Faculty of Science

SUBJECT: PHYSICS

M.Sc. III Semester

Under CBCS System

Credit and Marking Scheme

	Credits	Marks		Total Marks
		Internal	External	
Theory	4	10	40	**50**
Practical	2	10	40	**50**
Total	**6**	**100**		

Evaluation Scheme

	Marks	
	Internal	External
Theory	Test+ Presentation	1 External Exams (At the End of Semester)
Practical	Internal Exams (During the Semester)	1 External Exams (At the End of Semester)

Paper-I
QUANTUM MECHANICS – II
Course Outcomes

	Course Outcomes	Cognitive Level
CO-I	he Learner will get familiar with quantum mechanics formulation and approximation methods.	U,
CO-II	The Learner will understand and apply Time dependent and Independent perturbation theories	R, U, Ap, An
CO-III	he Learner will understand and explain the influence of electric and magnetic fields on atoms. (Stark effect and Zeeman Effect).	R, U, Ap, An
CO-IV	he Learner will understand and develop the Scattering theory through Born approximation and partial wave analysis.	U ,R, Ap, E, C
CO-V	The Learner will understand Relativistic quantum Mechanics.	U, R

Content of the Course

Theory

No. of Lectures (in hours per week): 4.5 Hrs. per week

Total No. of Lectures: 60 Hrs. **Maximum Marks:** 40

Units	Topics	No. of Lectures
I	**Approximation method for bound states** : Rayleigh-Schrodinger perturbation theory of non-degenerate and degenerate levels and their application to perturbation of an oscillator and First order Stark effect in Hydrogen. **Variation method** and its application to ground state of helium, **W.K.B. approximation method**, connection formula, Ideas on potential barrier with applications to the theory of alpha decay.	12
II	**Time dependent perturbation theory**: Method of variation of constants, constant and harmonic perturbation, transition probability, adiabatic and sudden approximation. Hamiltonian for a charged particle under the influence of external electromagnetic field, Absorption and induced emission, Transition probability in Electric dipole transition, Einstein's A and B coefficients.	12
III	Theory of scattering, Physical concepts, Differential and total cross sections, scattering amplitudes using Green"s function. **Born approximation**, Validity of Born Approx., scattering by screened coulomb potential **Partial wave analysis**, phase shift, optical theorem, scattering by square well potential and perfectly rigid sphere.	12
IV	**Schrodinger's relativistic equation** (Klein-Gordon equation), Probability and current density, Klein-Gordon equation in presence of electromagnetic field, Hydrogen atom, short comings of Klein-Gordon equation. **Dirac's relativistic equation** for a free electron, Dirac"s matrices, Probability and current density, spin of an electron, spin - orbit interaction , Equation of motion for operators, position momentum and angular momentum, Dirac"s relativistic equation in electromagnetic field, Zitterbewegung, negative energy states and their interpretation, Energy levels of Hydrogen atom	12

V	This unit will have tutorial problems covering all the four units. Some sample problems are: 1. Normal Zeeman Effect. 2. Anomalous Zeeman Effect. 3. Van der Waals interactions. 4. Evaluate Einstein"s A coefficient for the transition from state |310> to state |200> in the hydrogen atom. 5. Selection rules for single and many particle systems. 6. Ramasuer- Townsend effect. 7. Evaluate the scattering amplitude in the Born approximation for scattering by the Yukawa potential $V(r) = \frac{V_0 e^{-\alpha r}}{r}$, Where V_0 and α are constant 8. Covariance form of Dirac equation. 9. The probability current density is defined by the relation **j**(**r**,t)= c ψ*αψ, where ψ is the four-component wave vector. Write expressions for j_x, j_y and j_z in terms of the components of ψ. 10. Show that (α.A)(α.B)=(A.B)+iσ".(A×B), where A and B commute with α and $\sigma'' = \begin{bmatrix} \sigma & 0 \\ 0 & \sigma \end{bmatrix}$ 11. Magnetic moment and spin of a Dirac"s electron.	**12**

Test/Reference Books

Quantum Mechanics	:	L. I. Schiff
Quantum Mechanics	:	S. Gasiorowicz
Quantum Physics	:	B. Craseman and J.D. Powell
Quantum Mechanics	:	A.P. Messiah
Modern Quantum Mechanics	:	J.J. Sakurai
Quantum Mechanics	:	Mathews and Venkatesan
Quantum Mechanics	:	A.K. Ghatak and Loknathan
Quantum Mechanics	:	G. Ar

M.Sc. III Semester
Paper-II

NUCLEAR AND PARTICLE PHYSICS

Course Outcome

	Course Outcomes	Cognitive Level
CO-I	The Learner will summarize the properties of a nucleus, packing fraction and binding energy, binding energy per nucleon vs. mass number graph, explanation of fusion and fission from the nature of the binding energy graph.	U, R, E
CO-II	The Learner will interpret Nuclear models and their roles in explaining the ground state properties of the nucleus.	U, R. Ap
CO-III	The Learner will analyze the Process of radioactivity and radioactive decay laws.	U, Ap, An
CO-IV	Learner will understand the basic aspects of Nuclear detectors and particle accelerators.	U , Ap, E, C
CO-V	Learner will understand the importance of Cosmic Rays.	U

Content of the Course

Theory

No. of Lectures (in hours per week): 4.5 Hrs. per week

Total No. of Lectures: 60 Hrs. **Maximum Marks:** 60

Units	Topics	No. of Lectures
I	**Nuclear Interactions and Nuclear Reactions** Nucleon- nucleon interaction, exchange forces and tensor forces, meson theory of nuclear forces, nucleon, nucleon scattering, Effective range theory, spin dependence of nuclear forces, charge independence and charge symmetry of nuclear forces, Isospin formalism, Yukawa interaction. Direct and compound nuclear reaction mechanisms, cross sections in terms of partial wave amplitudes, compound nucleus, scattering matrix, Reciprocity theorem, Breit- Wigner one–level formula, Resonance scattering.	12
II	**Nuclear Models** Liquid drop model, Bohr–wheeler theory of fission, Experimental evidence for shell effects- shell model, spin, orbit coupling, magic numbers, Angular momenta and parities of nuclear ground states, Qualitative discussion and estimates of transition rates, magnetic moment and Schmidt lines, Collective model of Bohr and Mottelson .	12
III	**Nuclear Decay** Beta decay, Fermi theory of beta decay, Comparative half, lives, Parity violation, Two component theory of neutrino decay, Detection and properties of neutrino Gamma decay, Multipole transition in nuclei Angular momentum and parity selection rules Internal conversion, Nuclear isomerism. General ideas of nuclear radiation detectors, Linear acceleration, Betatron, Proton- synchrotron, Electron synchrotron	12
IV	**Elementary particle physics** Types of interaction between elementary particles, Hadrons and leptons, Symmetry and conservation laws, Elementary ideas of : CP and CPT invariance, Classification of hadrons, lie algebra, SU(2) – SU (3) multiplets, Quark model, Gell Mann- Okubo mass formula for octet and decuplet	12

	hadrons, Charm, bottom and top quarks. Cosmic Rays Nature, composition, charge and energy spectrum of primary cosmic rays, production and propagation of secondary cosmic rays. Soft, penetrating and nucleonic components, Origin of cosmic rays, Rossi curve, Bhabha – Heitler theory of cascade showers.	
V	This unit will have tutorial problems covering all the four units. Some sample problems are: 1. Scattering Matrix. 2. Nucleon- Nucleon phase Shifts. 3. Double Scattering Experiment to measure polarization. 4. Ground state spectroscopic configuration of nuclei on the basis of single particle shell model. 5. The Q – Equation. 6. Calculation of Absorption Cross Section. 7. Nuclear Quadrapole moment. 8. Kurie Plot 9. Selection Rules for β and α decay. 10. Parity Violation Experiment. 11. Neutrino Helicity. 12. Isospin Symmetry. 13. Lie Algebra. 14. Origin of cosmic rays. 15. Bhabha-Heitler theory. In addition to above the tutorial will also consist of solving problems given in the Text and Reference books.	**12**

References

Test/Reference Books:

- Kenneth S. Kiane. Introductory Nuclear Physics, Wiley New York 1988..
- H.A. Enge, Introduction to Nuclear Physics, Addison- Wesley ,,1975.
- G.E.Brown and A.D. Jackson, Introduction to Nuclean nucleon Interaction, North – Holland, Amsterdam, 1976.
- Y.R. Waghmare, Introductory Nuclear Physics, Oxford-IBH Bombay,1981
- I. Kaplan, Nuclear Physics, 2" Ed. Narosa, Madras, 1989
- R.D.Evans, Atomic Nucleus, McGraw Hill, New York, 1955.
- B.L. Cohen, Concepts of Nuclear Physics, TMGH, Bombay, 1971.
- R.R. Roy and B.P. Nigam Nuclear Physics, Wiley- Eastem Ltd, 1983.
- Bruno Rossi, Cosmic Rays
- B.N. Shrivastava, Basic Nuclear Physics and Cosmic Rays
- M.P. Khanna, Particle Physics, Prentice Hall
- Burcham, Nuclear Physics

M.Sc. III Semester
Paper-III
CONDENSED MATTER PHYSICS – I

COURSE OUTCOME

	Course Outcomes	Cognitive Level
CO-I	Learner will recall and compare the Imperfections and dislocations in crystals	U, R
CO-II	Learner will understand partial dislocations and the techniques of observing them through like XRD, TEM, SEM and AFM.	U, Ap, E
CO-III	Learner will understand the importance of Thin films, surface topography.	U, C, R
CO-IV	Learner will understand and analyse Lattice Dynamics, Optical Properties of Solids and their related phenomena.	U, An
CO-V	Learner will understand various optical properties of Solids	U, R, E

Content of the Course

Theory

No. of Lectures (in hours per week): 4.5 Hrs. per week

Total No. of Lectures: 60 Hrs. **Maximum Marks:** 40

Units	Topics	No. of Lectures
I	**Imperfection in Crystals** Mechanism of plastic deformation in solids, stress and strain field of screw and edge dislocations. Elastic energy of dislocations. Forces between dislocations. Stress needed to operate Frank-Read source, dislocations in fcc, hcp and bcc lattices	12
II	Partial dislocations and stacking faults in closed packed structures. Experimental methods of observing dislocations and stacking faults. Electron microscopy, kinematical theory of diffraction contrast and lattice imaging. Elementary concepts of surface crystallography. Scanning tunneling and atomic force microscopy.	12
III	**Films and Surface** Study of surface topography by multiple-beam interferometry, conditions for accurate determination of step height and film thickness (Fizeau Fringes). Electrical conductivity of thin films, difference of behaviour of thin films from bulk, Boltzmann transport equation for a thin film (for diffused scattering), expression for temperature coefficient of resistivity of thin films.	12
IV	**Lattice Dynamics** Lattice Dynamics of monatomic and Diatomic lattice, Optical phonons and dielectric constants. Mossbauer effect, Debye – Waller factor Anharmonicity, Thermal expansion and thermal conductivity. Umklapp process, Interaction of electrons and phonons with photons. **Optical Properties of Solids** Direct and indirect transitions. Absorption in insulators, polaritons, one phonon absorption, optical properties of metals, skin effect and anomalous skin effect.	12
V	This unit will have tutorial problems covering all the four units. Some sample problems are: 1. Consider two parallel dislocation lying on the same slip plane.	12

Their Burgers vectors lie parallel to the slip plane but are not parallel to each other. Their magnitudes are equal. Find all possible orientations of the Burgers vectors for which the component of the force between the dislocations that acts parallel to the slip plane is zero.

2. Prove that the stress □$_{ZZ}$ never exerts a force on a dislocation in which burgers vector lies parallel to the x direction regardless of the orientation of the dislocation line.

3. Derive Taylor‟s relation between dislocation density and applied stress.

4. Discuss the working of atomic force microscope

5. Bring out the essential differences between diffuse and specular electron scattering from the conventional solid: bulk and films by taking the specific property of electrical conductivity.

6. What are thin and thick film? With reference to electronic conduction which films can be referred to as thin and which as thick taking into account the mean free path as a reference parameters.

7. Estimate for 300 K the root mean square thermal dilation AV/V for a primitive cell of sodium. Take the bulk modufus as 7 □ 10^{10} erg cm^{-3}. Note that the Debye temperature 158 K is less than 300 K so that the thermal energy is of the order of K_BT. Use this result to estimate the root mean square thermal fluctuation □a/a of the lattice parameter.

8. Consider a classical harmonic oscillator with small anharmonic terms so that the potential energy is $V(x) = ax^2 + bx^3 + cx^4$. Using the partition function approach show that the mean energy (□) and mean thermal displacement from equilibrium
(x) are :

$$(□) = K_BT\ [15b^2/16a^2 - 3c/4a^2]\ (K_BT)^2$$

$$(x) \quad = -(3b/4a^2)\ K_BT$$

The former leads to a high temperature contribution to the specific heat that is linear in temperature. The latter is an indication of the origin of thermal expansion (and the proper sign of the coefficient)

References

Test/Reference Books:

X-ray crystallography	:	Azaroff
Elementary Dislocation Theory	:	Weertman & Weertman
Crystallography for Solid State Physics	:	Verma & Srivastava Solid
State Physics	:	Kittel
The Powder Method	:	Azaroff & Buerger
Crystal Structure Analysis	:	Buerger
Transmission Electron Microscopy	:	Thomas
Multiple Beam Interferometry	:	Tolansky
Thin films	:	Heavens
Physics of thin film	:	Chopra
Introduction to Solid State Theory	:	Medelung
Quantum Theory of Solid State	:	Callaway

M.Sc. III Semester
Paper-IV

A Course In COMPUTATIONAL PHYSICS USING MATHEMATICA– I

COURSE OUTCOME

	Course Outcomes	Cognitive Level
CO-I	The learner will use various computer algebra commands for different mathematical operations and plot different functions and data sets	U, C
CO-II	The learner will apply the Mathematica ® system to solve equations and do manipulations of matrices and determine eigen values and eigen vectors	R,U, Ap, E
CO-III	The learner will use the Mathematica® environment to create user defined functions	U, Ap, C
CO-IV	Learner will use the Mathematica® to plot and interpret different functions/models in Physics	U , Ap, E
CO-V	Learner will use the Mathematica® to Simulate ODE Models	U, An, C

Content of the Course

Theory

No. of Lectures (in hours per week): 4.5 Hrs. per week

Total No. of Lectures: 60 Hrs. **Maximum Marks:** 40

Units	Topics	No. of Lectures
I	**Basics of Mathematica Programming. Mathematica commands** I: Introduction, commands and variables, numerical calculations with examples such as Factorial, Exponential etc. Symbolic calculations: Use of Solve on equations. Calculus (differential and integrals). Manipulations with matrices, eigen values and eigen vectors. Write a program to calculate and print roots of a quadratic $ax^2+bx+c = 0$ (a□ 0).Write a program to add and multiply two matrices. Plots of data and functions.	I
II	**Mathematica commands II:** DSolve, Map, Part, With, Block, Module, Replace(/.), Conditional commands(Piecewise). Use of the commands: Import and Export. Importing data into a notebook from a file with „xls", „txt", „dat" extension. Import of images in „jpeg" format. Exporting data from a notebook into a file with „xls", „txt", „dat" extension. Exporting of images in „jpeg" format.	II
III	**Mathematica commands III:** Pure Functions; SetDelayed; Table. Illustrate the use of a User-Defined function by a program. Make a plot of the User-Defined function by using 'Plot' also by using 'Table' and 'ListPlot'.(1)Relativistic variation of mass with velocity.(2) P-N Junction (semiconductor diode) current equation. (3)Potential Energy Curve for the Lennard-Jones Potential.(4)Van der Waals' Equation of State for a Non-Ideal Gas.(5) Resonance plots of a LCR circuit.	III
IV	**Application of Mathematica to problems in physics - I:** (1) Escape velocity for a particle tossed upward from the surface of the earth. escape velocities for other planets;(2)Orbital velocity, geo-synchronous orbit; (3)Study of " harmonic motion :- mx''+cx'+sx = 0. for c^2-4mk>0 , over damped; c^2-4mk=0, critically damped; c^2-4mk<0, under damped"; (4) "Phase plot of a system undergoing linear oscillations ";(5) Potential energy and kinetic energy diagram of the linear harmonic	IV

	oscillator.	
V	**Application of Mathematica to problems in Physics - II:** (1) Application of Kirchhoff"s Voltage Law and Current Law to electrical meshes(Use of Simultaneous Equations/Matrices), (2) Charging and Discharging in a R-C Circuit, (3) Study of Charging and Discharging in circuits with inductors, capacitors and resistors, (4)Nuclear Forces(Comparison of Yukawa Potential, Exponential Potential, Gaussian Potential and Hard Core Potential) , (5) Radioactive Decay and Half Life.	**V**

References

Test/Reference Books:

1. Programming in Mathematica: Roman Maeder, Addison Wesley.
2. Mathematica in the Laboratory: Samuel, Dick, Alfred Riddle, Douglas Stein, Cambridge University Press.
3. Introductory Statistics and Random phenomena: Manfred Denker and Wobor A. Woyczynski, Springer (India) Pvt. Limited.
4. Computational Physics: R. C. Verma, P. K. Ahluwalia and K.C. Sharma, New Age Publishers (1999)
5. Numerical Recipes in C ; Press W.H., Teukolsky S.A. Vellerling W.T. and Flannery B.P. (Cambridge Univ. Press 1992)
6. Simulation using Personal Computers: Carroll, J.M. (Prentice Hall, 1987)
7. www.wolfram.com
8. http://demonstrations.wolfram.com/HeatCapacityOfSolidsInTheDebyeApproximation/
9. http://demonstrations.wolfram.com/PlotsOfTheFermiDiracDistribution/
10. http://demonstrations.wolfram.com/FermiDiracDistributionsForFreeElectronsInMetals/

Faculty of Science

SUBJECT: PHYSICS

M.Sc. IV Semester

Under CBCS System

2021 Onwards

Credit and Marking Scheme

	Credits	Marks		Total Marks
		Internal	External	
Theory	4	10	40	**50**
Practical	2	40	60	**100**
Total	**6**	**200**		

Evaluation Scheme

	Marks	
	Internal	**External**
Theory	3 Internal Exams of 20 Marks (During the Semester) (Best 2 will be taken)	1 External Exams (At the End of Semester)
Practical	3 Internal Exams (During the Semester) (Best 2 will be taken)	1 External Exams (At the End of Semester)

Paper-I

ATOMIC AND MOLECULAR PHYSICS

Course Outcomes

	Course Outcomes	Cognitive Level
CO-I	Learner will be able to analyse Quantum states, spectra of one and many electron systems along with hyperfine structure	U,
CO-II	Learner will be able to differentiate between Normal and anomalous Zeeman effect	U, Ap
CO-III	Learner will be able to explain Intensity and Rotational Spectra of diatomic molecules, Isotopic effect, Microwave Spectroscopy	U, Ap, An, E
CO-IV	Learner will be able to differentiate between Vibrational and rotational motion of molecules and explain transition rules and do an analysis of IR spectrum	U, Ap, E
CO-V	Learner will be able to explain Raman Spectra, Electronic spectra, Photo Electron Spectroscopy, Photo acoustic Spectroscopy, Mossbauer spectroscopy and NMR Spectroscopy	U,C

Content of the Course

Theory

No. of Lectures (in hours per week): 2 Hrs. per week

Total No. of Lectures: 60 Hrs. **Maximum Marks:** 40

Units	Topics	No. of Lectures
I	Quantum states of one electron atoms Atomic orbitals, Hydrogen spectrum, Paulis principle. Spectra of alkali elements, spin orbit interaction and line structure of alkali spectra, Two electron system, interaction energy in LS and JJ coupling, Hyperfine structure (qualitative), line broadening mechanisms (general ideas), Normal and anomalous Zeeman effect, Lande g-factor.	12
II	**Microwave Spectroscopy:** Introduction to molecular spectroscopy, Regions of the Spectrum. Types of molecules, Diatomic linear, symmetric top, asymmetric top and spherical top molecules, Rotational spectra of diatomic molecules as a rigid rotator, Energy level and spectra of non-rigid rotator, intensity of rotational lines, Isotopic effect in Rotational Spectra, Technique and Instrumentation for Microwave Spectroscopy.	12
III	**Infra-red Spectroscopy:** Vibrational energy of diatomic molecule, diatomic molecule as a simple harmonic oscillator, Energy levels and spectrum, Morse potential energy curve, Molecules as vibrating rotator, vibration spectrum of diatomic molecule PQR branches, Technique and Instrumentation for Infra-red Spectroscopy, Example of Analysis of IR Spectrum.	12
IV	**Raman spectroscopy:** Introduction, Pure rotational and vibrational spectra, Techniques and instrumentation, Stimulated Raman spectroscopy. **Electronic Spectra of Diatomic Molecules:** The Born Oppenheimer Approximation, Vibrational Coarse Structure Progressions, Rotational fine structure of Electronic- Vibrational Transitions. **Experimental techniques:** Photo Electron Spectroscopy, Elementary idea about Photoacoustic Spectroscopy, Mossbauer spectroscopy and NMR	12

	Spectroscopy.	
V	This unit will have tutorial problems covering all the four units. Some sample problems are: 1. Write all possible term symbols for the following electron configurations (a)[Be]2p3p (b) [He]2s2p 2. Compute the Zeeman pattern, Arising terms, No. of Zeeman level, g-factor and Shift in Lorentz unit for following: (a) ${}^2D_{3/2}$-${}^2P_{1/2}$ (b) ${}^3P - {}^3S$ 3. The measured value of the first line (J = 0) in the rotational spectrum of carbon monoxide is 3.84235 cm^{-1}. Determine the moment of inertia and bond length of the molecule. 4. The data for the ${}^1H^{35}Cl$ molecule are : Bond length = 127.5 pm Bond force constant = 516.3 Nm^{-1} Atomic masses : ${}^1H = 1.673 \times 10^{-27}$kg, ${}^{35}Cl = 58.066 \times 10^{-27}$ kg Determine the following: (a) The energy of fundamental vibration ν_o. (b) The rotational constant B. (c) The wave numbers of the line $P_{(1)}$, $P_{(2)}$, $R_{(0)}$, $R_{(1)}$ and $R_{(2)}$. (d) Sketch the expected vibration-rotation 5. How many normal models of vibration are possible for the H_2O molecule? 6. The bond between the hydrogen and chlorine atoms in a ${}^1_1H$ ${}^{17}_{35}Cl$ molecule has a force constant of 516 nt/m. Calculate the energy difference between the lowest and first excited vibrational level. 7. The molecules of ${}^1_1H$ ${}^{17}_{35}Cl$ show$_{35}$a strong absorption line of wavelength 3.456 microns. Assuming origin of line due to vibration, calculate the force constant for ${}^1_1H$ ${}^{17}_{35}Cl$ bond. (h=6.6×10^{-34}Jsec, 1amu=1.67×10^{-27}kg) 8. With which type of spectroscopy would one observe the pure rotational spectrum of H_2? If the bond length of H_2 is	12 35

	0.07417 nm. What would be the spacing of the lines in the spectrum ? 9. A substance shows a Raman line at 4567Å when exciting line 4358 Å is used. Deduce the position of Stoke and anti-stoke lines for the same substance when the exciting line 4047 Å is used. 10. In the Raman spectra of HCl, the displacement from the exciting line are represented by $\Delta\upsilon = \pm (62.4 + 41.6\, J)\ cm^{-1}$ Calculate the moment of inertia of the HCl molecule ($h = 6.62\times10^{-27}$ erg-sec, $c = 3\times10^{10} cm\text{-}sec^{-1}$	

References

Test/Reference Books:

- Introduction to Atomic Spectra : H.E. White
- Fundamentals of molecular spectroscopy : C.B. Banwell
- Atomic & Molecular Spectroscopy : Rajkumar
- Spectroscopy vol. I, II & III : Walker and Stanghen
- Introduction to molecular spectroscopy : G.M. Barrow
- Spectra of diatomic molecules : Herzberg.
- Molecular spectroscopy : Jeanne L. Mc Hale
- Molecular spectroscopy : J.M.Brown
- Spectra of atoms and molecules : P.F.Bemath.
- Modern spectroscopy : J.M. Halian
- Spectroscopy : Gour
- Atomic & Molecular Physics : Rajkumar

M.Sc. IV Semester

Under CBCS System

2021 Onwards

Paper-II

CONCISE STUDY OF NON-LINEAR SYSTEM

COURSE OUTCOME

	Course Outcomes	Cognitive Level
CO-I	To enable students to classify singular points and their stability and generate phase space and trajectories in phase space	R, U, Ap, An, E
CO-II	To enable students to define, characterize and detect chaos and its sensitive dependence on initial conditions with examples from the Logistic Map problem and other physical systems Lorentz equation etc. To enable students to use Lyapunov"s theorem for stability	U, Ap, An, E
CO-III	To enable students to identify examples of fractals as self-similar structures from Nature and find the fractal Dimension	U, Ap, An, E
CO-IV	To acquire the ability to comprehend, understand and do qualitative analysis of illustrated examples of dynamical systems from other disciplines like chemistry, biology and electronics	U, Ap, An, E
CO-V	To enable students to do Simulation of Simple Population Models, Experimental growth and Decay, Logistic growth, Species Competition, Predator-Prey Dynamics, Simple electric circuits	U, C, Ap, An, E

Content of the Course

Theory

No. of Lectures (in hours per week): 2 Hrs. per week
Total No. of Lectures: 60 Hrs. **Maximum Marks:** 40

Units	Topics	No. of Lectures
I	Phase space, orbits, attractors and basin of attraction. Use of the Jacobian matrix in Analysis of Singular points. Classification of Singular points and their stability. Poincare"s theorem for the vortex. Use of Lyapunov"s theorem for stability. Limit cycles. Poincare sections (Stroboscopic section and transverse sections). Distinction between Non conservative and Conservative Maps taking as example the Henon map	12
II	Iterated functions. The Logistic Map. Its geometrical representation and period doubling cascade to chaos. Bifurcation, stability and Feigenbaum number. Characterizing chaos by the Lyapunov exponent. Strange attractors in the form of the Lorenz system and Rossler system.	12
III	Non-fractal dimensions (Euclidean and topological). Fractal Dimensions and similarity dimension. Cantor Sets, Koch curve and Sierpinski gasket. Fractal boundaries and box counting dimension. The structured walk technique and the divider dimension. The Richardson plot. The perimeter-area relationship in fractals.	12
IV	Overview of different nonlinear systems. (Study based on phase plot or graphical representation of the equations of nonlinear systems) a. Nonlinear Mechanics: The Simple Pendulum b. Biological Systems: Volterra-Lotka Competition Equations c. Electronic Systems: Van der Pol Oscillator d. Chemical Systems: Chemical Oscillators(The Brusselator / Oregonator) e. Fluid Motion: Rayleigh–Benard Convection f. Solitons: Shallow water waves (KdV equation)	12

V	**This unit will have tutorial problems covering all the four units. Some sample problems are:** Overview of different nonlinear systems. (Study based on phase plot or graphical representation of the equations of nonlinear systems.) (1) Chaotic oscillation of the Duffing Oscillator (2) Self similarity (Fractal structure) in the Henon map (3) Self similarity (Fractal nature) of Julia sets (4) Self similarity (Fractal nature) of Mandelbrot sets (5) Cellular Automata as examples of simple rules leading to complex patterns. (6) Self similarity (Fractal nature) of Cellular Automata	12

References

Test/Reference Books:

a. The New Kind of Science Book by Stephen Wolfram
b. Non linear Dynamics by H G Solari, M A Natiello and G B Mindlin
c. Introduction to Chaos by H Nagashima and Y Baba
d. Deterministic Chaos by N Kumar
e. Fractals and Chaos by Paul S Addison
f. Non linear Physics for Students and Engineers by Enns and Mc Guire
g. Non Linear Dynamics and Turbulence by Barenblatt, Looss and Jos

M.Sc. IV Semester

Under CBCS System

2021 Onwards

Paper-III

CONDENSED MATTER PHYSICS – II

COURSE OUTCOME

	Course Outcomes	Cognitive Level
CO-I	Learner will be able to recall and explain Acoustic, optical phonons and polarons. Theories of Superconductors, Josephson Effect	U,
CO-II	Learner will be able to recall and explain Point defects , Structure and symmetries of liquid crystals and amorphous solids	U, Ap
CO-III	Learner will be able to recall and explain Point defects , Structure and symmetries of liquid crystals and amorphous solids. Learner will be able to recall and analyse CNT's and its applications	R, U, Ap, An
CO-IV	Learner will be able to recall and explain Disorder in condensed matter, Anderson model for random systems	U, Ap, An
CO-V	Learner will be able to recall and explain, solve problems connected with various systems in the above four units	C, U , Ap, E

Content of the Course

Theory

No. of Lectures (in hours per week): 2 Hrs. per week

Total No. of Lectures: 60 Hrs. **Maximum Marks:** 40

Units	Topics	No. of Lectures
I	Interaction of electrons with acoustic and optical phonons, polarons, Superconductivity : Manifestations of energy gap, Cooper pairing due to phonons, BCS theory of superconductivity, Ginzsburg –Landau theory and application to Josephson effect : d-c- Josephson effect, a-c Josephson effect, macroscopic quantum interference. Vortices and type II superconductors, high temperature superconductivity (elementary).	12
II	Point defects : Shallow impurity states in semiconductors. Localized lattice vibrational states in solids, vacancies, interstitial and colour centers in ionic crystals. Structure and symmetries of liquids, liquid crystals and amorphous solids. Aperiodic solids and quasicrystals; Fibonaccy sequence, penrose lattice and their extension to 3-dimensions	12
III	Special carbon solids; fullerenes and tubules, formation and characterization of fullerenes and tubules. Single wall and multi -wall carbon tubules. Electronic properties of tubules. Carbon nanotubule based electronic devices. Definition and properties of nanostructured materials. Methods of synthesis of nanostructures materials. Special experimental techniques for characterization of nanostructured materials. Quantum size effect and its applications.	12
IV	Disorder in condense matter, subsitutional, positional and topographical disorder, short and long range order, Atomic correlation function and structural descriptions of glasses and liquids. Anderson model for random systems and electron localization, mobility edge, qualitative application of the idea to amorphous semiconductors and hopping conduction.	12

V	**This unit will have tutorial problems covering all the four units. Some sample problems are:** 1. Draw diagrams showing some possible two-phonon processes in which a neutron enters with momentum p and leaves with momentum P''. In labeling the diagrams take due account of the conservation law. 2. The average rate of dissipation of energy for an electromagnetic wave is W = < E.J.> where the average is over a complete cycle. Show that $W = (\omega\varepsilon_2/ 8\pi)E_o^2 = \sigma E_o^2/2 = \sigma_1 E^2$ 3. How do the (2l+1) fold degenerate energy levels of a free atom split up in a crystal field invariant to all proper rotations which transform a cube into itself ? The free atom is invariant to operations of the (infinite) rotation group. The characters of the irreducible representations of this group are $\lambda^{(l)}(\varphi) = \sin (l + ½) \phi/ \sin \phi/2$ The point group of the crystal field has 24 elements in five classes and hence also five irreducible representations. Set up character table for this group 4. (a) Show whether periodicity can exist together with a periodicity in a structure (b) What is golden mean ratio ? How it is relevant to quasi crystals. 5. Band structure formula for crystals is not quite valid for Nanostructure, why? 6. Distinguish between crystalline, amorphous solids and liquids. 7. What are onion carbon structure ? How are they related with fullerene. 8. Calculate the lifetime of electrons and holes in a semiconductor with recombination centers (acceptors with levels E_R in the energy gap) Treat explicitly the limits of large and small defect concentration n_r. Discuss the recombination mechanism in both cases. Compare the two possible definitions : $\delta n(t) – \exp (-t/ \tau)$ (decay time) and $\delta n = G\tau$ (steady state). 9. The carbon nanotubles can be both semiconducting and metallic why	**12**

References

Test/Reference Books:

Crystal Structure Analysis	:	Burger
The Physics of Quasicrystals,	:	Eds steinhardt and Ostulond Hand
Book of Nanostructured Materials and Nanotechnology (Vol. l to 4)	:	Ed. Hari Singh Nalwa
Quantum Theory of Solid State	:	Callaway
Theoretical Solid State Physics	:	Huang
Quantum Theory of Solids	:	Kittle Introduction to
Solid State Theory	:	Madelung Solid
State Physics	:	J.P. Shrivastava
X-ray Crystallography	:	Azaroff
Elementary Dislocation theory	:	Weertman and Weertman
Crystallography for Solid State Physics	:	Verma and Shrivastava Solid
State Physics	:	Kittel
Elementary Solid State physics	:	M. Ali Omar

M.Sc. IV Semester

Under CBCS System

2021 Onwards

Paper-IV

A Course In COMPUTATIONAL PHYSICS USING MATHEMATICA– II

COURSE OUTCOME

	Course Outcomes	Cognitive Level
CO-I	Students will be to do simulation of diffraction patterns of a straight edge and single slit and simulation of interference patterns in Newton rings	U,
CO-II	Students will be to do to obtain the eigen values and plot the wave functions of a simple harmonic oscillator, particle bound in an infinite potential well, the energy values of the hydrogen atom as per the Bohr theory	U, Ap
CO-III	Students will be to: (1) plot the Energy density/ distribution of energy of Free Electrons in Metals; (2) to do find a numerical solution to the Diffusion/heat equation; (3) plot the Planck formula for blackbody radiation; (4) plot the Phase Plot of a Chaotic non-linear circuit; (5) plot the phase plots of a non linear simple pendulum	U, Ap, An
CO-IV	Students will be (1) to plot the Frequency Response of LCR circuits; (2) to plot the Fermi-Dirac Distribution of Metals; (3) to plot the Specific Heat of Solids in the Debye Approximation; (4) to do a simulation of a Random walk; (5) to plot the the Richardson Dushman equation	U , Ap, E

CO-V	Students will be able to: 1. Give the graphical depiction of the variation of the diameter of Newton‟s rings and variation of the square of the diameter of Newton‟s rings with the order of the rings. 2. Give the graphical depiction of the Poincare section in the chaotic domain of a non-linear simple pendulum. 3. Give the graphical depiction of the one-dimensional, Gaussian wave packet 4. Give the graphical depiction of the of Hermite, Laguerre and LegendreP polynomials by Mathematica 5. Give the graphical depiction of the Energy Eigen values of a rigid rotator 6. Find out the solution of a Differential Equation of a of a LCR circuit using Laplace Transform. 7. Do Fourier Analysis 8. Do Modeling and simulation of a predator and prey problem	

Content of the Course

Theory

No. of Lectures (in hours per week): 2 Hrs. per week

Total No. of Lectures: 60 Hrs. **Maximum Marks:** 40

Units	Topics	No. of Lectures
I	**Application of Mathematica to problems in Optics** Generation of Cornu"s Spiral. Plot of the intensity – distance curve for: (1) a straight edge, (2) Fraunhofer diffraction at a single slit, (3) Fresnel diffraction at a single slit. Simulation of the diffraction patterns for: (1) a straight edge, (2) Fraunhofer diffraction at a single slit, (3) Fresnel diffraction at a single slit. Simulation of Newton rings for reflected light.	12
II	**Application of Mathematica to problems in solving in Quantum Mechanics** (1) Solving one dimensional Schrodinger equation for stationary states, (2) Solution of time independent Schrodinger equation for linear harmonic oscillator: Harmonic Oscillator Eigen functions, Harmonic Oscillator wave functions ,(3) Particle bound in an Infinite Potential Well: Energy Eigen values, wave functions.,(4)The Bohr theory and energy levels of the hydrogen atom	12
III	**Application of Mathematica to miscellaneous areas of interest in Physics** (1) Energy density/ distribution of energy of Free Electrons in Metals, (3) Numerical solution to the Diffusion/heat equation, (3).The Planck formula for blackbody radiation, (4) Phase Plot of a Chaotic non-linear circuit, (5) Study of the phase plots of a non linear simple. pendulum	12
IV	**Computer Simulation using the Mathematica command Manipulate:** 1. Frequency Response of LCR circuits 2. Fermi-Dirac Distribution of Metals, 3. Specific Heat of Solids in the Debye Approximation 4. Random walk 5. Richardson Dushman equation	12

V	This unit will have questions based on tutorial problems covering all the four units. Some sample problems are: 1. The graphical depiction of the variation of the diameter of Newton"s rings and variation of the square of the diameter of Newton"s rings with the order of the rings. 2. The Poincare section in the chaotic domain of a non-linear simple pendulum. 3. The propagation of free wave packets. The spreading of the one dimensional, Gaussian wave packet can be demonstrated graphically. 4. Plotting of Hermite, Laguerre and LegendreP polynomials by Mathematica. 5. Energy Eigen values of a rigid rotator. 6. Solution of the Differential Equation of a of a LCR circuit using Laplace Transform. 7. Fourier Analysis. 8. Modeling and simulation of a predator and prey problem.	**12**

References

Test/Reference Books:

1. . Programming in Mathematica: Roman Maeder, Addison Wesley.
2. Mathematica in the Laboratory: Samuel, Dick, Alfred Riddle, Douglas Stein, Cambridge University Press.
3. Introductory Statistics and Random phenomena: Manfred Denker and Wobor A. Woyczynski, Springer (India) Pvt. Limited.
4. Computational Physics: R. C. Verma, P. K. Ahluwalia and K.C. Sharma, New Age Publishers (1999)
5. Ajoy Ghatak, "Optics", 5th edition, Tata McGraw Hill Education Private Limited (2012)
6. Joseph Valasek, "Theoretical and Experimental Optics", John Wiley and Sons, Inc., New York (1949)
7. Francis S. Jenkins, Harvey E. White, "Fundamentals of Optics", 3rd edition, McGraw-Hill Book Company, Inc.(1957)
8. K. D. Moller, "Optics: Learning by Computing, With Examples Using MathCad", Springer-Verlag (2003)
9. Numerical Recipes in C ; Press W.H., Teukolsky S.A. Vellerling W.T. and Flannery B.P. (Cambridge Univ. Press 1992)
10. Simulation using Personal Computers: Carroll, J.M. (Prentice Hall, 1987)
11. www.wolfram.com
12. http://demonstrations.wolfram.com/HeatCapacityOfSolidsInTheDebyeApproximat ion/
13. http://demonstrations.wolfram.com/PlotsOfTheFermiDiracDistribution/
14. http://demonstrations.wolfram.com/FermiDiracDistributionsForFreeElectronsInMe tals/
15. http://demonstrations.wolfram.com/FrequencyResponseOfAnLCRCircuit/

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M.SC. (PHYSICS) III & IV SEMESTER: PRACTICAL

Note: Appropriate other experiments can be added based on prescribed syllabus in both labs A and B

LAB –A (CONDENSED MATTER PHYSICS –I & II)

(Preferably five experiments per semester to be performed by the students)

1. To find the Hall Coefficient, Carrier Density and Mobility of the Sample material (Ge).
2. To determine the Resistivity and the Energy Band Gap of Semiconductor (Ge) by Four Probe Method.
3. To find the refractive index of a polymer film and to study the variation of refractive index with wavelength of light source.
4. To find the refractive index of Sugar Solution to study the variation of refractive index with different molar concentration (Using Green Laser).
5. To determine the Plateau and optimal operating voltage of a GM Counter.
6. Determination of Beta Particle range and maximum Energy (by Half Thickness Method).
7. To Study the Variations of Counter rate for different materials (absorber of same thickness) with constant voltage.
8. To verify the Lambert – beer"s law for different Concentration of $KMnO_4$ Solution using Spectrometer.
9. To Analyze material qualitatively using an FTIR Spectrophotometer.
10. To Measure the magnetic Susceptibility of $FeCl_3$ solution by Quincke"s Method.
11. To find the crystallite size of Sample (CdS powder) using X-ray Diffractometer.
12. To find the miller indicies (hkl) of Sample (Known/Unknown) using X-ray Diffractometer.
13. To study crystal symmetry using Crystal model.
14. To measure the absorbance of different material using Spectro photometer.
15. Study of the dispersion relation for the monoatomic lattice- comparison with the theory.
16. Determination of the cut off frequency of the monoatomic lattice.
17. Study of the Dispersion relation for the diatomic lattice- acoustical mode and optical mode energy gap. Comparison with theory.

M.SC. (PHYSICS) III & IV SEMESTER: PRACTICAL: PRACTICAL COURSE

Note: Appropriate other experiments can be added based on prescribed syllabus in both labs A and B

LAB –B (MATHEMATICA –I & II)

(Preferably five experiments per semester to be performed by the students)

Analysis and Simulation of the following problems in Physics using Mathematica.

Addition and deletion of exercises can be done as per the need.

1. Write and execute a program to calculate and print roots of a quadratic $ax^2+bx+c = 0$ (a□ 0) .
2. Write and execute a program in Mathematica to add and multiply two matrices.
3. Write and execute a program in Mathematica to determine the Eigen value of matrices.
4. Write and execute a program in Mathematica to determine the Eigen vector of matrices.
5. Converting graphics into „jpeg" format. Exporting of images in „jpeg" format.
6. Using DSolve to solve a differential equation and using Extract to obtain the solutions.
7. Using DSolve to solve a differential equation and plotting the solutions.
8. Study of " Harmonic Motion :- mx"+cx'+sx = 0";"c^2-4mk>0 , overdamped; c^2-4mk=0, critically damped; c^2-4mk<0, underdamped";
9. Phase Plot of a system undergoing linear Oscillations.
10. Potential Energy and Kinetic Energy diagram of the Linear Harmonic Oscillator.
11. Resonance Plots of a LCR circuit.
12. Study of Charging and Discharging in circuits with inductors, capacitors and resistors
13. Plot of the intensity – distance curve for a straight edge.
14. Plot of the intensity – distance curve for Fraunhofer diffraction at a single slit.
15. Plot of the intensity – distance curve for Fresnel diffraction at a single slit.
16. Simulation of the diffraction patterns for a straight edge.
17. Simulation of the diffraction patterns for Fraunhofer diffraction at a single slit.
18. Simulation of the diffraction patterns for Fresnel diffraction at a single slit.
19. Simulation of Newton rings for reflected light.
20. Obtaining the Energy Eigen values of a Particle bound in an Infinite Potential Well and plotting of the wave functions.
21. Obtaining the Energy Eigen values of the hydrogen atom by applying the Bohr theory and

plotting of the energy level diagrams.

22. Computer Simulation of the Frequency Response of LCR circuits.
23. Computer Simulation of the Fermi-Dirac Distribution Plots of Metals.
24. Modeling and simulation of a predator and prey problem