SEMESTER I (HONS.)

Core T1 – Mathematical Physics TEACHER: TM & TS

60 Lectures	4 Credits
Calculus	**20 Lectures**
Recapitulation: Limits, continuity, average and instantaneous quantities, differentiation. Plotting functions. Intuitive ideas of continuous, differentiable, etc. functions and plotting of curves. Approximation: Taylor and binomial series (statements only). Convergence condition of Taylor series and corresponding tests. First Order and Second Order Differential equations: First Order Differential Equations and Integrating Factor. Homogeneous and Inhomogeneous Equations with constant coefficients, particular integral. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems. Particular Integral. Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers.	
Vector Calculus	**30 Lectures**
Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields. Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities using Kronecker delta and Levi-civita symbols. Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes	

Theorems and their applications (no rigorous proofs). Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.	
Introduction to probability	**10 Lectures**
Independent random variables: Probability distribution functions; binomial, Gaussian, and Poisson, with examples. Mean and variance. Dependent events: Conditional Probability. Bayes' Theorem.	

Core P1 – Mathematical Physics Lab TEACHER: DB & SS

60 class hours	2 credits

General Topics

Computer architecture and organization, memory and Input/output devices.

Basics of scientific computing: Binary and decimal arithmetic, Floating point numbers, algorithms, Sequence, Selection and Repetition, single and double precision arithmetic, underflow &overflow- emphasize the importance of making equations in terms of dimensionless variables, Iterative methods.

Errors and error Analysis: Truncation and round off errors, Absolute and relative errors, Floating point computations.

Introduction to plotting graphs with QtiPlot (or equivalent)

Basic 2D and 3D graph plotting - plotting functions and datafiles, fitting data using qtiplot's fit function, polar and parametric plots, modifying the appearance of graphs, Surface and contour plots, exporting plots.

Introduction to programming in python:

- Python as a number calculator
- algebraic calculation through python interactively
- help searching
- standard I/O statements
- program with formula crunching
- string, list, tuple and the corresponding methods
- Control structures

Programs as applications

• finite series summation • Taylor series summation with a given precision
File handling in Python
• File I/O statements
Least square fitting
• Linear and linearised Least square fitting with supplied data
User defined functions in Python
• User defined function, default argument.
synthetic data generation and plotting
• synthetic data generation and plotting with QtiPlot (or equivalent).
Finding largest and smallest values within a dataset
• Finding largest and smallest values over a time-series data. • Estimating largest and smallest values of a function within an interval using fixed step size.
Solution of Algebraic and Transcendental equations
• Root finding: Bisection & New Raphson Method (Initial guess to be determined by plotting) for non-linear equations. • Applications in simple physical problems (including those of mathematical Physics)

CORE T2 – MECHANICS **TEACHER: SC & RM**

60 Lectures	**4 Credits**
Fundamentals of Dynamics	**5 Lectures**
Reference frames. Inertial frames; Review of Newton's Laws of Motion. Galilean transformations; Galilean invariance. Momentum of variable- mass system: motion of rocket. Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum. Impulse.	
Work and Energy	**4 Lectures**
Work and Kinetic Energy Theorem. Conservative and non- conservative forces. Potential Energy. Qualitative study of one dimensional motion from potential energy curves. Stable and unstable equilibrium. Elastic potential energy. Force as gradient of potential energy. Work & Potential energy. Work done by non-conservative forces. Law of conservation of Energy.	
Collisions	**3 Lectures**
Elastic and inelastic collisions between particles. Centre of Mass and Laboratory frames.	
Rotational Dynamics	**10 Lectures**
Angular momentum of a particle and system of particles. Torque. Principle of conservation of angular momentum. Rotation about a fixed axis. Moment of Inertia. Perpedicular axes theorem and parallel axes theorem and their applications in calculations of moment of inertia for rectangular, cylindrical and spherical bodies. Kinetic energy of rotation. Motion involving both translation and rotation.	
Elasticity	**6 Lectures**
Relation between Elastic constants. Twisting torque on a Cylinder or Wire. Bending of a beam – internal bending moment..	

Fluid Motion	**4 Lectures**
Kinematics of Moving Fluids: Equation of continuity. Idea of streamiline and turbulent flow, Reynold's number. Poiseuille's Equation for Flow of a viscous Liquid through a Capillary Tube.	
Gravitation and Central Force Motion	**9 Lectures**
Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere. Motion of a particle under a central force field. Two-body problem and its reduction to one-body problem and its solution. The energy equation and energy diagram. Kepler's Laws. Satellite in circular orbit and applications. Geosynchronous orbits. Weightlessness. Basic idea of global positioning system (GPS).	
Oscillations	**7 Lectures**
SHM: Simple Harmonic Oscillations. Differential equation of SHM and its solution. Kinetic energy, potential energy, total energy and their time-average values. Damped oscillation. Forced oscillations: Transient and steady states; Resonances, sharpness of resonance; power dissipation and Quality Factor.	
Non-Inertial Systems:	**4 Lectures**
Non-inertial frames and fictitious forces. Uniformly rotating frame. Laws of Physics in rotating coordinate systems. Centrifugal force. Coriolis force and its applications.	
Special Theory of Relativity	**8 Lectures**
Michelson-Morley Experiment and its outcome. Postulates of Special Theory of Relativity. Lorentz Transformations. Simultaneity and order of events. Lorentz contraction. Time dilation. Relativistic transformation of velocity, frequency and wave number. Relativistic addition of velocities.Relativistic Doppler effect.	

Core P2 – Mechanics Lab TEACHER: TM & TS

60 class hours	2 Credits

General Topic

Discussion on random errors in observations. Measurement principles of length (or diameter) using vernier caliper, screw gauge and travelling microscope. Discussion on the parts of Sextant.

List of Practical

1. To study the random error in observations of time period of some oscillation using chronometer.
2. To determine the Moment of Inertia of a regular body using another auxilary body and a cradle suspeded by a metalic wire.
3. To determine g and velocity for a freely falling body using Digital Timing Technique
4. To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
5. To determine the Young's Modulus by flexure method.
6. To determine the Modulus of Rigidity of a Wire by a torsional pendulum.
7. To determine the height of a building using a Sextant.
8. To determine the elastic Constants of a wire by Searle's method.
9. To determine the value of g using Bar Pendulum.
10. To determine the value of g using Kater's Pendulum.
11. To study the Motion of Spring and calculate, (a) Spring constant, (b) g and (c) Modulus of rigidity.

SEMESTER I (GEN)

GE T1 - Mechanics TEACHER: TM, TS & RM

60 Lectures	4 Credits
Mathematical Methods	
Vectors: Vector algebra. Scalar and vector products. Derivatives of a vector with respect to a parameter. Ordinary Differential Equations: 1st order homogeneous differential equations. 2nd order homogeneous and inhomogeneous differential equations with constant coefficients.	
Particle Dynamics	
Laws of Motion: Frames of reference. Newton's Laws of motion. Dynamics of a system of particles. Centre of Mass. Momentum and Energy: Conservation of momentum. Work and energy. Conservation of energy. Motion of rockets.Rotational Motion: Angular velocity and angular momentum. Torque. Conservation of angular momentum.	
Gravitation	
Gravitation: Newton's Law of Gravitation. Motion of a particle in a central force field (motion is in a plane, angular momentum is conserved, areal velocity is constant). Kepler's Laws (statement only). Satellite in circular orbit and applications. Geosynchronous orbits. Weightlessness. Basic idea of global positioning system (GPS).	
Oscillations	
Oscillations: Differential equation of SHM and its solutions. Kinetic and Potential Energy, Total Energy and their time averages. Damped oscillations. Forced harmonic oscillations, resonance.	

Elasticity
Hooke's law - Stress-strain diagram - Elastic moduli-Relation between elastic constants - Poisson's Ratio-Expression for Poisson's ratio in terms of elastic constants - Work done in stretching and work done in twisting a wire - Twisting couple on a cylinder - Determination of Rigidity modulus by static torsion – Torsional pendulum.- Bending of beam.
Special Theory of Relativity
Special Theory of Relativity: Constancy of speed of light. Postulates of Special Theory of Relativity. Length contraction. Time dilation. Relativistic addition of velocities.

GE P1 – Mechanics Lab TEACHER : SC & RM

60 class hours	**2 Credits**
List of Practical	
1. To study the random error in observations of time period of some oscillation using chronometer. 2. To determine the Moment of Inertia of a regular body using another auxilary body and a cradle suspeded by a metalic wire. 3. To determine g and velocity for a freely falling body using Digital Timing Technique 4. To determine the Young's Modulus by flexure method. 5. To determine the Modulus of Rigidity of a Wire by a torsional pendulum. 6. To determine the height of a building using a Sextant. 7. To determine the elastic Constants of a wire by Searle's method. 8. To determine the value of g using Bar Pendulum. 9. To determine the value of g using Kater's Pendulum. 10. To study the Motion of Spring and calculate, (a) Spring constant, (b) g and (c) Modulus of rigidity.	

SEMESTER III(HONS.)

Core T5 - Mathematical Physics-II **TEACHER : TM & TS**

60 Lectures	**4 Credits**
Fourier Series	**10 Lectures**
Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Euler relation -- 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. Application. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity.	
Frobenius Method and Special Functions	**25 Lectures**
Singular Points of Second Order Linear Differential Equations and their importance. 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. Multipole expansion in Electrostatics. Orthonormality of Hermite and Laguerre polynomials (statements only). Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions (Jo(x) and J1(x))and Orthogonality. Airy's disc for Fraunhofer diffraction through circular aperture, resolving power of a telescope.	
Some Special Integrals	**4 Lectures**
Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral).	
Variational calculus in physics	**5 Lectures**

Idea of functionals. Euler-Lagrange equation from calculus of variation. Idea of constraints (holonomic only), degrees of freedom and generalised co-ordinates. Hamilton's principle and Lagrange's equation from it.

Analytical Dynamics	**10 Lectures**

Applications of Lagrange's equation in simple problems. Canonically cojugate momentum. Idea of cyclic co-ordinate and conservation principles from different symmetries.

Idea of Legendre transformation. Its application in mechanics and thermodynamics. Definition of Hamiltonian. Canonical equations of motion. Poisson bracket and its properties. Time variation of a dynamical variable in terms of in terms of Poisson bracket and the condition related to the constants of motion.

Partial Differential Equations	**6 Lectures**

Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular symmetry. Wave equation and its solution for vibrational modes of a stretched string.

Core P5 – Mathematical Physics II Lab TEACHER : DB & SS

60 class hours	2 Credits
General Topics: Introduction to the python numpy module. Arrays in numpy, array operations, array item selection, slicing, shaping arrays. Introduction to online graph plotting using matplotlib. Use scipy to generate Legendre Polynomials and Bessel function and then plot those using matplotlib. Detailed discussion on the underlying theory of the following numerical methods including efficiency of the method in each case. Simple physical problems based on these methods are to be introduced.	
Sorting:	
• bubble sort • insertion sort	
Statistical Calculations :	
• mean, median and standard deviation for a set of discrete data points	
Interpolation:	
• Newton-Gregory forward & backward formula	
Numerical differentiation	
• Forward and Backward difference formula	
Numerical Integration	
• By trapezoidal rule. • By Simpson's 1/3 rd rule.Integration by stochastic method	
Integration by stochastic method	
• Monte Carlo random dot method	
Solution of ODE First order Differential equation	
• Euler Method	

Core T6 - Thermal Physics **TEACHER: SC & RM**

60 Lectures	**4 Credits**
Introduction to Thermodynamics	**25 Lectures**
Zeroth and First Law of Thermodynamics: Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics & Concept of Temperature, Concept of Work & Heat, State Functions, First Law of Thermodynamics and its differential form, Internal Energy, First Law & various processes, Applications of First Law: General Relation between CP and CV, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient. Second Law of Thermodynamics: Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine & efficiency. Refrigerator & coefficient of performance, 2nd Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence. Carnot's Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale. Entropy: Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Temperature–Entropy diagrams for Cycle. Third Law of Thermodynamics. Unattainability of Absolute Zero.	
Thermodynamic Potentials	**15 Lectures**
Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy. Their Definitions, Properties and Applications. Surface Films and Variation of Surface Tension with Temperature. Magnetic Work, Cooling due to adiabatic demagnetization (basic principle only), First and second order Phase Transitions with	

examples, Clausius Clapeyron Equation and Ehrenfest equations Derivations and applications of Maxwell's Relations, Maxwell's Relations:(1) Clausius Clapeyron equation, (2) Values of Cp-Cv, (3) TdS Equations, (4) Joule-Kelvin coefficient for Ideal and Van der Waal Gases, (5) Energy equations, (6) Change of Temperature during Adiabatic Process.	
Kinetic Theory of Gases	**20 Lectures**
Distribution of Velocities: Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases. Molecular Collisions: Mean Free Path. Collision Probability. Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance. Real Gases: Behavior of Real Gases: Deviations from the Ideal Gas Equation. The Virial Equation. Andrew's Experiments on CO2 Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapour and Gas. Boyle Temperature. Van der Waal's Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States. Comparison with Experimental Curves. P-V Diagrams. Joule's Experiment. 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.	

Core P6 – Thermal Physics Lab TEACHER: SC & SS

60 class hours	2 Credits

General Topics:

Discussion on logscale plot to study power law dependence, decay constant etc. Discussion on the properties of PRT, thermocouple, diode sensor etc.

List of Practical

1. Verification of Stefan's law using a torch bulb.
2. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.
3. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT) using constant current source
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 by Null Method using a potentiometer.
6. To calibrate a thermocouple to measure temperature in a specified Range by direct measurement using Op-Amp differential amplifier and to determine Neutral Temperature
7. Mesuring unknown temperature using a diode sensor.
8. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
9. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
10. To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.

Core T7 - Digital Systems and Applications TEACHER : DB & SS

60 Lectures	**4 Credits**
Introduction	**4 Lectures**
Electronic Components and Measuring devices (which are generally used for studying the following circuits) and their general Characteristics, Cathode-Ray Oscilloscope(CRO), Block diagram of CRO. Electron Gun. Deflection System and Time Base. Deflection Sensitivity. Applications of CRO:1)Study of waveform, 2) Measurement of Voltage , Current, Frequency and Phase difference.	
Integrated Circuits	**5 Lectures**
Active & Passive components. Discrete components. Wafer. 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.	
Digital Circuits	**16 Lectures**
Difference between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers. De Morgan's Theorems. Boolean Laws. AND, OR and NOT Gates (realization using Diodes and Transistor). Simplification of Logic Circuit using Boolean Algebra. NAND and NOR Gates as Universal Gates. XOR and XNOR Gates and application as Parity Checkers. Fundamental Products. Idea of Minterms and Maxterms. Conversion of a Truth table into Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map.	
Arithmatic circuits	**5 Lectures**
Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor.	
Data processing circuits	**5 Lectures**
Basic idea of Multiplexers, De-multiplexers, Decoders, Encoders.	
Sequential circuits	**6 Lectures**

SR, D, and JK Flip-Flops. Clocked (Level and Edge Triggered) Flip-Flops. Preset and Clear operations. Race-around conditions in JK Flip-Flop. M/S JK Flip-Flop. M/S JK Flip-Flop, Combinational logic for the development of sequential circuit.	
Timers	**4 Lectures**
IC 555: block diagram and applications: Astable multivibrator and Monostable multivibrator.	
Registers	**4 Lectures**
Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out and Parallel-in-Parallel-out Shift Registers (only up to 4 bits).	
Counters (4 bits)	**4 Lectures**
Ring Counter. Asynchronous counters, Decade Counter. Synchronous Counter.	
Computer Organization	**7 Lectures**
Input/Output Devices. Data storage (idea of RAM and ROM). Computer memory. Memory organization & addressing. Memory Interfacing. Memory Map.	

Core P7 – Digital Systems and Applications Lab TEACHER: TS & RM

60 class hours	2 Credits

1) In the Beginning of practical course a *brief history of development of electronics* should be introduced.
2) In continuation of the previous topic, physically introduce the Valve, Transformer, Resistance, Capacitor, Potentiometer etc. and also Impotant measuring instruments (viz. digital & analog multimeter, power supply, function generator, Oscilloscope) to be used in the following experiments. Describe their characteristics with an explanation of their working principle).
3) In rest of the all practical classes: Approximately 25% of the class period should be used in introducing the perspectives and importance of the experiments to be done; details of the experiments and discussion on the observations of last class.1. a) To measure (a) Voltage, and (b) Time period of a periodic waveform using CRO.

List of Practical

1. a) To measure (i) Voltage, and (ii) Time period of a periodic waveform using CRO.

   b) To test a Diode and Transistor using a Multimeter.

2. a) To design a switch (NOT gate) using a transistor.

   b) To verify and design AND, OR, NOT and XOR gates using NAND gates.

3. For a given truth table find logic equation, minimize and design the circuit using logic gate ICs.

4. Half Adder, Full Adder and 4-bit binary Adder.

5. To build Flip-Flop (RS, D-type and JK) circuits using NAND gates.

6. To design an astable multivibrator of given specifications using 555 Timer.

7. To design a monostable multivibrator of given specifications using 555 Timer.

8. Half Subtractor, Full Subtractor, Adder-Subtractor using Full Adder I.C.

9. To build JK Master-slave flip-flop using Flip-Flop ICs

10. To build a 4-bit Counter using D-type/JK Flip-Flop ICs and study timing diagram.

11. To make a 4-bit Shift Register (serial and parallel) using D-type/JK Flip-Flop ICs.

SEC T4 - Basic Instrumentation Skills TEACHER: DB & SS

30 class hours	2 Credits
Basic of Measurement	
Instruments accuracy, precision, sensitivity, resolution range etc. Errors in measurements and loading effects. Multimeter: Principles of measurement of dc voltage and dc current, ac voltage, ac current and resistance. Specifications of a multimeter and their significance.	
Electronic Voltmeter	
Advantage over conventional multimeter for voltage measurement with respect to input impedance and sensitivity. Principles of voltage, measurement (block diagram only). Specifications of an electronic Voltmeter/ Multimeter and their significance. AC millivoltmeter: Type of AC millivoltmeters: Amplifier-rectifier, and rectifier- amplifier. Block diagram ac millivoltmeter, specifications and their significance.	
Cathode Ray Oscilloscope	
Block diagram of basic CRO. Construction of CRT, Electron gun, electrostatic focusing and acceleration (Explanation only– no mathematical treatment), brief discussion on screen phosphor, visual persistence & chemical composition. Time base operation, synchronization. Front panel controls. Specifications of a CRO and their significance. Use of CRO for the measurement of voltage (dc and ac frequency, time period. Special features of dual trace, introduction to digital oscilloscope, probes. Digital storage Oscilloscope: Block diagram and principle of working.	
Signal Generators and Analysis Instruments	
Block diagram, explanation and specifications of low frequency signal generators. Pulse generator, and function generator. Brief idea for testing, specifications. Distortion factor meter, wave analysis.	
Impedance Bridges & Q-Meters	
Block diagram of bridge: working principles of basic (balancing type) RLC bridge. Specifications of RLC bridge. Block diagram & working principles of a Q- Meter. Digital LCR bridges.	
Digital Instruments	

Principle and working of digital meters. Comparison of analog & digital instruments. Characteristics of a digital meter. Working principles of digital voltmeter.

Digital Multimeter

Block diagram and working of a digital multimeter. Working principle of time interval, frequency and period measurement using universal counter/ frequency counter, time- base stability, accuracy and resolution.

The test of lab skills will be of the following test items:

1. Use of an oscilloscope.
2. CRO as a versatile measuring device.
3. Circuit tracing of Laboratory electronic equipment,
4. Use of Digital multimeter/VTVM for measuring voltages
5. Circuit tracing of Laboratory electronic equipment,
6. Winding a coil / transformer.
7. Study the layout of receiver circuit.
8. Trouble shooting a circuit
9. Balancing of bridges

Laboratory Exercises

1. To observe the loading effect of a multimeter while measuring voltage across a low resistance and high resistance.
2. To observe the limitations of a multimeter for measuring high frequency voltage and currents.
3. To measure Q of a coil and its dependence on frequency, using a Q- meter.
4. Measurement of voltage, frequency, time period and phase angle using CRO.
5. Measurement of time period, frequency, average period using universal counter/ frequency counter.
6. Measurement of rise, fall and delay times using a CRO.
7. Measurement of distortion of a RF signal generator using distortion factor meter.
8. Measurement of R, L and C using a LCR bridge/ universal bridge.

Open Ended Experiments

1. Using a Dual Trace Oscilloscope
2. Converting the range of a given measuring instrument (voltmeter, ammeter)

GE T3 - Thermal Physics and Statistical Mechanics TEACHER: RM & SC

60 Lectures	**4 Credits**
Laws of Thermodynamics	
Thermodynamic Description of system: Zeroth Law of thermodynamics and temperature. First law and internal energy, conversion of heat into work, Various Thermodynamical Processes, Applications of First Law: General Relation between CP and CV, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Coefficient, Reversible and irreversible processes, Second law and Entropy, Carnot's cycle & theorem, Entropy changes in reversible & irreversible processes, Entropy-temperature diagrams, Third law of thermodynamics, Unattainability of absolute zero.	
Thermodynamical Potentials	
Enthalpy, Gibbs, Helmholtz and Internal Energy functions, Maxwell's relations and applications - Joule-Thompson Effect, Clausius- Clapeyron Equation, Expression for (CP – CV), CP/CV, TdS equations.	
Kinetic Theory of Gases	
Derivation of Maxwell's law of distribution of velocities and its experimental verification, Mean free path (Zeroth Order), Transport Phenomena: Viscosity, Conduction and Diffusion (for vertical case), Law of equipartition of energy (no derivation) and its applications to specific heat of gases; mono-atomic and diatomic gases.	
Theory of Radiation	
Blackbody radiation, Spectral distribution, Concept of Energy Density, Derivation of Planck's law, Deduction of Wien's distribution law, Rayleigh- Jeans Law, Stefan Boltzmann Law and Wien's displacement law from Planck's law.	
Statistical Mechanics	
Phase space, Macrostate and Microstate, Entropy and Thermodynamic probability, Maxwell-Boltzmann law - distribution of velocity - Quantum statistics (qualitative discussion only) - Fermi-Dirac distribution law (statement only) - electron gas as an example of Fermi gas - Bose-Einstein distribution law (statement only) - photon gas as an example of Bose gas- comparison of three statistics.	

GE P3 – Thermal Physics and Statistical Lab TEACHER: TM & TS

60 class hours	2 Credits
List of Practical	

1. Verification of Stefan's law using a torch bulb.
2. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.
3. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT).using constant current source
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 by Null Method using a potentiometer.
6. To calibrate a thermocouple to measure temperature in a specified Range by direct measurement using Op-Amp differential amplifier and to determine Neutral Temperature
7. Measurement of unknown temperature using Diode sensor.
8. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
9. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
10. To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.

SEMESTER V(HONS.)

Core T11 - Quantum Mechanics and Applications TEACHER : TM & RM

60 Lectures	4 Credits

Basic Formalism	12 Lectures

Departure from matter wave description. Quantum mechanics as a new framework to describe the rules of the microscopic world. Postulates of quantum mechanics: State as a vector in a complex vector space, inner product, its properties using Dirac bra-ket notation. Physical observables as Hermitian operators on state space – eigenvalues, eigenvectors and completeness property of the eigenvectors – matrix representation. Measurement statistics. Unitary time-evolution. Demonstration of the rules in 2-level systems.

Wave-function as the probability amplitude distribution of a state for the observables with continuous eigenvalues. Position representation and momentum representation of wave-functions and operators. Position, momentum and Hamiltonian operators. Non-commuting observables and incompatible measurement, uncertainty relation. Position-momentum uncertainty principle as an example.

Commuting observables and degeneracy; complete set of commuting observables.

Schrodinger Equation	12 Lectures

Time dependent Schrodinger equation: Time dependent Schrodinger 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 and Linear Superposition Principles of the solutions of Schoedinger equation. Wave Function of a Free Particle. Explanation of wave-particle duality in two slit experiment with microscopic particles from the above formalism.

Time independent Schrodinger equation-Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wavefunction as a linear combination of energy eigenfunctions; General solution of the time dependent Schrodinger equation in terms of linear

combinations of stationary states; Application to spread of Gaussian wave-packet for a free particle in one dimension; wave packets, Fourier transforms and momentum space wave-function; consistency with position-momentum uncertainty principle. Quantum mechanical scattering and tunnelling in one dimension-across a step potential & rectangular potential barrier. Tunnelling effect in the case of alpha decay and in scanning tunnel microscopes (qualitative discussion only).	
Bound states in an arbitrary potential	**8 Lectures**
Bound states – continuity of wave function, boundary condition and emergence of discrete energy levels. One dimensional infinitely rigid box- energy eigenvalues and eigenfunctions, normalization; generalisation for three dimension and degeneracy of energy levels. Quantum dot as example. Quantum mechanics of simple harmonic oscillator-energy levels and energy eigenfunctions; Hermite polynomials; ground state, zero point energy & uncertainty principle. Raising-lowering operator and their applications.	
Quantum theory of hydrogen-like atoms	**10 Lectures**
Time independent Schrodinger equation in spherical polar coordinates with spherically symmetric potential; separation of variables for second order partial differential equation; angular momentum operators, commutation relations, ladder operators & quantum numbers; spherical co-ordinate representation of angular momentum operators. Radial wavefunctions for Coulomb potential; shapes of the probability densities for ground & first excited states. Commuting observables and degeneracy of energy levels. Orbital angular momentum quantum numbers l and m; s, p, d,shells-subshells. Applications for Hydrogen atom, He^+ ion, positronium and alikes.	
Applications of Quantization Rules in Atomic Physics	**18 Lectures**
Absence of exact stationary state solutions for relativistic effects and for multi-electron atoms. Approximate description by semi-classical vector model of atoms.	

Electron angular momentum quantization rules. Space quantization. Orbital Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr magneton. Electron Spin as relativistic quantum effect (qualitative discussion only), Spin Angular Momentum. Spin Magnetic Moment. Stern-Gerlach Experiment. Larmor Precession.

Multi-electron atoms. Pauli's Exclusion Principle (statement only). Spectral Notations for atomic States. Aufbau principle, $n+l$ rule (qualitative discussion only). Periodic table.

Spin orbit interaction. Addition of angular momentum (statement only). Total angular momentum of electron. Total energy level correction due to relativistic effects and spin-orbit interaction (statement only). Fine structure splitting.

Normal and Anomalous Zeeman Effect, Lande g factor, Paschen Back effect. Stark Effect (Qualitative Discussion only).

Spin-orbit coupling in atoms – L-S and J-J coupling schemes. Hund's Rule. Term symbols. Spectra of Hydrogen and Alkali Atoms (Na etc.). Mosley's law and its explanation from Bohr theory.

Core P11 – Quantum Mechanics and Applications Lab TEACHER : DB &SS

60 class hours	**2 Credits**
General Topics: Detailed discussion on the underlying theory of the following numerical methods including efficiency of the method in each case.	
List of Practical	

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

   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) and m = $0.511x10^6$ eV/c^2.

2. Solve the s-wave radial Schrodinger equation for an atom:

   where m is the reduced mass of the system (which can be chosen to be the mass of an electron), for the screened coulomb potential

   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 = 0.511x106 eV/c2, 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:

   For the anharmonic oscillator potential

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/c^2, 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:

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

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 = 940x106eV/C^2, D = 0.755501 eV, α = 1.44, r_o = 0.131349 Å

Core T12 - Solid State Physics **TEACHER : SC & DB**

60 Lectures	**4 Credits**
Crystal Structure	**12 Lectures**
Solids: 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. Laue's condition and Bragg's Law. Structure Factor.	
Elementary Lattice Dynamics	**10 Lectures**
Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, its limitations. Einstein's theories of specific heat of solids, its limitations.	
Magnetic Properties of Matter	**8 Lectures**
Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of dia– and Paramagnetic Domains. Quantum Mechanical Treatment of Paramagnetism. Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains. Discussion of B-H Curve. Hysteresis and Energy Loss.	
Dielectric Properties of Materials	**8 Lectures**
Polarization. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability. Clausius Mosotti Equation. Classical Theory of Electric Polarizability. Normal and Anomalous Dispersion. Cauchy and Sellmeir relations. Langevin-Debye equation. Complex Dielectric Constant. Optical Phenomena.	
Ferroelectric Properties of Materials	**6 Lectures**
Structural phase transition, Classification of crystals, Piezoelectric effect, Pyroelectric effect, Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop.	

Drude's theory	**6 Lectures**
Free electron gas in metals, effective mass, drift current, mobility and conductivity, Hall effect in metals. Thermal conductivity. Lorentz number, limitation of Drude's theory	
Elementary band theory	**10 Lectures**
Kronig Penny model. Band Gap. Conductor, Semiconductor (P and N type) and insulator. Conductivity of Semiconductor, mobility, Hall Effect. Measurement of conductivity (04 probe method) & Hall coefficient.	
Superconductivity	**6 Lectures**
Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth. Isotope effect.	

Core P12 – Solid State Physics Lab TEACHER : DB & SC

60 class hours	2 Credits
General Topics: Discussion on the operation of the relevant circuits used for the different studies in the following experiments.	
List of Practical	

1. To determine the Coupling Coefficient of a Piezoelectric crystal.
2. To measure the Dielectric Constant of a dielectric Materials with frequency
3. To study the characteristics of a Ferroelectric Crystal.
4. To draw the BH curve of Fe using Solenoid & determine energy loss from Hysteresis.
5. To measure the resistivity of a semiconductor (Ge) with temperature by reverse bias characteristics of Ge diode (room temperature to 80 oC) and to determine its band gap.
6. To determine the Hall coefficient of a semiconductor sample.
7. To study temperature coefficient of a semiconductor (NTC thermistor)
8. Measurement of susceptibility of paramagnetic solution (Quinck`s Tube Method)
9. To measure the Magnetic susceptibility of Solids.
10. To determine the complex dielectric constant and plasma frequency of metal using Surface Plasmon resonance (SPR)
11. To determine the refractive index of a dielectric layer using SPR

DSE – Advanced Dynamics **TEACHER : DB & SS**

75 Lectures	**6 Credits**
Lagrangian & Hamiltonian Dynamics	**15 Lectures**
Lagrange's equation for the cases with semi-holonomic constraints. Evaluation of constraint forces in general. Simple problems with both time-dependent and time independent constraints. Idea of canonical transformations. Generating functions. Properties of canonical transformation. Invariance of Poisson bracket. Use of canonical transformations in solving Hamilton's equations; harmonic oscillator problem as test case.	
Rigid Body Mechanics	**10 Lectures**
Definition of rigid body. General motion as combination of translation and rotation. Rotation of rigid body and the relation between its angular momentum and angular velocity. Moment of inertia and product of inertia. Kinetic energy of rotation. Principal axis transformation and principal moments of inertia, application in simple cases. Euler equations for free top and their solutions describing the motion of symmetric bodies.	
Small Amplitude Oscillations	**10 Lectures**
Minima of potential energy and points of stable equilibrium, expansion of the potential energy around a minimum, small amplitude oscillations about the minimum, normal modes of oscillations example of N identical masses connected in a linear fashion to (N -1) - identical springs.	
Dynamical Systems	**25 Lectures**
Definition of a continuous dynamical system. The idea of phase space, flows and trajectories. Autonomous and non-autonomous systems, dimensionality. Linear stability analysis to study the behaviour of an 1-dimensional autonomous system. Illustration of the	

method using the single particle system described by v=f(x) and comparing it with the exact analytical solution. Extension of the method for simple mechanical systems as 2-dimensional dynamical systems, categorisation of equilibrium/fixed points : illustrations for the free particle, particle under uniform gravity, simple and damped harmonic oscillator (both under-damped and over-damped). Sketching flows and trajectories in phase space; sketching variables as functions of time, relating the equations and pictures to the underlying physical intuition. Study on the behaviour of the quartic oscillator with an attractive or repulsive quadratic term in the potential; idea of bifurcation. Phase space diagram for the general motion of a pendulum and its behaviour. Oscillator with non-linear damping, Van-der-Pol oscillator as the example, behaviour in large dqamping limit, idea of limit cycle.

Discrete time dynamical systems, examples. Description by iterative map. Logistic map: Dynamics from time series. Cobweb iteration (using calculator or simple programs only). Fixed points. Parameter dependence- steady, periodic and chaos states. Idea of chaos and Lyapunov exponent.

Fluid Dynamics	**15 Lectures**

Basic physics of fluids: The continuum hypothesis- concept of fluid element or fluid parcel; Definition of a fluid- shear stress; Fluid properties- viscosity, thermal conductivity, mass diffusivity, other fluid properties and equation of state; Flow phenomena- flow dimensionality, steady and unsteady flows, uniform & non-uniform flows, viscous & inviscid flows, incompressible & compressible flows, laminar and turbulent flows, rotational and irrotational flows. Euler equation and Navier-Stokes equation, qualitative description of turbulence, Reynolds number.

DSET4 - Nuclear and Particle Physics **TEACHER : TS & SS**

75 Lectures	**6 Credits**
General Properties of Nuclei	**10 Lectures**
Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excites states.	
Nuclear Models	**12 Lectures**
Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas), evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force.	
Radioactivity decay	**10 Lectures**
(a) Alpha decay: basics of α-decay processes, theory of α- emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy. (b) □-decay: energy kinematics for □-decay, positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission & kinematics, internal conversion.	
Nuclear Reactions	**8 Lectures**
Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct Reaction, resonance reaction, Coulomb scattering (Rutherford scattering).	
Interaction of Nuclear Radiation with matter	**8 Lectures**
Energy loss due to ionization (Bethe- Block formula), energy loss of electrons, Cerenkov	

radiation. Gamma ray interaction through matter, photoelectric effect, Compton scattering, pair production, neutron interaction with matter.	
Detector for Nuclear Radiations	**8 Lectures**
Gas detectors: estimation of electric field, mobility of particle, for ionization chamber and GM Counter. Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT). Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector.	
Particle Accelerators	**5 Lectures**
Accelerator facility available in India: Van-de Graaff generator (Tandem accelerator), Linear accelerator, Cyclotron, Synchrotrons.	
Particle physics	**14 Lectures**
Particle interactions; basic features, types of particles and its families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, concept of quark model, color quantum number and gluons.	

SEMESTER V (GEN)

GE T5 - Digital, Analog Circuits and Instrumentation

TEACHER: SC & DB

60 Lectures	**4 Credits**
Digital Circuits	**15 Lectures**
Difference between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion, AND, OR and NOT Gates (Realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates. 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 Binary Addition. Binary Subtraction using 2's Complement Method). Half Adders and Full Adders and Subtractors, 4-bit binary Adder-Subtractor.	
Semiconductor Devices and Amplifiers	**15 Lectures**
Semiconductor Diodes: P and N type semiconductors. Barrier Formation in PN Junction Diode. Qualitative Idea of Current Flow Mechanism in Forward and Reverse Biased Diode. PN junction and its characteristics. Static and Dynamic Resistance. Principle and structure of (1) LEDs, (2) Photodiode, (3) Solar Cell Bipolar Junction transistors: n-p-n and p-n-p Transistors. Characteristics of CB, CE and CC Configurations. Active, Cutoff & Saturation regions Current gains α and β. Relations between α and β. Load Line analysis of Transistors. DC Load line & Q- point. Voltage Divider Bias Circuit for CE Amplifier. H-parameter, Equivalent Circuit. Analysis of single-stage CE amplifier using hybrid Model. Input & output Impedance. Current, Voltage and Power gains. Class A, B & C Amplifiers.	

Operational Amplifiers (Black Box approach)	**14 Lectures**
Characteristics of an Ideal and Practical Op-Amp (IC 741), Open-loop and closed- loop Gain. CMRR, concept of Virtual ground. Applications of Op-Amps: (1) Inverting and non-inverting Amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Zero crossing detector. Sinusoidal Oscillators: Barkhausen's Criterion for Self-sustained Oscillations. Determination of Frequency of RC Oscillator	
Instrumentations	**16 Lectures**
Introduction to CRO: Block Diagram of CRO. Applications of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference. Power Supply: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers Calculation of Ripple Factor and Rectification Efficiency, Basic idea about capacitor filter, Zener Diode and Voltage Regulation. Timer IC: IC 555 Pin diagram and its application as Astable and Monostable Multivibrator.	

GE P5 – Digital, Analog Circuits and Instruments Lab

TEACHER: TM & RM

60 class hours	**2 Credits**
List of Practical	

1. To measure (a) Voltage, and (b) Frequency of a periodic waveform using CRO
2. To verify and design AND, OR, NOT and XOR gates using NAND gates.
3. To minimize a given logic circuit.
4. Half adder, Full adder and 4-bit Binary Adder.
5. Adder-Subtractor using Full Adder I.C.
6. To design an astable multivibrator of given specifications using 555 Timer.
7. To design a monostable multivibrator of given specifications using 555 Timer.
8. To study IV characteristics of PN diode, Zener and Light emitting diode
9. To study the characteristics of a Transistor in CE configuration.
10. To design a CE amplifier of given gain (mid-gain) using voltage divider bias.
11. To design an inverting amplifier of given gain using Op-amp 741 and study its frequency response.
12. To design a non-inverting amplifier of given gain using Op-amp 741 and study its Frequency Response.
13. To study Differential Amplifier of given I/O specification using Op-amp.
14. To investigate a differentiator made using op-amp.
15. To design a Wien Bridge Oscillator using an op-amp.