Structure of B.Sc. (3 Year Major in Physics)/ B.Sc. (4 Year Hons in Physics)/ B.Sc. (4 Year Hons with Research)/ Minor in Physics/B.Sc. Multidisciplinary Stream (Physics as one of the Core Subjects)

Note:

- **For 3 Year Major in Physics : First Six Semesters are to successfully completed**
- **For 4 in Hons in Physics : Alll eight semesters are to be successfully completed**
- **For 4 Year Hons with Research : In Semester VII only DS-18 is to be studied and the remaining credits are to be earned through a 15 credit research Paper code**

All Major and Minor courses are of 5 Credits. The courses which has 'P' written in the parenthesis are divided into 3 credits of Theory (45 Lectures per semester) and 2 credits of Laboratory (60 Hours per semester). Other Major/ Minor courses are of full 5 credits (60 Lectures per semester + 15 hours of Tutorial)

Six CORE courses are enlisted (CORE 1-COR-6) one in each semester. These are for B.Sc. in Multidisciplinary Stream.

A student with Minor in Physics and Major in any other discipline will have to study 4 courses.
Those are shown in the next table as:

Minor1, Minor 2, Minor3 and S Minor 1 (Semester I, II, III and VII respectively)

Physics department will offer only one MD course, namely, Current *perspectives of Physics.*
A student who has major in any discipline other than Physics and does not have Physics as Minor discipline may choose this course in one of the first three semesters (Only course code will be accordingly different) and a student of 3 year multidisciplinary stream who does not have Physics as a CORE discipline may choose the same course in one of the last three semesters. Only the course code will be appropriately changed.

This document contains the full 4- year structure and the detailed syllabus of the first year only. Remaining part of the detailed syllabus will be communicated as soon as possible.

List of Courses Under NEP 2020

To be effective from 2023-24

Major

Semester	Major	Minor/ CORE	MDC	SEC
I	Mathematical Methods I (P) DS-I PHSDSC101T+PHSDSC101P	Mechanics (P) Minor1/CORE1 PHSMIN101T+ PHSMIN101P/ PHSCOR101T+ PHSCOR101P	Current perspectives of Physics – MDC (Physics) PHSHMD101M	Basic Instrumentation Skills SEC-1 (3) PHSHSE101M
II	Mechanics I (P) (DS-2) PHSDSC202T+PHSDSC202P	Electricity and Magnetism (P) – Minor 2/ CORE2 PHSMIN202T+ PHSMIN202P/ PHSCOR202T+ PHSCOR202P	Current perspectives of Physics – MDC (Physics) PHSHMD201M	Computational Physics Skills SEC-2 (3) PHSHSE201M
III	Waves and Optics (P) DS-3 PHSDSC303T+PHSDSC303P	Fluids and Waves (P) - Minor 3/ CORE3 PHSMIN303T+ PHSMIN303P/ PHSCOR303T+ PHSCOR303P	Current perspectives of Physics – MDC (Physics) PHSHMD301M	SEC-3 Basic Instrumentation Skills SEC-1 (3) PHSHSE301M
IV	Electricity and Magnetism I (P) DS-4 PHSDSC404T+PHSDSC404P Mathematical Methods II (P) DS-5 PHSDSC405T+PHSDSC405P Thermal Physics (P) DS-6 PHSDSC406T+PHSDSC406P Mechanics II DS-7 PHSDSC407T	Thermal Physics and Statistical Mechanics (P) CORE-4 PHSCOR404T+ PHSCOR404P	Current perspectives of Physics – MDC (Physics) PHSGMD401M	Computational Physics Skills SEC-2 (3) PHSGSE401M
V	Mathematical Methods III (P) DS-8 PHSDSC508T+PHSDSC508P Modern Physics I (P) DS-9 PHSDSC509T+PHSDSC509P Analog Electronics (P) DS-10 PHSDSC510T+PHSDSC510P Electricity and Magnetism II (P) DS-11 PHSDSC511T+PHSDSC511P	Modern Physics CORE- 5 PHSCOR505T	Current perspectives of Physics – MDC (Physics) (3) PHSGMD501M	Basic Instrumentation Skills SEC-1 (3) PHSGSE501M
VI	Quantum Mechanics I (P) DS-12 PHSDSC612T+PHSDSC612P Statistical Mechanics (P) DS-13 PHSDSC613T+PHSDSC613P Electricity and Magnetism III DS-14 PHSDSC614T Digital Electronics (P) DS-15 PHSDSC615T+PHSDSC615P	Analog and Digital Electronics (P) CORE 6 PHSCOR606T+ PHSCOR606P	Current perspectives of Physics – MDC (Physics) (3) PHSGMD501M	Computational Physics Skills SEC-2 (3) PHSGSE601M
VII	Solid State Physics (P) DS-16 PHSDSC716T+PHSDSC716P Mathematical Methods 4 (P) DS-17 PHSDSC717T+PHSDSC717P	Solid State Physics (P) S Minor 1 PHSSMC701T+ PHSSMC701P		
VIII	Applications of Quantum Mechanics DS-18 PHSDSC818T Nuclear and Particle Physics DS-19 PHSDSC819T Mechanics III DS-20 PHSDSC820T Communication Electronics (P) DS-21 PHSDSC821T+PHSDSC821P			

***** For Hons with research DS-19,20,21 are to be replaced with 1 15 credit research with code PHSRES801M**

Detailed Syllabi

Each computational Physics laboratory course has a list of assignments. All of them are compulsory.

The mentioned programs are examples only. Each year the students should be given similar but different assignments and in the end semester examination students may be asked to write any simple program of similar difficulty level. It is expected that students should be able to learn how to write their programs on their own.

Semester I

DS-1

Mathematical Methods-I (Theory)

PHSDSC101T

45 Lectures **3 Credits**

Calculus **18 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 second order differential equations with constant coefficients, particular integral. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems. Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration.

Vector Calculus **27 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).

Reference:

1. Mathematical methods in the Physical Sciences, M. L. Boas, 2005, Wiley.
2. Vector Analysis with an Intro. to Tensor Analysis: Schaum’s Outline Series. M.R. Spiegel, 1981, McGraw Hill.
3. Introduction to Mathematical Physics. C. Harper, 1989, PHI.
4. Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.
5. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
6. Essential Mathematical Methods, K. F. Riley & M. P. Hobson, 2011, Cambridge Univ. Press

DS1-Lab

Mathematical Method -I (Lab)

PHSDSC101P

60 Lectures **2 Credits**

1. Introduction to plotting graphs with GNUPlot

a) Basic 2D and 3D graph plotting - plotting functions, modifying the appearance of graphs, polar and parametric plots,Surface and contour plots, exporting plots.

Importing multicolumn data. Plotting and fitting data using qtiplot's fit function.

2. Introduction to programming in python

- Python as a number calculator
- algebraic calculation through python interactively
- help searching of functions (from built-ins, idea of default argument)
- importing modules like math, cmath modules and)
- standard I/O statements (input, raw_input, print)
- string, list, tuple and the corresponding methods. (In the interactive mode. Slicing. Help searching for methods.)
- program with formula crunching.

Control structures (use of simple programs to learn the use of if, if-elif-else, for, while, try-except.

3. Programs as applications

- finite series summation [Example: AP, GP, power series, trigonometric series, etc.
- Taylor series summation with a given precision [for different f(x) about x=0 or about some non-zero value and comparison with library functions, where available.

4. File handling in Python

- File I/O statements: Example programs like

1. File I/O : Create a three column data (x,y,z) file using a text editor. Read it from python. Find the sum and standard deviation of y and z .
2. File I/O: Create a single column data containing repetitive integers of at least 20 entries. Read the file. Find the frequency table of the distinct elements. Output that in another file.

5. Least square fitting

Linear and linearisable Least square fitting with supplied data. The final fit should be displayed through Qtiplot or a similar software. Use data recorded from the suitable experiments in Mechanics paper.

6. User defined functions in Python

- User defined function, default argument, global

Example: Write functions for

i) $f(x) = x!!f(x) = x!!$

ii) $f(n) = n - \mathrm{thelementoftheFibonaccisequence} f(n) = n - \mathrm{thelementoftheFibonaccisequence}$

iii) linspace (start, stop, number), the third being a default argument

Write function $(a, x) = \exp(-ax)\sin(x)(a, x) = \exp(-ax)\sin(x)$: a being a global arguments

7. Solution of Algebraic and Transcendental equations by Bisection Method

- Root finding: Bisection (Initial guess to be determined by plotting) for non-linear equations.
- Determination of time of journey for a moving particle obeying x=f(t) or similar problems are to be worked out.

8. Solution of Algebraic and Transcendental equations by Newton -Raphson Method

- Root finding: Newton -Raphson Method (Initial guess to be determined by plotting) for non-linear equations.
- Applications in simple physical problems (including those of mathematical Physics) for are to be practiced.

Reference:

1. The Python Tutorial
2. PYTHON PROGRAMMING FOR PHYSICISTS
3. Scientific Computing in Python, Abhijit Kar Gupta, 2021, Techno World.

Semester 2

DS-2

Mechanics I (Theory)

PHSDSC202T

45 Lectures **3 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 nonconservative forces. Law of conservation of Energy.

Collisions **3 Lectures**

Elastic and inelastic collisions between particles. Centre of Mass and Laboratory frames.

Rotational Dynamics **8 Lectures**

Recapitulation: Angular momentum of a particle and system of particles. Torque. Principle of conservation of angular momentum. Rotation about a fixed axis. Moment of Inertia. Perpendicular 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 **8 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.

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.

Reference:

1. An introduction to mechanics, D. Kleppner, R.J. Kolenkow, 1973, McGraw-Hill.
2. Classical Dynamics of Particles and Systems. S.T. Thornton and J. B. Marion, 2009, Brooks/Cole.
3. Mechanics, Berkeley Physics, vol.1, C.Kittel, W.Knight, et.al. 2007, Tata McGraw-Hill.
4. Physics, Resnick, Halliday and Walker 8/e. 2008, Wiley.
5. Theoretical Mechanics, M.R. Spiegel, 2006, Tata McGraw Hill.
6. General Properties of Matter. F.H. Newman and V.H.L. Searle, 1957, Hodder and Stoughton.
7. General Properties of Matter. B. Brown, 1969, Springer Science.
8. Classical Mechanics and General Properties of Matter. S.N. Maiti and D.P. Raychaudhuri, New Age
9. Feynman Lectures, Vol. I, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education
10. Introduction to Classical Mechanics, R. G. Takwale and P. S. Puranik, 1979, Tata McGraw-Hill
11. Mechanics, K. R. Symon, 3rd ed., 1971, Addison-Wesley
12. Elements of Properties of Matter, D.S. Mathur, 2008, S. Chand and Company Limited.

DS-2 (Lab)

Mechanics -1 (Lab)

PHSDSC202P

60 Lectures **2 Credits**

List of Experiments:

1.To determine the Moment of Inertia of a regular body using another auxiliary body and a cradle suspended by a metallic wire.

2. To determine g and velocity for a freely falling body using Digital Timing Technique

3. To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).

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 value of g using Bar Pendulum.

7. To determine the value of g using Kater's Pendulum.

Reference:

1. Advanced Practical Physics for Students, B. I. Worsnop and H. T. Flint, 1957, Methuen & Co.
2. An Advanced Course in Practical Physics, D. Chattopadhyay and P. C. Rakshit, 8th ed., 2007, New Central Book Agency
3. Advanced Practical Physics, vol 1, B. Ghosh & K. G. Mazumdar, 7th ed., Sreedhar Publishers, 2006

Semester 3

DS-3

Waves and Optics (Theory)

PHSDSC303T

45 lectures **3 Credits**

Superposition of Harmonic Oscillation **5 Lectures**

Superposition of collinear harmonic oscillations: Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (Beats). Superposition of N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences.

Superposition of two perpendicular harmonic oscillations: Graphical and Analytical Methods. Lissajous Figures with equal and unequal frequencies and their uses.

Wave Motion **8 Lectures**

Plane and Spherical Waves. Longitudinal and Transverse Waves. Progressive (Travelling) Wave.

Phase velocities for harmonic waves.

A brief introduction to functions of several variables and partial derivatives. Differential equation for a travelling wave in one dimension: generalization to three dimensions (statement only).

Velocity of Longitudinal Waves in a Fluid in a Pipe. Newton's Formula for Velocity of Sound. Laplace's Correction. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Wave.

Velocity of Transverse Vibrations of Stretched Strings.

Superposition of Harmonic Waves **4 Lectures**

Superposition of two harmonic waves travelling in the same direction; interference of sound waves with example. Formation of standing waves: nodes and antinodes; stretched string tied at both ends: qualitative idea of normal modes. Wave groups and group velocity. Beats.

Wave optics **3 Lectures**

Electromagnetic nature of light. Concept of wave front. Huygens Principle. Temporal and Spatial Coherence. Characteristics of Laser light.

Interference and Interferometer **10 Lectures**

Division of amplitude and wavefront. Young's double slit experiment. Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal thickness (Fizeau Fringes). Newton's Rings: Measurement of wavelength and refractive index.

Michelson Interferometer (No analytical derivation). Applications of Michelson Interferometer. Fringes of Equal Inclination. Fabry-Perot interferometer. Visibility of Fringes.

Diffraction and Holography **15 Lectures**

Kirchhoff's Integral Theorem and Fresnel-Kirchhoff's Integral formula (Statement and Qualitative discussion on consequences only).
Fraunhofer diffraction: Single slit. Double slit. Multiple slits. Diffraction grating. Resolving power of grating.
Rayleigh's criteria. Resolving Power of an optical instrument.
Fresnel Diffraction: Fresnel's Assumptions. Fresnel's Half-Period Zones for Plane Wave. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Explanation of Rectilinear Propagation of Light. Fresnel's Integral, Fresnel diffraction pattern of a straight edge, a slit and a wire.
Holography: Basics Principle of Holography. Recording and Reconstruction of image from Hologram. Point source holograms. Applications and some advances of holography.

Reference:

1. The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.
2. The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.
3. Advanced Acoustics, D. P. Ray Chaudhury, 1980, The New Book Stall.
4. Optics. E. Hecht, 2003, Pearson Education.
5. Fundamentals of Optics, F. A. Jenkins and H. E. White, 4th ed., 2001, McGraw Hill
6. Principles of Optics, B.K. Mathur, 1995, Gopal Printing.
7. Optics, Ajay Ghatak, 6th ed., 2017, Tata McGraw Hill.

Waves and Optics (Lab)

PHSDSC303P

DS-3 (Lab)

60 lectures **2 Credits**

General Topic

Discussion on the working principles of electric tuning fork, sodium and mercury vapour lamps, CRO etc. Demonstrations on adjustments of spectrometer, Schuster's focusing, Newton's ring apparatus etc. Measurement principle on the circular scale in a spectrometer. Use of computers for plotting of experimental results and corresponding fitting of curves using numerical methods learnt in the last semester, are to be encouraged with evidences in laboratory notebooks

List of Experiments:

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify λ^2 –T law.
2. To study Lissajous Figures to determine the phase difference between two harmonic oscillations.
3. To determine the angle of prism and refractive index of the Material of a prism using sodium source.
4. To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
5. To determine wavelength of sodium light using Newton's Rings.
6. To determine dispersive power and resolving power of a plane diffraction grating.
7. To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.
8. To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.

Reference:

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House
2. A Laboratory Manual of Physics for undergraduate classes, D.P.Khandelwal, 1985, Vani Publications.
3. An Advanced Course in Practical Physics, D Chattopadhyay and P.C.Rakshit, New Central Book Agency.
4. A Text book on Practical Physics, K.G. Majumder and B.Ghosh, Sreedhar Publishers.

.

Semester-4

DS-4

Electricity and Magnetism I (Theory)

PHSDSC404T

45 Lectures **3 Credits**

Electric Field and Potential **21 lectures**

Dirac Delta Function : Definition of Dirac Delta Function, Properties of Dirac Delta Function, Three dimensional Dirac Delta Function

Electric Field: Electric field lines. Electric flux. Gauss' law with applications to charge distributions with spherical, cylindrical and planar symmetry. Charge density of a point Charge. Conservative nature of Electrostatic Field.

Electrostatic Potential. Calculation of potential for linear, surface and volume charge distributions, potential for a uniformly charged spherical shell and solid sphere. Calculation of electric field from potential. Potential and Electric Field of an electric dipole. Force and Torque on a dipole.

Uniqueness theorem. Method of Images and its application to: Plane Infinite metal sheet, Semi-infinite dielectric medium and metal Sphere

Electrostatic energy of system of charges. Electrostatic energy of a charged sphere. Conductors in an electrostatic Field. Surface charge and force on a conductor. Capacitance of an isolated conductor. Energy stored in Electrostatic field

Magnetic Field **12 lectures**

Magnetic force between current elements and definition of Magnetic Field B. Biot - Savart's Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with Electric Dipole)

Ampere's Circuital Law and its application to (1) infinite straight wire, (2) infinite planar surface current and (3) solenoid. Properties of B : curl and divergence. Axial vector property of B and its consequences. Vector potential. Calculation of vector potential and magnetic induction in simple cases – straight wire, magnetic field due to small current-loop.

Magnetic Force on (1) point charge, (2) current carrying wire, (3) between current elements. Torque on a current loop in a uniform magnetic field. Application in Ballistic Galvanometer: Current and Charge Sensitivity. Electromagnetic damping, Logarithmic damping, CDR.

Electrical Circuits **9 lectures**

Charge Conservation –equation of continuity. Transients in D.C :Growth and decay of current, charging and discharging of capacitors in CR, LR and LCR circuits; oscillatory discharge; time constant; time variation of total energy in LCR circuit.

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

Thermoelectricity **3 lectures**

Seebeck Effect, Peltier Effect, Thomson Effect and their origin. Application of Thermodynamics to Thermoelectric Effects.

Reference:

1. Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.
2. Feynman Lectures Vol.2, R.P.Feynman, R.B.Leighton, M. Sands, 2008, Pearson Education
3. Classical Electromagnetism, J Franklin, 2008, Pearson Education
4. Elements of Electromagnetics, M.N.O. Sadiku, 2010, Oxford University
5. Electromagnetics, J.A. Edminster, Schaum Series, 2006, Tata McGraw Hill
6. Electricity and Magnetism, D.C.Tayal, 1993, Himalaya Publishing House
7. Electricity and Magnetism, J H Fewkes & J Yarwood, Oxford University Press, Calcutta, 1985.

DS-4 (Lab)

Electricity and Magnetism I (Lab)

PHSDSC404P

List of Experiments

1. To determine an unknown Low Resistance using Carey Foster's Bridge.
2. a) To verify the Thevenin and Norton theorems. (b) To verify the Superposition and Maximum Power Transfer theorems.
3. To determine the resistance of a galvanometer using Thomson's method.
4. Measurement of field strength B and its variation in a solenoid (determine dB/dx)
5. To study the variation of Thermo-Emf of a Thermocouple with Difference of Temperature of its Two Junctions to find 'a' and 'b' coefficients by null method
6. To calibrate a thermocouple to measure temperature in a specified Range by Null Method using a potentiometer.

Reference:

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. Engineering Practical Physics, S.Panigrahi and B.Mallick, 2015, Cengage Learning.
4. A Laboratory Manual of Physics for undergraduate classes, D.P.Khandelwal, 1985, Vani Publications.
5. An Advanced Course in Practical Physics, D Chattopadhyay and P.C.Rakshit.

DS-5

Mathematical Methods II (Theory)

PHSDSC405T

45 Lectures **3 Credits**

Probability **3 Lectures**

Definition, idea of sample space, probability addition and multiplication theorems, probability calculation by counting, probability density of random variables: Probability distribution functions.

Constrained Maximization using Lagrange Multipliers. **2 Lectures**

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 **21 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. Qualitative discussion on the zeros of Bessel Functions and Orthogonality. Airy's disc for Fraunhofer diffraction through circular aperture, resolving power of a telescope.

Some Special Integrals **3 Lectures**

Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral).

Partial Differential Equations **6 Lectures**

Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular symmetry. Wave equation: General solution for propagating waves; standing wave solution for vibrational modes of a stretched string.

Reference:

1. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 2013, 7 th Edn., Elsevier.
2. Mathematical methods in the Physical Sciences, M. L. Boas, 2005, Wiley.
3. Introduction to Mathematical Physics. C. Harper, 1989, PHI.
4. Differential Equations, George F. Simmons, 2007, McGraw Hill.
5. Mathematical methods for Scientists and Engineers, D.A. McQuarrie, 2003, Viva Book
6. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
7. Essential Mathematical Methods, K.F.Riley & M.P.Hobson, 2011, Cambridge Univ. Press.

DS-5 (Lab)

Mathematical Methods II (Lab)

PHSDSC405P

60 Lectures **2 credits**

25% of the hours, on an average, allotted for this lab component per week, should be devoted regularly to the detailed discussions on the underlying theory of the following numerical methods including efficiency of the methods in each case and to the discussion on the results of the assignments performed in the previous class. It is recommended to use an IDE, preferably Spyder, to write programs by the students. For documentation and sharing purpose Jupyter may also be used.

1. Introduction to Numpy:

a. Creation of different types of arrays — 1D & 2D with different dtype; special arrays.
b. Array reshaping, splitting, merging, slicing & indexing.
c. Vectorised operations: addition, subtraction, multiplication, dot and cross products of vectors.
d. Evaluation of functions in vectorised form.
e. logical operations and comparison in vectorised form.
f. Reading and writing of arrays from and to a file.

Guideline: Numpy is to be introduced with elementary methods covering at least those explicitly mentioned here. Simple physical problems are to be solved using numpy to demonstrate its advantages over core python.

2. Introduction to Matplotlib:

a. Plotting user defined functions.

b. Plotting single/multiple data-set from datafiles.
c. Online graph plotting from programs.
d. Different plot styles (scattered points, line, line-points etc) with different line-styles, symbols, colours are to be implemented. Controlling axes, scales (linear/logarithimic), axis labels, legends are to be introduced.

Guideline: Plotting methods using matplotlib.pyplot are to be introduced. Introductory features, covering at least the methods mentioned above, are to be implemented with at least one example of each shown in the notebook. The dataset already recorded in laboratory works in other papers are encouraged to use.

3. Interpolation:

a. Interpolation algorithm by Newton-Gregory forward difference formula.
b. Interpolation algorithm Newton-Gregory backward difference formula.
c. Plotting data points and the value at the interpolated point on same plot using numpy and matplotlib

Guideline: Interpolation algorithms are to be implemented explicitly without any ready-made library function for interpolation. At least one application in physical problems should be in the LNB. Suitability of forward and difference formula in different cases should be demonstrated.

4. Numerical differentiation:

a. Differentiation algorithm using forward difference formula.
b. Differentiation algorithm using backward difference formula.
c. Plotting some user defined functions along with their derivatives using both the above

algorithms on the same graph. Also the derivatives evaluated calculated using derivative library function in scipy are to be plotted on it for comparison.

d. Verify recurrence relations either for Legendre polynomials or for Bessel functions involving derivatives, using any one of the algorithms implemented here.

Guideline: Comparison between results from forward and backward formula is to be demonstrated (with fixed length of differences) after implementing those explicitly. Applications of those in some physical problems such as charge -current relationship in capacitor charging-discharging, velocityacceleration relationship in kinematics etc should be worked out (at least one such case should be found in LNB). For derivative library function import scipy.misc.

5. Numerical Integration:

a. Integration using trapezoidal rule.
b. Integration using Simpson's 1/3 rd rule.
c. Plotting a user defined function and its running integral, $\int f(x)dx$

, on the same graph using both the algorithms. Plot the integral using library function quad in scipy for comparison.

d. Verification of orthogonality relations either for Legendre polynomials or for Bessel functions using any one of the numerical algorithms used here.

Guideline: Use of numpy and/or list comprehension is strongly recommended here. Comparison between results (final subinterval lengths) from trapezoidal and Simpson's 1/3 rules is to be demonstrated after implementing those explicitly with pre-assigned value of accuracy. Applications of those in some physical problems such as current -charge relationship in capacitor charging discharging, velocity-displacement relationship in kinematics, calculation of thermodynamic work done in simple systems etc should be worked out (at least one such case should be found in LNB). For quad library function import scipy.integrate.

6. Solution of ODE — First order differential equations:

a. Solve a first order differential equation using Euler method and plot it using matplotlib.
b. Compare it with the result coming from the libary function odeint.
c. Solve and plot family of solutions for a family of initial conditions.

Guideline: Choose the first order differential equations of different physical problems like drawing velocity profile for motion under gravity or simple harmonic motion from the force law and charging discharging problem of CR circuit or growth-decay in cutrrent in LR circuit etc. Solution of, at least, one such cases should be shown on LNB. For using odeint import scipy.integrate.

DS-6

Thermal Physics (Theory)

PHSDSC406T

45 Lectures **3 Credits**

Introduction to Thermodynamics **22 Lectures**

Zeroth Law of Thermodynamics & concept of temperature, Concept of thermodynamic variable and equilibrium, Concept of state and path functions, Concept of internal energy, work & heat, First Law of Thermodynamics and its differential form, work done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient.

Reversible and Irreversible process, Heat Engines: Carnot's Cycle, Carnot engine & efficiency Refrigerator & coefficient of performance, Background of Second Law of Thermodynamics, Second Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence, Carnot's Theorem, Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale.

Clausius Theorem, Concept of Entropy, Entropy Changes in Reversible and Irreversible Processes, Principle of Increase of Entropy & unavailable energy, Third Law of Thermodynamics, Unattainability of Absolute Zero.

Thermodynamic Potentials and Maxwell's Relations **7 Lectures**

Helmholtz Free Energy, Gibb's Free Energy, Enthalpy, First and Second Order Phase Transitions with examples, Clausius Clapeyron Equation and Ehrenfest equations, Gibbs' phase rule.

Derivations of Maxwell's Relations, Application of Maxwell's Relations: General Relation between C_P and C_V, Tds Equations.

Kinetic Theory of Gases **16 Lectures**

Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas, Mean, RMS and Most Probable Speeds. Degrees of Freedom, Law of Equipartition of Energy (No proof required), Specific Heats of Gases, 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, Einstein's Formula; Determination of Avogadro number.

Andrew's Experiment on CO_2 Gas, Van der Waals Equation of State, Critical Constants, Law of Corresponding States, Virial Coefficients, Boyle Temperature.

Joule's Experiment, Free Adiabatic Expansion of a Perfect Gas. Joule-Thomson Porous Plug Experiment. Joule- Thomson Effect, Temperature of Inversion.

Reference:

1. Thermodynamics. E. Fermi, 1956, Dover.
2. Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Ed., 2012, Oxford Univ Press.
3. Principles of Thermodynamics. M. Kaufman, 2002, Marcel Dekker.
4. Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill.
5. Thermodynamics, Kinetic Theory, and Statistical Thermodynamics. F. W. Sears and G.L. Salinger, 1998, Narosa.
6. A Treatise on Heat, Meghnad Saha, and B.N. Srivastava, 1969, Indian Press.
7. Basic Thermodynamics. E. Guha, 2010, Narosa.
8. Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition, 1993, Tata McGraw-Hill
9. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer.
10. Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa.
11. Thermodynamics and an introduction to thermostatistics, H. B. Callen, 1985, Wiley.
12. Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. Chand Publications

DS-6 (Lab)

Thermal Physics (Lab)

PHSDSC406P

60 Lectures **2 Credits**

List of Experiments

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. Measurement of unknown temperature using Diode sensor.
5. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
6. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.

Reference:

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.

DS-7

Mechanics II (theory)

PHSDSC407T

60 Lectures **5 Credits**

1. **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.

2. **Rigid Body Mechanics** **14 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.

3. **Small Amplitude Oscillations** **12 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 in linear triatomic molecule and its extension to N identical masses connected in a linear fashion to (N -1) - identical springs.

4. **Fluid Dynamics** **15 Lectures**

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 & nonuniform 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.

5. **Special Theory of Relativity** **15 Lectures**

Michelson-Morley Experiment and its outcome, Postulates of Special Relativity, Invariance of spacetime interval, Types of spacetime interval, Gedanken experiment to demonstrate relativity of simultaneity, Light clock and Time dilation, example: Muon decay, Twin paradox, Lorentz transformation, Length contraction, Relativistic velocity addition theorem, Relativistic transformation of velocity, frequency and wave number, Relativistic Doppler effect (transverse and longitudinal), Relativistic momentum, force and Work, Relativistic energy-momentum relation, Equivalence of mass and energy.

Reference:

1. An Introduction to Mechanics , D. Kleppner, R.J. Kolenkow, Cambridge University Press; 2nd Edition (22 March 2021).
2. Classical Dynamics of Particles and Systems, S.T. Thornton and J. B. Marion, 2009, Brooks/Cole.
3. Mechanics, Berkeley Physics, vol.1, C.Kittel, W.Knight et.al. 2007, Tata McGraw-Hill.
4. Mechanics, Keith R. Symon, Pearson; 3rd edition (1 January 1971).
5. Schaum's outline series on Theoretical Mechanics , Murray Spiegel, McGraw Hill Education (1 July 2017).
6. The Feynman Lectures on Physics: The Millenium Edition, Vol. 1, R.P.Feynman, R.B.Leighton, M.Sands, Pearson Education; First Edition (1 January 2012).
7. Mechanics, Course of Theoretical Physics - Vol. 1 L. D. Landau and E. M. Lifshitz, cbspd, Third edition (1 January 2010).
8. Classical Mechanics: A Course of Lectures, A. K. Raychaudhuri, OUP India (1 December 1983).
9. An Introduction to Fluid Dynamics, G. K. Batchelor, Cambridge University Press , 2000.
10. Fluid Mechanics: : Volume 6 (Course of Theoretical Physics Series), E.M. Lifshitz, L. D. Landau, Butterworth-Heinemann Ltd; 2nd edition (17 August 1987)
11. Special Relativity (M.I.T. Introductory Physics), A.P. French, 2018, CRC Press.
12. Introduction To Special Relativity, Robert Resnick, Wiley, 1st edition (1 January 2007).
13. The Classical Theory of Fields: Volume 2 (Course of Theoretical Physics Series), L. D. Landau, E.M. Lifshitz , Butterworth-Heinemann; 4th edition.

Semester-5

DS-8

Mathematical Methods III (Theory)

PHSDSC508T

45 Lectures **3 Credits**

Fourier Transforms **15 Lectures**

Fourier Integral theorem. Fourier transform : examples. Fourier transform of Gaussian, finite wave train & other functions. Fourier transform of even and odd functions. Representation of Dirac delta function as a Fourier Integral. Fourier transform of derivatives, Inverse Fourier transform, Convolution theorem. Parsevals 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

Boundary Value Problems **14 Lectures**

Solutions of Laplace equation in plane polar, cylindrical and spherical polar coordinates for appropriate boundary conditions: examples from Electrostatics. Solutions of heat diffusion equation with boundary conditions of rectangular symmetry.

Matrices **16 Lectures**

Hermitian conjugate of a Matrix. Hermitian and Skew- Hermitian Matrices. Singular and Non-Singular matrices. Orthogonal and Unitary Matrices. Trace and determinant of a Matrix. Inner Product of matrices.

Eigenvalues and eigenvectors – calculation, charateristic equation. Cayley- Hamiliton Theorem. Trace and determinant: relation with eigenvalues. Similarity transformation with properties. Diagonalization of Matrices. Properties of Hermitian Matrices. Solutions of Coupled Linear Ordinary Differential Equations. Functions of a Matrix.

Reference:

1. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 2013, 7th Edn., Elsevier.
2. Mathematical methods in the Physical Sciences, M. L. Boas, 2005, Wiley.
3. Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
4. Classical Electrodynamics, J.D. Jackson, 3rd ed., 2007, Wiley.
5. Introduction to Electrodynamics, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings
6. Foundations of Electromagnetic Theory. J.R. Reitz, F.J. Milford and R.W. Christy, 2010, Pearson.

DS-8 (Lab)

Mathematical Physics III (Lab)

PHSDSC508P

60 Lectures **2 Credits**

1. Fourier Series:

Define a period function (use *def* keyword to define a function like half sign wave, or square wave etc ...). Plot the function over a few periods. Reconstruct this function with its Fourier Components.

Guidelines: Find the Fourier coefficients by direct integration using scipy.integrate.quad(). Use partial sums and plot along with the original function. Determine the infinite sum using user given tolerance.

2. Fourier Transform:

a) Calculate the real and imaginary parts of the Fourier Transform of a real and even function of x by calculating two different integrals numerically. Show that the Euclidean norm of the imaginary part is zero. Plot the real part as a function of k, the conjugate variable.

b) Calculate the real and imaginary parts of the Fourier Transform of a real and odd function of x by calculating two different integrals numerically. Show that the Euclidean norm of the real part is zero. Plot the imaginary part as a function of k, the conjugate variable.

c) Calculate the real and imaginary parts of the Fourier Transform of a real which is neither odd nor even function of x by calculating two different integrals numerically. Plot the power spectrum as a function of k, the conjugate variable

Guideline: Use quad from scipy.integrate to carry out the integrations separately for real and imaginary part of the integrals for an appropriate range of values of k.

3. ODE initial value problems by RK2 & RK4:

(a) Find numerical solution of a given first order ordinary differential equation with a given initial value over a given range of the independent variable. using

i. Euler method,

ii. RK2 method,

iii. RK4 method;

taking a small step size and plot all the solutions on the same graph using matplotlib.pyplot() for comparison.

(b) Reduce the step size by a given factor of the previous one and repeat the work.

(c) Solve the Hamilton's equations of one dimensional motion of a particle with unit mass attached with a spring (of spring constant 2) fixed with a rigid support at the other end and draw its phase space plot applying Euler method and RK4 method on same graph paper along with the plot from analytical solution.

Guideline: Different line-types are to be used for plotting multiple plot on the same graph paper. For the part (c) the plot should be done for at least two complete cycles using $\Delta t = 0.02$.

4. Simple Matrix processing:

Use of numpy ndarray objects for various matrix operations.

(a) Matrix generation including special matrices- Diagonal, tri-diagonal, upper triangular etc

(b)reshaping, addition, subtraction, transposition, matrix multiplication, element-wise product, trace calculation, slicing and concatenation using numpy ndarray

(c) Checking Hermiticity and Unitarity of matrices.

Guideline: All the operations should involve ndarray objects only (*without any use of numpy matrix objects* to avoid any possible confusion during initiation). Codes are to be written for matrices of any arbitrary dimension. A function for calculation of transpose conjugate will be useful

Hint:a) A+A is Hermitian for all square matrix A,

b) U=exp(iH) is a unitary matrix when H is Hermitian. Use scipy.linalg.expm()

Use numpy.all() to verify the condition on matrix equalities

5. Solution of linear system of equations by Gauss-Seidal iterative method.

(a) Solution of linear system of equations with three unknowns using Gauss-Seidel iterative method.

(b) Choosing suitable set of constants in the inhomogeneous part of linear equations to find the inverse of the coefficient matrix.

(c) Use the code for determinant calculation through Gauss elimination method to show that the determinant of the inverse matrix is the reciprocal of the same of the original matrix.

Guideline: In part (b) the solutions of the linear system has to be found for three times using only one non-vanishing constant (unity) as the inhomogeneous term of the system of equations in each case. The student should be aware of the limitations of Gauss-Seidal method

6. Boundary value problems (by finite difference method with fixed grid size): (any one to be performed in the class)

(a) Laplace equation in 2D with Dirichlet boundary condition.

(b) 1D Fourier heat equation with Dirichlet boundary condition.

(c) Poisson equation in 2D with Dirichlet boundary condition.

(d) Wave equation in 1D on a string fixed at two ends with a given initial configuration

Guideline: Numpy array operations should be used instead of explicit loops. The final solution should be plotted in 3-d using matplotlib.pyplot. The grid size should be small enough to minimize discretization effect and hence it has to be optimized according to the memory and speed of the computing machine. Care should be taken to choose optimum relation between grid sizes of two independent variables to ensure convergence, where required. It is encouraged to allot different equations (from the above four) to different groups of students in a class and the final results are shared among all the students of the class, so that every student in the class gets aware of the characteristics of all the solutions.

Reference:

1. Learning Scientific Programming with Python. C. Hill, 2016, Chambridge.

2. Computational Physics: Problem solving with Computers, R. H. Landau, M.J. Páez, C.C. Bordeianu, WILEY-VCH Verlag GmbH & Co. KgaA, 2012.

3. Numerical Method for Physics, Aljandro L Garcia, Amazon Digital Services; Revised edition (6 June 2015)

4. Numerical Recipes 3rd Edition: The Art of Scientific Computing, W.H. Press et al. , Cambridge University Press; 3rd edition (6 September 2007)

5. An Introduction to Computational Physics, T.Pang, 2nd Edn.,2006, Cambridge Univ.Press

DS-9

Modern Physics I (Theory)

PHSDSC509T

45 Lectures **3 Credits**

Emergence of Quantum Theory: **20 Lectures**

Blackbody radiation, derivation of Rayleigh-Jeans law: ultraviolet catastrophe; Planck's quantum postulate, Planck's distribution law for blackbody Radiation– Wien's displacement law and Stefan-Boltzmann law as its consequence . Photoelectric effect and Compton scattering. Light as a collection of photons; Wilson-Sommerfield quantization rule unifying Planck's quantization rule and Bohr's angular momentum quantization rule. de Broglie wavelength and matter waves; Davisson-Germer experiment. Wave description of particles by wave packets. Group and Phase velocities and relation between them.

Double slit interference experiment with electrons and photons. Wave-particle duality, Bohr's complementarity principle. Matter waves and wave function, linear superposition principle as a consequence; Born's probabilistic interpretation of wave function bridging between wave description and particle description.

Position measurement– gamma ray microscope thought experiment; Heisenberg uncertainty principle as a consequence of wave description. Estimating minimum energy of a confined particle using the uncertainty principle. Energy-time uncertainty principle.

Lasers: **5 Lectures**

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

Nuclear Physics **20 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, N-Z graph, Liquid Drop model: semi-empirical mass formula and binding energy, Nuclear Shell Model and magic numbers.

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.

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).

Reference:

1. Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.
2. Optics, Ajay Ghatak, (2020), McGraw Hill, 7th Ed,
3. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles. R. Eisberg and R. Resnick, 1985, Wiley.
4. Theory and Problems of Modern Physics, Schaum's outline, R. Gautreau and W. Savin, 2nd Edn, Tata McGraw-Hill Publishing Co. Ltd.
5. Introduction to Modern Physics, RichtMeyer, Kennard, Coop, 2002, Tata McGraw Hill
6. Feynman Lectures vol. 3, 2012, Pearson
7. An Introduction to Nuclear Physics. W. N. Cottingham and D.A. Greenwood, 2004, Cambridge.
8. Quantum Mechanics: Theory & Applications, A.K.Ghatak & S.Lokanathan, 2004, Macmillan
9. Nuclear Physics, I. Kaplan, 2002, Narosa.
10. Elements of Quantum Mechanics, B. Dutta-Roy, 2009, New Age International.
11. Nuclear Physics, S. N. Ghoshal, S. Chand & Company Ltd. New Delhi, 1994.

DS-9 (Lab)

Modern Physics (Lab)

PHSDSC509P

60 Lectures **2 Credits**

List of Experiments

1. To determine the wavelength of H-alpha emission line of Hydrogen atom.
2. To determine the value of e/m of electron by using a bar magnet.
3. To determine wavelength using of a laser source using plane diffraction grating
4. Photo-electric effect: photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light
5. To determine the Planck's constant using LEDs of at least 4 different colours.
6. To determine the wavelength of laser source using diffraction of single slit.
7. Measurement of Planck's constant using black body radiation and photo-detector.
8. To determine the ionization potential of mercury.

DS-10

Analog Electronics (Theory) **PHSDSC510T**

45 Lectures **3 Credits**

Introduction **3 Lectures**

Electronic Components and Measuring devices (which are generally used for studying the following circuits) viz. DC and AC Voltmeters, Ammeters and Multimeters and their general Characteristics, Cathode-Ray Oscilloscope (CRO), Block diagram of CRO. Electron Gun. Deflection System and Time Base. Applications of CRO: 1)Study of waveform, 2) Measurement of Voltage , Current, Frequency and Phase difference.

Semiconductor Diodes **6 Lectures**

Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity. Barrier Formation in PN Junction Diode. Static and Dynamic Resistance. Current Flow Mechanism in Forward and Reverse Biased Diode. Derivation for Barrier Potential, Barrier Width and Current for Step Junction.

Two-terminal Devices and their Applications **5 Lectures**

Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter & π- filter (qualitative, expression only), Zener Diode and Voltage Regulation. Principle and structure of (1) LEDs, (2) Photodiode and (3) Solar Cell.

Bipolar Junction transistors **6 Lectures**

Physical Mechanism of Current Flow (unbiased).Current gains α and β, Relations between α and β, Load Line analysis of Transistors. DC Load line and Q-point. Active, Cutoff and Saturation Regions.

Field Effect transistors **3 Lectures**

Basic principle of operation of JFET, JFET parameters and CS characteristics

Amplifiers **8 Lectures**

Amplifiers: Transistor Biasing and Stabilization Circuits.Voltage Divider Bias. h-parameter Equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model. Input and Output Impedance. Current, Voltage and Power Gains.Classification of Class A, B & C Amplifiers. Two stage RC-coupled amplifier and its frequency response.

Feedback in Amplifiers **3 Lectures**

Concept of feedback. Effects of Positive and Negative Feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise.

Sinusoidal Oscillators **4 Lectures**

Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency. Hartley & Colpitts oscillators.

Operational Amplifiers (Black Box approach) **2 Lectures**

Characteristics of an Ideal and Practical Op-Amp. (IC 741) Open-loop and Closed-loop Gain.Frequency Response.CMRR. Slew Rate and concept of Virtual ground

Applications of Op-Amps **5 Lectures**

Linear - (1) Inverting and non-inverting amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Log amplifier, (7) Zero crossing detector (8) Wein bridge oscillator (9) Schmidt triggers.

Resistive network (Weighted and R-2R Ladder). A/D Conversion (successive approximation).

Reference:

1. Electronic Devices and Circuit Theory. R.L. Boylestad and L. Nashelsky, 2012, Pearson.
2. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata McGraw Hill.
3. Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
4. Solid State Electronic Devices, B.G.Streetman & S.K.Banerjee, 6th Edn.,2009, PHI Learning
5. Electronic Devices & Circuits, S.Salivahanan & N.S.Kumar, 3rd Ed., 2012, Tata McGraw Hill
6. Op-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall.

DS-10 (Lab)

Analog Electronics (Lab)

PHSADSC510P

60 Lectures **2 Credits**

General Topics: Discussion on the operational principles of the relevant circuits used in the experiments.

List of Experiments

1. To study V-I characteristics of PN junction diode and Light emitting diode (LED) (using voltage source).
2. To study the V-I characteristics of a Zener diode and its use as voltage regulator.
3. Study of V-I & power curves of Solar Cells and find maximum power point and efficiency.
4. To study the characteristics of a Bipolar Junction Transistor in CE configuration.
5. To study the frequency response of voltage gain of a RC – coupled transistor amplifier.
6. To design inverting, non- inverting and buffer amplifiers, and adder using Op-Amp (741/351) for dc voltage.
7. To design a Wien bridge oscillator for a given frequency using Op-Amp.
8. To investigate the use of an Op-Amp a) as an Integrator, and b) as a Differentiator.
9. To study the analog to digital converter (ADC) IC.
10. Using Schmitt trigger and associated circuits (with Op-Amp) to generate different waveforms.

Reference:

1. Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, McGraw Hill.
2. OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall.
3. Electronic Principle, Albert Malvino, 2008, Tata McGraw Hill.
4. Electronic Devices & circuit Theory, R.L. Boylestad & L.D. Nashelsky, 2009, Pearson
5. Advanced Practical Physics Vol.-II, B. Ghosh, Sreedhar Publishers.

DS-11

Electricity and Magnetism II (Theory)

PHSDSC511T

45 Lectures **3 Credits**

AC Circuits **6 lectures**

AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Phasor diagram. Series LCR Circuit: (1) resonance, (2) power dissipation, (3) quality factor and (4) band width. Parallel LCR Circuit.

AC Bridge : Anderson Bridge for measuring self inductance.

Dielectric Properties of Matter **8 lectures**

Electric Field in matter. Polarization, Polarization Charges. Electrical Susceptibility and Dielectric Constant. Capacitor (parallel plate, spherical, cylindrical) filled with dielectric. Displacement vector **D**. Relations between **E**, **P** and **D**. Gauss' Law in dielectrics. Boundary conditions at the interface of two media.

Magnetic Properties of Matter **5 lectures**

Magnetization vector (**M**). Magnetic Intensity (**H**). Magnetic Susceptibility and permeability. Relation between **B**, **H**, **M**. Ferromagnetism. B-H curve and hysteresis. Boundary conditions at the interface of two media.

Electromagnetic Induction **8 lectures**

Faraday's Law. Lenz's Law. Self-Inductance and Mutual Inductance, calculation in simple cases (e.g. circular loops, solenoids). Reciprocity Theorem. Energy stored in a Magnetic Field.

Introduction to Maxwell's Equations. Charge Conservation. Displacement Current and Equation of Continuity.

Polarization of Electromagnetic Waves **18 lectures**

Description of Linear, Circular and Elliptical Polarization. Propagation of E.M. Waves in Anisotropic Media. Symmetric Nature of Dielectric Tensor. Fresnel's Formula.

Uniaxial and Biaxial Crystals. Light Propagation in Uniaxial Crystal. Double Refraction. Polarization by Double Refraction. Nicol Prism. Ordinary & extraordinary refractive indices.

Phase Retardation Plates: Quarter-Wave and Half-Wave Plates. Production & analysis of polarized light (plane, circular and elliptical). Babinet Compensator and its Uses.

Rotatory Polarization: Optical Rotation. Biot's Laws for Rotatory Polarization. Fresnel's Theory of optical rotation. Calculation of angle of rotation. Experimental verification of Fresnel's theory. Specific rotation. Laurent's half-shade and bi-quartz polarimeters.

Reference:

1. Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.
2. Feynman Lectures Vol.2, R.P.Feynman, R.B.Leighton, M. Sands, 2008, Pearson Education
3. Classical Electromagnetism, J Franklin, 2008, Pearson Education
4. Elements of Electromagnetics, M.N.O. Sadiku, 2010, Oxford University
5. Electromagnetics, J.A. Edminster, Schaum Series, 2006, Tata McGraw Hill
6. Electricity and Magnetism, D.C.Tayal, 1993, Himalaya Publishing House.
7. Optics, E. Hecht, 2016, Pearson.
8. Optics, Ajay Ghatak, 2018, McGraw Hill Education India (Private) Limited

DS-11 (Lab)

Electricity and Magnetism II (Lab)

PHSDSC511P

60 Lectures **2 Credits**

List of Experiments

1. To study the response curve of a Series LCR circuit and determine its (a) Resonant frequency, (b) Impedance at resonance, (c) Quality factor Q and (d) Band width.
2. To study the response curve of a parallel LCR circuit and determine its (a) Anti- resonant frequency and (b) Quality factor Q.
3. To study the characteristics of a series RC Circuit.
4. To determine self-inductance of a coil by Anderson's bridge.
5. To verify the law of Malus for plane polarized light.
6. To determine the specific rotation of sugar solution using a Polarimeter.
7. To study the polarization of light by reflection and determine the polarizing angle for air-glass interface.

Reference:

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. Engineering Practical Physics, S.Panigrahi and B.Mallick, 2015, Cengage Learning.
4. A Laboratory Manual of Physics for undergraduate classes, D.P.Khandelwal, 1985, Vani Publications.
5. An Advanced Course in Practical Physics, D Chattopadhyay and P.C.Rakshit
6. Electricity and Magnetism Vol-I, J. Yarwood. Harper and Collins. March, 1973.
7. Electro-magnetism. I.S. Grant and W.R. Phillips. Wiley. 2nd Edition, 1990.

Semester-6

DS-12

Quantum Mechanics I (Theory)

PHSDSC612T

45 Lectures **3 Credits**

Basic Formalism of Quantum Mechanics **10 Lectures**

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.

Schrödinger equation **10 Lectures**

Time dependent Schrödinger equation: Time dependent Schrödinger equation and dynamical evolution of a quantum state; Interpretation of Wave Function: Probability and probability current densities in three dimensions; Conditions for physical acceptability of Wave Functions. Normalization and Linear Superposition Principle of the solutions of Schrödinger equation. Wave Function of a Free Particle.

Time independent Schrödinger 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 Schrödinger equation in terms of linear combinations of stationary states; Fourier transforms and momentum space wave-function; spread of Gaussian wave-packet in one dimension and its consistency with position-momentum uncertainty principle

Application of Quantum Mechanics in one dimension **9 Lectures**

Bound states: boundary condition and emergence of discrete energy levels.

One dimensional infinitely rigid box– energy eigenvalues and eigenfunctions, normalization; generalisation for three dimensions and degeneracy of energy levels. Quantum dot as an example.

Quantum mechanics of simple harmonic oscillator-energy levels and energy eigenfunctions; Hermite polynomials; ground state, zero point energy & uncertainty principle. Raising-lowering operators and their applications.

Reflection and transmission in one dimension– across a step potential & rectangular potential barrier. Tunnelling effect in the case of alpha decay (qualitative discussion only).

Angular momentum **6 Lectures**

Orbital Angular Momentum operators and their algebra. Representation in a spherical polar coordinate system. Eigenvalues and eigenvectors of L^2 and L_z; Orbital angular momentum quantum numbers *l* and *m*. Raising and Lowering operators and their commutation relations: Calculation of eigenvalues of L^2 and L_z; integral and half integral values of *l*.

Quantum Mechanics of Hydrogenic atoms **10 Lectures**

Time independent Schrodinger equation in spherical polar coordinates with spherically symmetric potential; separation of variables for second order partial differential equation; Wave-functions as products of a radial part and spherical harmonics. Radial part of the wave-function for Coulomb potential; calculation of radial probability density; shapes of the probability densities. Commuting observables and degeneracy of energy levels.; *s*, *p*, *d* shells-subshells. Applications for Hydrogenic atoms: He+ ion, Li++ ion.

Stern Gerlach experiment and the concept of spin (half integral angular momentum).

Specification of electronic states of hydrogenic atoms in terms of quantum numbers. $\{n, l, m_l, m_s\}\{n, l, m_l, m_s\}$

Reference:

1. D. J. Griffiths, Introduction to Quantum Mechanics, Prentice Hall, NJ, 1995
2. Binayak Dutta Roy, Elements of Quantum Mechanics, New Age, New Delhi, 2009
3. N. Zettili, Quantum Mechanics: Concepts and Applications, Wiley India, 2016
4. Quantum Mechanics: Theory & Applications, A.K.Ghatak & S.Lokanathan, Macmillan, 2004

Mathews

DS-12 (Lab)

Quantum Mechanics I (Lab)

PHSDSC612P

60 Lectures **2 Credits**

25% of the hours, on an average, allotted for this lab component per week, should be devoted regularly to the detailed discussions on the underlying theory of the following numerical methods including efficiency of the methods in each case and to the discussion on the results of the assignments performed in the previous class. Initial assignments in this list are included here to prepare the students for writing the programmes mentioned in *the syllabus. The programmes should be written in Python. It is recommended to use an IDE, preferably Spyder for Python write programs by the students. For documentation and sharing purposes notebook applications like Jupyter may also be used.*

1. A spin-1/2 particle is placed within a magnetic field $\hat{B}$ along *x*-direction so that the interaction Hamiltonian is given by $\hat{B} = g\,\hat{S}_x B$ where, $\hat{S}_x = \frac{\hbar}{2}\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$. Use scipy to find out the eigenvalues and eigenvectors and appropriate similarity transformation to construct the time evolution operator $\hat{U}(t) = e^{-i\frac{\hat{H}t}{\hbar}}$. Plot the time variation of probability of finding the particle in either up or down state of $\hat{S}_z = \frac{\hbar}{2}\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$. Initial state may be chosen in either up or down state.

2. Find the energy eigenvalues and eigenfunctions for the ground state and the first excited stationary state for a one dimensional square well of infinite depth, using the shooting method.

Guideline: Apply shooting method for solving the relevant energy eigenvalue equation. Use scipy.integrate.odeint (in Python) as integrator. As multiple eigenvalues exist, the use of bisection root finding method is recommended to find the energy eigenvalues precisely. Construct the wave-function. Use scipy.integrate.simps (in Python) for normalization.

3. Find the energy eigenvalues and eigenfunctions of a linear harmonic oscillator in one dimension.

Guideline: Write down the appropriate Schrödinger equation and convert it in a dimensionless form. Apply shooting method. Only energy eigenvalues of the ground state and the first excited state are to be computed along with the plot of corresponding probability distributions of position measurement.

4. From the analytical solutions of Hydrogen atom energy eigenvalue problem check numerically the orthonormality conditions of stationary states and plot the radial wave- function. Plot the radial and angular distribution of probability for finding position of the electron, in ground state and in first excited states. Find the radial distance $r_{0.99}$ within which the probability of finding the electron is 0.99

Guideline: Use scipy.special for special functions and scipy.integrate. Plot the angular distribution in polar plot using matplotlib.pyplot.polar. For $r_{0.99}$ set a transcendental equation and solve using Newton Raphson method.

5. Solve the s-wave Schrödinger equation (radial part) with Coulomb potential for the ground state and the first excited state of the hydrogen atom:

$$\frac{d^2u}{dr^2} = -\frac{2\mu}{\hbar^2}\left(E - V(r)\right), \qquad V(r) = -\frac{e^2}{r}$$

Given $\psi_{ns} = \frac{u(r)}{r}$

Here, μ is the mass of the electron. Obtain the energy eigenvalues and plot the corresponding radial probability distributions. Remember that the ground state energy of the hydrogen atom is −13.6 eV. Take *e* =3.795 $(\text{eVÅ})^{1/2}$, $\hbar c$ = 1973 (eVÅ) and μ = 0.511 × 106 eV/c^2.

Guideline: The differential equation must be written in a dimensionless form first, by scaling the variables with suitable physical constants, e.g. radial distance is to be scaled by Bohr radius = 5.29×10^{-11} m, which may be calculated from the constants displayed in the assignment itself. Use either shooting method. Plot the radial probability distribution and compare it with plots obtained from analytical solutions.

Reference:

1. Computational Physics: Problem solving with Computers, R. H. Landau, M.J. Páez, C.C. Bordeianu, WILEY-VCH Verlag GmbH & Co. KgaA, 2012.

2. Computational Quantum Mechanics, Joshua Izaac, Jingbo Wang, Springer, 2019

DS-13

Statistical Mechanics (Theory)

PHSDSC613T

45 Lectures **3 Credits**

Classical Statistical Mechanics **19 Lectures**

Macrostate & Microstate, concept of time averaging in a macroscopic measurement. Ergodic hypothesis (statement only). Elementary Concept of Ensemble, Liouville's theorem. Microcanonical ensemble, Phase Space, postulate of equal a priori probability, Entropy and Thermodynamic Probability, Canonical ensemble, Partition Function, Density of states: for ideal gas. Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox, Sackur Tetrode equation, Law of Equipartition of Energy (with proof) – Applications to Specific Heat and its Limitations, Thermodynamic Functions of a Two-Energy Levels System, Negative Temperature. Grand canonical ensemble and chemical potential. Equivalence of microcanonical, canonical and grand canonical ensemble for large systems (qualitative discussion only).

Chemical Equilibrium **2 Lectures**

Law of chemical equilibrium, Chemical equilibrium of classical ideal gas, Saha ionization equation.

Theory of Blackbody Radiation **3 Lectures**

Properties of Thermal Radiation, Blackbody Radiation, Pure temperature dependence, Kirchhoff's law, Stefan-Boltzmann law: Thermodynamic proof. Radiation Pressure.

System of identical particles **3 Lectures**

Identical particle and symmetry requirements. Classical approach. Quantum-mechanical approach: Bosons and Fermions, Pauli exclusion principle for Fermions, Spin statistics theorem (statement only). Distinguishability and indistinguishability, Maxwell-Boltzmann distribution. Bose Einstein distribution. Fermi-Dirac distribution.

Bose-Einstein Statistics **9 Lectures**

Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas, Bose derivation of Planck's law. Phonon gas. Debye theory of specific heat of solids. T^3 law.

Fermi-Dirac Statistics **9 Lectures**

Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Fermi temperature, Fermi momentum, Sommerfield correction to free electron theory in a Metal. Specific Heat of Metals

Reference:

1. Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Ed., 2012, Oxford Univ. Press
2. Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill
3. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed.,1996, Oxford University Press
4. An Introductory Course of Statistical Mechanics. P.B. Pal, 2008, Narosa.
5. Statistical and Thermal Physics, S. Lokanathan and R.S. Gambhir. 1991, Prentice Hall
6. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.
7. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer
8. An Introduction to Statistical Mechanics & Thermodynamics, R.H. Swendsen, 2012, Oxford Univ. Press

DS-13 (Lab)

Statistical Mechanics (Lab)

PHSDSC613P

60 Lectures **2 Credits**

1. Write a python function to compute the canonical Maxwell -Boltzmann partition function of a 2 -level system with energies ϵ and 2ϵ as a function of kBT. Generate an array for kBT. (Students must be encouraged to find appropriate range and increment for this array). Calculate the partition function (Z) as another array using the above function. From the partition function calculate the following quantities and plot each of them as a function of kBT:

(a) internal energy U,

(b) energy fluctuation ΔE,

(c) specific heat at constant volume CV,

(d) Free energy F, Entropy S,

Finally show how the occupation numbers of the states vary with temperature. (You may take the value of ϵ = 1).

2. Extend the assignment no. 1 for a quantum harmonic oscillator En = (n + $\frac{1}{2}$)$\hbar\omega$ (Take $\hbar\omega$ = 1) (Infinite levels. However partition function is a well convergent series).

3. Write a function to generate a canonical partition function, $Z = \Sigma\ exp\ (-\beta E$i), Ei= $\Sigma\ \epsilon$k , ϵk being the k-th single particle level (ϵk = $k\gamma$) of n fermions distributed in N levels. (n and N are arbitrary input variables) (*combinations)* in the *itertoo*l module of python may be used). Perform the calculations and plots of the thermodynamic parameters mentioned in assignment no. 1.

4. Generate a list of microstates of n bosons distributed in N levels. (n and N are arbitrary input variables)

5. Calculate the canonical partition function of 2 bosons in three levels (ϵ, 2ϵ, 3ϵ) as a function of temperature and calculate the thermodynamic properties mentioned in assignment no. 1. Manual listing of the two particle energy levels are to be avoided. You may use the program written in the previous question. For the following problems use of scipy.constants may be encouraged.

6. (a) Plot Planck's law for Black Body radiation and Rayleigh-Jeans Law superposed on the same graph at T = 4000 and T = 8000 (Set the frequency (ν) in the range [1, 15 $\frac{k_B T}{h}$]

(b) In both the cases print the frequency at which the energy density is maximum. Which region of EM spectrum do these frequencies belong to?

(c) Calculate the minimum frequency, ν_c where the difference between the energy densities predicted by these laws are more than 10% ($\frac{\Delta U}{U_{Planck}} \geq 0.1$) at T=300

(d) Calculate the total energy in the visible spectrum (ν=4 × $10^{14} - 7.5 \times 10^{14}$ Hz) in the range $T \in$ [100,400] by direct integration. Plot the visible energy as a function of temperature.

7. Plot Specific Heat of Solids as a function of T according to

(a) Dulong-Petit law,

(b) Einstein formula, (Take three values of θE)

(c) Debye formula, (Take three values of θD)

8. Plot the following functions with energy at different temperatures. Choose a suitable value of μ in each case

a) Maxwell-Boltzmann distribution function

b) Fermi-Dirac distribution function

c) Bose-Einstein distribution function

Reference:

1. Elementary Numerical Analysis, K.E.Atkinson, 3 rd Edn . 20 07 , Wiley India Edition
2. Statistical and Thermal Physics with computer applications, Harvey Gould and Jan Tobochnik, Princeton University Press, 2010

DS-14

Electricity and Magnetism III (Theory)

PHSDSC614T

60 Lectures **5 Credits**

Electrodynamics **10 lectures**

Review of Maxwell's equations. Boundary Conditions at Interface between Different Media. Vector and Scalar Potentials. Gauge Transformations: Lorentz and Coulomb Gauge. Poynting Theorem and Poynting Vector. Electromagnetic (EM) Energy Density. Physical Concept of Electromagnetic Field Energy Density. Momentum Density and Angular Momentum Density (statement only).

EM Wave Propagation in Unbounded Media **10 lectures**

Plane EM waves through vacuum and isotropic dielectric medium, transverse nature of plane EM waves, refractive index and dielectric constant, wave impedance. Propagation through conducting media, relaxation time, skin depth. Wave propagation through dilute plasma, electrical conductivity of ionized gases, plasma frequency, refractive index, skin depth, application to propagation through ionosphere

EM Wave Propagation in bounded Media **12 lectures**

Dispersion **5 lectures**

Electromagnetic theory of dispersion. Normal and anomalous dispersion.

Electromagnetic Radiation **8 lectures**

Retarded Potentials. Radiation from an electric dipole. Radiation from a magnetic dipole

Wave guides **8 lectures**

Planar optical wave guides. Planar dielectric wave guide. Condition of continuity at interface. Phase shift on total reflection. Eigenvalue equations. Phase and group velocity of guided waves. Field energy and Power transmission.

Optical Fibre **7 lectures**

Basic Principles. Acceptance Angle and numerical aperture. Step and Graded Indices. Single and Multiple Mode Fibres. Losses in optical fibres. Outline of fibre optics communication system.

Reference:

1. Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.
2. Feynman Lectures Vol.2, R.P.Feynman, R.B.Leighton, M. Sands, 2008, Pearson Education
3. Electromagnetic field Theory, R.S. Kshetrimayun, 2012, Cengage Learning
4. Elements of Electromagnetics, M.N.O. Sadiku, 2010, Oxford University
5. Electromagnetic Fields & Waves, P.Lorrain & D.Corson, 1970, W.H.Freeman & Co.
6. Electromagnetics, J.A. Edminster, Schaum Series, 2006, Tata McGraw Hill.
7. Electromagnetic field theory fundamentals, B. Guru and H. Hiziroglu, 2004,Cambridge University Press
8. Fibre-Optic Communication System, G.P.Agarwal, 2002, John-Wiley and Sons

DS-15

Digital Systems and Applications (theory)

PHSDSC615T

45 Lectures **3 Credits**

Integrated Circuits **3 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).

Digital Circuits **12 Lectures**

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.

Arithmetic circuits **3 Lectures**

Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor

Data processing circuits **3 Lectures**

Basic idea of Multiplexers, De-multiplexers, Decoders, Encoders

Sequential circuits **7 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.

Timers **4 Lectures**

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

Registers **5 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 **4 Lectures**

Input/ Output Devices. Data storage (idea of RAM and ROM).Computer memory

Reference:

1. Digital Principles and Applications, A.P. Malvino, D. P. Leach and Saha, 7th Ed., 2011, TMH
2. Digital Computer Electronics.A.P. Malvino and J.A. Brown, 2005, TMH.
3. Fundamentals of Digital Circuits, Anand Kumar, 2nd Edn, 2009, PHI Learning Pvt. Ltd.
4. Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
5. Digital Electronics, SubrataGhoshal, 2012, Cengage Learning.
6. Digital Electronics, S.K. Mandal, 2010, 1st edition, McGraw Hill
7. Microprocessor Architecture Programming & applications with 8085, 2002, R.S. Gaonkar, Prentice Hall

DS-15 (Lab)

Digital Systems and Applications (Lab)

PHSDSC615P

60 Lectures **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 ,Transformer, Resistance, Capacitor, Potentiometer etc. and also Important 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 Experiments

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

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

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

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

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

Reference:

1. Modern Digital Electronics, R.P. Jain, 4th Edition, 2010, Tata McGraw Hill.
2. Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, Mc-Graw Hill
3. Advanced Practical Physics Vol.-II, B. Ghosh, Sreedhar Publisher**s.**

Semester 7

DS-16

Solid State Physics (Theory)

PHSDSC716T

45 Lectures **3 Credits**

Crystal Structure **10 Lectures**

Solids: Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis. Unit Cell. Miller Indices, Types of Lattices, Reciprocal Lattice. Diffraction of X-rays by Crystals. Laue's condition and Bragg's Law, Brillouin Zones, Structure Factor.

Elementary Lattice Dynamics **6 Lectures**

Lattice Vibrations and Phonons: Linear Monatomic and Diatomic Chains. Acoustic and Optical Phonons. Dulong and Petit's Law, its limitations. Einstein's theory of specific heat of solids, its limitations. Debye's correction (qualitative idea), T^3 law (statement only).

Free electron theory of Metals **7 Lectures**

Free electron gas in metals: Drude's theory, drift current, mobility and conductivity, Hall effect in metals. Thermal conductivity. Lorentz number, limitation of Drude's theory. Sommerfeld correction to free electron theory in a Metal: Review of Fermi Energy, Fermi temperature, Fermi momentum. Ground state energy. Electronic specific heat at low temperatures (explanation of linear behaviour in T using exclusion principle).

Elementary band theory **9 Lectures**

Electronic states in a periodic solid: Bloch's theorem (statement only); Idea of electronic energy bands using the Kronig Penny model. Idea of effective mass in a band. Band Gap. Classification of Conductor, Semiconductor (intrinsic, as well as P and N types) and Insulator. Conductivity of Semiconductor, mobility, Hall Effect.

Magnetic Properties of Matter **8 Lectures**

Dia-, Para-, and Ferromagnetic Materials. Classical Langevin Theory of dia- and Paramagnetism. 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.

Superconductivity **5 Lectures**

Experimental Results. Critical Temperature. Critical magnetic field, Type I and type II Superconductors. Meissner effect. Londons' equations: penetration depth.

Reference:

1. Introduction to Solid State Physics, Charles Kittel, 8th Edition, 2004, Wiley India Pvt. Ltd.
2. Elementary Solid State Physics, 1/e M. Ali Omar, 1999, Pearson India
3. Introduction to Solids, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill
4. The Oxford Solid State Basics. S. H. Simon, 2013, Oxford.
5. Elements of Solid State Physics, J.P. Srivastava, 4th Edition, 2015, Prentice-Hall of India
6. Solid State Physics, M.A. Wahab, 2011, Narosa Publications
7. Solid State Physics, A. J. Dekker , 1958, Vol. 269, McMillan student editions.

DS-16 (Lab)

Solid State Physics (Lab)

PHSDSC716P

60 Lectures **2 Credits**

List of Experiments

1. To draw the BH curve of Fe using Solenoid & determine energy loss from Hysteresis.
2. To measure the resistivity of a semiconductor (Ge) with temperature by reverse bias characteristics of Ge diode (room temperature to 80^0C) and to determine its band gap.
3. To determine the Hall coefficient of a doped semiconductor sample.
4. Measurement of susceptibility of paramagnetic solution (Quinck`s Tube Method).

1. To measure the Magnetic susceptibility of paramagnetic Solids (Gouy’s Method).

DS-17

Mathematical Methods IV (Theory)

PHSDSC717T

45 Lectures **3 Credits**

Complex Variables **20 Lectures**

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. Laurent and Taylor’s expansion, Integration of a function of a complex variable. Cauchy's inequality. Cauchy’s integral formula. Simply and multiply connected regions. Residues and Residue Theorem. Application in solving definite and improper integrals.

Linear Vector Space **16 Lectures**

Binary Operators. Introduction to Groups and Fields. Vector Spaces and Subspaces. Linear Independence and Dependence of Vectors. Basis and Dimensions of a Vector Space. Change of basis. Homomorphism and Isomorphism of Vector Spaces. Linear Transformations. Algebra of Linear Transformations. Non-singular Transformations. Inner products, norm, metric. Gram-Schmidt orthogonalization. Representation of Linear Transformations by Matrices..

Vectors in curvilinear coordinates and Tensors **9 Lectures**

Transformation of coordinates: orthogonal curvilinear coordinates: unit vectors, arc length and metric in three dimensions; volume element, gradient divergence and curl in curvilinear coordinate systems; special orthogonal systems : spherical and cylindrical polar coordinates.

Spaces of N dimensions: coordinate transformations: contravariant and covariant components of an N dimensional vector. Contravariant, covariant and mixed tensors: tensors of rank greater than two: tensor fields: fundamental operations with tensors, line element and metric tensor, associated tensor.

Reference:

1. Mathematical Methods for Physicists & Engineers, K.F.Riley, M.P.Hobson, S.J.Bence, 3rd Ed., 2006, Cambridge University Press
2. Schaum's outlines: Vector Analysis and and Introduction to Tensor Analysis, Lipschutz, Spellman and Spiegel, 2nd ed., 2009, McGraw Hill·
3. Schaum's outlines: Complex Variables: Spiegel
4. Mathematical Physics, P.K. Chattopadhyay, 1990, New Age.
5. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, and F.E. Harris, 1970, Elsevier.
6. Mathematical Methods. S. Hassani, 2009, Springer Science.
7. Introduction to Matrices and Linear Transformations, D.T. Finkbeiner, 1978, Dover Pub.
8. A Basic Course of Tensor Analysis. S. Mukhopadhyay, 2017, Academic Publishers.

DS-17 (Lab)

Mathematical Methods IV (Lab)

PHSDSC717P

60 Lectures **2 Credits**

1. a) Find the Cube roots of a complex number by forming two simultaneous equations from the ral and imaginary parts and solve them by two dimensional Newton Raphson algorithm.

b) Calculate the roots by De Moivre's formula and compare the results obtained from the part a)

c) Find complex roots of an arbitrary algebraic equation.

Guideline: For finding nth root of a complex number z_o, first construct the complex equation of the form $z^n - z_0 = 0$. Separate the complex equation into two real equations equating real and imaginary parts separately from either side, to find their solution using Newton-Raphson method in 2-dimension. Newton-Raphson method in D-dimension should be discussed before implementing it in two dimensions. Cramer's rule may be used to solve the simultaneous equations and numpy.linalg.det() can be used to calculate the determinants. Verify the result of part (a) using power of the complex number (z**(⅓)) . For part (b) calculate the magnitude and the argument of the complex number using *cmath.polar()* after importing *cmath* and then use Euler's formula to find all the values of the cube roots. For part (c), use newton from scipy.optimize to verify the solution directly.

2. Evaluate the improper integral of the type

$$\int_{-\infty}^{\infty} dx \frac{1}{(1+x^2)^2}$$

a) By taking the limit $\lim_{M\to\infty} \int_{-M}^{M} dx \frac{1}{(1+x^2)^2}$

b) Also show that the absolute value of the integral in a complex plane over a semicircle of radius R goes to zero as $R \to \infty$

3. Gram Schimdt orthogonalization routine:

a) Apply the method for two arbitrarily chosen linearly independent *n* dimensional vectors and verify the result explicitly with inner products.

b) Apply the same for *k* arbitrarily chosen linearly independent vectors *n* using file input and output methods.

Guideline: The programs should run for any arbitrary value of *n* and *k.* At the end of the program in each case, the orthogonality of the vectors hence obtained should be checked by forming a matrix by horizontal stacking of column vectors and testing the matrix for unitarity.

4. Solution of Linear system of equations by Gauss elimination method and by Gauss Jordan method.

(a) Calculation of the determinant of a square matrix by Gaussian elimination

(b) Solution of linear system of equations with three unknowns using Gauss elimination method.

(c) Solution of linear system of equations with three unknowns using Gauss-Jordan method.

(d) Calculation of inverse of a matrix by Gauss-Jordan method.

(e) Generalisation of the above codes for arbitrary numbers of variables and equations.

Guideline: In part (a) the code may determine the determinant first and if the determinant is found to be non-zero it will proceed to find the solution using back substitution in part (b). In the part (c) too the code should find the determinant first and if it is found to be non-zero, then only should proceed to find the inverse and solution. In either case pivoting technique need not be implemented, but students should be aware of limitations of the methods without using pivoting technique.

5. Explicit calculation of largest eigenvalue**:** calculation by power iterative method for real symmetric matrix and corresponding eigenvector.

(a) Use power method for a 3×3 real symmetric matrix to find the largest eigenvalue by magnitude and corresponding eigenvector. Also find the normalized eigenvector.

(b) Generalize the previous code for the real symmetric matrices of arbitrary dimension with le I/O.

Guideline: For part (b) the input matrices should be read from an input file and the program should check the dimension of an input matrix to ensure it is a square matrix, before processing it. Also show that the eigenvalue and eigenvector so found, satisfies the eigenvalue equation of the matrix itself. Use the smallest eigenvalue using the above

6. Eigenvalue and eigenvector calculation by Jacobi Method

Guideline: Also show that the eigenvalue and eigenvector so found, satisfies the eigenvalue equation of the matrix itself. Compare the values obtained from numpy.linalg.eig().

Reference :

1. An Introduction to computational Physics, T.Pang, 2nd Edn., 2006,Cambridge Univ. Press

2. Numerical Method for Physics, Aljandro L Garcia, Amazon Digital Services; Revised edition (6 June 2015)

3. Numerical Recipes 3rd Edition: The Art of Scientific Computing, W.H. Press et al. , Cambridge University Press; 3rd edition (6 September 2007)

Semester- 8

DS-18

Application of Quantum Mechanics (Theory)

PHSDSC818T

60 Lectures **5 Credits**

Approximate methods for stationary states: **10 Lectures**

Time-independent perturbation: Non degenerate and degenerate perturbation. Stark Effect as an application.

Approximate methods for time dependent problems: **6 Lectures**

Solvable two level system, time dependent perturbation theory

Method of variation and Variational Theorem **6 Lectures**

Estimation of upper bound of ground state energy using given trial wave functions. in the case of Harmonic oscillator and hydrogen atom. Applications to He atom and Hydrogen molecular ion.

Elements of Atomic Physics **20 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. Larmor Precession.

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.

Multi-electron atoms. Pauli's Exclusion Principle (statement only). Electronic configuration of many electron atoms in ground state. Aufbau principle, $n+l$ rule (qualitative discussion only). Periodic table.

Normal and Anomalous Zeeman Effect, Lande g factor, Paschen Back effect.

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.

Elements of Molecular Physics **18 Lectures**

Basics of Molecular Spectroscopy: Born-Oppenheimer approximation –Decoupling of electronic and nuclear degrees of freedom, Rigid rotor model for diatomic molecule, decoupling of rotational and vibrational degrees of freedom.

Microwave spectroscopy: Rotational spectrum of rigid diatomic molecule – Selection rules (no formal derivation) and intensities, rotational spectrum of non-rigid rotor (no formal derivation).

Infrared spectroscopy: Simple harmonic oscillator model of a vibrating diatomic molecule; selection rule (no formal derivation) and spectrum, qualitative idea of anharmonic effects; vibration – rotation spectrum of a diatomic molecule– breakdown of Born-Oppenheimer approximation ;

Raman effect – Stokes and anti-Stokes lines (qualitative idea based on quantum theory); Classical Theory based on molecular polarizability. Pure rotational Raman spectra of linear molecules.

Reference:

1. D. J. Griffiths, Introduction to Quantum Mechanics, Prentice Hall, NJ, 1995
2. Binayak Dutta Roy, Elements of Quantum Mechanics, New Age, New Delhi, 2009
3. N. Zettili, Quantum Mechanics: Concepts and Applications, Wiley India, 2016
4. A. Beiser, Concepts of Modern Physics, 6th. ed., McGraw-Hill, New York, 2003
5. R. B. Leighton, Principles of Modern Physics, McGraw-Hill, New York. 1959
6. F. K. Richtmyer, E. H. Kennard, J. N. Cooper, Introduction to Modern Physics, 6th. ed., Tata McGraw-Hill, New Delhi. 1976
7. C. M. Banwell and E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th. ed., McGraw-Hill, London. 1994
8. Introduction to Quantum Mechanics, P. T. Matthews. McGraw-Hill, New York. 1968.

DS-19

Nuclear and Particle Physics (Theory)

PHSDSC819T

60 Lectures **5 Credits**

General Properties of Nuclei **5 Lectures**

Recapitulation: Nuclear constituents, mass, radii, charge and matter densities, binding energy, binding energy with mass number curve, N-Z plot, angular momentum, parity, electric and magnetic moments, excited states.

Radioactive decay **8 Lectures**

Recapitulation: alpha, beta and gamma decay,
Theory of alpha decay and Gamow factor, alpha-spectroscopy, Fermi's theory of beta decay, Kurie plot, Gamma decay: Transitions and selection rule (no derivation), Mossbauer spectroscopy, internal conversion.

Nuclear Models **7 Lectures**

Recapitulation: Liquid drop model approach, semi empirical mass formula and significance of its various terms, evidence for shell structure and concept of magic numbers.
Liquid drop model: Condition of nuclear stability, two nucleon separation energies.
Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas).
Shell model: basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force.

Nuclear Reactions **9 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): derivation using classical mechanics.

Interaction of Nuclear Radiation with matter **8 Lectures**

Energy loss due to ionization (Bethe- Bloch 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 particles 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**

Van-de Graaff generator (Tandem accelerator), Linear accelerator, Cyclotron, Limitations of Cyclotron and remedies, Synchrotron, Accelerator facility available in India.

Particle physics **10 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.

Reference:

1. Nuclear and Particle Physics. B.R. Martin, 2006, John Wiley & Sons.
2. An Introduction to Nuclear Physics. W. N. Cottingham and D.A. Greenwood, 2004, Chambridge.
3. Introductory nuclear Physics by Kenneth S. Krane (Wiley India Pvt. Ltd., 2008).
4. Concepts of nuclear physics by Bernard L. Cohen. (Tata Mcgraw Hill, 1998).
5. Introduction to Elementary Particles, D. Griffith, John Wiley & Sons.
6. Basic ideas and concepts in Nuclear Physics - An Introductory Approach by.
   K. Heyde (IOP- Institute of Physics Publishing, 2004).
7. Concepts of Modern Physics, A. Beiser, Tata McGraw Hill
8. Radiation detection and measurement, G.F. Knoll (John Wiley & Sons, 2000).
9. Theoretical Nuclear Physics, J.M. Blatt &V.F.Weisskopf (Dover Pub.Inc., 1991)
10. Nuclear Physics, S.N.Ghoshal,2006, S. Chand & Company ltd.

DS-20

Mechanics III (Theory)

PHSDSC820T

60 Lectures **5 Credits**

1. Lagrangian Dynamics **15 Lectures**

Generalised Coordinate system, Constraints, Virtual displacement and Principle of virtual work, Lagrange's equation for the cases with semi-holonomic constraints from D'Alembert's principle and Lagrangian, Cyclic coordinates, Evaluation of constraint forces in general, Simple problems with both time-dependent and time independent constraints, Concept of action and Lagrange's equation from Least Action Principle.

2. Symmetries and Conservation principle **3Lectures**

Homogeneity and isotropy of space and the conservation of linear and angular momentum, homogeneity of time and conservation of Hamiltonian.

3. Hamiltonian dynamics **12 Lectures**

Hamiltonian as a Legendre transform of the Lagrangian, 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.

4. Dynamical Systems **16 Lectures**

Definition of a continuous dynamical system. T. Autonomous and non-autonomous systems, dimensionality. he idea of phase space, flows and trajectories. Linear stability analysis to study the behaviour of a one-dimensional autonomous system. Illustration of the method using a system described by $v = f(x)$ and comparing it with the exact analytical solution. Extension of the method for simple mechanical systems as two-dimensional dynamical systems, calculation of eigensystems of the Jacobian, categorisation of fixed points: Example of non linearizable systems. Nullclines. Flows from nullclines. illustrations for a particle under uniform gravity, simple and damped harmonic oscillators (both under-damped and over-damped). Sketching of flows and trajectories in phase space.

5. Nonlinear Dynamics **14 Lectures**

Phase space diagram for the general motion of a pendulum and its behaviour. Oscillator with non-linear damping, Vander-Pol oscillator as the example, idea of limit cycle Study on the behaviour of the quartic oscillator with an attractive or repulsive quadratic term in the potential; . 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 and their stability. Parameter dependence of logistic map- steady, periodic and chaos states. Idea of chaos and Lyapunov exponent, Self-similarity, Fractal and Fractal dimensions.

Reference:

1. Classical Mechanics, Herbert Goldstein, Pearson Education; 3rd edition (1 January 2011).
2. Classical Mechanics: A Course of Lectures, A. K. Raychaudhuri, OUP India (1 December 1983).
3. Classical Dynamics of Particles and Systems, S.T. Thornton and J. B. Marion, Brooks/Cole; 5th edition (7 July 2003).
4. Schaum's outline series on Theoretical Mechanics , Murray Spiegel, McGraw Hill Education (1 July 2017).
5. Mechanics, Course of Theoretical Physics - Vol. 1 L. D. Landau and E. M. Lifshitz, cbspd, Third edition (1 January 2010).
6. Classical Mechanics. Takwale and Puranike
7. Classical Mechanics, Rana & Joag
8. Nonlinear Dynamics and Chaos, S.H. Strogartz, Westview Press; 2nd edition.

DS-21

Communication Electronics (Theory)

PHSDSC821T

45 Lectures **3 Credits**

Electronic communication **7 Lectures**

Introduction to communication–Need for modulation. Block diagram of an electronic communication system. Electromagnetic spectrum, Brief idea of frequency allocation for radio communication system in India (TRAI), band designations and usage. Channels and base-band signals. Concept of Noise, signal-to-noise (S/N) ratio, Noise figure.

Analog Modulation **12Lectures**

Amplitude Modulation, modulation index and frequency spectrum. Generation of AM (Emitter Modulation), Amplitude Demodulation (diode detector), Concept of Single side band generation and detection. Frequency Modulation (FM) and Phase Modulation (PM), modulation index and frequency spectrum, equivalence between FM and PM, Generation of FM using VCO, FM detector (slope detector), Qualitative idea of Super heterodyne receiver, utility of Heterodyning, Different Stages.

Analog Pulse Modulation **5 Lectures**

Channel Capacity, Sampling Theorem, Basic principles of PAM, PWM, PPM, Modulation and Detection Techniques for PAM only, Multiplexing, TDM and FDM.

Digital Carrier Modulation Techniques **9 Lectures**

Need for Digital Transmission, Block Diagram of Digital Transmission and Reception, Pulse Code Modulation, Sampling, Quantization (Uniform and Non-uniform), Quantization Error, Companding, Encoding, Decoding, Regeneration, Concept of Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), Binary Phase Shift Keying (BPSK) and Quadrature Phase Shift Keying (QPSK), Advantages and Disadvantages of Digital Communication, Characteristics of Data Transmission Circuits, Shannon Limit for Information Capacity, Bandwidth Requirements, Data Transmission Speed (Bit Rate and Baud Rate), Noise, Cross Talk, Echo Suppressors, Distortion and Equalizer.

Satellite Communication **5 Lectures**

Satellite Communication– Introduction, need, Geosynchronous satellite orbits, geostationary satellite, advantages of geostationary satellites. Satellite visibility, transponders (C-Band), path loss, ground station, simplified block diagram of earth station. Uplink and downlink.

Cellular Communication **7 Lectures**

Concept of Cellular Mobile Communication, Frequency Bands used in Cellular Communication, Concept of Cell Sectoring and Cell Splitting, Mobile Telephony System – Basic concept of mobile communication, frequency bands used in mobile communication, SIM number, IMEI number, need for data encryption, architecture (block diagram) of mobile communication network, idea of GSM, CDMA, TDMA and FDMA technologies, simplified block diagram of mobile phone handset, 2G, 3G and 4G concepts (qualitative only).

Reference:

1. Electronic Communications, D. Roddy and J. Coolen, Pearson Education India.
2. Advanced Electronics Communication Systems- Tomasi, 6th edition, Prentice Hall.
3. Electronic Communication systems, G. Kennedy, 3rd Edn, 1999, Tata McGraw Hill.
4. Principles of Electronic communication systems – Frenzel, 3rd edition, McGraw Hill
5. Communication Systems, S. Haykin, 2006, Wiley India
6. Electronic Communication system, Blake, Cengage, 5th edition.
7. Wireless communications, Andrea Goldsmith, 2015, Cambridge University Press.

DS-21 (Lab)

Communication Electronics (Lab)

PHSDSC821P

60 Lectures **2 Credits**

List of Experiments

1. To Design an Amplitude Modulator using Transistor.
2. To Design an Amplitude Demodulator by linear diode detector.
3. To design a simple Pulse Amplitude Demodulator using R-C circuit.
4. To study FM – Generator and Detector circuit.
5. To study Pulse amplitude modulation (PAM).
6. To study Pulse Position Modulation (PPM) and Pulse Width Modulation (PWM).
7. To study Time Division Multiplexing (TDM).
8. To study ASK, PSK and FSK modulators

Minor Courses

Semester 1

Minor 1/Core 1

Mechanics (Theory)

PHSMIN101T/PHSCOR101T

45 Lectures **3 Credits**

Vectors **10 Lectures**

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 **14 Lectures**

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 **7 Lectures**

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.

Oscillations **6 Lectures**

Differential equation of SHM and its solutions. Kinetic and Potential Energy, Total Energy and their time averages. Damped oscillations. Forced harmonic oscillations, resonance.

Elasticity **8 Lectures**

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.

Reference:

1. Introduction to Mathematical Physics. C. Harper, 1989, PHI.
2. An introduction to mechanics, D. Kleppner, R.J. Kolenkow, 1973, McGraw-Hill.
3. Physics, Resnick, Halliday and Walker 8/e. 2008, Wiley.
4. Theoretical Mechanics, M.R. Spiegel, 2006, Tata McGraw Hill.
5. Classical Mechanics and General Properties of Matter. S.N. Maiti and D.P. Raychaudhuri, New Age
6. Introduction to Classical Mechanics, R. G. Takwale and P. S. Puranik, 1979, Tata McGraw-Hill
7. Elements of Properties of Matter, D.S. Mathur, 2008, S. Chand and Company Limited

Mechanics (Minor 1/Core 1) Lab

PHSMIN101P/PHSCOR101P

60 lectures **2 Credits**

List of Experiments:

1.To determine the Moment of Inertia of a regular body using another auxiliary body and a cradle suspended by a metallic wire.

2. To determine g and velocity for a freely falling body using Digital Timing Technique.

3. To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).

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 value of g using Bar Pendulum.

7. To determine the value of g using Kater's Pendulum.

Reference:

1. An Advanced Course in Practical Physics, D. Chattopadhyay and P. C. Rakshit, 8th ed., 2007, New Central Book Agency
2. Advanced Practical Physics, vol 1, B. Ghosh & K. G. Mazumdar, 7th ed., Sreedhar Publishers, 2006

Semester 2

Minor 2/Core 2

Electricity and Magnetism (Theory)

PHSMIN202T/PHSCOR202T

45 Lectures **3 Credits**

Vector Analysis **10 Lectures**

Gradient, divergence, Curl and their significance, Vector Integration, Line, surface and volume integrals of Vector fields, Gauss-divergence theorem and Stoke’s theorem of vectors (statement only).

Electrostatics **16 Lectures**

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. Electric potential due to an electric dipole. Calculation of electric field from potential. Capacitance of an isolated spherical conductor. Parallel plate 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.

Magnetism **9 Lectures**

Magnetostatics: Biot-Savart's law & 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.

Electromagnetic Induction **5 Lectures**

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.

Linear Network **5 Lectures**

Impedance of L, C, R and their combinations. Thevenin & Norton’s Theorem. Maximum power transfer theorem and superposition theorem. Anderson’s bridge.

Reference:

1. Vector Analysis with an Intro. to Tensor Analysis: Schaum’s Outline Series. M.R. Spiegel, McGraw Hill.
2. Foundations of Electromagnetic Theory. J.R. Reitz, F.J. Milford and R.W. Christy, 2010, Pearson.
3. Introduction to Electrodynamics, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.
4. Electricity and Magnetism, vol. 1, J. H. Fewkes and J. Yarwood, 2nd. ed., 1965, Oxford University Press
5. Electromagnetism. I.S. Grant and W.R. Phillips, 2013, Wiley.
6. Classical Electromagnetism. J. Franklin, 2008, Pearson Education.
7. Elements of Electromagnetics, M.N.O. Sadiku, 2010, Oxford University Press.
8. Electricity, Magnetism & Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw Hill.
9. A text book in Electrical Technology, B L Theraja, S Chand and Co.

Electricity and Magnetism (Minor 2/Core 2) Lab

PHSMIN202P/PHSCOR202P

60 lectures **2 Credits**

List of Experiments:

1.To determine an unknown Low Resistance using Carey Foster's Bridge.

2. To verify the Thevenin and Norton theorems.
3. To verify the Superposition and Maximum Power Transfer theorems.
4. To determine self-inductance of a coil by Anderson's bridge.
5. To study response curve of a Series LCR circuit and determine its (a) Resonant frequency, (b) Impedance at resonance, (c) Quality factor Q, and (d) Band width.
6. To determine an unknown Low Resistance using Potentiometer.
7. Measurement of field strength B and its variation in a solenoid (determine dB/dx)

Reference:

1. An Advanced Course in Practical Physics, D. Chattopadhyay and P. C. Rakshit, 8th ed., 2007, New Central Book Agency
2. Advanced Practical Physics, vol 1, B. Ghosh & K. G. Mazumdar, 7th ed., Sreedhar Publishers, 2006
3. Advanced Practical Physics, vol 2, B. Ghosh, 2nd ed., Sreedhar Publishers, 2005

4. Semester 3

Minor 3/Core 3

Fluids and Waves (Theory)

PHSMIN303T/PHSCOR303T

45 lectures **3 Credits**

Fluids **5 lectures**

Surface Tension: Synclastic and anticlastic surface - Excess of pressure - Application to spherical and cylindrical drops and bubbles - variation of surface tension with temperature.

Viscosity: Viscosity - Rate flow of liquid in a capillary tube - Poiseuille's formula - Determination of coefficient of viscosity of a liquid - Variations of viscosity of a liquid with temperature.

Superposition of Harmonic Oscillations **6 lectures**

Linearity & Superposition Principle. (1) Oscillations having equal frequencies and (2) Oscillations having different frequencies (Beats).

Superposition of two perpendicular harmonic oscillations: Graphical and Analytical Methods. Lissajous Figures with equal frequency and their uses.

Wave Motion – General **5 lectures**

Transverse waves on a string. Travelling and standing waves on a string. Normal Modes of a string. Group velocity, Phase velocity. Wave intensity.

Wave optics **2 lectures**

Electromagnetic nature of light. Concept of wave front. Huygens Principle.

Interference and Interferometer **10 lectures**

Division of amplitude and wavefront. Young's double slit experiment. Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal thickness (Fizeau Fringes). Newton's Rings: Measurement of wavelength and refractive index.

Michelson Interferometer (No analytical derivation). Applications of Michelson interferometer. Fringes of Equal Inclination. Fabry-Perot interferometer. Visibility of Fringes.

Diffraction **13 lectures**

Fraunhofer diffraction- Single slit; Double Slit. Multiple slits and Diffraction grating. Fresnel Diffraction: Half-period zones. Zone plate. Fresnel Diffraction pattern of a straight edge, a slit and a wire using half-period zone analysis.

Polarization **4 lectures**

Transverse nature of light waves. Plane polarized light – production and analysis. Circular and elliptical polarization.

Reference:

1. Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.
2. The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.
3. Advanced Acoustics, D.P.Ray Chaudhury, The New Book Stall
4. The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.
5. Optics. E. Hecht, 2003, Pearson Education.
6. Principles of Optics, B.K. Mathur, 1995, Gopal Printing
7. Classical Mechanics and General Properties of Matter. S.N. Maiti and D.P. Raychaudhuri, New Age

Minor 3/CORE3

Fluids and Waves (Lab)

PHSMIN303P+PHSCOR303P

60 lectures **2 Credits**

List of Experiments:

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify λ^2 –T law.
2. To study Lissajous Figures to determine the phase difference between two harmonic oscillations.
3. To determine the angle of prism and refractive index of the Material of a prism using sodium source.
4. To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
5. To determine wavelength of sodium light using Newton's Rings.
6. To determine wavelength of Na source using plane diffraction grating.
7. To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).

Reference:

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House
2. A Laboratory Manual of Physics for undergraduate classes, D.P.Khandelwal, 1985, Vani Publications.
3. An Advanced Course in Practical Physics, D Chattopadhyay and P.C.Rakshit, New Central Book Agency.
4. A Text book on Practical Physics, K.G. Majumder and B.Ghosh, Sreedhar Publishers.

Semester 4

Minor 4/Core 4

Thermal Physics and Statistical Mechanics (Theory)

PHSMIN404T/PHSCOR404T

45 Lectures **3 Credits**

Laws of Thermodynamics **22 Lectures**

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.

Thermodynamic Potentials **7 Lectures**

Internal Energy, Enthalpy, Gibbs free energy and Helmholtz free energy, Maxwell's relations and applications– Joule-Thompson Effect, Clausius-Clapeyron Equation, General relation between Cp and Cv, TdS equations.

Kinetic Theory of Gases **7 Lectures**

Maxwell-Boltzmann Law of distribution of speed in an Ideal Gas (derivation required), Mean, RMS and Most Probable Speeds. Degrees of Freedom, Law of Equipartition of Energy (no proof required), Specific Heats of Gases: mono-atomic and diatomic gases, Mean Free Path and estimates of Mean Free Path.
Transport Phenomena: Viscosity, Conduction and Diffusion (no derivation required).

Statistical Mechanics **9 Lectures**

Phase space, Macrostate and Microstate, Entropy and Thermodynamic probability, Classical statistics – Boltzmann distribution; Quantum statistics (qualitative discussion only) - Fermi-Dirac distribution law (statement only) - electron gas as an example of Fermi gas: Low temperature specific heat of electron gas (order of magnitude estimate); Bose-Einstein distribution law (statement only) - photon gas as an example of Bose gas- comparison of three statistics.

Reference:

1. Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Ed., 2012, Oxford Univ Press
2. Thermal Physics, S. Garg, R. Bansal and C. Ghosh, 1993, Tata McGraw-Hill.
3. A Treatise on Heat, Meghnad Saha, and B.N. Srivastava, 1969, Indian Press.
4. Thermodynamics, Enrico Fermi, 1956, Courier Dover Publications.
5. Heat and Thermodynamics, M.W.Zemasky and R. Dittman, 1981, McGraw Hill
6. Thermodynamics, Kinetic theory & Statistical thermodynamics, F.W.Sears and G.L. Salinger. 1988, Narosa
7. University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.
8. Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. Chand

Thermal Physics and Statistical Mechanics (Minor 4/Core 4) Lab
PHSMIN404P/PHSCOR404P

60 Lectures **2 Credits**

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 method.
3. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT) using constant current source.
4. Measurement of unknown temperature using Diode sensor.
5. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
6. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.

Reference:

1. Advanced Practical Physics for students, B.L.Flint & H.T.Worsnop, 1971, Asia Publishing House.
2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
3. A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.
4. A Laboratory Manual of Physics for Undergraduate Classes, D.P. Khandelwal, 1985, Vani Publication.

Minor 5/Core 5

Modern Physics (Theory)

PHSMIN505T/PHSCOR505T

60 Lectures **5 Credits**

Elements of Special Relativity **8 Lectures**

Brief summary of Lorentz transformation and time dilation, length contraction, velocity addition etc. (no derivation required). Elastic collision between two particles as observed from two inertial frames with relative velocity, idea of relativistic momentum and relativistic mass. Mass-energy equivalence.

Quantum Theory of Light **4 Lectures**

Review on the limitations of classical theory of electromagnetic radiation within a cavity and its solution by Planck's quantum hypothesis (no derivation required). Statement of Planck's law of black body radiation. Photoelectric effect. Einstein's postulate on light as a stream of photons. Compton's scattering and its explanation.

Bohr's model **3 Lectures**

Limitations of Ruherford's model of atomic structure. Bohr's model, its successes and limitations. Moseley's law: explanation from Bohr's model.

Wave-particle Duality **3 Lectures**

De Broglie's hypothesis – wave particle duality. Davisson-Germer experiment. Connection with Einstein's postulate on photons and with Bohr's quantization postulate for stationary orbits. Heisenberg's uncertainty relation as a consequence of wave-particle duality. Demonstration by γ-ray microscope thought experiment. Estimating minimum energy of a confined particle using uncertainty principle.

Wavefunction Description **3 Lectures**

Two slit interference experiment with photons, atoms & particles; linear superposition principle of associated wave functions as a consequence; Departure from matter wave interpretation and probabilistic interpretation of wave function; Schroedinger equation for non-relativistic particles; Momentum and Energy operators; stationary states. Properties of wave function. Probability and probability current densities in one dimension.

Stationary State Problems **7 Lectures**

One Dimensional infinitely rigid box, energy eigenvalues and eigenfunctions, normalization; Quantum dot as an example. Quantum mechanical scattering and tunnelling in one dimension - across a step potential and across a rectangular potential barrier: boundary conditions.

Atomic Physics **12 Lectures**

Quantization rules energy and orbital angular momentum from Hydrogen and Hydrogen like atoms (no derivation); s, p, d shells-subshells. Space quantization. Orbital Magnetic Moment and Magnetic Energy of electron, Gyromagnetic Ratio and Bohr magneton. Zeeman effect.

Electron Spin as relativistic quantum effect (qualitative discussion only), Spin Angular Momentum. Spin Magnetic Moment. Stern-Gerlach Experiment. Larmor Precession. Spin-orbit interaction. Addition of angular momentum (statement only). Energy correction due to relativistic effect and spin-orbit ineraction (statement only). Fine-structure splitting.

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

Nuclear Physics **15 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. Binding energy curve.

Radioactivity: stability of the nucleus; Law of radioactive decay; Mean life and half-life; Alpha decay, beta decay, gamma emission – basic characteristics.

Fission and fusion- mass deficit, relativity and generation of energy; Fission - nature of fragments and emission of neutrons. Basic principle of a nuclear reactor: slow neutrons interacting with Uranium 235; Fusion and basic principle of thermonuclear reactions

Structure of Solids **5 Lectures**

Amorphous and crystalline solids. Lattice structure of crystalline (no categorisation required). Unit cell and basis vectors of a lattice. Diffraction of X-ray by crystalline solid. Bragg's law.

Reference:

1. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles. R. Eisberg and R. Resnick, 1985, Wiley.
2. Concept of Modern Physics. 6 ed., A. Beiser, 2003, McGraw-Hill.
3. Introduction to Modern Physics, Rich Meyer, Kennard, Coop, 2002, Tata McGraw Hill

4. Introduction to Quantum Mechanics, David J. Griffith, 2005, Pearson Education.

5. Physics for scientists and Engineers with Modern Physics, Jewett and Serway, 2010, Cengage Learning. 6. Modern Physics, G.Kaur and G.R. Pickrell, 2014, McGraw Hill

Semester-6

Minor 6/Core 6
Analog and Digital Electronics (Theory)
PHSMIN606T/PHSCOR606T

45 Lectures **3 Credits**

Semiconductor Devices and Amplifiers **10 Lectures**

Barrier Formation in PN Junction Diode. Qualitative Idea of Current Flow Mechanism in Forward and Reverse Biased Diode. Principle and structure of (1) LEDs, (2) Photodiode, (3) Solar Cell 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) **12 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, Sinusoidal Oscillators: Barkhausen's Criterion for Self-sustained Oscillations. Determination of Frequency of RC Oscillator.

Instrumentations **13 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: 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 Multivibrator.

Digital Circuits **10 Lectures**

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. Half Adders and Full Adders and Subtractors, 4-bit binary Adder-Subtractor.

Reference:

1. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
2. Electronic devices & circuits, S. Salivahanan& N.S. Kumar, 2012, Tata Mc-Graw Hill
3. Modern Electronic Instrumentation and Measurement Tech., Helfrick and Cooper, 1990, PHI Learning
4. Digital Principles and Applications, A.P. Malvino, D.P. Leach and Saha, 7th Ed., 2011, Tata McGraw Hill
5. Fundamentals of Digital Circuits, A. Anand Kumar, 2nd Edition, 2009, PHI Learning Pvt. Ltd.
6. OP-AMP & Linear Digital Circuits, R.A. Gayakwad, 2000, PHI Learning Pvt. Ltd.

Analog and Digital Electronics (Minor 6/Core 6) Lab
PHSMIN606P/PHSCOR606P

60 Lectures **2 Credits**

List of Experiments

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

Reference:

1. Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, Mc-Graw Hill.
2. Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
3. OP-Amps & Linear Integrated Circuit, R.A. Gayakwad, 4th Edn, 2000, Prentice Hall.
4. Electronic Principle, Albert Malvino, 2008, Tata Mc-Graw Hill.
5. Advanced Practical Physics Vol.-II, B. Ghosh, Sreedhar Publishers

Semester-7

S Minor-1

PHSSMC01T

Solid State Physics (Theory)

45 Lectures **3 Credits**

Elements of Modern Physics **8 Lectures**

Brief introduction to limitations of classical physics and advent of quantum physics. Brief review of Bohr's atomic model and photoelectric effect. Einstein's postulate on light as a stream of photons. Davisson-Germer experiment. De Broglie's hypothesis – wave particle duality. Schroedinger equation for non-relativistic particles. Probabilistic interpretation of wave function. Particle moving in one dimensional box: energy eigenvalues and eigenfunctions; normalization.

Statistical behavior of a many particle system: idea of distribution function. Maxwell-Boltzman distribution law (statement only): example of velocity distribution in an ideal gas (qualitative). Classical equipartition theorem (statement only). Distribution function for quantum paticles: Fermi-Dirac and Bose-Einstein distributions (statement only). Examples of fermions and bosons.

Crystal Structure **8 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.

Elementary Lattice Dynamics **7 Lectures**

Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustic and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, its limitations. Einstein's theory of specific heat of solids, its limitations. Debye's correction (qualitative idea), T^3 law (statement only).

Free electron theory of Metals 8 Lectures

Free electron gas in metals: Drude's theory, drift current, mobility and conductivity, Hall effect in metals. Thermal conductivity. Lorentz number, limitation of Drude's theory. Sommerfield correction to free electron theory in a Metal: Fermi Energy – dependence on density, Fermi temperature, Fermi momentum. Ground state energy. Electronic specific heat at low temperatures (explanation of linear behavior in T using exclusion principle).

Elementary band theory 5 Lectures

Idea of electronic energy bands using the Kronig Penny model. Band Gap. Classification of Conductor, Semiconductor (intrinsic, as well as P and N types) and Insulator. Conductivity of Semiconductor, mobility, Hall Effect.

Magnetic Properties of Matter 6 Lectures

Dia-, Para-, and Ferromagnetic Materials. Classical Langevin Theory of dia- and Paramagnetism. Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains. Discussion of B-H Curve. Hysteresis and Energy Loss.

Superconductivity 3 Lectures

Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors.

Reference:

1. Concepts of Modern Physics, Arthur Beiser, 6th Edition, 2005, Tata McGraw Hill
2. Introduction to Solid State Physics, Charles Kittel, 8th Edition, 2004, Wiley India Pvt. Ltd.
3. Elementary Solid State Physics, 1/e M. Ali Omar, 1999, Pearson India
4. Introduction to Solids, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill
5. The Oxford Solid State Basics. S. H. Simon, 2013, Oxford.
6. Elements of Solid State Physics, J.P. Srivastava, 4th Edition, 2015, Prentice-Hall of India
7. Solid State Physics, M.A. Wahab, 2011, Narosa Publications

S Minor-1

Solid State Physics Lab

PHSSMC701P

60 Lectures **2 Credits**

List of Experiments:

2. To draw the *B-H* curve of Fe using Solenoid & determine energy loss from Hysteresis.

3. To measure the resistivity of a semiconductor (Ge) with temperature by reverse bias characteristics of a Ge diode (room temperature to 80^{o}C) and to determine its band gap.

4. To determine the Hall coefficient of a doped semiconductor sample.

5. Measurement of susceptibility of paramagnetic solution (Quinck's Tube Method).

6. To measure the Magnetic susceptibility of paramagnetic Solids (Gouy's Method).

Skill Enhancement Courses

Physics

Semester 1/Semester 3

SEC (Physics) 1

Basic Instrumentation Skills

PHSHSE101M/PHSGSE301M/PHSGSE501M

45 Lectures **3 Credits**

1. **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.

2. **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.

3. **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.

4. **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.

5. **Digital Instruments**

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

6. **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. Trouble shooting a circuit
8. 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. Measurement of voltage, frequency, time period and phase angle using CRO.
4. Measurement of time period, frequency, average period using universal counter/ frequency counter.
5. Measurement of rise, fall and delay times using a CRO.
6. Measurement of distortion of a RF signal generator using distortion factor meter.

Reference:

1. A text book in Electrical Technology - B L Theraja - S Chand and Co.
2. Performance and design of AC machines - M G Say ELBS Edn.
3. Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
4. Logic circuit design, Shimon P. Vingron, 2012, Springer.
5. Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.
6. Electronic Devices and circuits, S. Salivahanan & N. S.Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill
7. Electronic circuits: Handbook of design and applications, U.Tietze, Ch.Schenk, 2008, Springer
8. Electronic Devices, 7/e Thomas L. Floyd, 2008, Pearson India

Semester 2/ Semester 4

SEC (Physics) 2

Computational Physics Skills

PHSHSE202M/PHSGSE402M/PHSGSE602M

45 Lectures **3 Credits**

Introduction

Importance of computers in Physics, paradigm for solving physics problems for solution. Usage of linux as an Editor. Algorithms and Flowcharts: Algorithm: Definition, properties and development. Flowchart: Concept of flowchart, symbols, guidelines, types. Examples: Cartesian to Spherical Polar Coordinates, Roots of Quadratic Equation, Sum of two matrices, Sum and Product of a finite series, calculation of sin(x) as a series, algorithm for plotting (1) lissajous figures and (2) trajectory of a projectile thrown at an angle with the horizontal.

Scientific Programming

Some fundamental Linux Commands (Internal and External commands). Development of FORTRAN/ C++, Basic elements of FORTRAN 90/95 or C++: Character Set, Constants and their types, Variables and their types, Keywords, Variable Declaration and concept of instruction and program. Operators: Arithmetic, Relational, Logical and Assignment Operators. Expressions: Arithmetic, Relational, Logical, Character and Assignment Expressions. Fortran Statements: I/O Statements (unformatted/formatted), Executable and Non-Executable Statements, Layout of Fortran 90/95 or C++ Program, Format of writing Program and concept of coding, Initialization and Replacement Logic. Examples from physics problems.

Control Statements

Types of Logic (Sequential, Selection, Repetition), Branching Statements, Looping Statements, Jumping Statements, Subscripted Variables (Arrays: Types of Arrays, DIMENSION Statement, Reading and Writing Arrays), Functions and Subroutines (Arithmetic Statement Function, Function Subprogram and Subroutine), RETURN, CALL, COMMON and EQUIVALENCE Statements), Structure, Disk I/O Statements, open a file, writing in a file, reading from a file. Examples from physics problems.

Programming

1. Exercises on syntax on usage of FORTRAN 90/95 or C++
2. Usage of GUI Windows, Linux Commands, familiarity with DOS commands and working in an editor to write sources codes in FORTRAN 90/95 or C++.
3. To print out all natural even/ odd numbers between given limits.
4. To find maximum, minimum and range of a given set of numbers.
5. Calculating Euler number using exp(x) series evaluated at x=1

Scientific word processing: Introduction to LaTeX

TeX/LaTeX word processor, preparing a basic LaTeX file, Document classes, Preparing an input file for LaTeX, Compiling LaTeX File, LaTeX tags for creating different environments, Defining LaTeX commands and environments, Changing the type style, Symbols from other languages. Equation representation: Formulae and equations, Figures and other floating bodies, Lining in columns- Tabbing and tabular environment, Generating table of contents, bibliography and citation, Making an index and glossary, List making environments, Fonts, Picture environment and colors, errors.

Visualization

Introduction to graphical analysis and its limitations. Introduction to Gnuplot. importance of visualization of computational and computational data, basic Gnuplot commands: simple plots, plotting data from a file, saving and exporting, multiple data sets per file, physics with Gnuplot (equations, building functions, user defined variables and functions), Understanding data with Gnuplot

Hands on exercises

1. To compile a frequency distribution and evaluate mean, standard deviation etc.
2. To evaluate sum of finite series and the area under a curve.
3. To find the product of two matrices
4. To find a set of prime numbers and Fibonacci series.
5. To write program to open a file and generate data for plotting using Gnuplot.
6. Plotting trajectory of a projectile projected horizontally.
7. Plotting trajectory of a projectile projected making an angle with the horizontally.
8. Creating an input Gnuplot file for plotting a data and saving the output for seeing on the screen. Saving it as an eps file and as a pdf file.
9. To find the roots of a quadratic equation.
10. Motion of a projectile using simulation and plot the output for visualization.
11. Numerical solution of equation of motion of simple harmonic oscillator and plot the outputs for visualization.

12. Motion of particle in a central force field and plot the output for visualization.

Reference:

1. Computer Programming in Fortran 90 and 95. V. Rajaraman, 1997 (Publisher: PHI).
2. Object Oriented Programming with C++. E. Balaguruswamy, 2017. McGraw Hill, India.
3. LaTeX–A Document Preparation System, Leslie Lamport (Second Edition, Addison- Wesley, 1994).
4. Gnuplot in action: understanding data with graphs, Philip K Janert, (Manning 2010)
5. Computational Physics: An Introduction, R.C. Verma, et al. New Age International Publishers, New Delhi(1999)

MDC (Physics)

Current perspectives of Physics

PHSHMD101M/PHSHMD201M/PHSHMD301M

PHSGMD401M/PHSGMD501M/PHSGMD601M

45 Lectures **3 Credits**

Course objective: To give an overview of some basic physical ideas at a semi-popular level – with minimal use of mathematics.

Course Pre-requisites: High school level exposure of physical science, algebra and geometry.

Module 1

1(a) Introduction : **2 lectures**

Qualitative idea of Systems, Observers, Reference frames and Forces originating from the fundamental Interactions of nature, long-range (gravity and electromagnetic) and short-range (strong and weak forces).

1(b) How Physics works: **12 lectures**

Examples of how observations lead to discovery of Laws of nature, how theories are constructed around these laws, how experiments verify theoretical predictions and theories are modified to suit the experimental findings.

Examples:

- Galilean and Newtonian Dynamics giving Laws of motion, Kepler's laws of Planetary motion explained by Newton's theory of gravity, Discovery of Neptune as a verification of Newton's gravity theory, Newton's gravitational constant. [3 lectures]

- Different empirical laws of Electromagnetism (Coulomb's law, Faraday's law, Ampere's law etc) connected by Maxwell's theory, Prediction of electromagnetic wave and its speed of propagation as a Universal constant. Inconsistency with laws of Galilean Relativity leading to discovery of Special Relativity. [4 lectures]

- Observation of atomic spectra and Black-body radiation leading to Planck's quantum theory and Einstein's explanation of Photoelectric effect introducing Photon as a "quanta of energy"(Details to be covered in Module 3). Discovery of Bohr model of atom. Development of quantum mechanics, Planck's constant – a fundamental constant of nature.

[5 lectures]

Module 2

The grand scheme of Physics: **13 lectures**

The three fundamental constants of nature, *c*, *G* and $\hbar\hbar$.

($c^{-1}c^{-1}$ = 0, G = 0, $\hbar\hbar$ = 0) : Classical non-relativistic mechanics: the starting point.

($c^{-1}c^{-1}$ = 1, G = 0, $\hbar\hbar$ = 0) : Classical relativistic mechanics, SR, Electrodynamics

(*mention basic technologies like, cars, electricity, energy industry*) [1 lecture]

($c^{-1}c^{-1}$ = 0, G = 1, $\hbar\hbar$ = 0) : Classical Newtonian gravity, falling bodies, Structure of solar system, Galaxies. [1 lecture]

($c^{-1}c^{-1}$ = 0, G = 0, $\hbar\hbar$ = 1) : Non-relativistic quantum mechanics, basic structure of atoms, molecules, solid state physics. (Qualitative)

(*mention modern application in electronic and data storage devices, e.g., computers, mobiles*).

[4 lectures]

($c^{-1}c^{-1}$ = 1, G = 1, $\hbar\hbar$ = 0) : Classical General relativity, curved spacetime, fine-tuning of planetary motion, perihelion precession of Mercury, deflection of light by the Sun, recent observational evidence of Black-holes and Gravitational waves as predicted by theory.

(*modern applications in communication, e.g. GPS, astronomical telescopes giving information about the cosmological structure of the Universe*).

[5 lectures]

($c^{-1}c^{-1}$ = 1, G =0, $\hbar\hbar$ = 1) : Relativistic quantum mechanics, it's inconsistencies leading to Quantum field theory which explains sub-atomic structures, fundamental particles, standard model (LHC).

($c^{-1}c^{-1}$ = 1, G =1, $\hbar\hbar$ = 1) : Theory of Quantum Gravity, yet to be formalised. [2 lectures]

Module 3

3(a) Light and it's dual nature: **10 lectures**

Corpuscular and wave theories of light- a historical overview; merits and demerits of the two theories; simple experiments demonstrating dispersion of light using prism, diffraction of light with laser source, demonstration of Newton's rings and its qualitative explanation; naïve idea of black body radiation, Planck's proposal of energy quanta, photoelectric effect and particle nature of light;Scattering of light, Raman effect (qualitative).

3(b) The Electromagnetic Spectrum: **8 lectures**

Introduction to the entire electromagnetic spectrum; Light as an electromagnetic wave (mention Maxwell's theory, Hertz's experiment); usage of different parts of the electromagnetic spectrum - with examples from everyday life including x-rays and gamma-rays in medical science, microwaves and radio waves (mentioning India's Radio telescope site at GMRT), preliminary concepts of LASER, Holography and Fibre optics.

Reference:

1. Perspectives of Modern Physics, Arthur Beiser, McGraw-Hill Inc.,US, 1969.
2. The Feynman Lectures on Physics - Vol. I, II & III, Pearson Education; Combo edition, 2012.
3. At the root of Things, The subatomic world, Palash B. Paul, CRC Press, 2014.
4. □□ □□□□ □□□□□□□□□□ □□□, □□□□ □□□ □□□, □□□□□□□□□□ □□□□□ □□□□□□ □□□□□,□□ □□□□□□□, □□□□□
5. Seven Brief Lessons On Physics, Carlo Rovelli, Penguin Random House, UK, 2014.