Krishnaguru Adhyatmik Visvavidyalaya, Nasatra, Barpeta, Assam

M.Sc. Physics Syllabus

Department of Physics

2-year Post-Graduate Programme: Master of Science in Physics

M.Sc. Physics First Semester Syllabus

Course structure in Semester-I

Semester-I						
Total No. of core course	Marks		Credits			
	Sessional + End semester	Total	L	T	P	Total
PHY-101: Mathematical Physics	20+80	100	3	1	0	4
PHY-102: Classical Mechanics	20+80	100	3	1	0	4
PHY-103: Quantum Mechanics-I	20+80	100	3	1	0	4
PHY-104: Condensed Matter Physics	20+80	100	3	1	0	4
PHY-105: General Practicals	20+80	100	0	0	4	4

Course structure in Semester-II

Semester-II						
Total No. of core course	Marks		Credits			
	Sessional + End semester	Total	L	T	P	Total
PHY-201: Atomic, Molecular and Laser Physics	20+80	100	3	1	0	4
PHY-202: Nuclear Physics	20+80	100	3	1	0	4
PHY-203: Electrodynamics	20+80	100	3	1	0	4
PHY-204: Electromagnetic Theory & Electrodynamics	20+80	100	3	1	0	4
PHY-205: General Practical's	20+80	100	0	0	4	4

*L-Lecture, *T-Tutorial, *P-Practical

Course structure in Semester-III

Semester III							
	Paper	Marks		Credits			
	Semester IV	Sessional + End semester	Total	L	T	P	Total
	Paper	Marks			Credits		
	<u>Core Course</u> PHY 3014: Advanced Quantum mechanics	Sessional / 20+80	Total / 100	L / 3	T / 1	P / 0	Total / 4
Elective Courses (Group A): **Elective-I: Any one combination with total 8 credits to be chosen from Group A1 to Group A2**							
A1	PHY3024: Advanced Condensed Matter Physics-I	20+80	100	3	1	0	4
	PHY3034: Advanced Condensed Matter Physics Lab	20+80	100	0	0	4	4
A2	PHY3044: Nanophysics-I	20+80	100	3	1	0	4
	PHY3054: Nanophysics Lab	20+80	100	0	0	4	4
Elective Courses (Group B): **Elective-II:** ***Any one combination with total 8 credits to be chosen from Group B1 to Group B2***							
B1	PHY3064: Advanced Electronics-I	20+80	100	3	1	0	4
	PHY3074: Advanced Electronics Lab	20+80	100	0	0	4	4
B2	PHY3084: Lasers & Spectroscopy-I	20+80	100	3	1	0	4
	PHY3094: Lasers & Spectroscopy Lab	20+80	100	0	0	4	4

*L-Lecture, *T-Tutorial, *P-Practical

		+ End semester					
	<u>Core Course</u> PHY 4014: Statistical Mechanics	20+80	100	3	1	0	4
	PHY 4024: Numerical Analysis and Computer Programming	20+80	100	2	1	1	4
	Elective Courses (Group A): **Elective-III:** *One course of 4 credits in line with Group A1 to Group A 2 to be chosen*						
A1	PHY4034: Advanced Condensed Matter Physics-II	20+80	100	3	0	1	4
A2	PHY4044: Nanophysics-II	20+80	100	3	0	1	4
	Elective Courses (Group B): **Elective-IV:** *One course of 4 credits in line with Group B1 to Group B2 to be chosen*						
B1	PHY4054: Advanced Electronics-II	20+80	100	3	1	0	4
B2	PHY4064: Lasers & Spectroscopy-II	20+80	100	3	1	0	4
	PHY4074: Dissertation & Project Work (Core)	20+80	100	0	0	4	4

M.Sc. Physics Fourth Semester Syllabus

Course structure in Semester-IV

***L-Lecture, *T-Tutorial, *P-Practical**

PHY 101 :: Mathematical Physics

Type of the paper: **Core, Theory** Total Marks: **80 (Final) + 20 (Sessional)= 100** Credit: **4 (3L + IT)**

Course Outcome:

The students will be able to give mathematical form to the laws of physics. They will be able to apply abstract concepts of pure mathematics to the concrete problems of Nature.

Unit I: Linear Vector Spaces

N-dimensional linear vector space, orthonormal basis, Inner product, Hilbert space, Gram-Schmidt orthonormalisation, outer product. Linear operators and their algebra, matrix representation of operators, similarity transformation, diagonalisation of Hermatian, symmetric, complex and complex symmetric matrices,

Unit II: Special Function and Partial Differential Equations

Associated Legendre Polynomials and spherical Harmonics - Physical applications. Applications of Hermite's Polynomials, Bessel function and Spherical Bessel function. Gamma, Beta functions, Dirac delta- function. One dimensional wave equation, one dimensional heat flow equation (finite rod). Laplace's equation and its solution.

Unit III: Integral transformations

Laplace transform and inverse Laplace transform. Fourier transforms. Shifting theorem and convolution. Solution of differential equations with the help of Laplace and Fourier transform.

Unit IV: Group theory

Group axioms, permutation groups (S_2 and S_3) and symmetry operations of equilateral triangle, multiplication table, subgroup, classes, finite groups (Zn), direct and semi-direct products, block diagonalisation- reducible and irreducible representation.

Recommended books

1) Mathematical methods for physicists: Arfken and Weber

2) Mathematical Physics: PK Chattopadhyay

3) Mathematical Physics: BS Rajput

4) Matrices and tensors in Physics: A W Joshi

5) Mathematics for physicists: P Dennery and A Krzywick

6) Partial differential equations of Mathematical Physics: AG Webster

7) Differential equations and their applications: Zafar Ahsan

PHY102 :: Classical Mechanics

Type of the paper: **Core, Theory** Total Marks: **80 (Final) + 20 (Sessional) = 100** Credit: **4 (3L + 1T)**

Course Outcome:

The students will be able to describe a wide variety of physical phenomena by the sophisticated mathematical formalism such as the Lagrangian and the Hamiltonian. They will be able to generalise the laws of physics in higher dimensions, and will also be able to apply the formalism of classical mechanics to rigid body dynamics, and classical fields.

Unit I: Lagrangian and Hamiltonian formalisms

Lagrangian and Hamiltonian formalisms and equations of motion-their applications to physical problems. Lagrangian and Hamiltonian of a relativistic particle, examples, Lagrangian and Hamiltonian formulation of relativistic mechanics

Unit II: Rigid body dynamics

Rigid body dynamics, moment of inertia tensor, non-inertial frames and pseudo forces. Principal axes and principal moments of inertia. Euler's equation of motion. Symmetric top motion and Foucault's pendulum.

Unit III: Canonical transformations

Theory of canonical transformations and generating function. Canonical variables and Poisson brackets, properties, Jacobi identity, Hamilton's equation in terms of Poisson bracket.

Unit IV: Action-angle variables

Action-angle variables, application to simple harmonic oscillator, planetary motion, adiabatic invariants. Hamilton's Jacobi theory and its application to solve central force problem.

Recommended books

1) Classical Mechanics- H. Goldstein

2) Classical Mechanics- Rana and Joag

3) Mechanics- Landau and Lifshitz

4) Classical Mechanics- V. B. Bhatia

5) Classical Mechanics -A. K. Raychaudhury

6) Classical Mechanics of Particles and Rigid Bodies K. C. Gupta

PHY103:: Quantum Mechanics

Type of the paper: **Core, Theory** Total Marks: **80 (Final) + 20 (Sessional) = 100** Credit: **4 (3L + 1T)**

Course Outcome:

The students will be able to calculate the probability of finding a particle at different locations. They will be able to solve the Schrodinger equation by approximate methods.

Unit I: Basic principles of quantum mechanics

Essence of wave mechanics, physical interpretation of wave function, central potential, spherical harmonics and complete wave function (H-atom), angular momentum, matrix formulation of quantum mechanics, Bra and Ket vectors, their algebra and applications, orthonormality, completeness and closure, simultaneous eigenstates , expectation values, linear harmonic oscillator in operator method, Heisenberg's uncertainty principle using wave and matrix mechanics, Heisenberg's equation of motion and its physical equivalence with Schrodinger equation.

Unit II: Indistinguishable and identical particles in quantum mechanics

Combinations of wave functions for a system of particles, symmetric and antisymmetric wave functions, spin- statistics connection, evolution of quantum statistics, exchange interaction and exchange energy.

Unit III: Symmetry, invariance principle, and conservation

Space and time translations, rotational invariance under infinitesimal and finite rotations. Angular momentum operators, ladder operators, addition of angular momentum -Clebsch-Gordan coefficients.

Unit IV: Approximation methods in quantum mechanics

Time independent perturbation theory, Stark and Zeeman effects, variational method and its applications, WKB approximation, time dependent perturbation theory, transition to continuum states, Fermi's Golden rule, adiabatic and sudden approximation.

Recommended books

1) Quantum mechanics - L. I. Schiff

2) Quantum Mechanics -S. N. Biswas

3) Introductory Quantum Mechanics- R. L. Liboff

4) Principles of Quantum Mechanics -R. Shankar

5) Quantum Mechanics: concepts and applications - N. Zettili

6) Quantum Mechanics -A. K. Ghatak and S. Lokanathan

PHY 104 :: Condensed Matter Physics

Type of the paper**: Core, Theory** Total Marks: **80 (Final) + 20 (Sessional) = 100** Credit: **4 (3L+ 1T)**

Course Outcome:

Acquiring the knowledge of matter in condensed phase, their structural, electrical and magnetic properties, the students will be able to compute parameters related to extent and Type of crystallinity, conductivity, defects etc and the way these affect some basic properties.

Unit I: Crystalline Solids

Fundamentals of crystal structure, symmetry operations, point groups and space groups, X-ray diffraction, reciprocal lattice, atomic scattering factor, geometrical structure factor, Quasicrystals, Imperfection in solids

Unit II: Energy bands in Solids
Bloch function, Kronig-Penney model, Brillouin zones, effective mass of charge carriers. Tight binding and Wigner-Seitz method. Very brief idea about Thin Film Physics, Nanophysics, and Soft Condensed Matter Physics.

Unit III: Dielectric, Ferroelectric and Magnetic properties of solid

Complex de dielectric constant and dielectric loss, dielectric relaxation, Debye equations, dipole theory of ferroelectric domains, anti-ferroelectricity. Fundamental concepts, quantum theory of diamagnetism and paramagnetism, diamagnetic and paramagnetic susceptibilities of free electrons, molecular field theory of ferromagnetism, anti-ferromagnetism and ferrimagnetism, electron paramagnetic resonance and nuclear magnetic resonance.

Unit IV: Semiconductors

Intrinsic and extrinsic semiconductor, number density of carriers in intrinsic and extrinsic semiconductors, expression for Fermi levels, recombination processes, photoconductivity, Hall effect in metals and semiconductors.

Unit V: Superconductivity

Thermodynamics of superconducting state, London equations, coherence length, idea of BCS theory, flux quantisation, Josephson effect.

Recommended books

1) Introduction to Solid State Physics - C Kittel.
2) Lattice Dynamics -A. K. Ghatak and L. S. Kothari
3) Solid State Physics- A. J. Dekker
4) Introductory Solid State Physics - H. P. Myers
5) Solid State Physics -N. W. Ashcroft and N. D. Mermin
6) Magnetism in solids- D. H. Martin
7) Physics of Magnetism -S. Chikazumi

PHY 105 :: General Practicals

Total Marks: **80+20=100** Credit: 4

NOTE

1. A minimum of six experiments to be performed in the semester by the students.

2. Error analysis and estimation will be an integral part of all experiments.

3. Students are required to go through electronics workshop practice. A 20% weightage of the practical paper will be given to this workshop.

4. Students are required to give at least one seminar on experiments performed during the program or any other topic related to physics. This will be a part of their continuous evaluation.

List of Laboratory Experiments

Exp.1
Determination of Refractive Index of air at different pressures using Michelson's interferometer.

Exp.2
Determination of the Refractive index of air by Jamin interferometer using He-Ne Laser.

Exp.3
Determination of unknown wavelength of a source using Lloyd's Mirror.

Exp.4
Determination of Band Gap of a semiconductor using four probe method.

Exp.5
Study of para-ferromagnetic phase transition.

Exp.6
Measurement of Dielectric constant of a given material using Marconi Bridge.

Exp.7
Designing a Wein Bridge Oscillator and find the frequency of oscillation and compare the results with theoritical values.

Electronics workshop

The course of this workshop will be notified by the department in course of time.

Recommended books
1) Lab Manuals
2) Books/Notes suggested by the Lab instructor

PHY 201 :: Atomic, Molecular and Laser Physics

Type of the paper: **Core, Theory** Total Marks: **80 (Final) +20 (Sessional) = 100** Credit: **4 (3L + 1T)**

Course Outcome:

The students will be able to determine certain parameters associated with length, mass, time and energy from atomic and molecular spectra. They will be able to explain the working of a few laser systems.

Unit I: Atomic physics

Pauli exclusion principle: spectral terms from two equivalent electrons, Vector model for three or more valence electrons and spectral terms, branching rule, Land interval rule, LS and JJ coupling schemes, energy levels, selection rules, spectra of oxygen, nitrogen and manganese atoms; Zeeman effect, Paschen-Back effect, Stark effect in hydrogen, hyperfine structure, determination of nuclear spin and nuclear g factors, Breadth of spectrum lines: natural broadening, Doppler broadening, collision broadening, and Stark broadening.

Unit II: Molecular physics

IR spectra Rotation, vibration and rotation-vibration spectra of diatomic molecules, selection rules, determination of rotational constants. Electronic spectra: Born-Oppenheimer approximation, vibrational structure of electronic transition, progressions and sequences of vibrational bands, Intensity distribution, Franck Condon principle. Raman spectra: Classical theory of Raman effect, Vibrational Raman spectrum, selection rules, Stokes and anti-Stokes lines, Rotational Raman spectrum, selection rule.

Unit III: Lasers

Basic elements of a laser, properties of laser light; spontaneous and stimulated emission: Einstein coefficients, light amplification, population inversion and threshold condition for laser oscillations, optical resonator modes of a rectangular cavity, rate equations: two-level, three-level and four-level systems; ammonia maser, ruby laser, He-Ne laser

Recommended books

1) Introduction to Atomic Spectra- H. E. White.

2) Physics of atoms and molecules -B. H. Bransden and C. J. Joachain

3) Fundamentals of Molecular Spectroscopy- C. N. Banwell and E. M. McCash.

4) Spectra of Diatomic Molecules (Vol. 1) -G. Herzberg.

5) Lasers and Nonlinear Optics -B. B. Laud.

6) Lasers: Theory and Applications- K. Thyagarajan and A. K. Ghatak.

PHY 202 :: Nuclear Physics

Type of the paper: **Core, Theory** Total Marks: **80 (Final) + 20 (Sessional) = 100** Credit: **4 (3L + 1T)**

Course Outcome:

The students will be able to give an in-depth description of the nucleus and its various properties. They will be able to describe the structure of the nucleus and the Type of the interaction that keeps the nucleus bound.

Unit I: General Properties of Nuclei

Basic Nuclear Properties: size, shape and charge distribution, spin, parity and isospin of nucleon and nuclei.

Unit II: Nuclear ß decay

Essential condition of beta decays, beta ray spectrum, apparent violation of energy-momentum conservation rules in beta decay, Pauli's neutrino hypothesis, experimental discovery of neutrino Cowan's experiment, Fermi's theory of beta decay, Kurie plot and concept of massive neutrino, 2v and 0v double beta decays.

Unit III: Models of Nuclei

Liquid drop Model: Semi empirical mass formula and its applications in (i) Estimation of energy released in fission reactions, (ii) predicting the most stable member of an isobaric family, (iii) predicting the condition for spontaneous fission. Failure of Liquid drop Model. Shell Model: Magic numbers and experimental evidences of shell models, Single particle shell model and its application in predicting the spin and parity of even A and odd A nuclei, Failures of extreme single particle shell model. Concepts of collective model of nuclei.

Unit IV: Nuclear Reaction

Classifications of nuclear reactions, Kinematics of two body nuclear reaction Lab and CMS co-ordinate systems, Rutherford alpha particle scattering experiment corrections for extended object, quantum mechanical and relativistic effects. Concept of nuclear reaction Bohr compound nucleus hypothesis and Ghosal experiment.

Unit V: Nuclear Instrumentation

Radiation Detectors: Interaction of charged particles and radiation with matter, detector response, efficiency and resolution of a detector. Gas filled detector: current vs applied voltage curve, Ionisation region, Proportional region, GM region and spark region. Construction and working principle of GM counting system, its advantages and limitations. Linear accelerator (LINAC): Pelletron-construction and principle of operation, its advantages and limitations. Cyclotron: Construction and principle of operation, its advantages and limitations.

Unit VI: Elementary Particles

Classifications of elementary particles and their interactions, conservation laws, symmetry principles and quantum numbers, strangeness and isospin, Gellman-Nishijima scheme, Quark model.

Recommended books

1) Introductory Nuclear Physics -Kenneth S Krane.
2) Atomic and Nuclear Physics (Vol. 2) -SN Ghoshal.
3) Concepts of Modern Physics- Arthur Beiser.

4) Techniques for Nuclear and Particle Physics Experiments- WR Leo.
5) Nuclear reactions and structure studies -PE Hodeson.

PHY 203 :: Electro-magnetic Theory & Electrodynamics

Type of the paper: **Core, Theory** Total Marks: **80 (Final) + 20 (Sessional) =100** Credit: **4 (3L+1T)**

Course Outcome:

The students will acquire advanced knowledge of electromagnetic fields. They will be able to investigate the collective behaviour of charged particles and their dynamics, which provides the basic working model of plasma.

Unit I: Review of Maxwell's equations

Potential formulation of electrodynamics: electromagnetic potentials, gauge transformation, Lorentz and Coulomb gauge, gauge invariance, four-potential and four-current in Minkowski's formalism, covariant formulation of Maxwell's equations. Electrodynamics in tensorial notations: Transformation properties of electric and magnetic fields, electromagnetic field tensor and Maxwell's equations.

Unit II: Formalisms of Electrodynamics

Lagrangian Formulation of Electrodynamics: Lagrangian for a relativistic charged particle in an E.M. field, interaction between charged particles and fields. Energy-momentum tensor, conservation of energy- momentum.

Unit III: Propagation of EM waves

Non relativistic motion of a charged particle in uniform constant E and B fields, in a slowly varying fields, curvature, gradient and external force drift, Adiabatic invariance of magnetic moment of a charged particle, principle of magnetic mirror.

Unit IV: Scattering of EM waves

Scattering of e. m. waves due to free electrons, Thomson scattering, scattering from bound electrons, Rayleigh scattering and resonance fluorescence, dispersion- normal and anomalous.

Unit V: Wave-guides

Wave-guides and cavity resonance, EM wave propagation of various types of EM modes in different types of wave guides.

Recommended books

1) Introduction to Electrodynamics- David J Griffiths
2) Foundation of Electromagnetic Theory- JR Reitz, F J Milford and RW Christy
3) Electricity and Magnetism -MH Nayfeh and MK Brussel
4) Classical Electrodynamics -JD Jackson
5) The Feynman Lectures on Physics Vol II
6) Introduction to Plasma Physics - FF Chen
7) Plasma Physics- RJ Goldstone and PH Rutherford

PHY204 :: Electronics

Type of the paper: **Core, Theory** Total Marks: **80 (Final) + 20 (Sessional) = 100** Credit: **4 (3L+1T)**

Course Outcome:

The students will become acquainted with important electronic devices, circuits and communication principles.

Unit I: Electronic devices

Carrier concentrations in semiconductors; direct and indirect band gap semiconductors, Band structure of p n junction; Homo and hetero-junction devices; Thyristor devices: SCR, UJT, Triac; FET Devices: JFET, MOSFET, MESFET, CMOS; Opto Electronic Devices: Optical absorption, Beer-Lambert law, Solar Cell, Photodetectors, LED, Laser Diodes; Microwave devices: Basic principle of operation of a Klystron and Cavity Magnetron.

Unit II: Nanoelectronics

Introduction to quantum view of bulk solids: key ideas in electronic properties. Review of basic semiconductor device physics with a broad survey of modern device technology, Introduction to nanomaterials and their special features in electronics. Overview of Nanoelectronics devices and materials requirement.

Unit III: Operational amplifier and Linear Integrated Circuits

Differential Amplifier, OPAM circuits, comparators, logarithmic amplifiers, Analog Computation, Active filters, digital to analog converter: Binary Weighted R-2R ladder network, 555 timer, voltage regulators, voltage controlled oscillator, phase locked loop, waveform generators.

Unit IV: Digital Circuits

Logic families; Signal levels and noise margin; Boolean algebra; Combinational logic: adders, subtractors ; Encoders; Decoder: Multiplexer; Demultiplexer; Comparator; parity generator and checker; Sequential logic: flip-flop; Register; Counters; Memory Concepts, Analog to Digital Converter, Basics of microprocessor.

Recommended books

1) Electronic devices and circuit theory- R L Boylestad.
2) OPAMPS and Linear Integrated Circuits- Ramakant A Gayakwad.
3) Operational amplifier and linear integrated circuits -RF Coughlin and FF Driscoll.
4) Modern Digital and Analog Communication Systems -BP Lathi.
5) Electronic Communication System- George Kennedy.
6) Communication Systems - Simon Haykin

PHY 205 :: General Practicals

Total Marks: **80+20=100** Credit: 4

NOTE

1. A minimum of six experiments to be performed in the semester by the students.
2. Error analysis and estimation will be an integral part of all experiments.
3. Students are required to go through electronics workshop practice. A 20% weightage of the practical paper will be given to this workshop.
4. Students are required to give at least one seminar on experiments performed during the program or any other topic related to physics. This will be a part of their continuous evaluation.

List of Laboratory Experiments

Exp.1
Separation of D1-D 2 lines using Michelson's interferometer.

Exp.2
To study Faraday's effect using He-Ne Laser.

Exp.3
To study the diffraction of laser light due to a double slit, grating, and circular aperture. Hence determine

(a) the wavelength of the laser light,
(b) the ruling density of the grating, and
(c) the diameter of the circular aperture.

Exp.4
Determination of e/m of electron by normal Zeeman effects using Febry Perot Etalon.

Exp.5
Construct AND, OR, NOT, NOR, XOR and half adder with the help of NAND gates and verify their truth tables.

Exp.6
Simplification of given Boolean equation and verify with NAND/NOR Gates.

Exp.7
Using IC 741

(a) Design of integrator & differentiator circuit
(b) Drawing of waveform
(c) Measuring the rise and fall time
(d) Comparing the results with theoritical values.

Exp.8
Experiment on FET and MOSFET characterization and application as an amplifier.

Electronics workshop

The course of this workshop will be notified by the department in course of time.

Recommended books
1) Lab Manuals
2) Books/Notes suggested by the Lab instructor

PHY301: Advanced Quantum mechanics

Type of the paper: Core, Theory Total Marks: 80(Final)+ 20(Sessional)=100 Credit: 4 (3L+1T)

Course Outcome: Objective of the current course is to familiarize the students to the formal structure of the subject and to equip them with the concept of relativistic quantum mechanics, scattering and their applications so that they can use such concepts in various branches of Physics as per requirement.

Unit-I: Relativistic Quantum Mechanics

Concept of four vectors, natural units, Minkowski space, Klein Gordon (KG) equation, Problem with KG equation, Dirac equation and evaluation of the Dirac matrices, Plane wave solution of Dirac equation, concept of negative energy and vacuum, non-relativistic limit of Dirac equation, prediction of spin of electron.

Unit-II: Scattering Theory

Introduction to scattering cross section and differential cross section. Scattering by a potential, partial wave analysis, optical theorem. Born series and Born approximation, scattering cross section for Yukawa, Coulomb and square well potential.

Unit-III: Interaction of Radiation with Matter

Electromagnetic field and its interaction with single electron atom, harmonic perturbation and transition rates, spontaneous and stimulated emission, absorption, Einstein A and B coefficients. Selection rules.

Unit- IV: Path Integral Approach to Quantum Mechanics

Distinguishable and Indistinguishable paths, Feynman's Path Integral method, equivalence of Feynman and Schrödinger equations.

Recommended Books:

1. Quantum Mechanics: C. Cohen-Tannoudji, B. Diu, and F. Laloe
2. The Principles of Quantum Mechanics: P. A. M. Dirac
3. Quantum Mechanics: N. Zettili
4. The Feynman Lectures on Physics: R. Feynman, R. Leighton and M. Sands
5. Quantum Mechanics: A. Ghatak and S. Lokanathan
6. Quantum Mechanics: A. Arhuldass
7. Quantum Mechanics: S N Biswas
8. Introduction to Quantum Mechanics: D. J. Griffiths
9. Modern Quantum Mechanics: J.J. Sakurai
10. Quantum Mechanics: Eugen Merzbacher

PHY302: Advanced Condensed Matter Physics-I

Type of the paper: Elective, Theory Total Marks: 80(Final)+ 20(Sessional)=100 Credit: 4 (3L+1T)

Course Outcome*: Assimilating the knowledge of this course, students will be able to acquire advanced theoretical knowledge of lattice vibration, optical, magnetic, and superconducting properties of matter. Later, they will be able to analyse some specific problems based on this course contents.*

Contents:

Unit-I: Phonon Spectrum

Phonon creation and annihilation operators, elastic scattering of electrons by phonon, inelastic scattering of photons by phonons, inelastic phonon- phonon scattering, normal and umklapp processes.

Unit-II: Optical Properties of Solids

Optical constants, dispersion relation of optical constants from Maxwell's equations, optical absorption and emission in semiconductors, exciton absorption, impurity and interband transitions, luminescence, activators, photoluminescence and thermoluminescence.

Unit-III: Superconductivity

Isotope effect, electron-phonon interaction and BCS theory of superconductivity, superconducting quantum interference device (SQUID), Ginsburg-Landau theory of the type II superconductivity, high temperature superconductivity.

Unit-IV: Magnetic Phenomena in Solids

Magnetoconductivity, cyclotron resonance, Landau levels and Landau cylinders, de Haas-van Alphen effect. Exchange interaction and exchange integral for two-electron system, Heisenberg Hamiltonian for exchange interaction, relationship between exchange energy and molecular field, ferromagnetic spin waves and antiferromagnetic spin waves, magnons and antiferromagnetic ordering.

Recommended Books:

1. *Lattice Dynamics*, A K Ghatak and L S Kothari

2. *Theory of Superconductivity*, J R Schriffer

3. *Solid State Physics*, A J Dekker

4. *Fundamentals of Solid-State Physics*, J R Christman

5. *Introduction to Solid State Physic,* C Kittel

6. *Solid State Theory*, W. Harrison

7. *Intermediate Quantum Theory of Crystalline Solids*, A O E Animalu

PHY303: Advanced Condensed Matter Physics Lab

Type of the paper: Elective, Practical Total Marks: 80(Final)+ 20(Sessional)=100 Credit: 4 (0L+0T+4P)

Course Outcome: *Objectives of this course is to provide hands-on laboratory training in Advanced Condensed Matter Physics. Performing these experiments, students will get an insights of the phenomena like electrical and optical transport, transport in magnetic field, dielectric phenomena and spin resonance.*

List of Experiments *(All experiments are compulsory)*

Expt 1: *Measurement of magnetoresistance of the supplied material*

Expt 2: *Study of temperature dependent Hall effect of the supplied semiconductor*

Expt 3: *Determination of Landé g factor using the ESR set-up*

Expt 4: *Determination of transition temperature of the supplied ferroelectric sample*

Expt 5: *Determination of solar cell characteristics using the supplied set up*

Suggested References

1. *Lab Manual*, Advanced Condensed Matter Physics Lab

PHY304: Nanophysics-I

Type of the paper: **Elective, Theory** **Total Marks:** **80(Final)+ 20(Sessional)=100** **Credit: 4 (3L+1T)**

Course Outcome: *This course is included, aiming to facilitate learning of nanoscale phenomena. Upon completion of the course, the students will be able to gain insight of the nucleation and growth processes, synthesis and characterization of nanostructured materials.*

Contents

Unit-I: Nucleation and Growth

Classical nucleation theory, critical nuclei size, homogeneous and heterogeneous nucleation, growth of nanocrystals in solution, LSW theory.

Unit-II: Nanostructure Synthesis and Characterization

Top-down and bottom-up approaches, chemical methods, chemical vapour deposition, physical vapour deposition, pulsed laser deposition, molecular beam epitaxy, lithography, biosynthesis, nanomanipulation. X-ray diffraction, crystallite size and strain, electron microscopy, absorption and luminescence spectroscopy, X-ray photoelectron spectroscopy.

Unit-III: Surface Effects

Increased surface-area-to-volume ratio, melting point suppression, increased reactivity, catalysis, superhydrophobicity

Unit-IV: Quantum Effects in Nanosized Semiconductors-I

Low dimensional structures (2D, 1D, 0D) and density of states, E–K diagram and band gap engineering.

Recommended Books:

1. *Kinetic Processes*, K A Jackson

2. *Nanophysics and Nanotechnology*, E L Wolf

3. *Elements of X-ray Diffraction*, B. D. Cullity, S. R. Stock

4. *Nano: The Essentials, Understanding Nanoscience and Nanotechnology,* T. Pradeep

5. *Nanotechnology: Principles and Fundamentals*, G. Schmid

6. *Springer Handbook of Nanotechnology*, B. Bhushan (Ed.)

7. *Introduction to Nanotechnology*, C. P. Poole, J. F. J. Owens

8. *Introduction to Nanoscience and Nanotechnology*, K. K. Chattopadhyay, A. N. Banerjee

PHY305: Nanophysics Lab

Type of the paper: Elective, Practical Total Marks: 80(Final)+ 20(Sessional)=100 Credit: 4 (0L+0T+4P)

Course Outcome: *This course aims at hands-on laboratory work of the students to visualize and realize the growth of nanostructured materials and to study their structural, electronic, and optical properties.*

Contents

List of Experiments *(All experiments are compulsory)*

Exp 1: *Familiarization with ORIGIN Graphing and Analysis Software for analysis of absorption & photoluminescence spectra and X-ray diffraction patterns.*

Exp 2: *Production and measurement of low pressure using high vacuum pumping system.*

Exp 3: *Synthesize CdS nanostructures by the chemical co-precipitation method and record UV-Visible absorption spectra. Examine possible quantum confinement effect.*

Exp 4: *Obtain the powder diffraction pattern of a polycrystalline material using the Debye-Scherrer method. Analyze the results to determine the crystal structure.*

Exp 5: *Prepare undoped ZnS and Mn-doped ZnS nanocrystals by chemical co-precipitation method. Record photoluminescence spectra and analyze your results.*

Suggested References

1. *Lab Manual,* Nanophysics Lab

2. *Instruments operation manual*

PHY306: Advanced Electronics-I

Type of the paper: Elective, Theory Total Marks: 80(Final)+ 20(Sessional)=100 Credit: 4 (3L+1T)

Course Outcome: *The course is introduced aiming to familiarize the students, the different areas of electronics like communication systems, use of OPAM, microcontrollers and nanoelectronics.*

Contents

Unit-I: Communication

Analog and digital Communication: Review of analog communication, Necessity of digital communication; Coherent and Non-coherent ASK, FSK, PSK, Differential PSK, MSK; QPSK; M-arysignaling; Error Control Code' Spread Spectrum modulation; Multiplexing: PCM; Differential PCM, Delta Modulation; Information theory: Information, channel and fundamental limits on performance, Random signal, uncertainty, entropy Source encoding theorem. Fibre Optic Communication: Propagation of optical signal through fibre, single mode, step index, graded fibre, Optical fibre performance; Optoelectronic communication circuits. Satellite communications: Orbital and Geostationary satellites, orbital patterns, GPS. Radar, Radar block diagram, Radar performance: range equation, noise; radar frequencies, Pulse system, antenna and scanning, display. Antenna: Parabolic antenna.

Unit-II: OPAMP

Butterworth Filters, Chebyshev Filters, Frequency, transformation, instrumentation amplifiers.

Unit-III: Microprocessor and Microcontrollers-I

Microprocessor as a CPU, Organization of a Microprocessor based system, 8085 Architecture, operations and pin diagram, 8085 programming model: Registers, Accumulator, Flags, Program counter and Stack pointer, Bus organization, Microprocessor communication and Bus Timing, 8085 programming: Instruction Set, Addressing Modes, Stack and Subroutine, Introduction to 8051 Microcontroller.

Unit-IV: Nanoelectronics-I

Fabrication techniques for nanostructures, Nanolithography, etching and other means for fabrication of nanostructures and nanodevices, Fabrication of nanoelectromechanical systems (NEMS).

Recommended Books:

1. *Communication Systems*, Simon Haykin

2. *Modern Analog and Digital Communication,* B P Lathi

3. *Microprocesors, Architecture, Programming and Applications with the 8085*, Ramesh Gaonkar

4. *Electronic Communication Systems*, George Kennedy

5. *Introduction to Nanoelectronics*, V. Mitin, V. Kochelap, M. Stroscio

6. *Fundamentals of Nanoelectronics*, George W. Hanson.

PHY307: Advanced Electronics Lab

Type of the paper: Elective, Practical Total Marks: 80(Final)+ 20(Sessional)=100 Credit: 4 (0L+0T+4P)

Course Outcome: *The course is designed keeping in minds that, the students will be able in handling the various electronic measuring devices like the Mixed Signal Oscilloscope (MSO), lock in amplifier and Vector Network analyzers. They will also have hands on practice on the use of VHDL in simple digital circuits design.*

Contents

List of Experiments (*All experiments are compulsory*)

Exp 1: *Design a Frequency modulation circuit using IC 555. Observe the components of the FM modulated spectrum for different modulation index. Compare the same with the theoretical value. Estimate the bandwidth required for the FM modulated signal.*

Exp 2: *Use the 8085 microprocessors for performing simple computation like addition, subtraction, division, multiplication, AND, OR, XOR etc. Also implement the system in a simulator.*

Exp 3: *Use an Optical Fibre for the following: (i) IV Characteristics (ii) analog transmission (iii) digital transmission, (iv) estimate the numerical aperture.*

Exp 4: *Implementation of simple circuits and systems in Programmable Logic and SoC*

Exp 5: *Use of hands-on test and measurement equipment's: VNA and MSO, lock in amplifier*

Suggested Reference

1. *Lab Manual*, Electronics Lab

PHY308: Lasers & Spectroscopy-I

Type of the paper: Elective, Theory Total Marks: 80(Final)+ 20(Sessional)=100 Credit: 4 (3L+1T)

Course Outcome: *The students will be able to analyse complex spectra and determine different atomic and molecular parameters. They will be able to explain the generation of modes and short-intense pulses, and determine the condition for stability of a laser cavity and achieving laser action.*

Contents

Unit-I: Atomic, Molecular and Fluorescence Spectra

Part A: Atomic Spectra – Intensity relations, Relative intensities of multiplet lines; Zeeman and Paschen- Back effects in complex spectra; X-ray spectra: X-ray emission and absorption spectra, X-ray doublet laws.

Part B: Electronic spectra of diatomic molecules – Fine structure of electronic transitions: rotational analysis, combination relations with and without Q branches, determination of rotational constants, internuclear distance and moment of inertia, determination of band origins; Wave mechanical formulation of Franck Condon principle: overlap integral, band intensities in emission and absorption. NMR & ESR spectra.

Part C: Fluorescence spectra – Luminescence: fluorescence and phosphorescence, Jablonski diagram, Characteristics of fluorescence emission, Fluorescence lifetimes and Quantum Yields, Fluorescence anisotropy, Resonance energy transfer, Steady state and Time-resolved fluorescence.

Unit-II: Lasers Fundamentals and Applications

Resonators – Modes of a resonant cavity: longitudinal & transverse laser modes; stability condition. Q switching; mode locking. Types of lasers – Nd:YAG laser, Semiconductor laser, Dye laser, Titanium sapphire laser and Excimer laser. Selected applications of lasers– Laser-induced fluorescence of vegetation and other biological materials.

Recommended Books:

1. *Laser Fundamentals*, W T Silfvast

2. *Principles of Fluorescence Spectroscopy*, J R Lakowicz

3. *Essentials of Laser and Nonlinear Optics*, G D Baruah

4. *Molecular Spectra and Molecular Structure (Vol. 2),* G Herzberg

PHY309: Lasers & Spectroscopy Lab

Type of the paper: Elective, Practical Total Marks: 80(Final)+ 20(Sessional)=100 Credit: 4 (0L+0T+4P)

Course Outcome: *The students will get hands- on experience, able to handle sophisticated equipment's and carry out advanced level experimentations based on this course contents.*

Contents

List of Experiments (*All experiments are compulsory)*

Exp 1: *Determine the vibrational frequency and anharmonicity constant of Aluminium oxide molecule by taking the emission spectrum of aluminium arc, using a high-resolution spectrometer.*

Exp 2: *Determine the variation of length of a material with magnetic field using Michelson Interferometer.*

Exp 3: *Determine the Bohr Magneton using Zeeman effect*

Exp 4: *Study the frequency response of a defocussed optical imaging system*

Exp 5: *Determine the heat of dissociation of iodine molecule in the ground state, taking absorption spectra.*

Exp 6: *Study the quantum defect in a sodium source*

Suggested Reference

1. *Lab Manual*, Lasers & Spectroscopy Lab

PHY4014: Statistical Mechanics

Type of the paper: **Core, Theory** **Total Marks:** **80(Final)+ 20(Sessional)=100** **Credit:** **4 (3L+1T)**

Course Outcome: *Objective of the current course is to familiarize the students to the formal structure of the subject and to equip them with the concept of classical and quantum statistics; phase transitions and Bose-Einstein condensation (BEC).*

Unit I: Classical Statistical Mechanics

Statistical basis of thermodynamics: the macroscopic and the microscopic states; postulates of equal a-priori probability; connection between statistical mechanics and thermodynamics. Elements of ensemble theory: Phase space of a classical system; Liouville's theorem; micro canonical, canonical and grand canonical ensemble; equivalence to other ensembles.

Unit II: Fluctuations

Thermodynamic fluctuations; Gaussian distribution; random walk and Brownian motion; diffusion equation; introduction to non-equilibrium processes.

Unit III: Formulation of Quantum Statistics

Basic principle; inadequacy of the classical theory; quantum mechanical ensemble theory; density matrix; ensembles in quantum statistical mechanics; Maxwell-Boltzmann statistics; Bose-Einstein statistics; Fermi Dirac statistics; properties of an ideal Bose gas system and ideal Fermi gas system and their equations of state; some application: black-body radiation, white dwarf.

Unit IV: Phase transitions

First and second order phase transitions; diamagnetism, Para magnetism and ferromagnetism; Ising model; Bose-Einstein condensation (BEC).

Recommended Books:

1. *Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2 nd Ed., 1996, Oxford University Press.*
2. *Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill*
3. *Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.*
4. *Statistical Mechanics B. K. Agarwal and M. Eisner*
5. *Perspectives of Modern Physics by A. Beiser*

PHY4024: Numerical Analysis and Computer Programming

Type of the paper: Core, Theory with Practical's Total Marks: 80(Final)+ 20(Sessional)=100
Credit: 4 (2L+1T+1P)

Course Outcome: *Objective of the current course is to familiarize the students to the formal structure of the subject and to equip them with the concept of computer programming and numerical analysis.*

Unit I: *Introduction*

Part A: Introduction to programming, basics of computer programming, concepts of file structure, directories, compilers and debuggers in relation to GNU Linux O/S. Basic commands in GNU Linux.

Part B: Introducing FORTRAN 90, FORTRAN 90 as a structured programming language for solving scientific problems. Basic structure of FORTRAN 90- concept of variables, operators, and precedence of operations. Difference between a mathematical statement and a FORTRAN statement - incrementing a variable. Global and local variables - concept of modules and indexed variables (arrays). Types of variables- integer, floating point, and character variables.

Unit II: *Numerical Analysis*

Part A: Introduction to numerical analysis. The need for numerical analysis and its limitations. Concept of errors with examples.

Part B: Solution of transcendental equations. Solving an equation with Newton-Raphson method and bisection, comparison of their limitations, propagation of errors.

Part C: Solution of ordinary differential equations (ODEs). Concept of finite differencing. Solution of a first order ODE with Euler's method and its limitations. Need for a higher-order method - solution of a first order ODE with Runge-Kutta method. Solving higher order ODE- coupled ODEs.

Part D: Numerical integration. The concept of numerical integration - quadrature. Trapezoidal and Simpson's rules and their relation to interpolation.

Recommended Books:

1. *Computer Oriented Numerical Methods, V Rajaraman*
2. *Numerical Recipes, W H Press, S A Teukolsky, W T Vetterling, B P Flannery*

PHY4034: Advanced Condensed Matter Physics-II

Type of the paper: Elective, Theory Total Marks: 80(Final)+ 20(Sessional)=100 Credit: 4 (3L+1T)

Course Outcome: *This course is introduced aiming to develop students understanding of thin films and nanomaterials at microscopic level with reduction in size and dealing with some unconventional condensed matter (soft matter). The students can apply these concepts for device fabrication and can go for research in the field of condensed matter physics and material science.*

Unit-I: *Physics of Thin Films*

Definition of a thin film, different methods of film preparation: thermal evaporation, sputtering. Film thickness measurement: optical interference methods and other methods, Analytical techniques for chemical, structural and surface studies. Nature of thin films: Theories of nucleation: the capillarity and the atomistic model, growth processes, epitaxial films and their growth. Mechanical properties of thin films: Internal stress, stress and adhesion. Electrical conduction in discontinuous and continuous metal and semiconducting films, theories of size effect, galvanomagnetic size effect. Magnetism in thin metal films, ferromagnetic and antiferromagnetic properties of thin films, surfaces and interfaces of ferromagnetic metals, spin dependent current. QHE and GMR, some thin film devices.

Unit-II: *Physics of Nanomaterials*

Definition of nanomaterials, Types of nanomaterials: Metal, semiconductor (elemental and compound), methods of preparation. Quantum confinement: One, Two and Three-dimensional. Electrical, Optical and magnetic properties of nanomaterials. Nanomaterial based devices: Electronic, photonic, spintronics.

Unit-III: Soft Condensed Matter Physics

Definition of soft matter, Different types of soft matter: Liquid Crystals, Polymers: high polymers and conducting polymers, Surfactants, Biological materials, Correlated and uncorrelated systems, Nonlinear dynamics in soft matter, Recent studies on soft condensed matter.

Recommended Books:

1. *Materials Science of Thin Films, M Ohring*
2. *Handbook of Thin Films, Maissel and Glang*
3. *Thin Film Phenomena, K L Chopra*
4. *Thin Film, Ashok Goswami*
5. *Soft Condensed Matter, R A L Jones*

PHY4044: Nanophysics-II

Type of the paper: **Elective, Theory** **Total Marks:** **80(Final)+ 20(Sessional)=100** **Credit:** **4 (3L+1T)**

Course Outcome: *This course is an advanced one for the students for gathering greater understanding of nanoscale physics. Through this course, the students will be able to explore fundamentals of plasmonics, origin of nanoscale magnetism and nanocomposites for various applications.*

Unit-I: Quantum Effects in Nanosized Semiconductors-II

Quantum island, shrinking to quantum dot (QD), energy gap of semiconductor quantum dot, shape effect, exciton Bohr radius and exciton binding energy, strong and weak confinement, core-shell QD and light emitting device, sub-nm QD and challenges.

Unit-II: Plasmonics

Dielectric function of free electrons, Lorentz oscillator model and Drude theory, bulk plasmons, surface plasmon polaritons (SPPs) at plane interfaces, excitation of SPPs, localized surface plasmons (LSPs) in metal particles, scattering and absorption cross-sections, scattering and emission enhancements, plasmonic effect in metal-semiconductor nanostructures.

Unit-III: Nanoscale Magnetism

Review of basic magnetism: exchange interaction, magneto crystalline anisotropy, magnetic domains, particle size and surface effects on magnetic behaviour, superparamagnetic, ultrasoft magnetism, magnetism in multilayers, dilute magnetic semiconductors, spintronics, ferrofluids, magnetic recording.

Unit-IV: Nanocomposites

Natural nanocomposites, biomimetic and bioinspired nanocomposites, metal/ceramic nanocomposites, polymer-based nanocomposites, dispersion of nanophase, mechanical properties of CNT/polymer composites, nanocomposites for opto-electronic applications.

Recommended Books:

1. *Nanotechnology: Principles and Fundamentals*, G Schmid
2. *Plasmonics: Fundamentals and Applications*, S A Maier
3. *Principles of Nanomagnetism*, A P Guimaraes
4. *Fundamental of Nanoelectronics*, G W Hanson
5. *Nanocomposite Science and Technology*, P M Ajayan, L S Schadler, P V Braun

PHY4054: Advanced Electronics-II

Type of the paper: Elective, Theory Total Marks: 80(Final)+ 20(Sessional)=100 Credit: 4 (3L+1T)

Course Outcome: *The course is intended to introduce the students digital signal processing, microcontrollers and control systems. The knowledge of the students will be enhanced in digital circuits and nanoelectronics.*

Unit-I: Digital Circuits

Simplification of boolean functions: Mapping and function minimization (SOP and POS) Sequential logic: RS, JK, D and T flip flop; shift register; synchronous and asynchronous counters; Memory Concepts. Fault detection in digital circuits. Synthesis and design of sequential circuits: Analysis and synthesis of synchronous and asynchronous circuits, hazard free asynchronous circuits, sequential machine. Flash Converter; Successive Approximation ADCs; Counting and Integrating ADC Architectures. Implementation of digital circuits in VHDL and FPGA.

Unit-II: Digital Signal Processing

Signals and systems, Impulse Response and Convolution sum, difference equation, FIR and IIR systems, Stable and Unstable systems. z transform, delay operator, System function, Stability Criterion, Frequency response of a system, Design of Digital Filters, discrete fourier transform, fast fourier transform, digital signal processor

Unit-III: Microprocessor and Microcontrollers-II

8051 microcontroller Architecture, on chip peripherals, Instruction Set, SFR, Introduction to Arduino programming.

Unit-IV: Nanoelectronics-II

Graphene, Carbon nanotubes, Single Electron Transistor, Carbon nanotube transistor, Graphene transistor, Semiconductor Nanowire transistor, Quantum dot transistor.

Recommended Books:

1. *Electronic Communication*, George Kennedy
2. *Digital Signal Processing*, J G Proakis and D Malonakis
3. *The 8051 Microcontroller and Embedded Systems*, Mazidi
4. *Introduction to Nanoelectronics*, V Mitin, V Kochelap, M Stroscio
5. *Fundamentals of Nanoelectronics,* G W Hanson

PHY4064: Lasers & Spectroscopy-II

Type of the paper: **Elective, Theory** **Total Marks:** **80(Final)+ 20(Sessional)=100** **Credit: 4 (3L+1T)**

Course Outcome: *The students will be able to interpret different types of molecular spectra. They could, in future, apply lasers in studies falling in areas of photo physics, photochemistry and photobiology.*

Unit-I: Spectroscopy

Part A: Spectra of diatomic molecules

Hund's coupling cases, symmetry properties of electronic states and rotational levels, selection rules, types of electronic transitions: $^1\Sigma$ - $^1\Sigma$, $^2\Sigma$ - $^2\Sigma$, $^1\Pi$ – $^1\Sigma$, $^2\Pi$ – $^2\Sigma$, Continuous and diffuse spectra: pre-dissociation, Auger effect, Heats of dissociation: determination of dissociation limits, band convergence, Birge-Sponer extrapolation.

Part B: Molecular orbital approximation

United and separated atom constructs, correlation of molecular orbitals, LCAO/MO theory, determination of terms and multiplicities from molecular orbitals.

Unit-II: Lasers

Part A: Nonlinear optics

Nonlinear susceptibility, second harmonic generation, phase matching, parametric oscillation, intensity dependent refractive index: self-focusing, phase conjugation: four wave mixing.

Part B: Laser spectroscopy

Preliminary ideas only: Laser Raman spectroscopy: experimental techniques, resonance Raman, stimulated Raman, hyper Raman and coherent anti Stokes Raman spectroscopy; Doppler limited spectroscopy: photoacoustic spectroscopy and laser-induced fluorescence; Time-resolved spectroscopy: phase shift method, pulse excitation and quantum beat spectroscopy.

Recommended Books:

1. *Chemical Applications of Group Theory*, F A Cotton
2. *Introduction to Molecular Spectroscopy*, G M Barrow
3. *Modern Spectroscopy*, J M Hollas
4. *Laser Age in Optics*, V Tarasov
5. *Laser Spectroscopy: Basic Concepts and Instrumentation*, W Demtröde

PHY4074: Dissertation & Project Work

Type of the paper: **Core, Theoretical/Experimental** **Total Marks:** **80(Final)+ 20(Sessional)=100**
Credit: 4

Course Outcome: *The project or dissertation course is offered to motivate a student to take a research problem and pursue theoretical or experimental work under the mentorship of a faculty member.*

Note: The faculty members of the department are usually the supervisors.