MAJOR COURSE- MJ 6	MATHEMATICAL PHYSICS- II	(Theory Credit -03) (Total Marks=60+15)

Course Objective:

This course introduces students to advanced mathematical techniques essential for solving problems in physics. It covers Fourier series, special functions, partial differential equations, and integral transforms, providing a strong foundation for theoretical and applied physics.

Course Outcomes:

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

1. **Understand and apply Fourier series** to represent periodic functions, determine Fourier coefficients, and use orthogonality properties of sine and cosine functions.
2. **Utilize complex Fourier series representation** and expand functions with arbitrary periods, including even and odd function expansions.
3. **Apply Fourier series techniques** to solve physical problems in heat conduction, signal processing, and wave analysis.
4. **Solve differential equations using the Frobenius method**, particularly in cases where power series solutions are needed.
5. **Analyze special functions** such as Legendre, Bessel, Hermite, and Laguerre functions, which frequently appear in physics problems.
6. **Understand the properties of Legendre polynomials**, including Rodrigues' formula, generating functions, orthogonality, and recurrence relations.
7. **Expand functions in a series of Legendre polynomials** and apply them to solve physics problems, especially in electrostatics and quantum mechanics.
8. **Understand Bessel functions**, their generating functions, recurrence relations, orthogonality, and the significance of their zeros.
9. **Solve partial differential equations (PDEs) using separation of variables** in Cartesian, cylindrical, and spherical coordinate systems.
10. **Apply PDE techniques to solve Laplace's equation** in symmetric physical problems.
11. **Solve the wave equation for vibrational modes of a stretched string**, understanding the role of boundary conditions.
12. **Understand Fourier transforms and the Fourier integral theorem** and apply them to represent non-periodic functions.
13. **Compute Fourier transforms** for trigonometric, Gaussian, and finite wave train functions.
14. **Express the Dirac delta function** as a Fourier integral and compute the Fourier transforms of derivatives.
15. **Understand inverse Fourier transforms** and their properties, including translation, scaling, and conjugation.
16. **Apply Fourier transforms to solve differential equations**, particularly in wave and heat conduction problems.
17. **Understand and compute Laplace transforms** for elementary functions and use properties such as shifting and scaling theorems.
18. **Evaluate Laplace transforms of derivatives and integrals** and apply them to solve differential equations.
19. **Compute the Laplace transform of the unit step function and periodic functions**, and use the convolution theorem in problem-solving.

This course equips students with essential mathematical techniques for advanced studies in quantum mechanics, electrodynamics, fluid mechanics, and other branches of physics.

Course Contents:

Fourier Series (10 HRS): Periodic functions. Orthogonality of sine and cosine functions, Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Complex representation of Fourier series. Expansion of functions with arbitrary period. Expansion of non-periodic functions over an interval. Even and odd functions and their Fourier expansions and its applications.

Frobenius Method and Special Functions (10 HRS): Frobenius method and its applications to differential equations. Legendre, Bessel, Hermite and Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. Expansion of function in a series of Legendre Polynomials, Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions ($J_0(x)$ and $J_1(x)$) and Orthogonality, Hermite differential equation. Rodrigues formula. Generating function. Recurrence relations. Orthogonality Laguerre differential equation. Rodrigues formula. Generating function. Recurrence relations.

Partial Differential Equations (05 HRS): Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string.

Integrals Transforms (10 HRS): Fourier Transforms: Fourier Integral theorem. Fourier Transform. Examples. Fourier transform of trigonometric, Gaussian, finite wave train & other functions. Representation of Dirac delta function as a Fourier Integral. Fourier transform of derivatives, Inverse Fourier transform, Properties of Fourier transforms (translation, change of scale, complex conjugation, etc.). Three dimensional Fourier transforms with examples. Application of Fourier Transforms to differential equations: One dimensional Wave and Diffusion/Heat Flow Equations.

Laplace Transforms (10 HRS): Laplace Transform (LT) of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of 1st and 2nd order Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. LT of Unit Step function, Periodic Functions. Convolution Theorem. Inverse LT. Application of Laplace Transforms to 2^{nd} order Differential Equations: Damped Harmonic Oscillator, Simple Electrical Circuits.

Reference Books:

1. Mathematical Methods for Physicists: Arfken, Weber, 2005, Harris, Elsevier.
2. Fourier Analysis by M.R. Spiegel, 2004, Tata McGraw-Hill.
3. Mathematics for Physicists, Susan M. Lea, 2004, Thomson Brooks/Cole.
4. Differential Equations, George F. Simmons, 2006, Tata McGraw-Hill.
5. Partial Differential Equations for Scientists & Engineers, S. J. Farlow, 1993, Dover Publication
6.

MAJOR COURSE- MJ 6	MATHEMATICAL PHYSICS- II	(Practical Credit-01) (Total Marks=25)

1. Write a program to compute and plot the Fourier series of a given periodic function, such as a square wave, triangular wave, or sawtooth wave. Visualize the convergence of the Fourier series by increasing the number of terms (harmonics) in the series. Observe how the approximation improves with more terms, and plot the original function alongside its Fourier series for comparison.
2. Write a program to compute and plot the first few Legendre polynomials Pn(x) using the recurrence relation or Rodrigues' formula. Plot these polynomials for different values of n and observe their behaviour as n increases. Compare the results with known properties of Legendre polynomials, such as orthogonal.
3. Implement a program to compute and plot the first few Bessel functions Jn(x) for varying n using a recurrence relation or integral representation. Visualize their behaviour for different values of x and analyze their oscillatory nature. Investigate the zeros of $J_0(x)$ and $J_1(x)$ and plot them.
4. Write a program to compute and plot the error function erf(x) for different values of x. Investigate its significance in statistics and probability, particularly in the context of normal distribution, and plot its values over a range of x.
5. Solve Laplace's equation in 2D or 3D using finite difference methods. Apply boundary conditions to the domain and observe the steady-state solutions. Visualize the potential field and analyze the effects of different boundary conditions on the solution.
6. Solve the 1D wave equation for a vibrating string using separation of variables or numerical methods like finite differences. Visualize the modes of vibration for various boundary conditions (fixed, free, etc.), and analyze how the wave propagates over time.
7. Write a program to compute and plot the Fourier transform of simple functions, such as a Gaussian, sine wave, or square pulse. Implement the inverse Fourier transform and verify the accuracy by comparing the transformed signal with the original function.
8. Solve the 1D diffusion equation using Fourier transforms. Visualize the evolution of the temperature distribution over time in a rod and observe how the solution behaves as time progresses.
9. Write a program to compute the Laplace transform and inverse Laplace transform of common functions like exponential, sine, and cosine. Use these transforms to solve second-order differential equations, such as the damped harmonic oscillator, and visualize the solution in the time domain.
10. Use Laplace transforms to model an electrical circuit consisting of resistors, capacitors, and inductors. Solve for the voltage and current in the circuit and visualize the transient response over time. Investigate the effect of varying component values on the circuit's behaviour

Reference 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. Mathematics for Physicists, P. Dennery and A. Krzywicki, 1967, Dover Publications
3. Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer ISBN: 978-3319067896
4. A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press.
5. Scilab by example: M. Affouf, 2012. ISBN: 978-1479203444
6. Scilab (A free software to Matlab): H. Ramchandran, A. S. Nair. 2011 S. Chand & Company.
7. Scilab Image Processing: Lambert M. Surhone. 2010 Betascript Publishing.

MAJOR COURSE- MJ 7	Heat and Thermodynamics	(Theory Credit -03) (Total Marks=60+15)

Course Objective:

This course provides a comprehensive understanding of the fundamental principles of heat and thermodynamics. It covers real gas behavior, thermodynamic laws, transport phenomena, thermodynamic potentials, and radiation theory. The course aims to develop problem-solving skills in classical thermodynamics and prepare students for advanced topics in statistical mechanics and thermal physics.

Course Outcomes:

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

1. **Understand the deviations of real gases from the ideal gas behavior** and analyze them using the Virial equation.
2. **Explain the concept of critical constants** and Boyle temperature and apply Van der Waals' equation of state to real gases.
3. **Interpret P-V diagrams and the Law of Corresponding States** to understand phase transitions in gases.
4. **Analyze free adiabatic expansion of a perfect gas** and study the Joule-Thomson effect for real and Van der Waals gases.
5. **Determine the Joule-Thomson coefficient** and understand the concept of the temperature of inversion.
6. **Explain transport phenomena in gases**, including mean free path, viscosity, thermal conductivity, and diffusion.
7. **Apply the First Law of Thermodynamics** to different thermodynamic processes, including isothermal and adiabatic processes.
8. **Derive relations between heat capacities (CP and CV)** and understand their implications in various thermodynamic systems.
9. **Calculate work done during isothermal and adiabatic processes** and apply these concepts to practical problems.
10. **Differentiate between reversible and irreversible processes** and understand their significance in thermodynamics.
11. **Explain the Second Law of Thermodynamics**, including the concepts of entropy, Carnot's cycle, and Carnot's theorem.
12. **Calculate entropy changes in reversible and irreversible processes** and interpret entropy-temperature diagrams.
13. **Understand the Third Law of Thermodynamics** and its implications on the unattainability of absolute zero.
14. **Define thermodynamic potentials** such as internal energy, enthalpy, Helmholtz free energy, and Gibbs free energy and explain their physical significance.
15. **Derive Maxwell's relations and apply them** to thermodynamic problems such as the Clausius-Clapeyron equation and TdS equations.
16. **Analyze first and second-order phase transitions** and their relevance in condensed matter physics.
17. **Explain the principles of black-body radiation** and the spectral distribution of radiation.
18. **Derive and apply laws of radiation**, including Stefan-Boltzmann law, Wien's displacement law, and Rayleigh-Jeans law.
19. **Understand Planck's hypothesis** and derive Planck's law of black-body radiation.

20. **Apply the concept of mean energy of an oscillator** to explain quantum aspects of thermal radiation.

This course builds a solid foundation in thermodynamics and heat transfer, preparing students for further studies in statistical mechanics, condensed matter physics, and thermal engineering.

Course Contents:

Behavior of Real Gases (12 HRS): Deviations from the Ideal Gas Equation. The Virial Equation. Critical Constants. Boyle Temperature. Van der Waal's Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States. P-V diagrams. Free Adiabatic Expansion of a Perfect Gas. Joule-Thomson Porous Plug Experiment. Joule-Thomson Effect for Real and Van Der Waal Gases. Temperature of Inversion. Joule- Thomson Cooling.

Transport Phenomena in Gases (05 HRS): Mean Free Path, Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: Viscosity, Thermal Conductivity and Diffusion.

Laws of thermodynamics (13 HRS): Zeroth Law of thermodynamics, Concept of heat, Work done, Internal energy, First law of thermodynamics, conversion of heat into work, Various thermodynamical Processes, Applications of First Law: General Relation between C_P and C_V, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Coefficient, Reversible and irreversible processes, Second law, Entropy, Carnot's cycle & theorem, Entropy changes in reversible and irreversible processes, Entropy-temperature diagrams, Third law of thermodynamics, unattainability of absolute Zero.

Thermodynamic Potentials & Maxwell's Relations (10 HRS): Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy, their definitions, properties and applications, cooling due to adiabatic demagnetization, first and second order Phase Transitions with examples, derivations and applications of Maxwell's Relations, Maxwell's Relations :(1) Clausius Clapeyron equation, (2) Values of Cp-Cv, TdS Equations.

Theory of radiation (05 HRS): Spectral Distribution of Black Body Radiation, Stefan-Boltzmann law, Wien's displacement law, Rayleigh-Jeans law, Planck's Hypothesis, Mean energy of an oscillator and Planck's law.

Reference Books:

1. Core Physics for Class 11, S B Mathur & A Kumar, Bharati Bhawan, Patna.
2. A Treatise on Heat, Meghnad Saha, and B. N. Srivastava, 1958, Indian Press
3. Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition, 1993, Tata McGraw-Hill
4. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer.
5. Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa.
6. Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Ed., 2012, Oxford University
7. Heat and Thermodynamics, Brij Lal and Subramanian.

MAJOR COURSE- MJ 7	Heat and Thermodynamics	(Practical Credit-01) (Total Marks=25)

1. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
2. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee's disc method.
3. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT).
4. To study the variation of Thermo-Emf of a Thermocouple with Difference of Temperature of its Two Junctions.
5. To calibrate a thermocouple to measure temperature in a specified Range using (1) Null Method and to determine Neutral Temperature.
6. Determination of Stefan's constant.
7. Verification of Planks radiation formulae.

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. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.
4. A Laboratory Manual of Physics for undergraduate classes, D.P. Khandelwal,1985, Vani Pub.

MAJOR COURSE- MJ 8	Digital Electronics	(Theory Credit -03) (Total Marks=60+15)

Course Objective:

The course provides an introduction to digital electronics, focusing on digital circuits, logic gates, Boolean algebra, arithmetic circuits, sequential circuits, and memory systems. It aims to equip students with the knowledge of designing and analyzing digital systems, both combinational and sequential, using fundamental concepts such as logic gates, flip-flops, timers, shift registers, and counters. Additionally, the course will introduce memory systems and microprocessors, preparing students for further studies in digital system design and microprocessor-based systems.

Course Outcomes:

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

1. **Differentiate between analog and digital circuits** and understand the significance of binary, octal, and hexadecimal number systems.
2. **Convert numbers between decimal, binary, octal, and hexadecimal** and understand the importance of BCD (Binary-Coded Decimal) representation in digital systems.
3. **Understand the basic logic gates** such as AND, OR, NOT, NAND, NOR, XOR, and XNOR, and apply these gates to build simple digital circuits.
4. **Apply Boolean algebra** to simplify logical circuits using Boolean laws and De Morgan’s Theorems, and convert truth tables into equivalent logic circuits using Sum of Products (SOP) method and Karnaugh Maps (K-map).
5. **Design and analyze binary arithmetic circuits** for addition and subtraction using 2’s complement and implement half and full adders, subtractors, and a 4-bit binary adder/subtractor.
6. **Understand sequential circuits** and design flip-flops, including SR, D, and JK flip-flops, both level-triggered and edge-triggered, and resolve issues like race-around conditions in JK flip-flops.
7. **Apply IC 555 timers** in astable and monostable multivibrator configurations for practical applications.
8. **Design and implement shift registers** of various types (SISO, SIPO, PISO, PIPO) and understand their use in serial and parallel data storage and transfer.
9. **Design and work with 4-bit counters**, including ring counters, asynchronous counters, decade counters, and *synchronous counters.
10. **Understand the principles of A/D conversion** using resistive networks and successive approximation, and evaluate the accuracy and resolution in conversion systems.
11. **Gain knowledge of memory systems**, including ROM, RAM, and DRAM basics, and understand their roles in digital circuits.
12. **Familiarize with microprocessors**, including the evolution of microprocessors, registers in the 8085 microprocessor, and the concept of data and address bus multiplexing.

By the end of the course, students will be able to design and analyze both combinational and sequential digital systems and understand the essential components used in memory and microprocessor-based systems.

Course Contents:

Digital Circuits (07 HRS): Introduction to the difference between analog and digital circuits. Binary numbers, conversions between decimal to binary and binary to decimal. BCD, octal, and hexadecimal number systems. Logic gates: AND, OR, NOT, NAND, NOR (universal gates), XOR, and XNOR.

Boolean algebra (08 HRS): Introduction to Boolean algebra, including de Morgan's Theorems and Boolean laws. Simplification of logical circuits using Boolean algebra. Understanding fundamental products, minterms, and maxterms. Conversion of truth tables to equivalent logic circuits using: 1. Sum of Products (SOP) method, Product of Sum(POS) 2. Karnaugh Maps (K-map) for simplification of Boolean expressions.

Arithmetic Circuits (05 HRS): Binary arithmetic: Binary addition, subtraction using 2's complement. Construction and working of half and full adders, half and full subtractors. Design and working of a 4-bit binary adder/subtractor.

Sequential Circuits (07 HRS): Overview of sequential circuits and flip-flops: SR, D, and JK flip-flops. Level-triggered and edge-triggered flip-flops. Preset and clear operations. Race-around condition in JK flip-flops and its resolution. Master/Slave JK flip-flop.

Timers (03 HRS): Classification of ICs: Linear and Digital ICs. Introduction to the IC 555 timer: Block diagram and its applications in astable multivibrator and monostable multivibrator configurations.

Shift registers (04 HRS): Types of shift registers: Serial-in-Serial-out (SISO), Serial-in-Parallel-out (SIPO), Parallel-in-Serial-out (PISO), and Parallel-in-Parallel-out (PIPO) shift registers (up to 4 bits).

Counters (4 bits) (03 HRS): Design and working of 4-bit counters: Ring counter, Asynchronous counters, Decade counters, and Synchronous counters.

Conversion (02 HRS): Resistive networks (Weighted and R-2R Ladder). Accuracy and resolution in conversion. Principles of A/D conversion using successive approximation.

Memory & Microprocessor (06 HRS): Overview of memory types: ROM (Read Only Memory), RAM (Random Access Memory), and DRAM basics. Introduction to microprocessors: Evolution of microprocessors, registers in 8085, data and address bus multiplexing in 8085, RISC and CISC instruction sets.

Reference Books:

1. Digital Computer Electronics, Malvino and Brown, 3/e, McGraw Hill Education
2. Digital Electronics G K Kharate ,2010, Oxford University Press
3. Digital Systems: Principles & Applications, R. J. Tocci, N. S. Widmer, 2001, PHI Learning
4. Logic circuit design, Shimon P. Vingron, 2012, Springer.
5. Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.
6. Digital Electronics, S.K. Mandal, 2010, 1st edition, McGraw Hill
7. Digital design, Moris Mano

MAJOR COURSE- MJ 8	Digital Electronics	(Practical Credit-01) (Total Marks=25)

1. To design a switch (NOT gate) using a transistor.
2. To verify and design AND, OR, NOT and XOR gates using NAND gates.
3. To design a combinational logic system for a specified Truth Table.
4. To convert a Boolean expression into logic circuit and design it using logic gate ICs.
5. To minimize a given logic circuit.
6. Half Adder, Full Adder and 4-bit binary Adder.
7. Half Adder and Full Adder Truth table verification using I.C.
8. To build Flip-Flop (RS, Clocked RS, D-type and JK) circuits using NAND gates.
9. To design an astable multivibrator of given specifications using 555 Timer.
10. To design a monostable multivibrator of given specifications using 555 Timer.