

## Semester V

### **Curriculum and Credit Framework for Undergraduate Programme of Physics Hons. (single Major) w.e.f. 2024 (NEP 2020)**

Course	Course Code	Name of the Paper	Course Type/ Nature	Teaching Scheme in hour per week			Credit	Marks
				Th	Pr	T		
CC- 8	PHSUMC C508	Mathematical Physics-III	Theory	4	0	0	4	50 (ESE=40, IA-7,CA-3)
CC- 9	PHSUMC C509	Mathematical Physics-II and Thermal Physics	Practical		8	0	4	50 CIA=30 ESE=20 (Expt=15, Viva=5)
CC-10	PHSUMC C510	Classical Mechanics	Theory	4	0	0	4	50
CC-11	PHSUMC C511	Modern Physics	Theory	4	0	0	4	50
DSE1	PHSUDSE 501	Advanced Analog and Digital Electronics	Theory	4	0	0	4	50
GE1C (MIC)	PHSUMIC 503	Electricity, Magnetism and EM Theory	Theory	4	0	0	4	50

**Th**= Lecture, **T**= Tutorial, **Pr** = Practical, **CC** - Core Course, **DSE**=Discipline Specific Elective, **IA**= Internal Assessment, **CA**= Class attendance.

**CIA**=Continuous Internal assessment, **ESE**=End semester examination, **Expt.**=Experiment

## CC-8: MATHEMATICAL PHYSICS-III

(Credits: 04, Lectures 60)

*The idea of this course is to teach some advanced mathematical concepts and applications of them into physics. The numerical methods and algorithms related to the same ideas are developed in order to compute through Python.*

**Vector spaces:** Vector spaces of  $n$  dimensions, inner product, Schmidt's orthogonalisation, Schwarz and Bessel inequality. **(5 lectures)**

**Complex Analysis:** Brief Revision of Complex Numbers and their Graphical Representation. Euler's formula, De Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity, branch cuts. Integration of a function of a complex variable. Cauchy's Inequality. Cauchy's Integral formula. Simply and multiply connected region. Laurent and Taylor's expansion. Residues and Residue Theorem. Application in solving Definite Integrals.

**(20 Lectures)**

### **Integrals Transforms:**

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, Convolution theorem. 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 transform and inverse Laplace transform. Solution of differential equation using Laplace transform.

**(20 Lectures)**

**Group Theory:** Definition and nomenclature; Rearrangement theorem; Cyclic groups, Subgroups and Cosets; Conjugate elements and class structure; factor groups; Isomorphy and Homomorphy; Direct product groups; Symmetric groups, Cayley's theorem; Representation of finite groups, Definition, Unitary representation, Schur's Lemma, Orthogonality theorem, Reducible and irreducible representations, Introduction to Lie groups. **(15 Lectures)**

### **Reference Books:**

- Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3<sup>rd</sup> ed., 2006, Cambridge University Press
- Mathematics for Physicists, P. Dennery and A. Krzywicki, 1967, Dover Publications
- Complex Variables, A.S. Fokas & M.J. Ablowitz, 8<sup>th</sup> Ed., 2011, Cambridge Univ. Press
- Complex Variables, A.K. Kapoor, 2014, Cambridge Univ. Press
- Complex Variables and Applications, J.W. Brown & R.V. Churchill, 7<sup>th</sup> Ed. 2003, Tata McGraw-Hill
- First course in complex analysis with applications, D.G. Zill and P.D. Shanahan, 1940, Jones & Bartlett

# CC9 : Mathematical Physics-II and Thermal Physics Practical

(Credits: 4, Practical)

## Group-A

### (Mathematical Physics-II)

#### Computation in Python with Numpy, Scipy and Matplotlib packages:

Introduction to the python numpy module. Arrays in numpy, array operations, array item selection, slicing, shaping arrays. Basic linear algebra using the linalg submodule. Introduction to online graph plotting using matplotlib. Introduction to the scipy module. Uses in optimization and solution of differential equations. Introduction to OCTAVE (if time permits)

#### Curve fitting, Least square fit, Goodness of fit, standard deviation:

Ohms law to calculate R, Hooke's law to calculate spring constant.

#### Solution of Linear system of equations by Gauss elimination method and Gauss Seidal method. Diagonalization of matrices, Inverse of a matrix, Eigen vectors, eigen values problems:

Solution of mesh equations of electric circuits (3 meshes)

Solution of coupled spring mass systems (3 masses)

#### Generation of Special functions using User defined functions

Generating and plotting Legendre Polynomials Generating and plotting Bessel function.

#### Solution of ODE: First order Differential equation - Euler, modified Euler and Runge-Kutta second order, 4<sup>th</sup> order, Second order differential equation Fixed difference method:

First order differential equation

1. Radioactive decay
2. Current in RC, LC circuits with DC source
3. Newton's law of cooling
4. Classical equations of motion Second order Differential Equation
5. Harmonic oscillator (no friction)
6. Damped Harmonic oscillator
7. Over damped
8. Critical damped
9. Oscillatory
10. Forced Harmonic oscillator
11. Transient and
12. Steady state solution
13. Apply above to LCR circuits also
14. Solve  $x^2 \frac{d^2y}{dx^2} - 4x(1+x) \frac{dy}{dx} + 2(1+x)y = x^3$  with the boundary condition at  $x=1, y = \frac{1}{2}e^2$ ,  $\frac{dy}{dx} = \frac{-3}{2}e^2 - 0.5$ , in the range  $1 \leq x \leq 3$ . Plot  $y$  and  $\frac{dy}{dx}$  against  $x$  in the given range in the same graph.

### **Partial differential equations:**

1. Wave equation
2. Heat equation
3. Poisson equation
4. Laplace equation

### **References of Books:**

- Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
- Complex Variables, A.S. Fokas & M.J. Ablowitz, 8th Ed., 2011, Cambridge Univ. Press
- Numpy beginners guide, Idris Alba, 2015, Packt Publishing
- Computational Physics, D.Walker, 1st Edn., 2015, Scientific International Pvt. Ltd.

### **Group-B (Thermal Physics)**

1. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
2. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
3. To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.
4. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.
5. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT).
6. To study the variation of Thermo-Emf of a Thermocouple with Difference of Temperature of its Two Junctions.
7. To calibrate a thermocouple to measure temperature in a specified Range using (1) Null Method, (2) Direct measurement using Op-Amp difference amplifier and to determine Neutral Temperature.

### **Reference Books**

- Advanced Practical Physics for students, B. L. Flint and H.T. Worsnop, 1971, Asia Publishing House
- A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11<sup>th</sup> Ed., 2011, Kitab Mahal
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4<sup>th</sup> Edition, reprinted 1985, Heinemann Educational Publishers.
- A Laboratory Manual of Physics for undergraduate classes, D.P. Khandelwal, 1985, Vani Pub.

## **CC 10: CLASSICAL MECHANICS:**

### **Theory**

**(Credits: 04, Lectures 60)**

*This course is to understand some advanced ideas and methods of Classical Mechanical systems. In addition, this includes the concepts and some simple applications of two other related subjects.*

**Classical Mechanics of Point Particles:** Review of Newtonian Mechanics, Lagrange and Hamiltonian of different systems, Lagrange & Hamiltonian for Non conservative system, Velocity-dependent potential, dissipation function, charge particle is moving in an electro-magnetic field, Gauge function for Lagrangian,

Canonical Transformations, Legendre Transformation, Poisson Bracket, Lagrange Bracket, Phase Space, Liouville's Theorem, Routhian Function. **(10 Lectures)**

**Fluid Dynamics:** Density  $\rho$  and pressure  $P$  in a fluid, an element of fluid and its velocity, continuity equation and mass conservation, Dynamics of ideal fluids, Euler Equation, Application of Bernoulli's theorem, Bernoulli's equation for gases. Navier-Stokes equation, qualitative description of turbulence, Reynolds number.

**(10 Lectures)**

**Calculus of Variation:** Hamilton's principle from Newton's equation & D'Alembert's Principle, Lagrange's equation from Hamilton's Principle, Euler-Lagrange equation, Principle of least action, Modified Hamilton's Principle, Hamilton's Canonical equations. **(10 Lectures)**

**Hamilton-Jacobi Theory,** Hamilton- Jacobi equation for Hamilton's Principle function, Physical significance of Hamilton's Principle function. Hamilton- Jacobi equation for Hamilton's Characteristics function. Physical significance of Hamilton's Characteristics function. Action angle Variables.

**(10 Lectures)**

**Small Amplitude Oscillations:** 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.

**(5 Lectures)**

**Special Theory of Relativity:** Postulates of Special Theory of Relativity. Lorentz Transformations. Minkowski space. The invariant interval, light cone and world lines. Space-time diagrams. Time-dilation, length contraction and twin paradox. Four-vectors: space-like, time-like and light-like. Four-velocity and acceleration. Metric and alternating tensors. Four-momentum and energy-momentum relation. Doppler effect from a four-vector perspective. Concept of four-force. Conservation of four-momentum. Relativistic kinematics. Application to two-body decay of an unstable particle.

**(15 Lectures)**

### Reference Books:

- Classical Mechanics, H.Goldstein, C.P. Poole, J.L. Safko, 3<sup>rd</sup> Edn. 2002, Pearson Education.
- Mechanics, L. D. Landau and E. M. Lifshitz, 1976, Pergamon.
- Classical Electrodynamics, J.D. Jackson, 3<sup>rd</sup> Edn., 1998, Wiley.
- The Classical Theory of Fields, L.D Landau, E.M Lifshitz, 4<sup>th</sup> Edn., 2003, Elsevier.
- Introduction to Electrodynamics, D.J. Griffiths, 2012, Pearson Education.
- Classical Mechanics, P.S. Joag, N.C. Rana, 1<sup>st</sup> Edn., McGraw Hall.
- Classical Mechanics, R. Douglas Gregory, 2015, Cambridge University Press.
- Classical Mechanics: An introduction, Dieter Strauch, 2009, Springer. Solved Problems in classical Mechanics, O.L. Delange and J. Pierrus, 2010, Oxford Press.

## CC 11: MODERN PHYSICS

(Credits: 04, Lectures 60)

*The idea behind this course is to understand the empirical approach to understand atomic and molecular systems. Some classic and some modern experiments are set to elucidate the ideas behind the quantum properties of matter.*

### Origin of Quantum Physics:

**Particle Aspect of radiation:** Blackbody radiation, Planck's quantum, Planck's constant and light as a collection of photons ; Photo-electric effect, Compton scattering and Pair Production. (4 Lectures)

**Wave Aspect of particles:** De Broglie wavelength and matter waves; Davisson-Germer experiment, Matter waves for macroscopic and microscopic objects. (2 Lectures)

**Particle Versus Wave:** Classical and quantum view of particles and waves, Two slit interference experiment with photons, atoms and particles; linear superposition principle as a consequence, Measurements interfere the state of microscopic objects, Position measurement- gamma ray microscope thought experiment; Wave-particle duality, Complementarity principle, Representation of particle as a localized wave packet, Motion of a wave packet, Group and Phase velocities and relation between them. (5 Lectures)

**Indeterministic nature of the microphysical world:** Heisenberg's uncertainty principle, Derivation from Wave Packets, Fourier Transform and momentum space wavefunction, Impossibility of a particle following a trajectory; Probabilistic Interpretation Estimating minimum energy of a confined particle using uncertainty principle; Energy-time uncertainty principle- application to virtual particles and range of an interaction.

(8 Lectures)

**Atomic Transition and Spectroscopy:** Bohr model of hydrogen atom, Energy levels and spectroscopy of hydrogen atom, de Broglie's hypothesis and Bohr's quantization condition. Experimental evidence of spin, Stern-Gerlach experiment. (3 Lectures)

**Schrodinger equation for non-relativistic particles;** Momentum and Energy operators; solution of Schrodinger equation for time independent potential, stationary states; Expansion of an arbitrary wavefunction as a linear combination of energy eigenfunctions; physical interpretation of a wave function, probabilities and normalization; Conditions for physical acceptability of wave functions, Probability and probability current densities in one dimension. (6 Lectures)

**Applications:** Properties of one dimensional motion, discrete spectrum( bound states), continuous spectrum (unbound states), Mixed spectrum, Symmetric potentials and parity; One dimensional infinitely symmetric and asymmetric square well potential- energy eigenvalues and eigenfunctions, normalization; Extension of idea to 3D case, degeneracy; Quantum dot as example Solution of delta function potential,; Quantum mechanical scattering and tunnelling in one dimension-across a step potential & rectangular potential barrier. (10 Lectures)

Size and structure of atomic nucleus and its relation with atomic weight; Impossibility of an electron being in the nucleus as a consequence of the uncertainty principle. Nature of nuclear force, NZ graph, Liquid Drop model: semi-empirical mass formula and binding energy, Nuclear Shell Model and magic numbers.

(6 Lectures)

Radioactivity: stability of the nucleus; Law of radioactive decay; Mean life and half-life; Alpha decay; Beta decay- energy released, spectrum and Pauli's prediction of neutrino; Gamma ray emission, energy-momentum conservation: electron-positron pair creation by gamma photons in the vicinity of a nucleus.

**(8 Lectures)**

Fission and fusion- mass deficit, relativity and generation of energy; Fission - nature of fragments and emission of neutrons. Nuclear reactor: slow neutrons interacting with Uranium 235; Fusion and thermonuclear reactions driving stellar energy (brief qualitative discussions).

**(3 Lectures)**

**Lasers:** Einstein's A and B coefficients. Metastable states. Spontaneous and Stimulated emissions. Optical Pumping and Population Inversion. Three-Level and Four-Level Lasers. Ruby Laser and He-Ne Laser. Basic lasing.

**(5 Lectures)**

### **Reference Books:**

- Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.
- Introduction to Modern Physics, Rich Meyer, Kennard, Coop, 2002, Tata McGraw Hill
- Introduction to Quantum Mechanics, David J. Griffith, 2005, Pearson Education.
- Physics for scientists and Engineers with Modern Physics, Jewett and Serway, 2010, Cengage Learning.
- Modern Physics, G. Kaur and G.R. Pickrell, 2014, McGraw Hill
- Quantum Mechanics: Theory & Applications, A.K. Ghatak & S. Lokanathan, 2004, Macmillan

### **Additional Books for Reference**

- Modern Physics, J.R. Taylor, C.D. Zafiratos, M.A. Dubson, 2004, PHI Learning.
- Theory and Problems of Modern Physics, Schaum's outline, R. Gautreau and W. Savin, 2<sup>nd</sup> Edn, Tata McGraw-Hill Publishing Co. Ltd.
- Quantum Physics, Berkeley Physics, Vol.4. E.H. Wichman, 1971, Tata McGraw-Hill Co.
- Basic ideas and concepts in Nuclear Physics, K. Heyde, 3<sup>rd</sup> Edn., Institute of Physics Pub.
- Six Ideas that Shaped Physics: Particle Behave like Waves, T.A. Moore, 2003, McGraw Hill

## **DSE1: Advanced Analog and Digital Electronics:**

**(Credits: 04, Lectures 60)**

*Students will learn about the principles and properties of analog electronic systems and their applications. Different laboratory techniques are taught and relevant experiments are performed to supplement the learning.*

### **Group-A**

**(Advanced Analog Electronics)**

**Coupled Amplifier:** Two stage RC coupled amplifier and its frequency response. **( 2 lectures)**

**FET and MOSFET :** Basic principles and operations of FET and MOSFET. **(4 Lectures)**

**Elements of Communication:** Principle of amplitude modulation (AM) and frequency modulation(FM). , AM spectrum and FM spectrum, channel band width and signal band width, side band frequency, Generation of transmitted carrier and suppressed carrier type AM signals with necessary circuits, principles of detection of different types of modulated signals (TC and SC types), principles of generation of FM wave with necessary

circuits, Detection of FM. Wave Discriminators. ( 6 lectures)

**Radio wave propagation:** Ground wave, Ionospheric wave and space and space wave and their characteristics, reflection and refraction of radio waves in ionosphere, critical frequency, skip distance, Maximum usable frequency, fading, Secant law, duet propagation. ( 5 lectures)

**Antenna:** Dipole antenna, half wave antenna, antenna with two half elements, N element array, Induction field and retardation field. ( 5 Lectures)

**Network analysis:** Network theorems, equivalent circuits, two-port parameters hybrid parameters, Topological descriptions of different commonly used networks,  $\Pi$  to  $T$  and  $T$  to  $\Pi$  conversions, reduction of a complicated network into its equivalent  $T$  and  $\Pi$  form.

**Filter Circuit:** L filter,  $\pi$  filter, iterative impedance, image impedance of a network, symmetrical network, characteristic impedance and propagation constant of a network. Methods of development of different constant-k filters like high pass, low pass, band pass, and band stop filter circuits. ( 8 lectures)

**Transmission Lines:** Line parameters, characteristic impedance and propagation constant of a transmission line, voltage and current equations of transmission line: Telegraphers's equation, attenuation constant, phase constant, line of finite length behaving as a line of infinite length, reflection coefficient in a line, velocity of signal in a line, voltage standing wave ratio, input impedance of Lossless line, line at radio frequency, distortion less line, cable fault location telephone cable. ( 5 lectures)

## Group-B:

### ( Advanced Digital Electronics)

**Combinational circuits:** MUX, DeMUX, Encoder, Decoder, comparator, A to D and D to A conversion. Resistive network (Weighted and R-2R Ladder). Accuracy and Resolution. A/D Conversion (Successive approximation) ( 5 lectures)

**The ALU:** ALU organization, Integer representation, Serial and parallel Adders, 1's and 2's complement arithmetic, Multiplication of signed binary numbers, Floating point representation, overflow detection, Status flag. ( 5 lectures)

**Memory unit:** Memory classification, Bipolar and MOS storage cells. Organization of RAM, address decoding, Registers and stack, ROM, PROM, EPROM, EEPROM, SRAM, DRAM and FPLA. Organization and erasing schemes, Magnetic memories, Optical Memories, Semiconductor memories. ( 5 Lectures)

**Review of 8085 Microprocessor :** Internal structure, organization and assembly language, Microprocessor programming. ( 5 Lectures)

**Basic Idea of Digital Communication:** Sampling theorem, Pulse amplitude modulation, Quantization, Pulse Coded communication System. ( 5 Lectures)

# GE1C (MIC) : Electricity, Magnetism and EM Theory

(Credits: 4, Lectures 60)

*This course offers fundamental concepts of electricity and magnetism. Students learn the ideas through problem solving and laboratory experiments. Applications involve electrical and magnetic properties of matter, electrical networks and devices.*

**Electrostatics:** Electrostatic Field, electric flux, Gauss's theorem of electrostatics. Applications of Gauss theorem- Electric field due to point charge, infinite line of charge, uniformly charged spherical shell and solid sphere, plane charged sheet, charged conductor. Electric potential as line integral of electric field, potential due to a point charge, electric dipole, uniformly charged spherical shell and solid sphere. Calculation of electric field from potential. Capacitance of an isolated spherical conductor. Parallel plate, spherical and cylindrical condenser. Energy per unit volume in electrostatic field. Dielectric medium, Polarisation, Displacement vector. Gauss's theorem in dielectrics. Parallel plate capacitor completely filled with dielectric.

(25 Lectures)

## **Magnetism:**

Magnetostatics: Biot-Savart's law and its applications- straight conductor, circular coil, solenoid carrying current. Divergence and curl of magnetic field. Magnetic vector potential. Ampere's circuital law. Magnetic properties of materials: Magnetic intensity, magnetic induction, permeability, magnetic susceptibility. Brief introduction of dia-, para-and ferro- magnetic materials.

(10 Lectures)

**Electromagnetic Induction:** Faraday's laws of electromagnetic induction, Lenz's law, self and mutual inductance, L of single coil, M of two coils. Energy stored in magnetic field.

(6 Lectures)

**Maxwell's equations and Electromagnetic wave propagation:** Equation of continuity of current, Displacement current, Maxwell's equations, Poynting vector, energy density in electromagnetic field, electromagnetic wave propagation through vacuum and isotropic dielectric medium, transverse nature of EM waves, polarization.

(10 Lectures)

**Electrical Circuits:** AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and (3) Quality Factor, and (4) Band Width. Parallel LCR Circuit.

(5 Lectures)

**Network theorems:** Ideal Constant-voltage and Constant-current Sources. Network Theorems: Thevenin theorem, Norton theorem, Superposition theorem, Reciprocity theorem, Maximum Power Transfer theorem. Applications to dc circuits.

(4 Lectures)

## **Reference Books:**

- Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education
- Electricity & Magnetism, J.H. Fewkes & J. Yarwood. Vol. I, 1991, Oxford Univ. Press
- Electricity and Magnetism, D C Tayal, 1988, Himalaya Publishing House.
- University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.

D.J.Griffiths, Introduction to Electrodynamics, 3rd Edn, 1998, Benjamin Cummings.