Semester VI

MAJOR COURSE- MJ 12	Computational Physics	(Theory Credit -03) (Total Marks=60+15)

Course Objective:

1. To introduce students to the fundamentals of numerical errors, floating-point computations, and iterative methods in computational physics.
2. To provide practical knowledge of solving algebraic, transcendental, and linear system equations using various numerical techniques.
3. To develop an understanding of eigenvalue problems and techniques for finding eigenvalues and eigenvectors.
4. To teach students interpolation, approximation, and curve-fitting methods, with a focus on least-squares fitting and B-splines.
5. To provide skills in numerical differentiation, integration, and solving ordinary differential equations using different methods.
6. To expose students to Monte Carlo methods and their application in physics simulations and optimization techniques.

Course Outcomes:

By the end of this course, students will be able to:

1. Understand and apply the concepts of numerical errors, floating-point arithmetic, and iterative methods to solve physical problems.
2. Solve algebraic, transcendental, and linear systems of equations efficiently using appropriate numerical methods.
3. Apply eigenvalue problems and calculate eigenvalues and eigenvectors for physical systems.
4. Use interpolation and curve-fitting techniques to approximate functions and data in physics applications.
5. Perform numerical differentiation and integration on physical models and extract meaningful results.
6. Solve initial and boundary value problems of ordinary differential equations using numerical methods, and understand their error estimations.
7. Implement Monte Carlo methods for simulations and optimization, and apply these methods to real-world physics problems.

Course Contents:

Errors and Iterative Methods (03 HRS): Truncation and Round off Errors. Floating Point Computation. Overflow and Underflow. Single and Double Precision Arithmetic. Iterative Methods, error analysis, Condition and Stability.

Solution of Algebraic and Transcendental Equations (03 HRS): Bisection Method, Secant Method, Newton-Raphson Method. Comparison and Error Estimation.

Matrices and Linear System of Equations (06 HRS): Secant Method, False Position, Newton-Raphson Method; Convergence of solutions; Solution of simultaneous linear equations: Gauss Elimination Method, Pivoting, Matrix Inversion, Singular Value Decomposition and Iterative Method.

Eigen values and Eigenvectors (03 HRS): Computation of Eigen values and Eigenvectors of Matrices by using Iterative Methods.

Interpolation and Approximation (04 HRS): Introduction to interpolation, Lagrange approximation, Newton approximation formula.

Curve Fitting, B-Splines and Approximation (06 HRS): Curve Fitting by Least Square Methods: Fitting a Straight Line, Non-Linear Curve Fitting: Power Function, Polynomial of nth Degree, and Exponential Function, Linear Weighed Least Square Approximation. Cubic Splines fitting.

Numerical Differentiation (04 HRS): Numerical Differentiation using (1) Newton's Interpolation Formulas and (2) Cubic Spline Method. Errors in Numeric Differentiation. Maximum and Minimum Values of a Tabulated Function.

Numerical Integration (04 HRS): General Quadrature Formula. Trapezoidal Rule. Simpson's Rules. Weddle's Rule. Gauss Quadrature Formulas: (1) Gauss- Hermite and (2) Gauss-Legendre Formulas.

Solution of Ordinary Differential Equations (ODE's) First Order ODEs (04 HRS): Solution of Initial Value Problems: (1) Euler's Method, (2) Modified Eulers's Method, (3) Runge-Kutta Method of Second Order with Error Estimation.

Second Order ODEs. (03 HRS): Solution of 2-Point Boundary Value Problems. Finite Difference Approximation of Derivatives. Finite Difference Method.

Random Variables and Monte Carlo Methods (05 HRS): Random Walk, Random numbers, Pseudo-random numbers, Monte Carlo integration, Monte Carlo Simulations, The Metropolis algorithm, Variational Methods and Optimization Techniques; Applications of Computer Simulations in Physics.

Reference books:

1. Computational Physics: Problem Solving with Python by Mark Newman, 2013, Princeton University Press
2. Computational Physics: A Practical Introduction to Computing with Python by Kurtis A. Fisher, 2017, Cambridge University Press
3. Numerical Methods in Physics with Python by Alexandru Buca, 2018, Springer
4. An Introduction to Computational Physics by Tao Pang, 2006, Cambridge University Press
5. Computational Physics: Simulation of Physical Systems by David S. Yevick, 2009, Cambridge University Press
6. Mathematica for Physics and Engineering by M. L. Duffy, 2003, Springer
7. Introduction to Computational Science: Modeling and Simulation for the Sciences by Angela B. Shiflet, George W. Shiflet, 2009, Princeton University Press
8. Computational Methods for Physics by Joel L. Schiff, 2008, Cambridge University Press
9. A Student's Guide to the Study, Practice, and Tools of Modern Mathematics by David B. S. Lippman, 2014, Cambridge University Press.
10. The Art of Scientific Computing by William H. Press, Saul A. Teukolsky, William T. Vetterling, Brian P. Flannery, 2007, Cambridge University Press

MAJOR COURSE- MJ 12	Computational Physics	(Practical Credit-01) (Total Marks=25)

Algebraic & Transcendental Equations

1. To find the Roots of an Algebraic Equation by Bisection Method.
2. To find the Roots of an Algebraic Equation by Secant Method.
3. To find the Roots of an Algebraic Equation by Newton-Raphson Method.
4. To find the Roots of a Transcendental Equation by Newton-Raphson

Linear Equations & Eigenvalue Problem

1. To find the Roots of Linear Equations by Gauss Elimination Method.
2. To find the Roots of Linear Equations by Gauss-Seidal Iterative Method.
3. To find the Eigen value and Eigen vector of a Matrix by iterative Method

Interpolation

1. To form a Forward Difference Table from a given set of Data Values.
2. To form a Backward Difference Table from a Given Set of Data Values.
3. To find the value of y near the beginning of a Table of values of(x,y).
4. To find the value of y near the end of a Table of values of (x,y).

Curve Fitting, B-Splines & Approximation

1. To fit a Straight Line to a given Set of Data Values.
2. To fit a Polynomial to a given Set of Data Values.
3. To fit Power series to a given Set of Data Values
4. To fit a logarithmic Function to a given Set of Data Values
5. To fit an Exponential Function to a given Set of Data Values.
6. To fit a natural Cubic B-Spline to a given Data.

Differentiation

1. To find the First and Second Derivatives near the beginning of a Table of values of (x,y).
2. To find the First and Second Derivatives near the end of a Table of values of (x,y).

Integration

1. To evaluate a Definite Integral by Trapezoidal Rule.
2. To evaluate a Definite Integral by Simpson’s 1/3 Rule.
3. To evaluate a Definite Integral by Simpson’s 3/8Rule.
4. To evaluate a Definite Integral by Gauss Quadrature Formula.
5. To evaluate an Integral by Monte Carlo method.

Differential Equations

1. To solve a Differential Equation by Euler’s Method.
2. To solve a Differential Equation by Modified Euler’s Method.
3. To solve a Differential Equation by Second Order Runge Kutta Method.
4. To solve a Differential Equation by Fourth Order Runge Kutta Method.

Others

1. Fast Fourier Transform
2. Test of randomness for random numbers generators
3. Monte Carlo integration
4. Use of a package for data generation and graph plotting.

MAJOR COURSE- MJ 13	Quantum Mechanics-I	(Theory Credit -03) (Total Marks=60+15)

Course Objective:

1. **Introduction to Quantum Concepts:** To introduce students to the fundamental concepts of quantum mechanics, including the limitations of classical physics, wave-particle duality, and the basic postulates of quantum mechanics.
2. **Mathematical Formulation:** To familiarize students with the mathematical formalism of quantum mechanics, including the Schrödinger equation, wave functions, operators, and Dirac notation, as well as their application to solving quantum systems.
3. **Applications of Quantum Mechanics:** To provide students with a deep understanding of the applications of quantum mechanics to real-world problems, such as the particle in a box, quantum tunneling, and the behavior of quantum systems like the harmonic oscillator and hydrogen atom.
4. **Development of Quantum Operators and States:** To explore the role of linear operators in quantum mechanics, their eigenvalues and eigenfunctions, and how these relate to observable physical quantities, such as energy and momentum.
5. **Understanding of Quantum Phenomena:** To explore quantum phenomena like the uncertainty principle, complementarity, and wave-particle duality through experiments like the Davisson-Germer experiment, and understand the relationship between classical and quantum descriptions of nature.
6. **Quantum Mechanical Representations:** To provide an understanding of various representations in quantum mechanics (Schrödinger and Heisenberg) and their applications to solving quantum systems.

Course Outcomes:

By the end of this course, students will be able to:

1. **Understand the Limitations of Classical Physics:** Explain the inadequacies of classical physics through phenomena like blackbody radiation, the photoelectric effect, and the Compton effect, and recognize the need for quantum theory.
2. **Apply Wave Mechanics:** Derive and solve the Schrödinger equation for simple systems such as a particle in a box, harmonic oscillator, and potential barriers, and understand the probabilistic nature of quantum states.
3. **Work with Quantum Operators:** Use the mathematical formalism of quantum mechanics to compute eigenvalues and eigenfunctions, apply commutation relations, and understand the significance of observables and their measurement.
4. **Interpret Wave Functions:** Understand and apply the physical interpretation of wave functions, including probability density, current density, and the normalization condition, in the context of quantum systems.
5. **Solve Problems Using Quantum Formalism:** Solve problems involving quantum states in both one-dimensional and three-dimensional potentials, applying the concepts of superposition and the uncertainty principle.
6. **Analyze Quantum Systems with Different Representations:** Apply Schrödinger and Heisenberg representations to analyze time-dependent and time-independent quantum systems, and compute physical observables using the corresponding operators.
7. **Explore Quantum Phenomena in Real-World Contexts:** Analyze and explain quantum mechanical phenomena such as tunneling, angular momentum quantization, and spin in various quantum systems, including the hydrogen atom.
8. **Master Quantum Mechanical Notation:** Utilize Dirac notation, bra-ket formalism, and the algebra of Hermitian operators to represent and solve quantum problems systematically.

Course Contents:

Limits of Classical Physics (02 HRS): Blackbody radiation (without derivation), Photoelectric effect, Compton effect.

Wave Packets and Uncertainty Relation (05 HRS): de Broglie hypothesis, Wave-particle duality, Davisson-Germer experiment, Wave packets, Group velocity and phase velocity, Uncertainty principle, Bohr's complementarity principle.

Wave Mechanics (15 HRS): Postulates of Quantum Mechanics, Time-dependent Schrödinger equation and dynamical evolution of a quantum state, Properties of Wave Function, Interpretation of Wave Function, Probability and probability current densities in three dimensions, Conditions for Physical Acceptability of Wave Functions, Normalization, Linearity and Superposition Principles, Eigenvalues and Eigenfunctions, Linear operators, Hermitian operators, Observables, Expectation values, Ehrenfest's theorem, Stationary states, Superposition principle, Commutation relations, Commuting observables and compatibility.

Application of Schrödinger Wave Equation (10 HRS): Particle in one-dimensional Box, Square well, Rectangular potential barrier and tunnelling, Linear harmonic oscillator, Spherically symmetric potential, Angular momentum operators and their eigenfunctions, Concept of spin, Hydrogen atom.

Mathematical Formalism of Quantum Mechanics (13 HRS): Dirac Notation, Representation of states and observables, Bra and ket vectors, Linear operators, Relation with wave mechanics, Algebra of Hermitian operators, Matrix representation, Unitary operators, Schrödinger and Heisenberg representations, Linear harmonic oscillator problem by operator method.

References:

1. Principles of Quantum Mechanics – R. Shankar (1994), Springer
2. Introduction to Quantum Mechanics – David J. Griffiths (2018), Pearson
3. Modern Quantum Mechanics – J. J. Sakurai and Jim Napolitano (2017), Addison-Wesley
4. Quantum Mechanics: Concepts and Applications – NouredineZettili (2009), Wiley
5. The Principles of Quantum Mechanics – Paul A. M. Dirac (1981), Oxford University Press
6. Introduction to Quantum Mechanics – Nikhil Ranjan Roy (2016), Vikash Publishing House Pvt. Ltd.
7. Quantum Mechanics, 2/e – V. Devanathan (2015), Narosa Publishing House
8. Quantum Mechanics – V. K. Thankappan (2012), New Age International Publishers

MAJOR COURSE- MJ 13	Quantum Mechanics-I	(Practical Credit -01) (Total Marks=25)

1. To verify the photoelectric effect and determine Planck's constant.
2. To observe electron diffraction and confirm the wave-particle duality of electrons.
3. Write a program to solve the Schrödinger equation for a particle in a one-dimensional infinite potential well and determine the energy eigenvalues and wavefunctions.
4. Write a program to study the energy levels and wavefunctions of a quantum harmonic oscillator.
5. Write a program to solve the Schrodinger equation for the ground state and the first excited state of the hydrogen atom.
6. Write a program to solve the Schrodinger equation for anharmonic oscillator potential,
$$V(r) = \frac{1}{2}kr^2 + \frac{1}{3}br^3$$
7. To verify the Heisenberg uncertainty principle.
8. To observe the inelastic scattering of electrons and measure the energy loss due to electron collisions with mercury atoms, verifying the quantized nature of atomic energy levels.

Reference books:

1. Advanced Practical Physics for Students – B.L. Worsnop and H.T. Flint
2. Experiments in Modern Physics – Adrian C. Melissinos
3. Physics Laboratory Experiments – Jerry D. Wilson, Cecilia A. Hernández-Hall
4. Computational Quantum Mechanics – Joshua Izaac, Jingbo Wang

MAJOR COURSE- MJ 14	Electrodynamics	(Theory Credit -03) (Total Marks=60+15)

Course Objective:

1. To understand the fundamental concepts and mathematical framework of electromagnetism through Maxwell's equations.
2. To explore the nature of electromagnetic waves, including their propagation in various media, and their interaction at boundaries between different materials.
3. To gain an understanding of the principles of electromagnetic radiation and its generation, particularly through dipole and point charge radiation.
4. To apply the concepts of relativity in electrodynamics, including Lorentz transformations and the covariant formulation of electromagnetism.
5. To develop the ability to solve problems involving wave propagation, reflection, refraction, and radiation in both unbounded and bounded media.

Course Outcomes:

Upon successful completion of this course, students will be able to:

1. Derive and solve Maxwell's equations and their boundary conditions in various media, including vacuum and dielectric materials.
2. Analyze and solve problems related to wave propagation in free space, dielectric media, and conducting media, including understanding the concept of skin depth and plasma frequency.
3. Apply the principles of reflection, refraction, and transmission at boundaries between different media and understand their physical implications.
4. Understand and calculate electromagnetic radiation from various sources, including electric and magnetic dipoles, as well as a moving point charge.
5. Utilize special relativity concepts in electromagnetism, including Lorentz transformations and the covariant formulation of electrodynamics to analyze electromagnetic field transformations.

Course Contents:

Maxwell Equations (10 HRS): 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 vector and Poynting Theorem, Maxwell’s stress tensor, Conservation of momentum. Electromagnetic (EM) Energy Density.

EM Wave Propagation in Unbounded Media (10 HRS): 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. Wave propagation through dilute plasma, electrical conductivity of ionized gases, plasma frequency, refractive index, skin depth.

EM Wave in Bounded Media (10 HRS): 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.

Electromagnetic radiation (05 HRS): Retarded potentials, Electric dipole radiation, magnetic dipole radiation, Radiation from a point charge: Lienard-Wiechart potentials, fields of a point charge in motion, power radiated by a point charge.

Relativity (10 HRS): Review of special theory of relativity and Lorentz transformations, Minkowski four vectors, energy-momentum four vector, covariant formulation of mechanics, Transformation of electric and magnetic fields under Lorentz transformations, field tensor, invariants of electromagnetic field, covariant formulation of electrodynamics.

References

1. Introduction to Electrodynamics, David J Griffiths, 2 nd Edition, Prentice Hall India, 1989.
2. Classical Electrodynamics, JD Jackson, 4 th Edition, John Wiley & Sons, 2005.
3. Classical Electromagnetic Radiation, MA Heald and JB Marion, Saunders, 1983.
4. Electrodynamics, Gupta, Kumar, Singh, Pragathi prakashan,18 th edition, 2010.

MAJOR COURSE- MJ 14	Electrodynamics	(Practical Credit -01) (Total Marks=25)

1. Experimentally verify the boundary conditions for electric and magnetic fields at the interface of two different dielectric media.
2. Analyze the power flow in an EM wave using the Poynting vector concept.
3. Determine the penetration depth of electromagnetic waves in conductors at different frequencies.
4. Measure the reflection and transmission coefficients and verify Fresnel's equations.
5. Experimentally determine Brewster's angle and study polarization effects.
6. Simulate the time-dependent electric and magnetic fields due to an oscillating dipole.
7. Compute and visualize the electric and magnetic fields of a moving charge.
8. Simulate the dispersion relation for EM waves in a plasma medium. (computational)
9. Study wave propagation characteristics in different media using computational techniques. (computational)
10. Simulate how electric and magnetic fields transform under Lorentz transformations. (Computational)

Reference book

1. Advanced Practical Physics for Students" – B.L. Worsnop and H.T. Flint
2. Experiments in Modern Physics" – Adrian C. Melissinos
3. Computational Electrodynamics: The Finite-Difference Time-Domain Method" – Allen Taflove, Susan C. Hagness

MAJOR COURSE- MJ 15	Analog Electronics	(Theory Credit -03) (Total Marks=60+15)

Course Objective:

1. To introduce students to the basic concepts and applications of two-terminal devices, including rectifiers, diodes, LEDs, and photodiodes.
2. To develop a deep understanding of the working principles, characteristics, and applications of Bipolar Junction Transistors (BJTs) in different configurations.
3. To familiarize students with transistor biasing techniques and the analysis of transistor circuits in various configurations.
4. To provide knowledge on the design and analysis of amplifiers, with a focus on frequency response, feedback effects, and gain.
5. To explore the concept of sinusoidal oscillators and their use in electronics, including RC, Hartley, and Colpitts oscillators.
6. To introduce Junction Field Effect Transistors (JFET) and MOSFET, including their principles of operation and characteristics.
7. To provide a detailed study of operational amplifiers (Op-Amps) and their applications in analog circuits, including inverting and non-inverting amplifiers, and specialized circuits like integrators and differentiators.

Course Outcomes:

1. Students will be able to analyze and design various rectifier circuits using diodes, understanding their efficiency and ripple factors.
2. Students will gain proficiency in analyzing and designing amplifier circuits, including biasing methods, and understand the effects of feedback on circuit performance.
3. Students will be able to design and analyze sinusoidal oscillators and apply Barkhausen's criterion for determining the frequency of oscillations.
4. Students will understand the characteristics and applications of BJTs, JFETs, MOSFETs, and Op-Amps in real-world analog circuits.
5. Students will acquire the ability to design practical circuits using BJTs, FETs, and Op-Amps, solving problems related to gain, stability, and frequency response.
6. Students will be able to evaluate the performance of transistors in different regions and use load line analysis to find the Q-point and predict the behavior of amplifiers.

Course Contents:

Two-terminal Devices and their Applications (10 HRS): Rectifier Diode: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter, Zener Diode and Voltage Regulation. Principle and structure of LEDs, Photodiode and Solar Cell.

Bipolar Junction Transistors (10 HRS): n-p-n and p-n-p Transistors. Characteristics of CB, CE and CC Configurations. Current gains α and β, Relations between α and β. Load Line analysis of Transistors. DC Load line and Q-point. Physical mechanism of current flow, Active, Cutoff and Saturation Regions.

Amplifiers (10 HRS): Transistor Biasing and Stabilization Circuits. Fixed Bias and Voltage Divider Bias. Transistor as 2-port Network. h- parameter Equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model. Input and Output Impedance. Current, Voltage and Power Gains. Classification of Class A, B & C Amplifiers. Two stage RC-coupled amplifier and its freq. response. Effects of Positive and Negative Feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise.

Sinusoidal Oscillators (04 HRS): Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency. Hartley & Colpitts oscillators.

Junction field effect transistor (07 HRS); band structure; construction and working principle; current – voltage characteristics; Metal semiconductor contacts – Schottky and ohmic contacts with band structure; Depletion and Enhancement mode MOSFET: Principle and working; calculation of threshold voltage; V-I characteristics.

Operational Amplifiers and Applications (04 HRS): Characteristics of an Ideal and Practical Op- Amp. (IC 741) Open- loop and Closed-loop Gain. Frequency Response. CMRR. Slew Rate and concept of Virtual ground. Inverting and non-inverting amplifiers, Adder, Subtractor, Differentiator, Integrator, Log amplifier.

Reference Books:

1. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
2. A first Course in Electronics, Khan & Dey, PHI, 1/e, 2006
3. Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
4. Solid State Electronic Devices, B.G.Streetman&S.K.Banerjee, 6th Edn.,2009, PHI Learning
5. Electronic Devices & circuits, S.Salivahanan&N.S.Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill
6. OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
7. Basic Electronics, Arun Kumar, Bharati Bhawan, 1/e, 2007
8. Microelectronic circuits, A.S. Sedra, K.C. Smith, A.N. Chandorkar, 2014, 6th Edn., Oxford Univ Press.
9. Analog Systems and Applications, Nutan Lata, Pragati Prakashan
10. Electronic circuits: Handbook of design & applications, U.Tietze, C.Schenk,2008, Springer
11. Semiconductor Devices: Physics and Technology, S.M. Sze, 2nd Ed., 2002, Wiley India
12. Operational Amplifiers and their Applications, Subir Kumar Sarkar.

MAJOR COURSE- MJ 15	Analog Electronics	(Practical Credit-01) (Total Marks=25)

1. To study V-I characteristics of PN junction diode, and verification of diode equation.
2. To study the V-I characteristics of a Zener diode and its use as voltage regulator.
3. Half Wave and Full wave Rectifiers: Calculation of ripple factor and rectification efficiency.
4. To study the characteristics of a Bipolar Junction Transistor in CE configuration.
5. Push-Pull Amplifier.
6. To design an inverting amplifier using Op-amp (741,351) for dc voltage of given gain.
7. To design non-inverting amplifier using Op-amp (741,351) and study its frequency response.
8. Use of OP-Amp (741, 351) as an integrator and as a differentiator.
9. To measure (a) Voltage, and (b) Time period of a periodic waveform using CRO.
10. FET – characteristics, biasing and its applications as an amplifier.
11. MOSFET – characteristics, biasing and its applications as an amplifier.

Reference Books:

1. Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, Mc-GrawHill.
2. Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, Mc-GrawHill.
3. OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall.
4. Electronic Principle, Albert Malvino, 2008, Tata Mc-Graw Hill.
5. Electronic Devices & circuit Theory, R.L. Boylestad& L.D. Nashelsky, 2009, Pearson
6. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House
7. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted1985, Heinemann Educational Publishers