physics Publishing.
2. Volker Heine, Group Theory in Quantum Mechanics, Pergamon Press.