Semester: IV

Paper Code	Paper No.	Paper Title	Credit
	C8	Introductory Quantum Mechanics	3+1+1
	C9	Digital Systems & Applications	3+1+1
	C10	Electromagnetic Theory	3+1+1
	GE4	Modern Physics, Special Theory of Relativity and Solid State Physics	3+0+1

Paper Code: **Paper No. C8**

Paper Name: Introductory Quantum Mechanics

Credit: 3+1+1

Theory: 48 Lectures

Planck's quantum theory: Development of quantum mechanics: black body radiation, failure of classical idea, Planck's quantum hypothesis, photoelectric effect, Compton effect, Franck-hertz experiment. De Broglie wavelength and matter waves; Davisson-Germer experiment. Two-Slit experiment with electrons. Probability. Wave amplitude and wave functions.

(7 Lectures)

Wave description of particles by wave packets. Group and Phase velocities and relation between them. Position measurement- gamma ray microscope thought experiment;- Wave particle duality, Complementarity principle, Heisenberg uncertainty principle (Uncertainty relations involving Canonical pair of variables): Derivation from Wave Packets impossibility of a particle following a trajectory; Estimating minimum energy of a confined particle using uncertainty principle; Energy-time uncertainty principle- application to virtual particles and range of an interaction.

(7 Lectures)

Quantum Mechanics: Basic postulates and Formalism: Energy, Momentum and Hamiltonian operators. Schroedinger's wave equation: time dependent and time independent ones. Wave equation and its probabilistic interpretation as probability amplitude; continuity equation, probability density and probability current density J; normalization condition and normalized wave function; properties of well-behaved wave function in quantum mechancics. Linearity and superposition principle. Eigenvalues and Eigenfunctions. Position, momentum and Energy operators; commutator of position and

momentum operators; Expectation value, Ehrenfest's theorem. Wave function for a free particle.
(12 Lectures)

Applications of Schroedinger's wave equation:
Scattering problems in one dimension: one dimensional finite step potential, reflection and transmission co-efficients; one-dimensional potential barrier and tunneling effect.
Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wave function as a linear combination of energy eigenfunctions; General solution of the time dependent Schrodinger equation in terms of linear combinations of stationary states.
(10Lectures)
General discussion of bound states:- Continuity of wave function, boundary condition and emergence of discrete energy levels; application to one-dimensional problem-square well potential; Quantum mechanics of simple harmonic oscillator-energy levels and energy eigenfunctions. zero point energy & uncertainty principle.
(6 Lectures)
Quantum theory of hydrogen atom: Particle in a spherically symmetric potential, Schroedinger equation, separation of variables, radial solutions and principal quantum number, orbital and magnetic quantum numbers, quantization of energy.
(6Lectures)

Reference Books:
1. A Text book of Quantum Mechanics, P.M. Mathews and K. Venkatesan, 2nd Ed., 2010, McGraw Hill
2. Quantum Mechanics, Robert Eisberg and Robert Resnick, 2nd Edn., 2002, Wiley.
3. Quantum Mechanics, Leonard I. Schiff, 3rd Edn. 2010, Tata McGraw Hill.
4. Quantum Mechanics for Scientists & Engineers, D.A.B. Miller, 2008, Cambridge University Press
5. Quantum Mechanics, Eugen Merzbacher, 2004, John Wiley and Sons, Inc.
6. Introduction to Quantum Mechanics, D.J. Griffith, 2nd Ed. 2005, Pearson Education

List of Experiments: Credit=1 (16 Classes of 2 hours each)

The aim of this Lab is to use the computational methods and to learn Scilab for solving physical problems. The course will consist of lectures (both theory and practical) in the Computer Lab. Evaluation done not on the basis of programming but on the basis of formulating the problem. At least two programs must be attempted from each programming section.

Introduction to Numerical Computation using Scilab:

Introduction to Numerical computation software Scilab	Introduction to Scilab, Advantages and disadvantages, Scilab environment, Command window, Figure window, Edit window, Variables and arrays, Initializing variables in Scilab, Multidimensional arrays, Sub-array, Special values, Displaying output data, data file, Scalar and array operations, Hierarchy of operations, Built in Scilab functions, Introduction to plotting, 2D and 3D plotting, Branching Statements and program design, Relational and logical operators, the while loop, for loop, details of loop operations, break and continue statements, nested loops, logical arrays and vectorization. User defined functions, Introduction to Scilab functions, Variable passing in Scilab, optional arguments, preserving data between calls to a function, Complex and Character data, string function, Multidimensional arrays an introduction to Scilab file processing, file opening and closing, Binary I/o functions, comparing binary and formatted functions, Numerical methods and developing the skills of writing a program.
Curve fitting, Least square fit, Goodness of fit, standard deviation using Scilab	Ohms law calculate R, Hooke's law, Calculate spring constant, Given Bessel's function at N points find its value at an intermediate point.
Solution of Linear system of equations by Gauss elimination method and Gauss Seidel method. Diagonalisation of matrices, Inverse of a matrix, Eigen vectors, eigen-values problems	Solution of mesh equations of electric circuits (3 meshes) Solution of coupled spring mass systems (3 masses)

Generation of Special functions using User defined functions in Scilab	Generating and plotting Legendre Polynomials Generating and plotting Bessel function
Solution of ODE First order Differential equation Euler, modified Euler and Runge-Kutta (RK) second and Fourth order methods Second order differential equation Fixed difference method Partial differential equations	First order differential equation: • Radioactive decay • Current in RC, LC circuits with DC source • Newton's law of cooling • Classical equations of motion Second order Differential Equation: • Harmonic oscillator (no friction) • Damped Harmonic oscillator 1. Overdamped 2. Critically damped 3. Oscillatory • Forced Harmonic oscillator 1. Transient and 2. Steady state solution • Apply above to LCR circuits also • Solve: $x^2\frac{d^2y}{dx^2} - 4x(1+x)\frac{dy}{dx} + 2(1+x)y$ with the boundary conditions at $x = 1, y = \frac{1}{2}e^2, \frac{dy}{dx} = -\frac{3}{2}e^2 - 0.5,$ in the range $1 \le x \le 3.$ Plot y and $\frac{dy}{dx}$ against x on the same graph. Partial Differential Equation: • Wave equation • Heat equation • Poisson equation • Laplace equation

Using Scicos/xcos	• Generating sine wave, square wave, saw tooth wave • Solution of harmonic oscillator • Study of heat phenomenon • Phase space plots

Problems based on Quantum Mechanics:

Use C++/Scilab for solving the following problems:

1. Solve the s-wave Schrodinger equation for the ground state and the first excited state of the hydrogen atom:

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2}[V(r) - E] \text{ where } V(r) = -\frac{e^2}{r}$$

   Here, m is the reduced mass of the electron. Obtain the energy eigenvalues and plot the corresponding wavefunctions. Remember that the ground state energy of the hydrogen atom is ≈ -13.6 eV. Take e=3.795$(eVÅ)^{1/2}$, ħc= 1973 (eVÅ), m=0.511 x10^2 eV/c^2.
2. Solve the s-wave radial Schrodinger equation for an atom:

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2}[V(r) - E]$$

   where m is the reduced mass of the system (which can be chosen to be the mass of the electron) for the screened Coulomb potential:

$$V(r) = -\frac{e^2}{r}e^{-r/a}$$

   Find the energy (in eV) of the ground state of the atom to an accuracy of three significant digits. Also, plot the corresponding wavefunction.
   Take e =3.795$(eVÅ)^{1/2}$, m=0.511 x10^2 eV/c^2, and a = 3 Å, 5 Å, 7 Å. In these units ħc = 1973 (eVÅ) . The ground state energy is expected to be above -12 eV in all three cases.
3. Solve the s-wave radial Schrodinger equation for a particle of mass m:

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2}[V(r) - E]$$

   For the an-harmonic oscillator potential

$$V(r) = \frac{1}{2}kr^2 + \frac{1}{3}br^3$$

   for the ground state energy (in MeV) of particle to an accuracy of three significant digits. Also, plot the corresponding wave function. Choose m = 940 MeV/c2, k = 100 MeV fm^{-2}, b = 0, 10, 30 MeV fm^{-3} In these units, cħ = 197.3 MeV fm. The ground state energy I expected to lie between 90 and 110 MeV for all three cases.
4. Solve the s-wave radial Schrodinger equation for the vibrations of hydrogen molecule:

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2\mu}{\hbar^2}[V(r) - E]$$

Where μ is the reduced mass of the two-atom system for the Morse potential

$$V(r) = D(e^{-2\alpha r'} - e^{-\alpha r'}), \quad r' = \frac{r - r_o}{r}$$

Find the lowest vibrational energy (in MeV) of the molecule to an accuracy of three significant digits. Also plot the corresponding wave function. Take: m = 940×10^6 eV/C^2, D = 0.755501 eV, α = 1.44, r_o = 0.131349 Å.

References Books:

1. Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
2. Complex Variables, A.S. Fokas & M.J. Ablowitz, 8th Ed., 2011, Cambridge Univ. Press
3. Computational Physics, D.Walker, 1st Edn., 2015, Scientific International Pvt. Ltd.
4. A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn.,Cambridge University Press
5. Getting started with Matlab, Rudra Pratap, 2010, Oxford University Press
6. Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A.V. Wouwer, P. Saucez, C.V. Fernández. 2014 Springer
7. Scilab by example: M. Affouf, 2012, ISBN: 978-1479203444
8. Scilab Image Processing:L.M.Surhone. 2010, Betascript Pub.,ISBN: 978-6133459274

…........................x...........................

Paper Code: **Paper No. C9**

Paper Name: Digital Systems & Applications

Credit: 3+1+1

Theory: 48 Lectures

Introduction to CRO:

Block Diagram of CRO, Electron Gun, Deflection System and Time Base, Deflection Sensitivity, Application of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency and Phase Difference.

(3 lectures)

Integrated Circuits: (Qualitative treatment only): Active and Passive components. Discrete components, Wafer and Chip, Advantages and drawbacks of ICs, Scale of integration: SSI, MSI, LSI and VLSI (basic idea and definitions only). Classification of ICs,Examples of Linear and Digital lCs.

(6 Lectures)

Digital Circuits:
Difference Between Analog and Digital Circuits, Binary Numbers, Decimal to Binary and binary to Decimal Conversion, Octal number, Hexadecimal, AND, OR and NOT Gates (Realization using Diodes and Transistors), NAND and NOR Gates and applications, Exclusive OR and Exclusive NOR Gates.

(6 lectures)

Boolean algebra: De Morgan's Theorems, Boolean Laws, Simplification of Logic Circuit using Boolean algebra, Fundamental Products, Minterms and Maxterms, Conversion of a Truth Table into an equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map.

(6 Lectures)

Timers: IC 555: block diagram and applications: Astable multivibrator and Monostable Multivibrator

(3 lectures)

Data processing circuits: Basic idea of Multiplexers, De-multiplexers, Decoders, Encoders, Parity Checkers

(3 lectures)

Arithmetic Circuits: Binary Addition, Binary Subtraction using 2's Compliment Method, Half Adders and Full Adders and Subtractors (only up to eight Bits).

(4lectures)

Sequential Circuits: RS, D , and JK Flip-Flops, Level Clocked and Edge Triggered Flip-Flops, Preset and Clear Operations, Race around Conditions in JK Flip-Flop, Master-slave JK Flip-Flop (As Building Block of Sequential Circuits.

(6 lectures)

Shift Registers: Serial-in-Serial-out, serial-in-parallel-out, Parallel-in-serial-out, and Parallel-in-parallel-out Shift Registers (only up to 4 bits).

(3 lectures)

Counters: Asynchronous and Synchronous Counters, Ring Counters, Decade Counters

(4 lectures)

8085 Microprocessor Architecture: Main features of 8085. Block diagram. Components, Pin-out diagram. Buses, Registers, ALU, Memory, Stack memory and Timing

(4 Lectures)

Introduction to Assembly Language: 1 byte, 2 byte and 3 byte instructions and Simple programming.

(4 Lectures)

List of Experiments: Credit=1 (16 Classes of 2 hours each)

1. Realisation of OR, AND, NOT, NOR, XOR (using Diodes and Transistors and Breadboard)
2. Realization of basic gates using NAND/NOR-gates.
3. Realization of De Morgan's Theorem using logic gates.
4. To design an astable multivibrator of given specifications using 555 Timer.
5. To design a monostable multivibrator of given specifications using 555 Timer.
6. Half Adder, Full Adder and 4-bit binary Adder.
7. To build Flip-Flop (RS, Clocked RS, D-type and JK) circuits using NAND gates
8. Microprocessor programming for addition and subtraction of numbers using direct addressing mode
9. Microprocessor programming for Addition and subtraction of numbers using indirect addressing mode
10. Microprocessor programming for Multiplication by repeated addition
11. Microprocessor programming for Division by repeated subtraction.

(*At least 05 experiments from the above list)*

Recommended Books:

1 Digital principle and applications by Donald P. Leach & Albert Paul Malvino (Glencoe, 1995)

1. Digital Fundamentals, 3rd edition by Thomas L. Floyd (Universal Book Stall, India, 1998)
2. Digital Electronics by R. P. Jain.
3. Operational Amplifiers and Linear Integrated Circuits, 4th Edition by Robert F Coughlin and Frederick F Driscoll (P.H.I. 1992)
4. Op-Amps and Linear Integrated Circuits by R. A/ Gayakwad (Pearson EducationAsia, 2000)

…..........................x...........................

Paper Code: **Paper No. C10**

Paper Name: Electromagnetic Theory

Credit: 3+1+1

Theory: 48 Lectures

Maxwell Equations: Review of Maxwell's equations. Displacement Current. Vector and Scalar Potentials. Gauge Transformations: Lorentz and Coulomb Gauge. Boundary Conditions at Interface between Different Media. Wave Equations. Plane Waves in Dielectric Media. Poynting Theorem and Poynting Vector. Electromagnetic (EM) Energy Density. Physical Concept of Electromagnetic Field Energy Density. Momentum

Density and Angular Momentum Density.

(10 Lectures)

EM Wave Propagation in Unbounded Media: Plane EM waves through vacuum and isotropic dielectric medium, transverse nature of plane EM waves, refractive index and dielectric constant, wave impedance. Propagation through conducting media, relaxation time, skin depth.

(6 Lectures)

EM Wave in Bounded Media: Boundary conditions at a plane interface between two media. Reflection & Refraction of plane waves at plane interface between two dielectric media-Laws of Reflection & Refraction. Fresnel's Formulae for perpendicular & parallel polarization cases, Brewster's law. Reflection & Transmission coefficients.Total internal reflection, evanescent waves. Metallic reflection (normal Incidence)

(10 Lectures)

Polarization of Electromagnetic Waves: Description of Linear, Circular and Elliptical Polarization. Propagation of E.M. Waves in Anisotropic Media. Symmetric Nature of Dielectric Tensor. Fresnel's Formula. Uniaxial and Biaxial Crystals. Light Propagation in Uniaxial Crystal. Double Refraction. Polarization by Double Refraction. Nicol Prism. Ordinary & extraordinary refractive indices. Production & detection of Plane, Circularly and Elliptically Polarized Light. Phase Retardation Plates: Quarter-Wave and Half-Wave Plates. Analysis of Polarized Light.

(10 Lectures)

Rotatory Polarization: Optical Rotation. Biot's Laws for Rotatory Polarization. Fresnel's Theory of optical rotation. Calculation of angle of rotation. Specific rotation. Laurent's half-shade polarimeter.

(4 Lectures)

Wave Guides: Planar optical wave guides. Planar dielectric wave guide. Condition of continuity at interface. Phase shift on total reflection. Eigenvalue equations. Phase and group velocity of guided waves. Field energy and Power transmission. Optical Fibres, Step and Graded Indices (Definitions Only)

(8 Lectures)

Reference Books:

1. Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.
2. Elements of Electromagnetics, M.N.O. Sadiku, 2001, Oxford University Press.
3. Fundamentals of Electromagnetics, M.A.W. Miah, 1982, Tata McGraw Hill
4. Engineering Electromagnetic, Willian H. Hayt, 8th Edition, 2012, McGraw Hill.
5. Electromagnetics, J.A. Edminster, Schaum Series, 2006, Tata McGraw Hill.
6. Electromagnetics, B.B. Laud, 2nd Eds., New Age International (P) Publishers, 1987
7. Electromagnetic field theory fundamentals, B. Guru and H. Hiziroglu, 2015, Cambridge University Press

List of Experiments: Credit=1 (16 Classes of 2 hours each)

1. To find the refractive index of a transparent bar using diode laser.
2. Determination of the wavelength of a diode laser using a diffraction grating.
3. To find the refractive index of a transparent material by measuring Brewster Angle.
4. To determine the Numerical Aperture of a given optical fibre from the measurement on the far field of fibre and Acceptance Angle.
5. To calibrate a polarimeter and hence to determine the Specific Rotation of sugar solution.
6. To study variation of light intensity from a polarizer and analyzer. (by Photo-resistor) combination.
7. To determine absorption and transmission coefficients of various optical filters. (by photoresistor)
8. To study dependence of radiation on angle for a simple Dipole antenna.
9. To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene, etc.) by studying the diffraction through ultrasonic grating.

(At least five experiments are to be performed)

…....................x...........................

Paper Code: **Paper No. GE4**

Paper Name: Modern Physics, Special Theory of Relativity and Solid State Physics

Credit: 3+0+1

Theory: 48 Lectures

Modern Physics: Problems with Rutherford model- instability of atoms and observation of discrete atomic spectra; Bohr's quantization rule and atomic stability; calculation of energy levels for hydrogen like atoms and their spectra.

(10 lectures)

Position measurement- gamma ray microscope thought experiment; Wave-particle duality, Heisenberg uncertainty principle; Energy-time uncertainty principle. Matter waves and wave amplitude; Schrodinger equation for non-relativistic particles; Momentum and Energy operators; stationary states; physical interpretation of wave function, probabilities and normalization; Probability and probability current densities in one dimension.

(12 classes)

Size d structure of atomic nucleus and its relation with atomic weight. Nature of nuclear force, NZ graph, semi-empirical mass formula and binding energy. Stability of nucleus; Law of radioactive decay; Mean life and half-life; α-decay, β-decay and γ-emission;

spectrum and Pauli's prediction of neutrino.

(10 classes)

Special Theory of Relativity: Constancy of speed of light. Postulates of Special Theory of Relativity. Length contraction. Time dilation. Relativistic addition of velocities.

(8 classes)

Solid State Physics: Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis. Unit Cell. Miller Indices. Reciprocal Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law.

(6 classes)

Reference Books:

1. Concepts of Modern Physics, Arthur Beiser, 2009, McGraw-Hill.
2. The Atomic Nucleus - R. D. Evans
3. Concept of Modern Physics -y A. Beiser
4. Nuclear Physics -S. N. Ghosal
5. Introduction to Special Relativity, Robert Resnick, John Wiley & Sons
6. Introduction to Solid State Physics, Charles Kittel, 8th Ed., 2004, Wiley India Pvt. Ltd.
7. Elements of Solid State Physics, J.P. Srivastava, 2nd Ed., 2006, Prentice-Hall of India.

List of Experiment:- GENERIC II LAB (1 Credit, 16 Periods of 2 hours)

(Modern Physics, Special Theory of Relativity and Solid State Physics**)**

(At least 05 experiments from the following)

1. To draw the characteristic curve of a photo cell and find the maximum velocity of emitted electron.
2. To determine the value of Planck's constant with the help of photo cell and monochromatic filter.
3. Study the emission spectrum of hydrogen and to determine Rydberg constant using plane transmission grating.
4. To study the use of GM counter with a beta emitter.
5. To prove the existence of atomic energy levels by using Franck Hertz experiment.
6. Determine the specific charge e/m of an electron.

Reference Books

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House. -
2. A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal
3. A Laboratory Manual of Physics for Undergraduate Classes, D.P.Khandelwal, 1985, Vani Publication.

…........................x..........................