

**ST. ALOYSISUS COLLEGE, JABALPUR**  
**SYLLABUS PRESCRIBED FOR THE EXAMINATION FOR THE**  
**DEGREE OF MASTER OF SCIENCE IN PHYSICS**  
**(THIRD AND FOURTH SEMESTERS) 2016-2017**  
**UNDER SEMESTER SYSTEM**

SCHEME OF EXAMINATION

**Semester - III**

<b>Paper</b>	<b>Paper Title</b>	<b>Max. Marks</b>
I	Quantum Mechanics - II	35+15 (CCE) = 50
II	Nuclear and Particle Physics	35+15 (CCE) = 50
III	Special paper	35+15 (CCE) = 50
IV	Special paper	35+15 (CCE) = 50
Lab A	} Based on paper III & IV	50
Lab B		50
	Project/Assignment/Seminar	50

**Total – 350**

Paper III and Paper IV are special papers. The student should offer any two of the following special papers:

- III & IV      (a)    Condensed Matter Physics – I
- (b)    A Course in Computational Physics Using Mathematica– I
- (c)    Electronics - I

## SEMESTER - IV

Paper	Paper Title	Max. Marks
I	Atomic and Molecular Physics	35+15 (CCE) = 50
II	Elective Paper	35+15 (CCE) = 50
III	Special Paper	35+15 (CCE) = 50
IV	Special Paper	35+15 (CCE) = 50
Lab A	} Based on paper III & IV	50
Lab B		50
	<b>Internship:</b> Project/Assignment/Seminar	100

**Total – 400**

(One of the following papers would be an Elective Paper)

- (a) Concise Study of Non-linear Systems
- (b) Physics of Lasers and Laser Applications
- (c) Physics of Nano-materials

Paper III and IV are special papers. Special papers in Semester IV will be the same as offered in semester III. The students should offer any two of the following special papers:

- III & IV (a) Condensed Matter Physics – II
- (b) A Course in Computational Physics Using Mathematica– II
- (c) Electronics - II

**SEMESTER - III**  
**PAPER - I**  
**QUANTUM MECHANICS – II**

**UNIT - 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.

**UNIT-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.

**UNIT - 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.

**UNIT - IV**

**Schrodinger's relativistic equation** (Klein-Gordon equation), Probability and current density, Klein-Gordon equation in presence of electromagnetic field, Hydrogen atom, shortcomings 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

**UNIT - 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  $|310\rangle$  to state  $|200\rangle$  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  $\alpha$  are constant
8. Covariance form of Dirac equation.
9. The probability current density is defined by the relation  $\mathbf{j}(\mathbf{r},t) = c \psi^* \boldsymbol{\alpha} \psi$ , where  $\psi$  is the four-component wave vector. Write expressions for  $j_x$ ,  $j_y$  and  $j_z$  in terms of the components of  $\psi$ .
10. Show that  $(\boldsymbol{\alpha} \cdot \mathbf{A})(\boldsymbol{\alpha} \cdot \mathbf{B}) = (\mathbf{A} \cdot \mathbf{B}) + i\boldsymbol{\sigma} \cdot (\mathbf{A} \times \mathbf{B})$ , where A and B commute with  $\boldsymbol{\alpha}$  and  $\boldsymbol{\sigma}' = \begin{bmatrix} \boldsymbol{\sigma} & 0 \\ 0 & \boldsymbol{\sigma} \end{bmatrix}$
11. Magnetic moment and spin of a Dirac's electron.

In addition to above the tutorial will also consist of solving problems given in the Text and References books.

#### Text and 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. Aruldhas

**SEMESTER – III**  
**PAPER II**  
**NUCLEAR AND PARTICLE PHYSICS**  
**UNIT – 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.

**UNIT - 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 .

**UNIT – 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.

**UNIT - 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 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.

**UNIT – 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 Quadrupole moment.
8. Kurie Plot
9. Selection Rules for  $\beta$  and  $\gamma$  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.

#### **Text and Reference Books**

- Kenneth S. Kian. 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 Nuclear nucleon Interaction, North – Holland, Amsterdam, 1976.
- Y.R. Waghmare, Introductory Nuclear Physics, Oxford-IBH Bombay,1981
- I. Kaplan, Nuclear Physics, 2<sup>nd</sup> 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

**SEMESTER - III**  
**PAPERS III**  
**SPECIAL PAPER (a) CONDENSED MATTER PHYSICS – I**

**UNIT - 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.

**UNIT - 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.

**UNIT - 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.

**UNIT – 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.

**UNIT – 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. 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  $\sigma_{zz}$  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  $\Delta V/V$  for a primitive cell of sodium. Take the bulk modulus as  $7 \times 10^{10}$  erg  $\text{cm}^{-3}$ . Note that the Debye temperature 158 K is less than 300 K so that the thermal energy is of the order of  $K_B T$ . Use this result to estimate the root mean square thermal fluctuation  $\Delta a/a$  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 ( $\xi$ ) and mean thermal displacement from equilibrium ( $x$ ) are :

$$\langle \xi \rangle = K_B T [15b^2/16a^2 - 3c/4a^2] (K_B T)^2$$

$$\langle x \rangle = -(3b/4a^2) K_B T$$

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)

In addition to above the tutorial will also consist of solving problems given in the Text and References books.

#### **Text and 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



**SEMESTER – III**  
**PAPER IV**  
**SPECIAL PAPER (b) A Course In COMPUTATIONAL PHYSICS USING**  
**MATHEMATICA– I**

**UNIT – 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  $ax^2+bx+c = 0$  ( $a \neq 0$ ). Write a program to add and multiply two matrices. Plots of data and functions.

**UNIT – II**

**Mathematica commands II:**

DSolve, Map, Part, With. Brief overview of a computer controlled data acquisition system. 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.

**UNIT – III**

**Mathematica commands III:**

Pure Functions; SetDelayed; Rule; 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.

Unit – 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 OSCILLATOR.

*UNIT – V*

**Application of Mathematica to problems in Physics - II:**

(1) Application of Kirchhoff's Voltage Law and Current Law to electrical meshes, (2) Charging and Discharging in a R-C Circuit, (3) Study of Charging and Discharging in circuits with inductors, capacitors and resistors, (4) Study of Compton Effect, (5) Radioactive Decay and Half Life.

**SEMESTER – III**  
**PAPER IV**  
**SPECIAL PAPER (c) ELECTRONICS - I**  
**UNIT - I**

**Communication Electronics**

Amplitude modulation- Generation of AM waves- Demodulation of AM waves DSBSC modulation. Generation of DSBSC waves, Coherent detection of DSBSC waves, SSB modulation, Generation and detection of SSB waves. Vestigial sideband modulation. Frequency division multiplexing (FDM).

**Microwave**

Advantages and disadvantages of microwave transmission, loss in free space, propagation of microwaves, atmospheric effects on propagation, Fresnel zone problem, ground reflection, fading sources, detectors, components, antennas used in MW communication systems.

Introduction to satellite communication, Geostationary satellite, orbital patterns, satellite systems link modules.

**UNIT-II**

**Microwave and Radar**

Klystrons, Magnetrons and Travelling Wave Tubes, Velocity modulation, Basic principles of two cavity Klystrons and Reflex Klystrons, principles of operation of magnetrons. Helix Travelling Wave Tubes, Wave Modes.

Radar block diagram and operation, radar frequencies, pulse considerations. Radar range equation, minimum detectable signal, derivation of radar range equation, Antenna parameters, system losses, propagation losses, Radar transmitters-receivers, display.

**UNIT-III**

Introduction to Intel 8085 microprocessor, instruction for 8085, and addressing modes, Data Transfer, Arithmetic, Logical and branch group of instructions. Stack, I/O and machine control group. (Examples related to each group of instructions). Timing and operation status, Memory read write, I/O read, I/O write, register move, and move immediate, Timing diagrams.

**Interrupts** : Various interrupts handling facilities of Intel 8085 vector and non vectored interrupt Maskable and non maskable interrupts.

**UNIT-IV**

**Programmable Interface devices:**

Internal Architecture and pin out diagrams of 8155 and 8255 programmable interface. Programmable interrupt controller Intel 8259, Direct memory access and 8257 DMA controller 8279 display/ key board controller.

**Interfacing with D/A and A/D converters**

Elementary method of digital to analog conversion. Working of DAC 0808 and programme for interfacing with 8255 in 8085 based system.

Basic technique for analog to digital conversion. Internal block diagram of ADC 809 and working. Interfacing of IC 809 with 8085 based system.

**UNIT – V**

**This unit will have tutorial problems covering all the four units.  
Some sample problems are:**

1. Effect of frequency and phase error in detection of DSBSC and SSBC signals.
2. Frequency considerations in satellite communication.
3. Make a clear distinction between velocity modulation and current modulation. Show how each occurs in Klystron amplifier, and explain how current modulation is necessary if the tube is to have significant power gain.
4. Different type of Radar system.
5. Timing diagrams for 8085 microprocessor instruction for fetch and execute machine cycles and calculation of T states used.
6. Program with flow chart to take in ten data samples of one microsecond interval and store them in memory.
7. Interfacing of 8255 with 8085 in MOD 0 and MOD 1.
8. Program for a interrupt driven clock using 50 Hz mains as an interrupting source.

In addition to above the tutorial will also consist of solving problems given in the Text and References books.

**Text and Reference Books**

Vacuums Tubes	:	Karl R. Spangenberg McGraw Hill
Communication System	:	Taub and Schilling McGraw Hill
Communication Electronics	:	John Kennedy
Microprocessor Architecture	:	Ramesh S. Gaonkar
Programming & Application with 8085		
Microprocessors	:	B. Ram
Microcomputer	:	Malvino
Microwaves	:	K.L. Gupta
Advance Electronics	:	Wayne Tamasi
Communication System		

## SEMESTER – IV

### PAPER - I

## ATOMIC AND MOLECULAR PHYSICS

### UNIT – I

Quantum states of one electron atoms Atomic orbitals, Hydrogen spectrum, Pauli's 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.

### UNIT – 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.

### UNIT – 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.

### UNIT – 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 Spectroscopy.

## UNIT –V

This unit will have tutorial problems covering all the four units. Some sample problems are:

- Write all possible term symbols for the following electron configurations
  - (a) [Be]2p<sup>3</sup>
  - (b) [He]2s2p
- 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)  $^3P - ^3S$
- The measured value of the first line ( $J = 0$ ) in the rotational spectrum of carbon monoxide is  $3.84235 \text{ cm}^{-1}$ . Determine the moment of inertia and bond length of the molecule.
- The data for the  $^1\text{H}^{35}\text{Cl}$  molecule are :  
Bond length = 127.5 pm  
Bond force constant =  $516.3 \text{ Nm}^{-1}$   
Atomic masses :  $^1\text{H} = 1.673 \times 10^{-27} \text{ kg}$ ,  $^{35}\text{Cl} = 58.066 \times 10^{-27} \text{ kg}$   
Determine the following:
  - (a) The energy of fundamental vibration  $\nu_0$ .
  - (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
- How many normal models of vibration are possible for the  $\text{H}_2\text{O}$  molecule?
- The bond between the hydrogen and chlorine atoms in a  $^1\text{H}^{17}\text{Cl}$  molecule has a force constant of 516 nt/m. Calculate the energy difference between the lowest and first excited vibrational level.
- The molecules of  $^1\text{H}^{17}\text{Cl}$  show a strong absorption line of wavelength 3.456 microns. Assuming origin of line due to vibration, calculate the force constant for  $^1\text{H}^{17}\text{Cl}$  bond. ( $h = 6.6 \times 10^{-34} \text{ Jsec}$ ,  $1 \text{ amu} = 1.67 \times 10^{-27} \text{ kg}$ )
- With which type of spectroscopy would one observe the pure rotational spectrum of  $\text{H}_2$ ? If the bond length of  $\text{H}_2$  is 0.07417 nm. What would be the spacing of the lines in the spectrum ?
- A substance shows a Raman line at  $4567 \text{ \AA}$  when exciting line  $4358 \text{ \AA}$  is used. Deduce the position of Stoke and anti-stoke lines for the same substance when the exciting line  $4047 \text{ \AA}$  is used.
- In the Raman spectra of HCl, the displacement from the exciting line are represented by

$$\Delta\nu = \pm (62.4 + 41.6 \text{ J}) \text{ cm}^{-1}$$

Calculate the moment of inertia of the HCl molecule ( $h = 6.62 \times 10^{-27}$  erg-sec,  $c = 3 \times 10^{10}$  cm-sec<sup>-1</sup>)

In addition to above the tutorial will also consist of solving problems given in the Text and References books.

**Text and 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

**SEMESTER – IV**  
**Paper - II**  
**ELECTIVE PAPER**  
**(ANY ONE TO BE OPTED)**

**ELECTIVE PAPER (a): CONCISE STUDY OF NON-LINEAR SYSTEMS**

**Unit 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

**Unit 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.

**Unit 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.

**Unit 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)



## Unit 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.)

- a. Chaotic oscillation of the Duffing Oscillator
- b. Self similarity (Fractal structure) in the Henon map
- c. Self similarity (Fractal nature) of Julia sets
- d. Self similarity (Fractal nature) of Mandelbrot sets
- e. Cellular Automata as examples of simple rules leading to complex patterns.
- f. Self similarity (Fractal nature) of Cellular Automata

In addition to above the tutorial will also consist of solving problems given in the Text and References books.

### **Suggested 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 Joseph

**SEMESTER – IV**  
**PAPER II**  
**ELECTIVE PAPER (b) : PHYSICS OF LASERS ITS APPLICATIONS**

**UNIT –I**

Working principle of laser, threshold condition characteristics of laser, Gaussian beam and its properties, optical Resonators, longitudinal and transverse modes of laser cavity, mode selection, gain in a Regenerative Laser cavity.

Rate equations and threshold for 3 and 4 level systems. Q switching, mode locking and obtaining ultrashort pulses. Spectral narrowing.

**UNIT – II**

Ruby laser, He-Ne laser, Nd based lasers, semiconductor lasers, Nitrogen laser, CO<sub>2</sub> laser, ion laser Dye laser, chemical laser, excimer laser, Higher power laser systems.

**UNIT –III**

Laser fluorescence and Raman scattering and their use in ranging and pollution studies; ultra high resolution spectroscopy with laser, and its application in isotope separation, single atom detection and rotational and vibrational level of molecules. Optical fibers, use of lasers in light waves communication. Qualitative treatment of medical and engineering applications of lasers.

**UNIT – IV**

Crystal optics, propagation of light in a medium with variable refractive index, Electro, optical effect. Non-linear interaction of light with matter, laser induced multiphoton processes, second harmonic generation phase matching, third harmonic generation optical mixing, Parametric generation of light self focusing of light, Frequency mixing in gases and vapours, Optical bistability and optical phase conjugation, Frequency up conversion.

**UNIT – V**

**This unit will have tutorial problems covering all the four units. Some sample problems are:**

1. Calculation of threshold population inversion for laser action in a cavity of given parameters.
2. Calculation of gain coefficient.
3. Determining line width of laser line.
4. Determining line pulse duration in case of Q switched or mode locked laser.
5. Calculation of power of the laser output in case of certain laser system.
6. Tuning of laser in order to obtain- a particular wave length
7. Finding distance of an object by laser range finder.
8. Determining vibrational levels of molecule by scattering of laser light.

9. Calculation of intensity of second harmonic and third harmonic generated by non-linear interaction of laser light with matter.
10. Calculate the wave length separation between the longitudinal modes of a 1530 nm semiconductor laser in which the active layer is 0-2  $\mu\text{m}$  long and has a refractive index of 4.0.

In addition to above the tutorial will also consist of solving problems given in the Text and References books.

**Text and Reference Book**

- Svelte : Lasers
- Yariv : Optical Electronics.
- Demtroder : Laser spectroscopy
- Letekhov : Non-Linear Laser spectroscopy
- Lasers : A.L. Siegman
- Optical Electronics : K.Tyagrajan & A.K. Ghatak.

**SEMESTER – IV**  
**PAPER II**  
**ELECTIVE PAPER (c) PHYSICS OF NANOMATERIALS**

**UNIT-I**

**Concept of Quantum Confinement**

Free electron theory (qualitative ideas) and its features. Idea of band structure, Metals, insulators and semiconductors, Density of states in bands, Variation of density of states with energy.

Electron confinement in infinitely deep square well, confinement in two and three dimension, Idea of quantum well, quantum wire and quantum dots, classification of nanostructured materials.

**UNIT-II**

**Quantum wells and Superlattices**

Energy levels and density of states in quantum wells. Band structure in quantum well, coupling between the wells, multiple quantum well structure, superlattice dispersion relation and density of states, Band structure in superlattice, Types of superlattices.

Techniques of Fabrication of MQW and SL structures (MBE, MOCVD, LPE etc).

**UNIT-III**

**Nanoparticles**

Synthesis of nanoparticles: Bottom up: cluster beam evaporation, ion beam deposition, chemical bath deposition with capping techniques; and Top up: Ball milling.

Physical properties of nanoparticles: Impurities and composition surface roughness, structure, thermodynamic properties. Determination of particle size by width of XRD peaks.

**UNIT-IV**

**Characteristics of nanoparticles**

Optical Properties: Absorption spectra, luminescence, Raman scattering, spectral response. Determination of particle size by shift in photoluminescence peaks.

Electrical properties of nanoparticles, nanostructured magnetic materials, stability of nanocrystals. Application of nanostructured materials.

**UNIT-V**

**This unit will have tutorial problems covering all the four units.**

**Some sample problems are:**

- (1) Density of state function in 1D, 2D and 3D systems.
- (2) Calculation of energy levels and change in band gap in a quantum well of given dimensions.
- (3) Energy difference between two levels in a double QW.
- (4) Variation of specific heat with size of crystal.
- (5) Calculation of crystal size from XRD peaks.
- (6) Calculation of crystal size from PL peaks.

In addition to above the tutorial will also consist of solving problems given in the Text and References books.

### **Text and References Books**

- Nanotechnology Molecularly designed material by Gan-Moog, Chow , Kenneth. E Gonsalves, AmericanChemical Society.
- Quantum dot heterostructure by D. Bimerg, M. Grundmann and N.N. Ledentsov John Wiley and sons 1998.
- Nanotechnology: Molecular Speculations on global abundance by B.C. Grandall MIT Press 1996.
- Physics of low dimensional semiconductors by John W. Davies, Cambridge Univ. Press 1999.
- Physics of semiconductor nanostructures by K.R. Jain Narosa 1999
- Nano-fabrication and bio-systems: Integrating materials science engineering Science and biology by Harvey C. Hoch, Harold G. Craighead and Lynn Jelinski, Cambridge Univ. Press- 1996.
- Nano particles and nano structured films: Preparation, characterization and application, Ed. J. H. Fendler, Jhon Wiley and sons 1998.
- Wave mechanics applied to semiconductor heterostructures by Gerald Bastard.

## SEMESTER – IV

### PAPERS III

#### SPECIAL PAPER (a) CONDENSED MATTER PHYSICS – II

##### UNIT – I

Interaction of electrons with acoustic and optical phonons, polarons, Superconductivity : Manifestations of energy gap, Cooper pairing due to phonons, BCS theory of superconductivity, Ginzburg –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).

##### UNIT – 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; Fibonacci sequence, Penrose lattice and their extension to 3-dimensions.

##### UNIT – 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 nanotube based electronic devices. Definition and properties of nanostructured materials. Methods of synthesis of nanostructured materials. Special experimental techniques for characterization of nanostructured materials. Quantum size effect and its applications.

##### UNIT - IV

Disorder in condensed matter, substitutional, 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.

##### UNIT - 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  $W = \langle E \cdot J \rangle$  where the average is over a complete cycle. Show that

$$W = (\omega \epsilon_2 / 8\pi) E_0^2 = \sigma E_0^2 / 2 = \sigma_1 E^2$$

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

$$\lambda^{(l)}(\phi) = \sin(l + 1/2)\phi / \sin \phi/2$$

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 nanotubes can be both semiconducting and metallic why?

In addition to above the tutorial will also consist of solving problems given in the Text and References books.

#### **Text and References Books**

Crystal Structure Analysis	:	Burger
The Physics of Quasicrystals,	:	Eds steinhardt and Ostulond
Hand Book of Nanostructured Materials	:	Ed. Hari Singh Nalwa
and Nanotechnology (Vol. 1 to 4)		
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

**SEMESTER – IV**  
**PAPER IV**  
**SPECIAL PAPER (b) : A Course In COMPUTATIONAL PHYSICS USING**  
**MATHEMATICA– II**

***UNIT – 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.

***UNIT – 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

***UNIT – 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.

***UNIT – 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

**UNIT - 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.

**In addition to above the tutorial will also consist of solving problems given in the text and reference books.**

**SEMESTER – IV**  
**PAPER IV**  
**SPECIAL PAPER (b) ELECTROINCS – II**

**UNIT-I**

**Digital Communication**

Pulse-Modulation Systems: Sampling theorem- Low pass and Band pass Signals, PAM, Channel Bandwidth for a PAM signal, Natural sampling, Flat-Top sampling, Signal recovery through Holding, Quantization of signal, Quantization, Differential PCM, delta Modulation, Adaptive Delta Modulation, CVSD.

Digital Modulation techniques: BPSK, DPSK, QPSK, PSK, QASK, BFSK, FSK, MSK.

**UNIT-II**

Noise in pulse code and Delta modulation systems: PCM transmission, calculation of Quantization noise, output-signal power, Effect of thermal noise, Output signal to noise ratio in PCM, DM, Quantization noise in DM, output signal power, DM output-signal –to Quantization- noise ratio. Effect of thermal noise in Delta modulation, output signal- noise ratio in DM.

Computer communication systems: Types of networks, Design of a communication network, examples TYMNET, ARPANET, ISDN, LAN.

Introduction to Mobile radio and satellites: Time division multiple Access (TDMA), Frequency Division Multiple Access (FDMA), ALOHA, Slotted ALOHA, Carrier Sense Multiple Access (CSMA) Poisson distribution, protocols.

**UNIT-III**

Introduction to 8086, Microprocessor chip, Internal Architecture, Introduction (Basics of) to Programming of 8086 and Assembly language. Programme development steps. Construction of machine code for 8086 Instructions, writing a programme for use with assembler, Assembly language program development tools.

Assembly Language Programming Technique : Simple sequence programmes. Basic idea of flags and jumps, While – Do, IF- THEN, IF –THEN-ELSE structure based simple programs. Writing and using Assembler Macros.

**UNIT – IV**

8086 System Connection Timings : 8086 Hardware Review, Addressing Memory and ports in microcomputer system , Basic Idea about Timing parameters, Minimum mode waveform and calculation for access time.

Interrupts : 8086 Interrupts and Interrupts response with some hardware applications.

Digital and Analog Interfacing of 8086 : Methods of parallel data transfer, single Handshake I/O , Double Handshake Data transfer. 8255 Handshake applications : Lathe control and speech synthesizer. Display and keyboard interfacing with 8279, D/A interfacing with microcompiler, A/D interfacing (introduction)

Elementary Idea about 80816, 80286, 80386 to Pentium processors

**UNIT - V**

**This unit will have tutorial problems covering all the four units. Some sample problems are:**

1. Explain the meaning of pulse code modulation. Draw one complete cycle diagram. Draw one complete cycle of some irregular waveform and show it is quantized using eight standard pulses.
2. Efficiency of PCM
3. Noise in PCM system
4. Signal to noise ratio in time division multiplexed PAM systems.
5. Program for creating a delay loop using 16 bit register pair.
6. Program for 8086 in Assembly Language using IF-THEN-ELSE structure.
7. Debugging Assembly Language Programs for 8086  $\mu$ p with simple examples.
8. Assembly Language for interrupts procedure in 8086.

In addition to above the tutorial will also consist of solving problems given in the Text and References books.

### **Text and References Books**

Principles of communication system	: Taub & Schilling (1994) II Edition
Communication systems	: Simon Haylein III Ed.
Microprocessors and Interfacing	: Douglas Hall 2 <sup>nd</sup> Ed. (1992)
Programming and Hardware	
The Intel Microprocessor 8086/8088/ 80186/80286/80386/80486 Pentium and Pentium ProProcessor Architecture	: Brey & Brey
Programming and Interfacing	