UNIVERSITY OF CALCUTTA

Notification No. CSR/25/2026

It is notified for information of all concerned that in terms of the provisions of Section 54 of the Calcutta University Act, 1979, (as amended), and, in the exercise of his powers under 9(6) of the said Act, the Vice-Chancellor has, by an order dated 27.02.2026, approved the new revised complete Syllabus of 4-year Honours & Honours with Research and 3-year MDC of Physics under CCF, 2022.

The above shall take effect from the Even semester examinations, 2026 and onwards.

10-04-2026

SENATE HOUSE
Kolkata-700073
10.04.2026

Prof.(Dr.) Debasis Das
Registrar

Syllabus for the Undergraduate Course in Physics
(Semesters 1 to 8)

(Major, Multidisciplinary, Minor, and Interdisciplinary papers)

Revised as per CSR/52/2025 and CSR/1/2026
with Option B as mentioned in CSR/1/2026 for the 7th and the 8th Semesters

as approved by the UG Board of Studies in Physics
in its meeting held on February 10, 2026

Contents

Summary of Course Content

Syllabus for the Undergraduate Course in Physics (Semesters 1 to 8)
Major, Minor, and Multidisciplinary

Paper code	Course	Paper name (Level)	Credit	Page[1]
Semester 1				
PHS-DSCC-1-1	Physics Major	Basic Physics - I (100)	Th: 3, Pr: 1	13
PHS-SEC-1-1	Physics Major	Introduction to Computer Programming and Graph Plotting (100)	Th: 0, Pr: 4	16
PHS-CC-1-1	MDC (Core)	Basic Physics - I (100)	Th: 3, Pr: 1	13
PHS-Minor4/1-1-1	Minor[2]	Basic Physics - I (100)	Th: 3, Pr: 1	13
PHS-CC-SEC-1-1	MDC (SEC)	Introduction to Computer Programming and Graph Plotting (100)[3]	Th: 0, Pr: 4	16
Semester 2				
PHS-DSCC-2-1	Physics Major	Basic Physics - II (100)	Th: 3, Pr: 1	18
PHS-SEC-2-1	Physics Major	Scientific Writing Skills (LaTeX)[4] (100)	Th: 0, Pr: 4	20
PHS-CC-2-1	MDC (Core)	Basic Physics - II (100)	Th: 3, Pr: 1	18
PHS-Minor4/1-2-1	Minor[5]	Basic Physics - II (100)	Th: 3, Pr: 1	18
Semester 3				
PHS-DSCC-3-1	Physics Major	Waves and Optics (200)	Th: 3, Pr: 1	22
PHS-DSCC-3-2	Physics Major	Mathematical Physics I (200)	Th: 3, Pr: 1	24
PHS-SEC-3-1	Physics Major	Arduino (200)	Th: 1, Pr: 3	27
PHS-SEC-3-2	Physics Major	Introductory Data Analysis[6] (200)	Th: 1, Pr: 3	30
PHS-CC-3-1	MDC (Core)	Waves and Optics (200)	Th: 3, Pr: 1	70
PHS-Minor3-3-1	MDC (Minor)	Basic Physics - I (100)	Th: 3, Pr: 1	13
PHS-Minor4/2-3-1	Minor[7]	Basic Physics - I (100)	Th: 3, Pr: 1	13
Semester 4				
PHS-DSCC-4-1	Physics Major	Modern Physics (200)	Th: 3, Pr: 1	32
PHS-DSCC-4-2	Physics Major	Electromagnetism (200)	Th: 3, Pr: 1	33
PHS-DSCC-4-3	Physics Major	Mathematical Physics II (200)	Th: 3, Pr: 1	35
PHS-DSCC-4-4	Physics Major	Classical Mechanics and Special Theory of Relativity (200)	Th: 3, Pr: 1	38
PHS-CC-4-1	MDC (Core)	Modern Physics (200)	Th: 3, Pr: 1	72
PHS-CC-4-2	MDC (Core)	Electromagnetism (200)	Th: 3, Pr: 1	73
PHS-Minor3-4-1	MDC (Minor)	Basic Physics - II (100)	Th: 3, Pr: 1	18
PHS-Minor4/2-4-1	Minor[8]	Basic Physics - II (100)	Th: 3, Pr: 1	18

[1] This is where the detailed structure is given.
[2] Physics as Minor-1
[3] In Sem-1/2/3 if Physics is MDC (1st Major/2nd Major/Minor).
[4] The student can also opt for Artificial Intelligence, centrally offered by the University.
[5] Physics as Minor-1
[6] The student has to opt for one of these two SEC courses.
[7] Physics as Minor-2
[8] Physics as Minor-2

Paper code	Course	Paper name (Level)	Credit	Page
Semester 5				
PHS-DSCC-5-1	Physics Major	Electronics I (300)	Th: 3, Pr: 1	40
PHS-DSCC-5-2	Physics Major	Nuclear and Particle Physics (300)	Th: 3, Tut: 1	42
PHS-DSCC-5-3	Physics Major	Quantum Mechanics (300)	Th: 3, Pr: 1	43
PHS-DSCC-5-4	Physics Major	Thermal Physics and Statistical Mechanics (300)	Th: 3, Pr: 1	46
PHS-CC-5-1	MDC (Core)	Electronics I (300)	Th: 3, Pr: 1	74
PHS-CC-5-2	MDC (Core)	Nuclear and Particle Physics (300)	Th: 3, Tut: 1	76
PHS-Minor3-5-1	MDC (Minor)	Waves and Optics (200)	Th: 3, Pr: 1	70
PHS-Minor3-5-2	MDC (Minor)	Electronics I (200)	Th: 3, Pr: 1	74
PHS-Minor4/1-5-1	Minor	Waves and Optics (200)	Th: 3, Pr: 1	70
PHS-Minor4/1-5-2	Minor	Modern Physics (200)	Th: 3, Pr: 1	72
Semester 6				
PHS-DSCC-6-1	Physics Major	Electronics II (300)	Th: 3, Pr: 1	49
PHS-DSCC-6-2	Physics Major	Solid State Physics (300)	Th: 3, Pr: 1	50
PHS-DSCC-6-3	Physics Major	Atomic, Molecular, and Laser Physics (300)	Th: 3, Tut: 1	52
PHS-CC-6-1	MDC (Core)	Nuclear and Particle Physics (300)	Th: 3, Tut: 1	76
PHS-CC-6-2	MDC (Core)	Electronics II (300)	Th: 3, Pr: 1	77
PHS-Minor3-6-1	MDC (Minor)	Modern Physics (200)	Th: 3, Pr: 1	72
PHS-Minor3-6-2	MDC (Minor)	Electromagnetism (200)	Th: 3, Pr: 1	73
PHS-Minor4/2-6-1	Minor	Waves and Optics (200)	Th: 3, Pr: 1	70
PHS-Minor4/2-6-2	Minor	Modern Physics (200)	Th: 3, Pr: 1	72
Semester 7				
PHS-DSCC-7-1	Physics Major	Mathematical Methods III (400)	Th: 3, Tut: 1	54
PHS-DSCC-7-2	Physics Major	Advanced Classical Mechanics (400)	Th: 3, Tut: 1	55
PHS-DSCC-7-3	Physics Major	Advanced Quantum Mechanics I (400)	Th: 3, Tut: 1	56
PHS-DSCC-7-4	Physics Major	Classical Electrodynamics (400)	Th: 3, Tut: 1	57
PHS-DSCC-7-5	Physics Major	General Laboratory I (400)	Pr: 4	58
Semester 8 (for 4-year Honours)				
PHS-DSCC-8-1	Physics Major	Advanced Quantum Mechanics II (400	Th: 3, Tut: 1	60
PHS-DSCC-8-2	Physics Major	Advanced Statistical Mechanics (400)	Th: 3, Tut: 1	61
PHS-DSCC-8-3	Physics Major	Electronics and Instrumentation (400)	Th: 3, Tut: 1	62
PHS-DSCC-8-4	Physics Major	Solid State Physics II (400)	Th: 3, Tut: 1	63
PHS-DSCC-8-5	Physics Major	General Laboratory II (400)	Pr: 4	64
Semester 8 (for 4-year Honours with Research)				
PHS-DSCC-8-1R	Physics Major	Research Methodology I (400)	Th: 3, Viva: 1	66
PHS-DSCC-8-2R	Physics Major	Research Methodology II (400)	Th: 3, Viva: 1	67
PHS-DSCC-8-3R	Physics Major	Research Internship (400)	Project: 4	68
PHS-DSCC-8-4R	Physics Major	Research Project (400)	Project: 8	68

Explanatory note

Convention for Paper Code: *Subject Code-Course-Semester-Paper no.*
For example, PHS-CC-6-1 means the first paper of semester 6 for MDC (Core) in Physics.

Course options are: DSCC (Major core), DSEL (Major elective, only for 7th and 8th semesters), SEC (SEC papers for Physics Major students), CC (MDC (Core), both Physics as Core-1 or Core-2), Minor3 (3-year Minor with MDC), Minor4/1 (4-year Minor with another Major where Physics is the first Minor), Minor4/2 (same, but where Physics is the second Minor).
Note: Paper codes used by the University for evaluation and examination related matters may differ from those shown here.

Papers offered for different courses

- **DSCC: Physics Major, core papers**

  Semester 1:
  PHS-DSCC-1-1 Basic Physics - I
  Semester 2:
  PHS-DSCC-2-1 Basic Physics - II
  Semester 3:
  PHS-DSCC-3-1 Waves and Optics
  PHS-DSCC-3-2 Mathematical Physics
  Semester 4:
  PHS-DSCC-4-1 Modern Physics
  PHS-DSCC-4-2 Electromagnetism
  PHS-DSCC-4-3 Mathematical Physics II
  PHS-DSCC-4-4 Classical Mechanics and Special Theory of Relativity
  Semester 5:
  PHS-DSCC-5-1 Electronics I
  PHS-DSCC-5-2 Nuclear and Particle Physics
  PHS-DSCC-5-3 Quantum Mechanics
  PHS-DSCC-5-4 Thermal Physics and Statistical Mechanics
  Semester 6:
  PHS-DSCC-6-1 Electronics II
  PHS-DSCC-6-2 Solid State Physics
  PHS-DSCC-6-3 Atomic, Molecular, and Laser Physics
  Semester 7:
  PHS-DSCC-7-1 Mathematical Methods III
  PHS-DSCC-7-2 Advanced Classical Mechanics
  PHS-DSCC-7-3 Advanced Quantum Mechanics I
  PHS-DSCC-7-4 Classical Electrodynamics
  PHS-DSCC-7-5 General Laboratory I
  Semester 8 (for 4-year Honours):
  PHS-DSCC-8-1 Advanced Quantum Mechanics II
  PHS-DSCC-8-2 Advanced Statistical Mechanics
  PHS-DSCC-8-3 Electronics and Instrumentation
  PHS-DSCC-8-4 Solid State Physics II
  PHS-DSCC-8-5 General Laboratory II
  Semester 8 (for 4-year Honours with Research):
  PHS-DSCC-8-1R Research Methodology I
  PHS-DSCC-8-2R Research Methodology II
  PHS-DSCC-8-3R Research Internship
  PHS-DSCC-8-4R Research Project

- **SEC: Physics Major**

  Semester 1:
  PHS-SEC-1-1 Introduction to Computer Programming and Graph Plotting
  Semester 2:
  PHS-SEC-2-1 Scientific Writing Skills (LaTeX)
  Semester 3:
  PHS-SEC-3-1 Arduino **OR**
  PHS-SEC-3-2 Introductory Data Analysis

- **CC: Multidisciplinary with Physics as Core-1 or Core-2**

  Semester 1:
  PHS-CC-1-1 Basic Physics - I
  PHS-CC-SEC-1-1 Introduction to Computer Programming and Graph Plotting[9]
  Semester 2:
  PHS-CC-2-1 Basic Physics - II
  Semester 3:
  PHS-CC-3-1 Waves and Optics
  Semester 4:
  PHS-CC-4-1 Modern Physics
  PHS-CC-4-2 Electromagnetism
  Semester 5:
  PHS-CC-5-1 Electronics I
  PHS-CC-5-2 Nuclear and Particle Physics
  Semester 6:
  PHS-CC-6-1 Nuclear and Particle Physics
  PHS-CC-6-2 Electronics II

- **Minor3: Multidisciplinary with Physics Minor**

  Semester 3:
  PHS-Minor3-3-1 Basic Physics - I
  Semester 4:
  PHS-Minor3-3-2 Basic Physics - II
  Semester 5:
  PHS-Minor3-5-1 Waves and Optics
  PHS-Minor3-5-2 Electronics I
  Semester 6:
  PHS-Minor3-6-1 Modern Physics
  PHS-Minor3-6-2 Electromagnetism

[9] In Semester 1/2/3 for MDC with Physics as 1st Major/2nd Major/Minor

- **Minor4/1: 4-year Minor with Physics as First Minor**

  Semester 1:
  PHS-Minor4/1-1-1 Basic Physics - I
  Semester 2:
  PHS-Minor4/1-2-1 Basic Physics - II
  Semester 5:
  PHS-Minor4/1-5-1 Waves and Optics
  PHS-Minor4/1-5-2 Modern Physics

- **Minor4/2: 4-year Minor with Physics as Second Minor**

  Semester 3:
  PHS-Minor4/2-3-1 Basic Physics - I
  Semester 4:
  PHS-Minor4/2-4-1 Basic Physics - II
  Semester 6:
  PHS-Minor4/2-6-1 Waves and Optics
  PHS-Minor4/2-6-2 Modern Physics

- **Interdisciplinary, for students with no Physics Major/Minor/Multidisciplinary**

  Semester 1, 2, or 3:
  PHS-IDC Frontiers in Physics

Syllabus for the Undergraduate (B.Sc.) course in Physics (Major)

The structure of the revised syllabus for the B.Sc. course in Physics (Semesters 1 to 8) is as follows.

Each paper carries 4 Credits, equivalent to 100 marks.

Th: Theory, Pr: Practical, Tut: Tutorial

For students with Physics Major (4-year Honours)

Semester	Paper code	Paper name	Credit
Semester 1	PHS-DSCC-1-1	Basic Physics - I	Th: 3, Pr: 1
	PHS-SEC-1-1	Introduction to Computer Programming and Graph Plotting	Th: 0, Pr: 4
Semester 2	PHS-DSCC-2-1	Basic Physics - II	Th: 3, Pr: 1
	PHS-SEC-2-1	Scientific Writing Skills (LaTeX)[10]	Th: 0, Pr: 4
Semester 3	PHS-DSCC-3-1	Waves and Optics	Th: 3, Pr: 1
	PHS-DSCC-3-2	Mathematical Physics I	Th: 3, Pr: 1
	PHS-SEC-3-1	Arduino	Th: 1, Pr: 3
	PHS-SEC-3-2	Introductory Data Analysis[11]	Th: 1, Pr: 3
Semester 4	PHS-DSCC-4-1	Modern Physics	Th: 3, Pr: 1
	PHS-DSCC-4-2	Electromagnetism	Th: 3, Pr: 1
	PHS-DSCC-4-3	Mathematical Physics II	Th: 3, Pr: 1
	PHS-DSCC-4-4	Classical Mechanics and Special Theory of Relativity	Th: 3, Pr: 1
Semester 5	PHS-DSCC-5-1	Electronics I	Th: 3, Pr: 1
	PHS-DSCC-5-2	Nuclear and Particle Physics	Th: 3, Tut: 1
	PHS-DSCC-5-3	Quantum Mechanics	Th: 3, Pr: 1
	PHS-DSCC-5-4	Thermal Physics and Statistical Mechanics	Th: 3, Pr: 1
Semester 6	PHS-DSCC-6-1	Electronics II	Th: 3, Pr: 1
	PHS-DSCC-6-2	Solid State Physics	Th: 3, Pr: 1
	PHS-DSCC-6-3	Atomic, Molecular, and Laser Physics	Th: 3, Tut: 1
Semester 7	PHS-DSCC-7-1	Mathematical Methods III	Th: 3, Tut: 1
	PHS-DSCC-7-2	Advanced Classical Mechanics	Th: 3, Tut: 1
	PHS-DSCC-7-3	Advanced Quantum Mechanics I	Th: 3, Tut: 1
	PHS-DSCC-7-4	Classical Electrodynamics	Th: 3, Tut: 1
	PHS-DSCC-7-5	General Laboratory I	Pr: 4
Semester 8	PHS-DSCC-8-1	Advanced Quantum Mechanics II	Th: 3, Tut: 1
	PHS-DSCC-8-2	Advanced Statistical Mechanics	Th: 3, Tut: 1
	PHS-DSCC-8-3	Electronics and Instrumentation	Th: 3, Tut: 1
	PHS-DSCC-8-4	Solid State Physics II	Th: 3, Tut: 1
	PHS-DSCC-8-5	General Laboratory II	Pr: 4

[10] The student can also opt for Artificial Intelligence, centrally offered by the University.

[11] The student has to opt for one of these two SEC papers.

For students with Physics Major (4-year Honours with Research)

The first 7 semesters are identical with Physics Major (4-year Honours).

Semester	Paper code	Paper name	Credit
Semester 8	PHS-DSCC-8-1R	Research Methodology I	Th: 3, Viva: 1
	PHS-DSCC-8-2R	Research Methodology II	Th: 3, Viva: 1
	PHS-DSCC-8-3R	Research Internship	Project: 4
	PHS-DSCC-8-4R	Research Project	Project: 8

1 Semester 1

PHS-DSCC-1-1 : Basic Physics - I

(Identical content with PHS-CC-1-1, PHS-Minor4/1-1-1, PHS-Minor4/2-3-1, PHS-Minor3-3-1)
Theory [3 Credits]

(A) Mathematical Physics (20)

1. **Preliminaries (5) •**
   SI system of units, dimensional analysis. Plotting of functions (both cartesian and polar), Limits, Intuitive ideas about continuity and differentiability of a function. Taylor series of one variable and binomial series (statements only); Maxima and minima for functions of one variable. Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials.

2. **Ordinary Differential Equations (2) •**
   First order linear differential equations and integrating factor. Linear second order homogeneous equations with constant coefficients. Simple harmonic motion as an example.

3. **Vectors (7) •**
   Dot, cross, scalar triple and vector triple products of cartesian vectors (using Levi-Civita symbol and summation convention). Vector differentiation. Scalar and vector fields — gradient, divergence, curl and Laplacian (for Cartesian coordinates), solenoidal and irrotational vector field. Statement and proof of Divergence theorem and Stokes' theorem; application to simple cases.

4. **Curvilinear coordinates (6) •**
   Plane polar, spherical polar and cylindrical polar coordinates: their unit vectors, role of unit vectors as basis vectors. Surface and volume element (from geometry). Line, surface and volume integrals. Form of the gradient operator in curvilinear coordinates. Velocity and acceleration of point particle in Cartesian, plane polar, spherical polar, cylindrical polar coordinates.

(B) Classical Mechanics (30)

1. **Review of Newton's Laws (6) •**
   Concepts of Inertial frames; force and mass. Galilean transformations and Galilean invariance; Newton's laws of motion, principle of conservation of linear momentum, Simple problems involving motion under resistive forces. Rotational motion: Angular velocity, angular acceleration, angular momentum, torque, principle of conservation of angular momentum.

2. **Potential (4) •**
   Work Kinetic Energy Theorem. Conservative forces: Force as the gradient of a scalar field. Concept of potential and potential energy. Other equivalent definitions of a conservative force. Conservation of energy. Qualitative study of one-dimensional motion from potential energy curves. Stable and unstable equilibrium. Simple harmonic oscillation for small displacement from a stable equilibrium.

3. **Dynamics of a system of particles (4) •**
   The problem of solving equation of motion; Action-reaction kind of forces and the two body problem; Reduced mass and centre of mass; Properties of the centre of mass; Effect of torque; Linear momentum, angular momentum and total energy of a system of particles.

4. **Central force (8) •**
   Newton's Law of Gravitation; Kepler's Laws; Conservation of angular momentum, Gauss's law for Gravitation (integral form); Gravitational potential and intensity due to uniform spherical shell, solid sphere of uniform density and infinite flat sheet. Differential equation for the path in a central force field. Motion under an inverse square force, calculation of orbits.

5. **Scattering (2) •**
   Two body collision and scattering.

6. **Mechanics of Continuum (6) •**
   Kinematics of Moving Fluids: Idea of compressible and incompressible fluids, Equation of continuity; streamline and turbulent flow, Reynold's number. Stokes' law from dimensional analysis; Euler's Equation and the special case of fluid statics. Simple applications (e.g.: Pascal's law and Archimedes principle). Bernoulli's Theorem.

Recommended reading

(For Mathematical Physics)

1. Mathematical Methods in the Physical Sciences, M. L. Boas, 2005, Wiley

2. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 2013, 7th Edn., Elsevier

3. Essential Mathematical Methods, K.F.Riley and M.P.Hobson, 2011, Cambridge Univ. Press

4. Vector Analysis and an introduction to Tensor Analysis, S. Lipschutz, D. Spellman, M.R. Spiegel, Schaum's Outline Series, Tata McGraw Hill Education, ed. 2009

5. Play with Graphs, Amit M. Agarwal, Arihant Publisher

(For Classical Mechanics)

1. An Introduction to Mechanics, D. Kleppner, R.J. Kolenkow, 1973, McGraw- Hill

2. Feynman Lectures, Vol. I, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education

3. Classical Mechanics and General Properties of Matter. S.N. Maiti and D.P. Raychaudhuri, New Age

4. Introduction to Classical Mechanics, R. G. Takwale and P.S.Puranik, Tata McGraw-Hill Publishing Company Ltd.

5. Theory and Problems of Theoretical Mechanics, M. R. Spiegel, McGraw Hill Education

6. Classical Mechanics , R.D. Gregory, 2006, Cambridge University Press
7. Introduction to Classical Mechanics With Problems and Solutions , D. Morin, Cambridge University Press
8. Mechanics, Berkeley Physics, vol.1, C.Kittel, W.Knight, et.al. 2007, Tata McGraw-Hill. Physics
9. Mechanics, Resnick, Halliday and Walker 8/e. 2008, Wiley
10. Mechanics , K. Symon, 2016, Pearson Education India
11. Mechanics, D.S. Mathur, S. Chand and Company Limited, 2000
12. University Physics. F.W. Sears, M.W. Zemansky, H.D. Young 13/e, 1986, Addison Wesley

Practical [1 Credit]

Pre-requisites: Measurements using slide calipers, screw gauge and travelling microscope; Ideas about rounding off experimental data in conformity with the least count of the measuring instrument; Idea of systematic and random errors introduced in different instruments. It is expected that the necessary theory for each of the experiments, for this and the subsequent semesters, will be discussed in brief in the laboratory itself.

1. Measurement of the diameter of a wire using screw gauge a number of times and to determine the mean, median, mode and standard deviation for study of random error in observation.
2. Measurement of a suitable vertical height using Sextant.
3. Determination of the Moment of Inertia of a metallic cylinder / rectangular rod about an axis passing through its centre of gravity.
4. Determination of modulus of rigidity of the material of a suspension wire by dynamical method.
5. To determine the coefficient of viscosity of water by Poiseuille's method.

Recommended reading

1. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press
2. B.Sc. Practical Physics, C.L. Arora, S Chand and Company Limited
3. Physics in Laboratory, Mandal, Chowdhury, Das, Das, Santra Publication
4. Advanced Practical Physics Vol 1, B. Ghosh, K.G. Majumder, Sreedhar Publisher
5. Practical Physics, P.R. Sasi Kumar, PHI Learning Private Limited
6. B.Sc. Practical Physics, Harnem Singh, P.S. Hemne, S Chand and Company Limited
7. Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning India Pvt. Ltd

PHS-SEC-1-1 : Introduction to Computer Programming and Graph Plotting

(Identical content with PHS-CC-SEC-1-1)
Practical [4 Credits, 60 lab periods]

1. **Introduction to Graph Plotting (2D only, using Gnuplot) •**
   (a) Plotting 2D graphs: both functions and data files. Changing plot range and plot styles: the options: with points (w p), with dots (w d), with lines (w l), with linespoints (w lp), linetype (lt), linewidth (lw). Using the set command for samples, xrange, yrange, xlabel, ylabel, title etc. The *using* option.
   (b) User defined functions [Including the use of ternary operator (? :) for piece-wise defined functions.]
   (c) Fitting data files using Gnuplot.
   (d) Polar and parametric plots
   (e) Conditional plotting of data from file using $, &&, || operators. (Graphs to be saved without using GUI)

2. **Introduction to programming in Python (Version 3) •**
   (a) Introduction
   Using the python interpreter as a calculator
   Variable and data types (int, float, complex, list, tuple, set, string, the type () function)
   Basic mathematical operations
   Compound statements in python
   – Conditionals (if, elif, else)
   – Loops (for, while)
   – User defined functions def: (return statement, default values for arguments, keyword arguments), lambda function.
   Importing modules with math and cmath as examples
   Using help and dir command to use the inbuilt manual
   Basic idea of namespaces – local and global
   Python scripts, I/O operations (including opening and writing to files)

   (b) The python data types
   List: defining lists, reading and changing elements from lists, slicing (with discussion on the difference between ll=mm and ll=mm[:], concatenation, list comprehension
   – built in functions involving lists: range(), len(), sum(), min(), max() – list methods: append(), extend(), count(), index(), sort(), insert(), pop(), remove(), reverse()
   Tuples: Contrast and compare with lists, packing/unpacking using tuples (including $a, b = b, a$ to swap variables)
   Sets : set methods: update(), pop(), remove(), Set Theoretic operations: union, intersection, difference and symmetric difference of two sets
   Strings: defining strings, the use of single, double or triple quotes as string delimiters, len(),indexing, slicing, string concatenation, some string methods: strip(), split(), join(), find(), count(), replace(), string formatting in python (using the

3. **Problems and Applications •**
   Finding factors of an integer
   Determining whether an integer is prime or not

Finding out prime number greater than or lesser than a given value
Finding out all prime numbers within a given range
Root finding for a single variable (basic theory and algorithm) using Newton-Raphson and Bisection method
Sorting of lists (algorithm, flowchart and code) using Bubble or Selection sort
Sum of series correct up to given decimal places (Sine, Cosine, Exponential etc.)
Simulation of motion of a particle in 1D under a given force $F(x, t, v)$ with given initial condition and plotting $(x, t), (x, v), (t, v)$. (Output to be saved in data files and Gnuplot to be used to plot graphs), using Euler's method only
Matrix Addition, Multiplication and Transpose using List Comprehension

Recommended reading

1. Gnuplot in Action understanding data and Graphs, Phillipp K. Janert
2. Scientific Computing in Python. Abhijit Kar Gupta, Techno World
3. Computational Physics, Mark Newman, Amazon Digital.
4. Physics in Laboratory including Python Programming (Semester I), Mandal, Chowdhury, Das, Das, Santra Publication
5. Introduction to Numerical Analysis, S.S. Sastry, 5th Edn. , 2012, PHI Learning Pvt. Ltd
6. Numerical Mathematical Analysis, J. B. Scarborough, OXFORD and IBH Co. Pvt. Ltd.
7. Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition
8. Gnuplot 5, Lee Phillips, Alogus Publishing, edition 2012.

2 Semester 2

PHS-DSCC-2-1 : Basic Physics - II

(Identical content with PHS-CC-2-1, PHS-Minor4/1-2-1, PHS-Minor4/2-4-1, PHS-Minor3-4-1)
Theory [3 Credits]

(A) Basic Electricity and Magnetism (22)

1. **Electrostatics (11) •**
   Coulomb's law, Electric field, Electric field lines. Superposition Principle. Electric flux. Idea of charge density (linear, surface, volume) and continuous charge distributions. Gauss' Law (in integral form) with applications to charge distributions with spherical, cylindrical and planar symmetry. Conservative nature of Electrostatic Field. Introduction to electrostatic potential, Equipotential surfaces. Calculation of potential for linear, surface and volume charge distributions: simple cases (*e.g.* uniform line charge, disc, spherical shell, sphere etc.). Potential and field due to a physical dipole; Torque, force and Potential Energy of an electric dipole in a uniform electric field. Electrostatic energy of system of charges, a charged sphere. Conductors in an electrostatic Field. Mechanical force on the surface of a charged conductor. Surface charge and force on a conductor. Capacitance of a system of charged conductors. Capacitance for parallel-plate, cylindrical, spherical capacitors (without dielectrics). Energy stored in Electrostatic field.

2. **Lorentz force (3) •**
   Force on a moving charge in simultaneous electric and magnetic fields, force on a current carrying conductor in a magnetic field. Trajectory of charged particles in uniform electric field, crossed uniform electric and magnetic fields. Basic principle of cyclotron.

3. **Magnetostatics (8) •**
   Concept of current density (linear, surface, volume). Equation of continuity. Biot and Savart's law, magnetic field due to a straight conductor, circular coil, Helmholtz coil, solenoid. Ampere's circuital law with applications (infinite long wire, infinite solenoid, infinite current sheet). Magnetic field due to a small current loop — concept of magnetic dipole. Torque and force on magnetic dipole in a uniform magnetic field.

(B) Introduction to Thermodynamics (28)

1. **Kinetic theory (3) •**
   Macroscopic and microscopic description of matter, Postulates of molecular kinetic theory of an ideal gas, Relation between microscopic and macroscopic state variables, Maxwell's velocity distribution, Concept of pressure and temperature.

2. **Zeroth and First Law of Thermodynamics (9) •**
   Extensive and intensive thermodynamic variables. Thermodynamic equilibrium, zeroth law of Thermodynamics and concept of temperature. Concept of work and heat, State Functions, internal energy and first law of Thermodynamics, its differential form, first law and various processes. Applications of first law: General relation between C_P and C_V, work done during isothermal and adiabatic processes, compressibility and expansion coefficient.

3. **Second Law of Thermodynamics (10) •**
   Reversible and irreversible process with examples. Interconversion of work and heat. Heat engines. Carnot's cycle, Carnot engine and efficiency. Refrigerator and coefficient of performance, Kelvin-Planck and Clausius statements for the second law and their equivalence. Carnot's Theorem. Applications of second law of Thermodynamics: Thermodynamic scale of temperature and its equivalence to perfect gas scale.

4. **Entropy (6) •**
   Concept of Entropy, Clausius theorem. Clausius inequality, Second law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Principle of increase of Entropy. Entropy changes in reversible and irreversible processes with examples. Entropy of the universe. Principle of increase of Entropy. Temperature-Entropy diagrams for different cycles. Third law of Thermodynamics. Unattainability of absolute zero.

Recommended reading

(For Basic Electricity and Magnetism)

1. Feynman Lectures Vol.2, R.P. Feynman, R.B. Leighton, M. Sands, 2008, Pearson Education
2. Introduction to Electrodynamics, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings
3. Electricity and Magnetism, D. Chattopadhyay and P.C. Rakshit, New Central Book Agency, 2011
4. Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw Hill
5. Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education
6. Elements of Electromagnetics, M.N.O. Sadiku, 2010, Oxford University Press
7. Classical Electromagnetism, Jerrold Franklin, Pearson Education
8. Electricity and Magnetism, J.H.Fewkes and J.Yarwood. Vol. I, 1991, Oxford Univ. Press

(For Introduction to Thermodynamics)

1. Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill
2. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Sears and Salinger. 1988, Narosa
3. Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Ed., 2012, Oxford University Press
4. Thermodynamics, E. Fermi, 2007, Sarat Book House
5. Basic Thermodynamics, E. Guha, 2010, Narosa
6. Kinetic theory of gases, Loeb, Radha Publishing House
7. A Treatise on Heat, Meghnad Saha, and B.N. Srivastava, 1969, Indian Press

8. Thermodynamics and an introduction to thermostatistics, H.B. Callen, 1985, Wiley
9. Elements of Classical Thermodynamics A.B. Pippard , 1957, Cambridge University Press
10. *Gas-er anobik tattva*, Pratip Choudhury, Paschimbanga Rajya Pustak Parshad (in Bengali)
11. *Tapgatitattva*, Ashok Ghosh, Paschimbanga Rajya Pustak Parshad (in Bengali)

Practical [1 Credit]

Pre-requisites: Ideas about handling electrical apparatus and components; Safety against electrical hazards; Use of digital multimeter; Reading colour codes for carbon resistors etc.

1. Conversion of an ammeter to voltmeter and vice versa.
2. Determination of an unknown low resistance using Carey-Foster's Bridge.
3. Measurement of current by potentiometer.
4. Measurement of pressure coefficient of expansion of air by Jolly's apparatus.
5. Measurement of coefficient of thermal expansion of a metallic rod by optical lever arrangement.

Recommended reading

1. Advance Practical Physics (Vol 2), B. Ghosh, Sreedhar Publication
2. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency

PHS-SEC-2-1 : Scientific Writing Skills (LaTeX)

Practical [4 Credits, 60 lab periods]

1. **Introduction to LaTeX •**
   The difference between WYSIWYG and WYSIWYM. Preparing a basic LaTeX file. Compiling LaTeX file.
2. **Document classes •**
   Different type of document classes, *e.g.*, article, report, book and beamer.
3. **Page Layout •**
   Titles, Abstract, Chapters, Sections, subsections, paragraph, verbatim, references, equation references, citation.
4. **List structures •**
   Itemize, enumerate, description etc.
5. **Representation of mathematical equations •**
   Inline math, equations, fractions, matrices, trigonometric, logarithmic, exponential functions, line-surface-volume integrals with and without limits, closed line integral, surface integrals, Scaling of parentheses, brackets etc.

6. **Customization of fonts •**
   Bold fonts, emphasize, mathbf, mathcal etc. Changing sizes Large, Larger, Huge, tiny, etc.

7. **Writing tables •**
   Creating tables with different alignments, placement of horizontal, vertical lines.

8. **Figures •**
   Changing and placing the figures, alignments Packages: amsmath, amssymb, graphics, graphicx, Geometry, algorithms, color, Hyperref etc. Use of Different LaTeX commands and environments, Changing the type style, symbols from other languages. Special characters.

Software required: LaTeX in Linux and MikTeX in Windows. Preferred editor: Kile / Emacs / TeXStudio in Linux and TeXStudio in Windows.

Recommended reading

1. LaTeX – A Document Preparation System, Leslie Lamport, 1994, Addison-Wesley
2. Walking with LaTeX, Suman Bandopadhyaya, Techno World
3. LaTeX Tutorials: A primer, Indian TeXuser group, E. Krishnan
4. Practical LaTeX , George Gratzer, Springer
5. Official LaTeX site: https://www.latex-project.org
6. The not-so-short introduction to LaTeX :
   http://mirror.iopb.res.in/tex-archive/info/lshort/english/lshort.pdf
7. LaTeX Wikibook, https://en.wikibooks.org/wiki/LaTeX
8. TeXLive, http://www.tug.org/texlive/

3 Semester 3

PHS-DSCC-3-1 : Waves and Optics

Theory [3 Credits]

1. **Oscillations (4) •**
   Differential equation of simple harmonic oscillation and its solution. Kinetic energy, potential energy, total energy and their time average values. Damped and forced oscillations: Transient and steady states, resonance, sharpness of resonance; power dissipation and Quality Factor.

2. **Superposition of Harmonic Oscillations (3) •**
   Superposition of two collinear Harmonic oscillations having equal frequencies and different frequencies (beats). Superposition of two Perpendicular Harmonic Oscillations for phase difference $\delta = 0, \pi, 2\pi$: Graphical and analytical methods, Lissajous' figures with equal and unequal frequency and their uses.

3. **Wave motion (2) •**
   Plane and spherical waves. Longitudinal and transverse waves. Plane progressive (travelling) waves. Wave equation for travelling waves. Particle and wave velocities.

4. **Superposition of harmonic Waves (7) •**
   Velocity of transverse vibrations of stretched strings; standing (stationary) waves in a string: fixed and free ends (analytical treatment). Changes with respect to position and time. Energy of vibrating string. Transfer of energy. Normal modes of stretched strings. Plucked and struck strings, Superposition of N harmonic waves. Phase and group velocities.

5. **Fermat's Principle (2) •**
   Fermat's principle, laws of reflection and refraction at a plane and curved surface.

6. **Interference (12) •**
   Huygens principle, 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 inclination (Haidinger fringes); Fringes of equal thickness (Fizeau fringes). Newton's Rings: Measurement of wavelength and refractive index. Michelson interferometer (no detailed theory required), Fabry-Perot interferometer. temporal and spatial coherence.

7. **Diffraction (10) •**
   Fraunhofer diffraction: Single slit, double slit and diffraction grating. Resolving power of grating. Rayleigh criterion for resolution. Circular aperture (qualitative discussion only). Fresnel diffraction: Fresnel's half-period zones for plane wave. Explanation of rectilinear propagation of light. Theory of a Zone Plate: Multiple foci of a Zone Plate.

8. **Polarization (10) •**
   Description of linear, circular and elliptical polarization. Propagation of electromagnetic waves in birefringent medium, polarization in uniaxial crystals. Double refraction. Polarization by double refraction. Nicol prism. Ordinary and extraordinary refractive indices.

Phase Retardation plates: Quarter-wave and Half-wave plates. Production and analysis of polarized light, Rotatory polarization, Biot's laws for rotatory polarization. Fresnel's theory of optical rotation. Calculation of angle of rotation. Specific rotation.

Recommended reading

1. The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.
2. Advanced Acoustics, D. P. RayChaudhuri, 1981, Chayan Publisher.
3. Vibrations And Waves, A. P. French, 2003, CBS.
4. Optics, 4th Edn., Eugene Hecht, 2014, Pearson Education Limited.
5. Optics, Ajoy Ghatak, 7th Edn, 2020, Tata McGraw-Hill.
6. Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.
7. Fundamentals of Optics, F.A. Jenkins & H.E. White, 1981, McGraw- Hill.
8. Introduction to Optics, F.L. Pedrotti, L.S. Pedrotti, L.M. Pedrotti, 2014, Pearson Education.
9. Principles of Optics, Max Born & Emil Wolf, 7th Edn., 1999, Pergamon Press.

Practical [1 Credit]

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify $\lambda^2 - T$ law.
2. To study the variation of refractive index of the Material of a prism with wavelengths and hence the Cauchy constants using mercury/helium source.
3. To determine wavelength of sodium light using Fresnel Biprism.
4. To determine wavelength of sodium light/radius of plano convex lens using Newton's Rings.
5. Measurement of the spacing between the adjacent slits in a grating by measuring $\sin\theta$ vs wavelength graph of a certain order of grating spectra.
6. To study the specific rotation of optically active solution using polarimeter.

Recommended reading

1. B.Sc. Practical Physics, C.L. Arora, 2010, S Chand and Company Limited.
2. Advanced Practical Physics, Vol 1, B. Ghosh, K.G.Majumdar, Shreedhar Publishers.
3. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency (P) Ltd.

PHS-DSCC-3-2 : Mathematical Physics I

Theory [3 Credits]

1. **Convergence of infinite series (4) •**
   Convergence of power series. Idea of interval of convergence . Different convergence tests of power series: D'Alembert's ratio test, Cauchy's root test, Integral test. Alternating series test. Absolute and conditional convergence.

2. **Fourier Series (6) •**
   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. 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. Applications. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity.

3. **Fourier Transform (6) •**
   Fourier Integral theorem. Fourier Transform (FT) with examples. FT of trigonometric, Gaussian, finite wave train, and other functions. Inverse Fourier transform, Properties of FT (translation, change of scale, complex conjugation, etc.). Parseval's identity. Applications of FT in single slit, double slit, rectangular aperture and N-slit grating.

4. **Partial Differential Equations (8) •**
   Solutions to partial differential equations using separation of variables: Solutions of Laplace's equation in problems with cartesian and spherically symmetric cases only. Wave equation and its solution for vibrational modes of a stretched string, Diffusion Equation in one dimension.

5. **Introduction to Probability (8) •**
   Probability for discrete events, and combined probability for uncorrelated events. Mean and variance. Independent random variables: Sample space and Probability distribution functions. Binomial, Gaussian, and Poisson distribution with examples. One dimensional random walk.

6. **Dirac δ-function (4) •**
   Definition of Dirac δ-function. Delta function as limit of different delta-sequence functions. Properties of δ-function: $\delta(-x)$, $\delta(f(x))$. Derivative of the step function. Fourier transform of δ-function. Two- and three-dimensional δ-function. Fourier transform of three-dimensional Coulomb potential, evaluation of $\nabla^2(1/r)$.

7. **Some special integrals (4) •**
   Beta and Gamma functions and relation between them. Expression of integrals in terms of Gamma functions. Error function (probability integral).

8. **Numerical Analysis I (10) •**
   Approximation in numerical computation: Truncation and rounding errors, Fixed and floating-point arithmetic, Propagation of errors: errors in normal distribution as quadrature (uncorrelated) .

Numerical solution of Algebraic equation: Bisection method, Newton-Raphson method.
Interpolation: Finite difference operators, Newton (Gregory) forward and backward interpolation, Lagrange's Interpolation.
Numerical integration: Trapezoidal rule, Simpson's 1/3 rule.
System of linear algebraic equations: Direct methods: Gaussian elimination; Iterative methods: Gauss-Jacobi method, Gauss-Seidel method. Some qualitative discussion on matrix inversion technique.
Numerical solution of ordinary differential equation: Euler's method, Runge-Kutta methods (order two and four).
Curve fitting: Curve fitting by the method of least squares. Fitting of curves of the form $y = ax + b$, $y = ax^b$ and $y = ax^2 + bx + c$.

Recommended reading

1. Mathematical Methods for Physicists: Arfken, Weber, 2005, Harris, Elsevier.

2. Fourier Analysis by M.R. Spiegel, 2004, Tata McGraw-Hill.

3. Differential Equations, George F. Simmons, 2006, Tata McGraw-Hill.

4. Differential Equations, S.L. Ross, 2007, Wiley.

5. Mathematical Physics, P.K. Chattopadhyay,2014, New Academic Science.

6. Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press.

7. Fourier Series and Boundary Value Problems , J.W. Brown and R.V. Churchill, 2017, McGraw Hill Education.

8. Introduction to Mathematical Physics, Charlie Harper, 1978, PHI Learning Pvt. Ltd.

9. Mathematical methods in the Physical Sciences, M. L. Boas, 2005, Wiley.

Practical [1 Credit]

1. Introduction to numpy

   - the numpy array
     - properties: size, shape, ndim, dtype
     - creating arrays: zeros, one(), full(), fill(), arange(), linspace(), logspace(), identity(), eye(),astype()
     - indexing and slicing arrays (view versus copy)
     - important array methods : reshape(), ravel(), flatten(), hstack() and vstack()
     - Element wise functions: native numpy functions,the vectorise() method
     - Aggregate functions: np.sum(), np.prod(), np.mean(), np.std(), np.var(), np.min(),np.max(), np.argmin(), np.argmax()
   - Using numpy for matrix operators (the 2D numpy array)
     - addition, multiplication(dot)

- Gauss elimination (using partial pivoting) (numpy code): for evaluating the determinant, for solving linear equation
- Gauss-Seidel method for solving system of linear equations (rearrangement of equations not required)
- the numpy linalg module for solving equations and diagonalisation

- Scientific Applications
    - Lagrange's Interpolation, Newton's forward and backward Interpolation
    - Numerical Integration using Trapezoidal and Simpson's $\frac{1}{3}$ rule (for given function and equispaced data)
    - Solution of first and second order ODE using Runge-Kutta method (both RK2 and RK4) (algorithm, numpy code and detailed theory required)
    - Curve fitting using numpy

2. Introduction to mathplotlib (Using the pyplot submodule, 2D Plot Only)
    - figure, axes, subplot
    - plot(), scatter(), show()
    - labels, legends, titles, styles, ticks
    - dynamically updating curves
    - saving graphs

Recommended reading

1. Numerical Methods, Arun Kr Jalan, Utpal Sarkar, 2015, University Press
2. Scientific Computing in Python. Abhijit Kar Gupta, 2022, Techno World
3. Physics in Laboratory including Python Programming (Semester III), Mandal, Chowdhuri, Das, Das, 2019, Santra Publication
4. Mathplotlib Plotting Cookbook, Alexandre Devert, 2014, PACKT Publishing
5. Programming for Computation-Python, Svein Linge, Hans Petter Lantangen, Springer
6. Numerical Python, Robert Johansson, 2018, Apress Publication
7. Introduction to Numerical Analysis, S.S. Sastry, 5th Edn. , 2012, PHI Learning Pvt. Ltd
8. Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition
9. An Introduction to computational Physics, T.Pang, 2nd Edn., 2006,Cambridge Univ. Press
10. Computational Physics problem solving with Computers, Landau, Paez, Bordeianu, textbook in Python 3rd Edition, 2015, Wiley-VCH

PHS-SEC-3-1 : Arduino

Prerequisite (10)

1. **Basic Electronics •**
   Familiarity with fundamental electronic components like resistors, capacitors,diodes, and transistors is essential. Understanding concepts like voltage, current, resistance, and Ohm's law is crucial for working with circuits.

2. **Circuit Design •**
   Knowing how to design and analyze simple circuits is important. This includes understanding circuit diagrams, breadboarding, and connecting components properly.

3. **Programming Fundamentals •**
   Basic programming knowledge is necessary since Arduino programming involves writing code in C/C++. Understanding variables, loops, conditional statements, and functions is vital.

4. **Understanding Sensors and Actuators •**
   Arduino projects often involve interfacing with sensors (e.g., temperature, light, motion) and actuators (e.g., motors, LEDs). Understanding how these devices work and how to interface them with the Arduino is essential.

5. **Digital and Analog Signals •**
   Understanding the difference between digital and analog signals, as well as concepts like analog-to-digital conversion (ADC) and pulse-width modulation (PWM), is crucial for working with Arduino.

6. **Serial Communication •**
   Knowing how to communicate between the Arduino and other devices (e.g.,computers, sensors) via serial communication (e.g., UART, I2C, SPI) is important for more advanced projects.

7. **Problem-Solving Skills •**
   Being able to troubleshoot and debug circuits and code is essential. This involves logical thinking and the ability to break down problems into smaller, more manageable parts.

Introduction of Microcontroller & Arduino (5)
Basic Idea about microcontroller; Introduction to Arduino: Brief history of the Arduino; Pin configurations of the board Arduino Uno. Brief idea about Arduino-nano/Arduino R4 Wi-Fi/Arduino MRGA. Sources of constant voltages 5 volt/3.3 volt and ground and corresponding pins of the respective boards. PWM and idea of duty cycle.

Arduino Programming (10)

1. Setting up the arduino board. Installation of IDE inPC/ laptop for Arduino programming (Sketch).

2. Program structure: Data types, variables, constants, operators, control statements, loops, functions, string. Conditional like if elseif; for and while loop. Idea about global variable and local variable. Use of serial monitor for input/output and serial plotter for observation of variation of data.

3. Some Basic Operations: (i) Binary operation through HIGH/LOW status of digital pin. Operation on inbuilt LED/ LED connected externally in series with a resistance e.g.,blinking. (ii) Sending analog voltage. Use of analog pins. Changing brightness of an LED. (iii) Measurement of voltage through appropriate pins

Sample experiments/Projects: [any 10] (25)

1. Attach an LDR (light dependent resistor) to Arduino Uno and employ Arduino Sketch to program it for detecting ambient light levels in the room/environment. When the light falls below a designated threshold, activate a lamp accordingly.
2. Connect an LDR (light dependent resistor) in series with a resistor to create a potential divider circuit. Place an LED facing the LDR to adjust its brightness. Establish a setup where the LED's brightness can be adjusted. Connect terminals across the resistor to Arduino Uno and utilize Arduino Sketch to program it for monitoring the voltage changes corresponding to the LED brightness variation. Display these voltage changes on the serial monitor.
3. Connect an ultrasonic distance sensor (HC-SR04) to Arduino Uno and utilize Arduino Sketch to program the measurement of object distance from the sensor and display it on the serial monitor.
4. Connect an IR sensor (TSOP1838) to Arduino Uno and utilize Arduino Sketch to detect Hex code generated from a TV remote for different button and print them on serial monitor.
5. Connect an HR-SC501 passive infrared (PIR) sensor to Arduino Uno and utilize Arduino Sketch to code for detecting movement in front of the PIR sensor. Illuminate an LED to indicate the detected movement
6. Construct the experimental set up for studying simple pendulum and hence determine the acceleration's due to gravity using appropriate sensor.
7. Attach a Seven Segment Display to Arduino Uno and utilize Arduino Sketch to exhibit a counter that increments from 0 to 9, pausing for 2 seconds between each increment, and continues displaying the count until a key is pressed to halt it. Employ one key to reset the count and another to initiate and halt the counting process.
8. Connect a 1.8-inch TFT/LCD to Arduino Uno and utilize Arduino Sketch to develop a program that print texts and data on that TFT/LCD.
9. Attach a Seven Segment Display to Arduino Uno and utilize Arduino Sketch to exhibit a counter that increments from 0 to 9, pausing for 2 seconds between each increment, and continues displaying the count until a key is pressed to halt it. Employ one key to reset the count and another to initiate and halt the counting process.
10. Connect a Dot Matrix Display to Arduino Uno and employ Arduino Sketch to showcase all numbers from 0 to 9 and the entire English alphabet, both in upper and lower case.

11. Connect a temperature and humidity module such as DHT-11/22, LM35D, or DS18B20/LM75 to Arduino Uno and utilize Arduino Sketch to code for reading temperature and humidity. Display the data either on the serial monitor or as a plotted graph showcasing the captured readings from the sensor over a specified duration.

12. Attach an LM393 sound sensor to Arduino Uno and employ Arduino Sketch to program the detection of sound levels surpassing a set threshold, adjustable via the sensor's potentiometer. Within the sketch, illuminate an LED when sound exceeds the threshold, and indicate on the serial monitor whether a new sound has been detected or if the previous sound has ceased.

13. Attach a D.C. motor RS-775 to Arduino Uno along with a motor driver L298. Write Arduino Sketch to control the speed of the motor.

14. Attach a stepper motor 28BYJ-48 UNL2003 5V to Arduino Uno along with a motor driver UNL2003. Write Arduino Sketch to rotate the motor at 10 0 angle after 5 second interval. control the speed of the motor. Employ one key to stop and another to initiate the rotation.

15. Use of Bluetooth module HC-05 and operation through smartphone or voice. [Use available smartphone app: ARDUINO BLUECONTROL/BLUETOOTH SERIAL CONTROLLER].

16. Construct data logger for studying charging and discharging of RC circuit.

Instruments, Equipments, devices etc.

1. **Microcontroller Kit •**
   Arduino Uno

2. **Power Supply •**
   (i) DC +5V Regulated Power supply with max 2-amp current capacity/Custom built power supply with +5V, −5V, +12V, −12V etc, (ii) Transformer 12-0-12, (iii) Rectifier diodes: 1N4007/1N5402/BY126, (iv) Power filters: 1000μF 35V, (v) Power regulators: 7805, 7905, 7812, 7912 or LM317, LM33.

3. **Sensors •**
   (i) Temperature sensor: DS18B20/LM75/LM35D, (ii) Temperature and Humidity sensor: DHT-11/22, (iii) Ultrasonic Sensor HC-SR04, (iv) IR sensor TSOP1838, (v) LDR (Light dependent resistor): TL01289, (vi) Sound sensor: LM393, (vii) Proximity sensor: HR-SC501.

4. **Display •**
   (i) Seven Segment Display-CA/CC, (ii) 1.8 inch ST7735 TFT Display, (iii) 8×8×4 Dot Matrix with MAX7219.

5. **Modules •**
   (i) 5V, 2 Channel relay module, (ii) Bluetooth module HC-04.

6. **Motors & Semiconductor devices •**
   (i) Stepper Motor 28BYJ-48, (ii) UNL 2003, (iii) L298 H bridge motor driver.

Recommended reading

1. Artful Arduino: Avishek Mukhopadhyay, Suman Bandyopadhyaya, Techno World
2. Programming Arduino Getting Started with Sketches: Simon Monk, McGraw Hill Education, second edition.
3. Arduino Cookbook: Michael Margolis, 2011, O'Reilly Media
4. Getting Started with Arduino: Massimo Banzi, 2009, O'Reilly Media
5. Arduino as a tool for physics experiments: Giovanni Organtini 2018 J. Phys.: Conf. Ser. 1076 012026
6. `https://www.arduino.cc/en/Guide/HomePage`
7. Physics Today 66, 11, 8 (2013) `https://doi.org/10.1063/PT.3.2160`
8. The Physics Teacher 52, 157 (2014) `https://doi.org/10.1119/1.4865518`

PHS-SEC-3-2 : Introductory Data Analysis

1. **Introduction to Data Analysis (5) •**
   Introduction: Introduction of data analysis, data analytics and data science: relations and differences. Idea of generation of data, data wearhouse and data product. Levels of data measurement (a) nominial (b) ordinal scale (c) interval scale and (d) ratio scale. Type of variables (a) categorical (b)numerical (i) discrete and (ii) continuous. Idea of population and samplings: utility of random sampling.

2. **Operations and Statistical Methods (10) •**
   Arrangement of data, grouped data, frequency distribution. Central tendency: Mean: mean, weighted mean, mean of grouped data, population mean and sample mean, Median: median of raw data, median of grouped data, Mode: mode of raw and grouped data, Quartile and Percentile. Dispersion of data: Mean Absolute Deviation, Variance, Standard Deviation, Range, Inter-quartile range, Coefficient of Variation. (Calculation on both population and sample data). Skewness: coefficient of skewness. Peakness of distribution: Leptokurtic, Mesokurtic and Platykurtic.

3. **Introduction to Pandas (20) •**
   Overview of Pandas and its importance in data analysis, Data Structures in Pandas, Series: Creation, manipulation, and indexing, DataFrame: Introduction, creation from various data sources (CSV, Excel, SQL), indexing, and basic operations. Data cleaning: Handling missing data (NaN values), data type conversion. Data transformation: Sorting, filtering, merging, joining, and concatenating datasets. Reshaping data: Pivot tables, stacking, and unstacking. Descriptive statistics: Summary statistics (mean, median, mode, variance, standard deviation), quantiles, and percentiles. Groupby operations: Aggregation, transformation, and filtering based on group properties.

4. **Introduction to NumPy (8) •**
   Overview of NumPy and its importance in numerical computing., NumPy Arrays, Creating arrays: 1D, 2D, and multidimensional arrays., Array attributes: Shape, size, data type,

indexing and slicing arrays, Element-wise operations: Arithmetic, comparison, logical, array broadcasting. Array manipulation, reshaping arrays, joining and splitting arrays, sorting arrays, array Indexing and selection.

5. **Matplotlib and Seaborn (7) •**
   Overview of Matplotlib and its role in data visualization., Line plots: Creating simple line plots, customizing colors, markers, and line styles. Scatter plots: Visualizing relationships between variables, customization options. Bar plots: Creating vertical, horizontal, and grouped bar plots., Overview of Seaborn and its advantages over Matplotlib. Histograms: Visualizing distributions of continuous variables, Box plots: Visualizing distribution quartiles and outliers.

Recommended reading

1. Python for Data Analysis, Wes McKinney, O'Reilly
2. Pandas for Everyone Python Data analysis, Daniel Y Chen, Pearson
3. Hands on Data Analysis and visualization with Pandas, Purna Chandra Rao, Kathula, BPB Publication
4. Hands on Data Analysis with Numpy and Pandas, Curtis Miller, PACKT Publication
5. Scientific Computing in Python. Abhijit Kar Gupta, Techno World
6. `https://pandas.pydata.org/docs/`

4 Semester 4

PHS-DSCC-4-1 : Modern Physics

Theory [3 Credits]

1. **Radiation and its nature (15) •**
   Black body Radiation, Planck's quantum hypothesis, Planck's constant (derivation of Planck formula is not required). Photoelectric effect and Compton scattering — light as a collection of photons. Davisson-Germer experiment. Bohr-Sommerfeld quantization of the form $\oint pdq = nh$. De Broglie wavelength and matter waves. Wave-particle duality. Wave description of particles by wave packets. Group and Phase velocities and relation between them. Probability interpretation: Normalized wave functions as probability amplitudes. Two-slit experiment with photons and electrons. Linear superposition principle as a consequence. Position measurement, γ-ray microscope thought experiment. Heisenberg uncertainty principle (Statement with illustrations). Impossibility of a trajectory of a particle.

2. **Basics of Quantum Mechanics (10) •**
   Quantum measurements- Deterministic vs probabilistic view points. Description of a particle using wave packets. Spread of the Gaussian wave-packet for a free particle in one dimension. Fourier transforms and momentum space wavefunction. Position-Momentum uncertainty. Simultaneous measurements: Compatible and incompatible observables and their relation to commutativity

3. **Schrödinger Equation (8) •**
   Schrödinger equation as a first principle. Probabilistic interpretation of wave function and equation of continuity (in 1-dimension). Time evolution of wave function . Stationary states. Time independent Schrödinger equation as an eigenvalue equation.

4. **Application to one dimensional systems (12) •**
   General discussion of bound states in an arbitrary potential: continuity of wave function, boundary conditions on wave functions and emergence of discrete energy levels. Particle in an infinitely rigid box: energy eigenvalues and eigenfunctions, normalization. Quantum mechanical tunnelling across a step potential and rectangular potential barrier, calculation of reflection and transmission probabilities. α-decay as an example. Application to one dimensional square well potential of finite depth (for bound states only).

5. **Quantum mechanics of simple harmonic oscillator (5) •**
   Setting up the eigenvalue equation for the Hamiltonian. Energy levels and energy eigenfunctions in terms of Hermite polynomials (Solution to Hermite differential equation may be assumed). Ground state, zero-point energy and uncertainty principle.

Recommended reading

1. Feynman Lectures Vol.3, R.P. Feynman, R.B. Leighton, M. Sands, 2008, Pearson Education.

2. Basic Quantum Mechanics, A.K.Ghatak , 2004, Macmillan.

3. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, Resnick and Eisberg, 2014, Wiley.
4. Introduction to Quantum Mechanics, David J. Griffiths, 2018, Cambridge University Press
5. Quantum Physics, Stephen Gasiorowicz, 2007, John Wiley & Sons, Inc.
6. Six Ideas that Shaped Physics: Particle Behave like Waves, T.A.Moore, 2003, McGraw Hill.
7. Physics for scientists and Engineers with Modern Physics, Jewett and Serway, 2010, Cengage Learning.
8. Schaum's outline, Theory and Problems of Modern Physics, R. Gautreau and W. Savin, 2nd Edn, 2020, Tata McGraw-Hill Publishing Co. Ltd.
9. Quantum Mechanics, Bransden and Joachin, 2004, Pearson .
10. Principles of Quantum Mechanics, R. Shankar, 1994, Kluwer Academic/Plenum Publishers.

Practical [1 Credit]

1. Measurement of Plank constant using LED.
2. Determination of e/m of electrons by using bar magnet.
3. To study the photoelectric effect: variation of photocurrent versus intensity and wavelength of light.
4. To show the tunneling effect in tunnel diode using $I-V$ characteristics.
5. To study the diffraction pattern of a grating with the help of a LASER source and to determine its wavelength.

Recommended reading

1. B.Sc. Practical Physics, C.L. Arora, 2010, S. Chand And Company Limited
2. Practical Physics Vol 1 and Vol 2, B. Ghosh, K. G. Majumder, 2023, Sreedhar Publishers

PHS-DSCC-4-2 : Electromagnetism

Theory [3 Credits]

1. **Alternating current (5)** •
   Mean and r.m.s. values of current and emf with sinusoidal wave form; LR, CR series and parallel LCR circuits, reactance, impedance, phase-angle, power dissipation in AC circuit-power factor, Resonance in a series and parallel LCR circuit, Q-factor.
2. **Electrostatics (3)** •
   Gauss' theorem of electrostatics: differential form. Multipole expansion in electrostatics. Dipole and quadrupole moment.

3. **Dielectric properties of matter (6) •**
Dielectric in an external electric field. Electric Fields inside matter, Electric Polarisation, bound charges, displacement density vector, relation between $\boldsymbol{E}$, $\boldsymbol{P}$ and $\boldsymbol{D}$. Gauss's theorem in dielectrics, linear Dielectric medium, electric susceptibility and permittivity. Electrostatic boundary conditions for $\boldsymbol{E}$ and $\boldsymbol{D}$.

4. **Laplace's and Poisson equations (3) •**
Laplace's and Poisson equations. Uniqueness Theorems. Earnshaw's theorem. Dirichlet Boundary value problems in electrostatics.

5. **Method of Images and its applications (4) •**
Plane Infinite metal sheet, Semi-infinite dielectric medium and metal Sphere.

6. **Magnetostatics (6) •**
Derivation of $\nabla.\boldsymbol{B} = 0$, $\nabla \times \boldsymbol{B} = \mu_0 \boldsymbol{J}$. Magnetic vector potential and magnetic dipole. Multipole expansion of vector potential for line currents. Magnetic field for magnetic dipole. Calculation for vector potential in simple cases (i) infinite straight wire (ii) Infinite Solenoid . Magnetic dipole moment for rotating rod, sphere, ring. Gyromagnetic ratio.

7. **Magnetic properties of matter (5) •**
(a) Potential and field due to a magnetic dipole. Magnetic dipole moment. Force and torque on a magnetic dipole in a uniform magnetic field. (b) Magnetization, bound currents. Magnetic intensity $\boldsymbol{H}$. Relation between $\boldsymbol{B}$, $\boldsymbol{H}$ and $\boldsymbol{M}$. Linear media. Magnetic Susceptibility and Permeability. Boundary conditions for $\boldsymbol{B}$ and $\boldsymbol{H}$.

8. **Electromagnetic induction (3) •**
Non-conservative nature of electric field. Faraday's law of induction: simple examples (*e.g.*: Motional EMF, Faraday disc); Lenz's law. Self and mutual inductances in simple cases, energy stored in inductors.

9. **Maxwell's equations (4) •**
Maxwell's equations. Gauge transformations: Lorenz and Coulomb Gauge. Wave equations. Poynting Theorem and Poynting vector. Electromagnetic (EM) Energy Density.

10. **EM Wave Propagation in unbounded media (4) •**
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.

11. **EM Wave in Bounded Media (7) •**
Boundary conditions at a plane interface between two media. Reflection and Refraction of plane waves at plane interface between two dielectric media. Laws of reflection and refraction. Fresnel's formulae for perpendicular and parallel polarization cases, Reflection and transmission coefficients, Brewster's law. Total internal reflection, evanescent waves. Metallic reflection (normal incidence).

Recommended reading

1. Feynman Lectures Vol.2, R.P.Feynman, R.B.Leighton, M. Sands, 2008, Pearson Education.

2. Introduction to Electrodynamics, D.J. Griffiths, 4th Edn., 2015, Pearson Education.

3. Electricity and Magnetism, D.Chattopadhyay and P.C.Rakshit, 2011, New Central Book Agency, 2011.

4. Fundamentals of Electricity and Magnetism, B. Ghosh, 2015, Books and Allied (P) Ltd., 4th edition, 2015.

5. Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education.

6. Introduction to Advanced Electrodynamics, Kaushik Bhattacharya and Soumik Mukhopadhyay, 2021, Springer

7. Elements of Electromagnetics, M.N.O. Sadiku, 2010, Oxford University Press.

8. Classical Electromagnetism, Jerrold Franklin, 2007, Pearson Education.

Practical [1 Credit]

1. To study series LCR circuit characteristics: resonance curve for two different R, variation with C, Phase angle plot.

2. To study mutual inductance between two coils.

3. To find horizontal component of Earth's magnetic field using magnetometer.

4. To verify Malus law using a pair of polaroids.

5. To verify Fresnel's equation by the reflection on the surface of a prism with help of two polariods.

Recommended reading

1. Advanced Practical Physics, B. Ghosh, K. G. Majumder, 2023, Sreedhar Publication

2. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency (P) Limited

PHS-DSCC-4-3 : Mathematical Physics II

Theory [3 Credits]

1. **Solution of 2nd order linear differential equations (15) •**
   Second order inhomogeneous differential equation; Linear independence of solutions: Wronskian, second solution. Singularity analysis at finite points. Power series solution of 2nd order differential equation. Frobenius method and its applications to differential equations. Legendre, Hermite Differential Equations. Properties of Legendre and Hermite Polynomials: Rodrigues Formula, Generating Function, Orthogonality and completeness relation (Statement only). Simple recurrence relations. Expansion of function in a series of Legendre Polynomials.

2. **Linear Vector Space (LVS) (5) •**
   Idea of LVS with 2-d and 3-d cartesian vectors. Introduction to bra and ket vectors. Definition of LVS with examples : 2-d , 3-d vectors, complex numbers, sinusoidal waveforms. Dual space. Inner product, Norm (defined in terms of inner product), Cauchy-Schwarz inequality, metric space. Linear independence and dependence of vectors. Completeness of a set of vectors. Dimension and basis. Orthogonality. Gram-Schmidt method for orthogonalization.

3. **Vectors (5) •**
   Vectors and scalars under rotation. Orthogonal curvilinear coordinates: Jacobian of transformation and its application to gradient, divergence, curl and Laplacian operators.

4. **Introduction to Tensor analysis(4) •**
   Definition of cartesian tensors in 3 dimensions. Transformation properties. Contraction of tensors in 3 dimensions.

5. **Matrices (15) •**
   Representation of linear operator in terms of matrices. Addition and multiplication of matrices. Null matrices. Diagonal, scalar and unit matrices. Transpose of a matrix. Symmetric and skew-symmetric matrices. Conjugate of a matrix. Hermitian and skew-hermitian matrices. Singular and non-singular matrices. Orthogonal and unitary matrices. Trace of a matrix. Similarity transformation. Invariance of trace and determinant under similarity transformation. Transformation of basis. Eigenvalues and eigenvectors (degenerate and non-degenerate). Commuting operators and simultaneous eigenvectors for non-degenerate and degenerate eigenvalues. Cayley-Hamilton Theorem. Diagonalization of matrices. Solutions of coupled linear ordinary homogeneous differential equations. Functions of a matrix, *e.g.*, exponential and trigonometric functions.

6. **Numerical Analysis II (6) •**
   Partial differential equation: Finite difference approximations to partial derivatives ($O(h^2)$). Solution of one dimensional heat conduction equation by explicit method. Qualitative idea of explicit and implicit methods. Laplace equation (2-d) using standard five point formula, Successive relaxation technique. Solution of 1-d Wave equation. Stability criterion — CFL condition (qualitative).

Recommended reading

1. Mathematical Methods for Physicists: Arfken, Weber, 2005, Harris, Elsevier

2. Differential Equations, S.L. Ross, 2007, 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. Mathematical Methods of Physics. J. Mathews and R.L. Walker, 2004, Pearson

5. Mathematics for Physicists, P. Dennery and A.Krzywicki, 1967, Dover Publications.

6. Matrix Methods: An Introduction , R. Bronson, 1991, Academic Press

7. Vector Spaces and Matrices in Physics , M.C. Jain, 2018, Narosa.

8. Linear Algebra, S. Lipschutz and M.L.Lipson, Schaums Outline Series, 2009 McGraw Hill

Practical [1 Credit]

1. Introduction to Scipy:
    - Interpolation Using scipy.interpolate.lagrange
    - Numerical Integration using:
      scipy.integrate.quad, scipy.integrate.trapz, scipy.integrate.simps
    - Solving first order and 2nd order ODE by scipy.integrate.odeint().
    - Use of special functions taken from scipy.special. Plotting and verification of the properties of special functions. Orthogonality relations and recursion relations. (Legendre and Hermite Only)
2. Numerically handling improper integrals over infinite intervals over the range $\int_a^\infty$ correct up to given decimal place without using Scipy.
3. Numerically verifying the Gaussian integral result

$$\int_{-\infty}^{\infty} \exp\left(-ax^2 + bx + c\right) dx = \sqrt{\frac{\pi}{a}} \exp\left(\frac{b^2}{4a} + c\right)$$

4. Verifying that $\int_{a-x_1}^{a+x_2} f(x)\delta(x-a)\,dx = f(a)$
5. Evaluate the Fourier coefficients of a given periodic function using scipy.integrate.quad(). Examples: square wave, triangular wave, saw-tooth wave. Plot to see a wave form from scipy.signal and the constructed series along with.
6. Curve Fitting with user defined functions using scipy.optimize module
7. Solution of some basic PDEs
    - Boundary value problems. Finite discrete method with fixed step sizes. Idea of stability. Application to simple physical problems. Dirichlet's Boundary conditions only.
    - Laplace equation $\frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} = 0$, on a square grid with specified potential at the boundaries.
    - Wave equation in 1+1 dimension: $\frac{\partial^2\phi}{\partial t^2} = \lambda\frac{\partial^2\phi}{\partial x^2}$. Vibration of a string with ends fixed with given initial configurations: $\phi(x,0)$ and $\left.\frac{\partial\phi}{\partial t}\right|_{(x,0)}$.
    - Heat equation in 1+1 dimension, $\frac{\partial u}{\partial t} = \alpha\frac{\partial^2 u}{\partial x^2}$ with specified value of temperature at the boundaries with given initial temperature at the boundaries with given initial temperature profile.

Recommended reading

1. Numerical Analysis, Mathematics of Scientific Computing, David Kincaid, Ward Cheney, Reprint First Indian Edition 2013, American Mathematical Society

2. Numerical Methods for Engineers, 2nd Edition, D.V. Griffiths and I.M. Smith, 2006, Chapman & Hall/CRC, Special Indian Edition

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

4. Scientific Computing in python, Avijit Kar Gupta, 2022, Techno World

5. Physics in Laboratory including python Programming (Semester III), Mandal, Chowdhuri, Das, Das, 2019, Santra Publication

6. Physics in Laboratory python Programming (Semester IV & V), Pradipta Kumar Mandal, 2020, Santra Publication

7. Computational Physics problem solving with Computers, Landau, Paez, Bordeianu, textbook in Python 3rd Edition, 2015, Wiley-VCH

8. Computational Methods for Physics, Joel Franklin, 2013, Cambridge University Press

9. Programming for Computation – Python, Svein Linge, Hans Petter Lantangen, 2016, Springer

10. Numerical Python, Robert Johansson, 2018, Apress Publication

PHS-DSCC-4-4 : Classical Mechanics and Special Theory of Relativity

Theory [3 Credits]

1. **Non-inertial Systems (8) •**
   Non-inertial frames and idea of fictitious forces. Equation of motion (EOM) with respect to a uniformly accelerating frame. EOM with respect to a uniformly rotating frame: Centrifugal and Coriolis forces. Applications: Surface of rotating liquid, deflection of falling mass, cyclone.

2. **Rotational Dynamics (10) •**
   The rigid body: Constraints defining the rigid body. Degrees of freedom for a rigid body; Relation between angular momentum and angular Velocity: Moment of inertia tensor. Calculation of moment of inertia for rectangular, cylindrical and spherical bodies. Equation of motion for rotation about a fixed axis. Principal Axes transformation. Transformation to a body fixed frame. EOM for the rigid body with one point fixed (Euler's equations of motion). Torque-free motion. Kinetic energy of rotation.

3. **Variational calculus in Physics (20) •**
   Basic ideas of functionals. Extremization of action as a basic principle in mechanics. Generalized coordinates, Constraint. Lagrangian formulation. Euler-Lagrange equations of motion for simple systems: harmonic oscillators, simple pendulum, spherical pendulum. Motion under Central force. Cyclic coordinates. Symmetries and conservation laws. Legendre transformations and the Hamiltonian formulation of mechanics. Canonical equations of motion. Applications to simple systems.

4. **Special theory of Relativity (12)** •
   Michelson-Morley Experiment and its outcome. Postulates of Special Theory of Relativity. Invariance of space-time interval. Derivation of Lorentz transformation equations. Length contraction. Time dilation. Simultaneity and order of events. Concept of causality. Relativistic transformation of velocity. Velocity addition. Relativistic dynamics. Energy-momentum dispersion relation. Massless particles. Mass-energy equivalence. Transformation of energy and momentum. Minkowski space-time [(ct, x, y, z) or (x, y, z, ct)] diagram.

Recommended reading

1. Introduction to Classical Mechanics With Problems and Solutions , D. Morin, Cambridge University Press
2. Classical Mechanics, A course of Lectures, A.K. Raychaudhuri, 1983, Oxford University Press
3. Classical Mechanics , N.C. Rana and P. Joag, 2017, McGraw Hill Education
4. Classical Mechanics, Goldstein, Poole and Safko, 2011, Pearson Education
5. Introduction to Special Relativity, R. Resnick, 2010, John Wiley and Sons
6. Introduction to Special Relativity , J.H. Smith, 2003, Dover Publications Inc
7. Introduction to Electrodynamics, D.J. Griffiths, 4th Edn., 2015, Pearson Education
8. Special Relativity: For the Enthusiastic Beginner, D. Morin, 2017, Createspace Independent Pub

Practical [1 Credit]

1. To determine the moment of inertia of a Flywheel.
2. To determine Young's modulus of the material of a rod by method of flexure.
3. To determine the elastic constants of the material of a wire by Searle's method.
4. To determine g using Bar Pendulum.
5. Study of simple pendulum ($x - t, v - t, x - v$ plot) using video analysis and modeling tool (Tracker software).

Recommended reading

1. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press
2. B.Sc. Practical Physics, C.L. Arora, 2010, S Chand and Company Limited
3. Physics in Laboratory, Mandal, Chowdhury, Das, Das, 2019, Santra Publication
4. Advanced Practical Physics Vol 1, B. Ghosh, K. G. Majumder, Sreedhar Publisher

5 Semester 5

PHS-DSCC-5-1 : Electronics I

Theory [3 Credits]

1. **Circuits and network (DC) (4) •**
   Discrete components, active and passive components, ideal constant voltage and constant current sources. Network analysis: Kirchhoff's laws, Thevenin's and Norton's theorem, Superposition theorem. Maximum power transfer theorem.

2. **Semiconductor diodes and applications (9) •**
   P and N type semiconductors. Energy level diagram. Conductivity and mobility, concept of drift velocity. PN junction fabrication (simple idea only). Barrier formation in PN junction diode. Static and dynamic resistance. Current flow mechanism in forward and reverse biased diode. Drift velocity. Rectifier diode: Half-wave rectifiers. Centre-tapped and Bridge full-wave rectifiers, Calculation of Ripple Factor and Rectification Efficiency, L and C filter. Circuit and operation of clipping and clamping circuit; principle and structure of LEDs, photodiode, solar cell.

3. **Bipolar junction transistors and biasing (10) •**
   n-p-n and p-n-p transistors. Characteristics of CB, CE and CC configurations. Physical mechanism of current flow. Relations between the current gains of the three modes. Active, cut-off and saturation regions. DC load line and Q-point; Transistor biasing and stabilization circuits. Fixed bias, collector to base bias, emitter or self bias, voltage divider bias. Transistor as 2-port network. h-parameter equivalent circuit. Analysis of a single-stage CE amplifier using hybrid model. Input and output impedance.

4. **Field Effect transistors (3) •**
   JFET and MOSFET (both depletion and enhancement type) as a part of MISFET. Basic structure and principle of operations and their characteristics. Pinch off, threshold voltage and short channel effect.

5. **Regulated power supply (3) •**
   Load regulation and line regulation. Zener diode as a voltage regulator. Problem with the Zener regulator circuit. Requirement of feedback and error amplifier. Study of series regulated power supply using pass and error transistor assisted by Zener diode as a reference voltage supplier.

6. **Amplifiers (5) •**
   Transistor amplifier; CB, CE and emitter follower circuit and their uses. Load Line analysis of transistor amplifier. Classification of class A, B and C amplifiers with respect to placement to Q point. Frequency response of a CE amplifier. Role of series and parallel capacitors for cut off frequencies.

7. **Feedback amplifiers and OPAMP (8) •**
   Effects of positive and negative feedback. Voltage series, current series, voltage shunt and current shunt feedback and uses for specific amplifiers. Estimation of input impedance, output impedance, gain, stability; Operational Amplifiers (black Box approach): Characteristics of ideal and practical OP-AMP (IC 741), Open-loop and closed-loop voltage

gain. Frequency response. CMRR. Slew rate and concept of virtual ground. Application of OP-AMP: DC application — inverting and non-inverting amplifiers, inverting and non-inverting adder, differentiator as subtractor, error amplifier, comparator, Schmidt trigger. AC applications: differentiator, integrator.

8. **Multivibrator (5)** •
   Transistor as a switch, Explanation using CE output characteristics. Construction and operation using wave shapes of collector coupled Bistable, Monostable and astable multivibrator circuits, Expression for time period.

9. **Oscillators (3)** •
   Sinusoidal oscillators: Barkhausen's criterion for self-sustained oscillations. RC phase shift oscillator, Wien bridge oscillator, determination of feedback factor and frequency of oscillation. Relaxation oscillator using OP-AMP.

Recommended reading

1. Circuits and Networks, Analysis and Synthesis, A Sudhakar, Shyammohan S Palli, 2017, Tata McGraw-Hill Education Private Ltd.

2. Solid State Electronic Devices, B.G.Streetman & S.K.Banerjee, 6th Edn.,2009, PHI Private Ltd.

3. Fundamental Principles of Electronics, B.Ghosh, 2nd ed, 2008, Books & Allied (P) Ltd.

4. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata McGraw-Hill Education Private Ltd.

5. Electronic Devices and Circuits, S. Salivahanan, N. Suresh Kumar, 2022, McGraw Hill Education Private Ltd.

6. Learning OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition,2000, Prentice Hall India Private Ltd.

7. Electronic Devices, Thomas L. Floyd, 7/e 2008, Pearson India

8. Fundamentals of Analog Electronics: Theory, Problems and Solutions, U.N. Nandi, 2022, Techno India.

Practical [1 Credit]

1. To study the static characteristics of BJT in CE Configuration.

2. To design and study the frequency response of the BJT amplifier in CE mode.

3. Construction of a series regulated power supply from an unregulated power supply.

4. To study OP-AMP: inverting amplifier, non inverting amplifier, adder, subtractor, comparator, Schmidt trigger, integrator, differentiator.

5. To design a Wien bridge oscillator for given frequency using an OP-AMP.

Recommended reading

1. Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, McGraw Hill

2. Advanced Practical Physics (volume II), B. Ghosh, Shreedhar Publication

3. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency

4. Laboratory Manual for Operational Amplifiers and Linear ICs, David A. Bell, 2006, Prentice Hall of India

PHS-DSCC-5-2 : Nuclear and Particle Physics

Theory: [3 Credits]

1. **Rutherford scattering (2) •**
   Calculation of differential cross-section.

2. **Nuclear properties and structure (15) •**
   Mass, charge, size, B.E, spin and magnetic moment of the nucleus; Impossibility of an electron being in the nucleus as a consequence of the uncertainty principle; Isotopes, isobars, isotones. Bainbridge Mass Spectrograph. Nature of nuclear force between nucleons, Stability and binding, N-Z plot. Nuclear models: Liquid Drop model. Bethe-Weizsäcker semi-empirical mass formula and binding energy. Some applications: explanation of α decay by heavy nuclei, mass parabola, explanation of β decay by mirror nuclei. Nuclear shell model and magic numbers, ground state spin parity, Nordheim's Rule (qualitative discussion on phenomenology with examples).

3. **Interaction with and within the nucleus (10) •**
   Radioactivity: α- decay — kinematics, range-energy relationship and Geiger-Nuttall Law; β-decay — energy released, spectrum and Pauli's prediction of neutrino; Energy levels and decay schemes, positron emission and electron capture, selection rules: Fermi and Gamow-Teller transitions. γ-ray emission, nuclear isomerism, energy-momentum conservation: electron-positron pair creation by gamma photons in the vicinity of a nucleus.

4. **Nuclear Reactions (10) •**
   Types of reactions, conservation laws, kinematics of reactions, Q-value, reaction rate, reaction cross-section. Concept of compound and direct reaction, Ghoshal's experiment. Resonance reaction, fission and fusion: mass deficit and generation of energy. Reaction characteristics, explanation in terms of liquid drop model, fission products and energy release, spontaneous and induced fission, transuranic elements. Chain reaction and basic principle of nuclear reactors. Nuclear fusion: energetics in terms of liquid drop model. Chain reaction and basic principle of nuclear reactors, slow neutrons interacting with U-235, Nuclear Fusion — energetics in terms of liquid drop model (brief qualitative discussions).

5. **Particle accelerators and detectors (3) •**
   Linear accelerator, cyclotron, betatron, gas detectors — GM Counters. Semiconductor detectors.

6. **Particle physics (7) •**
   Elementary particles and their families, interactions and basic features. Symmetry and conservation laws: energy and momentum, angular momentum, parity, baryon number, lepton number, isospin, hypercharge, and strangeness. Wu's experiment and basic idea of parity violation. Gell-Mann–Nishijima formula. The baryon and meson octet and baryon decuplet diagrams. Quark structure of hadrons. Concept of quark model, color quantum number and gluons (qualitative discussion only).

7. **Nuclear Astrophysics (3) •**
   Energy production in stars, p-p chain, CNO cycle. Production of heavier elements (qualitative discussion).

Tutorial [1 Credit]
Students must be given at least one assignment or a small set of problems. On the basis of regularity of submission and evaluation of assignment by the respective teacher, credits should be awarded to the students.

Recommended reading

1. Introductory nuclear Physics by Kenneth S. Krane, 2008, Wiley India
2. Nuclear and Particle Physics, S. Bhattacharyya, 2020, Universities Press .
3. Introduction to Elementary Particles, D. Griffiths, 2008, John Wiley & Sons
4. Basic ideas and concepts in Nuclear Physics - An Introductory Approach by K. Heyde, 2004, IOP Publishing
5. Radiation detection and measurement, G.F. Knoll, 2000, John Wiley & Sons
6. Nuclear Physics, Irving Kaplan, 2002, Narosa
7. Nuclear Physics, An Introduction, S.B. Patel, 2018, New Age International

PHS-DSCC-5-3 : Quantum Mechanics

Theory [3 Credits]

(A) Quantum Mechanics (30)

1. **Formulation of Quantum Mechanics in vector space language (13) •**
   State as a vector in a complex vector space, inner product, its properties using Dirac braket notation. Physical observables as Hermitian operators on state space; eigenvalues, eigenvectors and completeness property of the eigenvectors — matrix representation of Hermitian operators. Unitary time evolution. Wavefunction as the probability amplitude distribution of a state for the observables with continuous eigenvalues. Position representation and momentum representation of wave-functions and operators. Interpretation of $\psi(\boldsymbol{r}) = \langle \boldsymbol{r}|\psi\rangle$. One dimensional harmonic oscillator by raising and lowering operator method. Matrix representations of position and momentum operators.

2. **Two and three dimensional problems (4) •**
   Two and three dimensional problems in cartesian coordinates: separation of variables. Application for free particle, Particle in 2-d and 3-d box. Degeneracy of energy levels. Concept of symmetry and accidental degeneracy in 2-d box. Isotropic and anisotropic harmonic oscillator. Degeneracy for isotropic harmonic oscillator in 2-d and 3-d.

3. **Angular momentum algebra using Ladder operators (5) •**
   Construction of matrix representation of L_x, L_y, L_z for $\ell = 1$. Algebra with Ladder operators. Addition of angular momenta $\boldsymbol{\ell}_1 + \boldsymbol{\ell}_2$, and their projections. Spin as an intrinsic angular momentum and its relation with the Pauli matrices for spin-$\frac{1}{2}$.

4. **Quantum theory of hydrogen-like atoms (8) •**
   Reduction of a two-body problem to a one body problem. The time independent Schrödinger equation for a particle moving under a central force; the Schrödinger equation in spherical polar coordinates. Separation of variables. Angular equation and orbital angular momentum. Spherical harmonics (solution to Legendre differential equation may be assumed). Radial equation for attractive Coulomb interaction — Hydrogen atom. Solution for the radial wavefunctions (solution to Laguerre differential equation may be assumed). Sketch of probability densities. Orbital angular momentum quantum numbers ℓ and m; s, p, d shells.

(B) Quantum Statistical Mechanics (20)

1. **Systems of identical particles (8) •**
   Collection of non-interacting identical particles. Classical approach and quantum approach: distinguishability and indistinguishability. Composite system postulate and symmetry postulate of quantum mechanics (for a pair of particles only). Bosons and fermions. Symmetric and antisymmetric wave functions. Pauli Exclusion Principle for fermions. Derivation of Bose-Einstein and Fermi-Dirac distribution function using grand canonical ensemble.

2. **Bose-Einstein statistics (6) •**
   Thermodynamic functions of a strongly degenerate Bose gas. Bose derivation of Planck's law. Radiation as a photon gas and thermodynamic functions of photon gas. Chemical potential of photon gas. Bose-Einstein condensation and properties of liquid He-4 (qualitative description only).

3. **Fermi-Dirac statistics (6) •**
   Thermodynamic functions of strongly degenerate Fermi gas, Fermi energy, electron gas in a metal, Specific heat of metals due to electrons (qualitative discussions).

Recommended reading

1. Introduction to Quantum Mechanics, D.J. Griffiths, 2018, Cambridge University Press

2. Introduction to Quantum Mechanics, Krishnendu Sengupta and Palash B. Pal, 2023, Cambridge University Press

3. Quantum Mechanics: Classical Results, Modern Systems, and Visualized Examples, R. Robinett, 2006, Oxford University Press

4. Quantum Mechanics , Bransden and Joachain, 2004, Pearson

5. Quantum Mechanics, Walter Greiner, 4th Edn., 2001, Springer

6. Quantum Mechanics, Leonard I. Schiff, 3rd Edn. 2010, Tata McGraw-Hill

Practical (1 Credit]

1. **Finding eigenstates solving transcendental equation**: To find eigenvalues of the bound state particle of mass in a one dimensional potential well by solving the transcendental equation that appears as the eigenvalue condition (graphs are to be plotted for appropriate guess values, scipy root searching package may be used) and to solve the Schrödinger's equation for the determined eigenvalues to find and plot the eigenfunctions.

2. **Solving boundary problem of 2nd Order ODE using Shooting Algorithm**: (scipy.optimize.bisect or scipy.optimize.newton or scipy.optimize.root may be used)

3. **Shooting algorithm for solving bound state problems (solving the Time Independent Schrödinger's equation using both scipy.integrate.odeint and Numerov algorithms)**: conversion to dimensionless variable, eigenvalues and eigenvectors of the ground and first excited states.

   - in one dimension (for example, the Harmonic oscillator, the triangular well, infinite and finite square well)
   - the s wave radial equation for a particle moving in a central potential $\frac{d^2U(r)}{dr^2} = A(r)U(r)$, where $A(r) = \frac{2m}{\hbar^2}(V(r) - E)$
     $V(r) = -\frac{e^2}{r}$ (Coulomb Potential Only)

4. **Solving 1D time independent Schrödinger's equation for bound state using finite difference method** (use numpy.linalg): conversion to dimensionless variable, eigenvalues and eigenvectors of the ground and first excited states for infinite square well, finite square well and simple harmonic oscillator.

Once normalized wave function is obtained computation of $\langle x \rangle$, $\langle x^2 \rangle$, probability density to be done.

Recommended reading

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

2. Scientific Computing in Python, Abhijit Kar Gupta, 2022, Techno World

3. Physics in Laboratory Python Programming (Semester IV & V), Pradipta Kumar Mandal, 2020, Santra Publication

4. Computational Physics problem solving with Computers, Landau, Paez, Bordeianu, textbook in Python 3rd Edition, 2015, Wiley-VCH

5. Computational Methods for Physics, Joel Franklin, Cambridge University Press

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

PHS-DSCC-5-4 : Thermal Physics and Statistical Mechanics

Theory [**3 Credits**]

(A) Kinetic Theory of Gases (12)

1. **Transport phenomenon in ideal gas (5) •**
   Viscosity, thermal conductivity and diffusion. Brownian motion and its significance (Langevin approach).

2. **Conduction of heat (3) •**
   Thermal conductivity and diffusivity. Variable and steady state; Fourier's equation for heat conduction and its solution for rectilinear flow of heat.

3. **Real gas (4) •**
   Behavior of real gases: Deviations from the ideal gas equation. The Virial equation. Andrew's experiments on CO_2. Critical constants. Continuity of liquid and gaseous state. Vapour and gas. Boyle temperature. Van der Waals' equation of state for real gases. Values of critical constants. Law of corresponding states. Comparison with experiment. P-V diagrams.

(B) Thermodynamics (23)

1. **Thermodynamic Potentials (6) •**
   Generic conditions of stable equilibrium for (V,T) and (P,T) systems. Internal energy, enthalpy, Helmholtz free energy, Gibbs free energy. Use of Legendre transform in these cases. Properties and applications.

2. **Maxwell's thermodynamic relations (7) •**
   Derivation and applications: (i) TdS equations, (ii) Difference of specific heats $C_p - C_v$, (iii) Variation of specific heats $\left(\frac{\partial C_V}{\partial V}\right)_T$ and $\left(\frac{\partial C_P}{\partial P}\right)_T$, (iv) Ratios of volume expansivity β_X where $X = P$ or S, pressure coefficients α_X where $X = V$ or S, compressibilities (or its reciprocal Bulk moduli) κ_X where $X = T$ or S, in terms of C_p/C_v.
   Change of temperature during Adiabatic Process; Joule-Thomson effect. Porous plug experiment: Throttling process. Joule-Thomson effect for ideal and real gases. Temperature of inversion. Joule-Thomson cooling.

3. **Phase transition (3) •**
   Classification of phase transitions; First order phase transitions: Clausius-Clapeyron equation, Second latent heat equation; Continuous phase transitions: Ehrenfest's equation.

4. **Radiation (7) •**
   Classical and quantum aspects: Properties of thermal radiation. Black-body radiation. Temperature dependence. Kirchhoff's law. Stefan-Boltzmann law: thermodynamic proof. Calculation of energy density and pressure of radiation from thermodynamics.

Spectral distribution of black-body radiation. Rayleigh-Jeans law and the ultraviolet catastrophe, Planck's quantum postulates. Planck's law of black-body radiation. Deduction of Rayleigh-Jeans law, Stefan-Boltzmann law, Wien's displacement law from Planck's law.

(C) Classical Statistical Mechanics (15)

1. **Macrostate and Microstate (4) •**
   Elementary Concept of Ensemble and Ergodic Hypothesis (statement only). Phase space. Microcanonical ensemble, Postulate of equal *a priori* probability. Boltzmann hypothesis: Entropy and thermodynamic probability.

2. **Canonical ensemble (11) •**
   Partition function, Thermodynamic properties of an ideal gas. Thermodynamic properties of classical and quantum harmonic oscillator in one dimension using canonical ensemble. Classical entropy expression, Gibbs paradox. Equivalence of microcanonical and canonical ensembles. Sackur-Tetrode equation, Law of equipartition of energy (with proof) and its applications. Thermodynamic functions of a two-energy Level system. Negative temperature. Idea of chemical potential and grand canonical ensemble. Application of ideal gas using grand canonical ensemble.

Recommended reading

1. Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill
2. Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa
3. Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Ed., 2012, Oxford University Press
4. Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill Publishing Company Ltd.
5. Statistical Physics, F. Mandl, 2014, Wiley India Pvt. Ltd
6. Thermodynamics and Statistical Mechanics, W. Greiner, 2001, Springer
7. Statistical Mechanics: Theory, Problems and Solutions, U.N. Nandi, 4th Ed., 2024, Techno World

Practical [1 Credit]

1. Determination of the the coefficient of Thermal conductivity of a bad conductor by Lees method.
2. Calibration of a thermocouple by direct measurement of the thermo-emf using potentiometer. [One end of the couple in ice bath and other in a water bath which is to be heated]
3. Determination of the temperature coefficient of resistance by Carey Foster's method.

4. Determination of the temperature coefficient of resistance of platinum by using Platinum resistance thermometer.

5. Verification of Stefan-Boltzmann law using tungsten bulb .

Recommended reading

1. Advanced Practical Physics, B. Ghosh, K. G. Majumder, Sreedhar Publication

2. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency (P) Limited

6 Semester 6

PHS-DSCC-6-1 : Electronics II

Theory [3 Credits]

1. **Number System (8) •**
   (a) Binary numbers, Decimal to binary and reverse conversions; Binary addition and subtraction (1's Complement and 2's complement method), BCD, octal and hexadecimal numbers; signed and unsigned number representation of binary system. Representation of negative numbers.
   (b) OR, AND, NOT, NOR, NAND, XOR and XNOR gates — Truth tables. Statement of de Morgan's theorem. Realization of OR, AND, NOT using diodes and transistors.

2. **Digital Circuits (15) •**
   (a) Difference between analog and digital circuits. XOR and XNOR gates and application as parity checkers; Introduction to different logics like DTL, TTL.
   (b) Product term and sum term in logical expression; SOP, POS. Minterm and Maxterm in the expressions; Conversion between truth table and logical expression; Simplification of logical expression using Karnaugh Maps (4 variables).

3. **Implementation of different circuits (6) •**
   Half and full adders; subtractors; 4-bit binary adder/subtractor.; use of IC 7483 as adder and subtractor.

4. **Data processing circuits (5) •**
   Basic idea of multiplexers, de-multiplexers, decoders, encoders.

5. **Sequential circuits (6) •**
   Introduction to next state – present state table and excitation table for sequential circuits. SR, D, JK and T Flip-Flops. Clocked (level and edge triggered) Flip-Flops. Preset and Clear operations; Race condition in SR and race-around conditions in JK Flip-Flop. Master-slave JK Flip-Flop.

6. **Registers and Counters (8) •**
   (a) Shift registers: Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out and Parallel-in-Parallel-out Shift registers (only up to 4 bits).
   (b) Counters (4 bits): Asynchronous counters: ripple counter, Decade counter. Synchronous counter, Ring counter.

7. **Data conversion (2) •**
   D/A (Ladder and weighted resistance) and A/D conversion circuits.

Recommended reading

1. Digital Circuits, Part I & II, D. Raychaudhuri, 2015, Platinum Publishers

2. Digital Logic and Computer Design, M. Morris Mano, 2016, Pearson Education

3. Digital Principles and Applications, A.P. Malvino, D.P. Leach and Saha, 7th Ed., 2011, Tata McGraw-Hill

4. Electronic devices & circuits, S. Salivahanan & N.S. Kumar, 2012, Tata McGraw-Hill

5. Fundamental of Digital Circuits, A. Anand Kumar, 2016, Prentice Hall India Learning

6. Digital Systems, Principles and Applications, R. Tocci, N. S. Widemer, 2022, Pearson Education

7. Modern Digital Electronics, R. P. Jain, 2009, Tata McGraw-Hill

8. Digital Electronics An Introduction to Theory and Practice, W.H. Gothmann, 1982, Prentice Hall India Learning

9. Digital Computer Electronics, A. Malvino & Jerald Brown, 2017, Tata McGraw-Hill

Practical [1 Credit]

1. Construction of OR AND and NOT gates using diode and transistors.

2. Construction of half adder and full adder.

3. Construction of SR, D, JK, FF circuits using NAND gates.

4. Construction of a 4-bit binary counter using D-type/JK Flip-Flop and study timing diagram.

5. Construction of 4 bit shift registers (serial and parallel) using D type FF IC 7476.

6. Construction of 4×1 multiplexer using basic gates and IC 74151.

Recommended reading

1. Advanced Practical Physics, B. Ghosh, K. G. Majumder, Sreedhar Publication

2. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency (P) Limited

PHS-DSCC-6-2 : Solid State Physics

Theory [3 Credits]

1. **Crystal structure (10) •**
   Solids: amorphous and crystalline materials. Lattice translation vectors. Lattice with a basis; central and non-central elements. Unit cell. Miller indices. Reciprocal lattice. Types of lattices. Brillouin zones. Diffraction of X-rays by crystals. Laue and Bragg's laws and their equivalence. Atomic and geometrical structure factor. Basic idea of crystal indexing: examples with SC, BCC, FCC structure.

2. **Elementary lattice dynamics (7) •**
   Lattice vibrations and phonons: linear monatomic and diatomic chains. Acoustical and optical phonons. Qualitative description of the phonon spectrum in solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids, T^3 law.

3. **Drude's theory (3) •**
   Free electron gas in metals, effective mass, drift current, mobility and conductivity, Hall effect in metals. Thermal conductivity. Lorentz number, limitation of Drude's theory.

4. **Dielectric properties of materials (10) •**
   Polarization. Local electric field at an atom. Depolarization field. Electric susceptibility. Polarizability. Clausius-Mosotti equation. Classical theory of electric polarizability. Normal and anomalous dispersion. Cauchy and Sellmeier relations. Langevin-Debye equation. Complex dielectric constant.

5. **Elementary band theory (8) •**
   Kronig-Penney model. Band gap. Effective mass and effective mass tensor. Conductor, semiconductor (P and N type) and insulator. Conductivity of semiconductor, mobility, Hall effect. Measurement of conductivity (4 probe method) and Hall coefficient.

6. **Magnetic properties of matter (8) •**
   Dia, para, ferri and ferromagnetic materials. Classical Langevin theory of dia- and paramagnetic domains. Quantum mechanical treatment of paramagnetism (using partition function). Curie's law, Weiss's theory of ferromagnetism and ferromagnetic domains. B-H curve and hysteresis. Calculation of energy loss in B-H loop.

7. **Superconductivity (4) •**
   Experimental results. Critical temperature. Critical magnetic field. Meissner effect. Type I and type II superconductors, London equation and penetration depth. Isotope effect.

Recommended reading

1. Introduction to Solid State Physics, Charles Kittel, 8th Edition, 2004, Wiley India Pvt. Ltd.

2. Solid-state Physics, H. Ibach and H. Luth, 2009, Springer Solid State Physics, Rita John, 2014, McGraw Hill

3. Elementary Solid State Physics, M. Ali Omar, 1999, Pearson India

4. The Oxford Solid State Basics, S.H. Simon, 2017, Oxford University Press

5. Solid State Physics, M.A. Wahab, 2011, Narosa Publications

6. Solid State Physics, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning

Practical [1 Credit]

1. Drawing of the B-H hysteresis curve of the given ferromagnetic specimen in the form of an anchor ring.

2. Determination of the dielectric constant of given solid material/materials using fixed frequency ac source studying the resonance condition in a LC rejector circuit.

3. Measurement of variation of resistivity in a semiconductor and investigation of intrinsic band gap using linear four probe.

4. Measurement of hall voltage by four probe method.

5. To study temperature coefficient of a semiconductor (NTC thermistor) and construction of temperature controller with comparator and relay switch.

Recommended reading

1. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
2. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House
3. Elements of Solid State Physics, J.P. Srivastava, 2nd Ed., 2006, Prentice Hall of India

PHS-DSCC-6-3 : Atomic, Molecular, and Laser Physics

Theory [3 Credits]

1. **Generalized angular momenta and spin (7) •**
   Generalized angular momentum. Electron's magnetic moment and spin. Gyromagnetic ratio, Bohr Magneton, and the g-factor (derivation not required). Energy associated with a magnetic dipole placed in magnetic field. Larmor's theorem. Stern-Gerlach experiment. L-S and j-j couplings.

2. **Atoms in external magnetic field (4) •**
   Anomalous Zeeman effect. Splitting of spectral lines and selection rules (statement and application only, derivation of level splitting and selection rules not required).

3. **Many electron atoms (8) •**
   Identical particles, Symmetric and antisymmetric wavefunctions with Slater determinant, spin-singlet and spin-triplet states, ortho- and parahelium as an example. Pauli's Exclusion Principle; Hund's Rule; Periodic table. Fine structure splitting. L-S and j-j coupling for many-electron atoms. Spectral notations for atomic states and Term symbols for equivalent and inequivalent electrons; Spectra of alkali atoms (Na etc.): difference between hydrogen spectra and alkali spectra.

4. **Molecular spectra (5) •**
   Diatomic molecules — rotational and vibrational energy levels. Basic ideas about molecular spectra. Raman effect and its application to molecular spectroscopy (qualitative discussion only).

5. **Lasers (18) •**
   Radiative and non-radiative transitions. Absorption, spontaneous and stimulated emission, Einstein's A and B coefficients–their interrelation. Idea of metastable state, population inversion. Necessary condition for lasing, threshold population inversion. Two-level system: unattainability of population inversion. Three-level and four-level systems: rate equations and necessary condition for population inversion. Basic components of a laser system — active medium, pumping system and optical resonator. Free spectral range. Line broadening mechanism — natural broadening and pressure broadening (qualitative discussion), Doppler broadening. Ruby laser, He-Ne laser and semiconductor laser working principle.

6. **Fiber optics (8) •**
   Optical fiber, coherent bundle, numerical aperture. Step index and graded index fibers. Attenuation of optical fibers. Modes of a planar waveguide: TE and TM modes. Physical understanding of modes, Optical fibers: Guided modes of step-index fibers.

Recommended reading

1. Lasers: Theory and Applications, A. Ghatak & K. Thyagarajan, 2010, Springer Science
2. Laser and Non Linear Optics, B.B. Laud, 2011, New Age International (P) Ltd. Publishers
3. Introduction to Fiber Optics, A. Ghatak, 1998, Cambridge University Press
4. Introduction to Quantum Mechanics, D.J. Griffiths, 2018, Cambridge University Press
5. Quantum Mechanics, Bransden and Joachain, 2004, Pearson
6. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, Resnick and Eisberg, 2014, Wiley.

Tutorial [1 Credit]
Students must be given at least one assignment or a small set of problems. On the basis of regularity of submission and evaluation of assignment by the respective teacher, credits should be awarded to the students.

7 Semester 7

PHS-DSCC-7-1 : Mathematical Methods III

Theory [3 Credits]

1. **Group theory (14) •**
   Discrete groups:
   Definition; Multiplication table; Rearrangement theorem; Subgroups; Invariant subgroup; Isomorphism and homomorphism; Reducible and irreducible representation of groups; Illustration with Z_n ($n \le 4$) and S_3.
   Continuous groups:
   Lie groups and Lie algebra with U(1), SU(2) and SO(3) as examples. Fundamental, adjoint, and complex conjugate representations.

2. **Complex analysis (16) •**
   Cauchy-Riemann conditions, Cauchy's theorem, Cauchy's integral formula; Liouville's theorem; Taylor and Laurent expansion of a complex function; Analytic continuation; Classification of singularities; Branch point and branch cut; Residue theorem and evaluation of real integrals using this theorem.

3. **Theory of second order linear homogeneous differential equations (3) •**
   Sturm-Liouville theory; Adjoint, self-adjoint, and Hermitian operators, and their properties. Gram-Schmidt orthogonalisation of linearly independent functions.

4. **Inhomogeneous differential equations: Green's functions (8) •**
   General theory in 1-D; Solution of ODE with Dirichlet, Neumann and mixed boundary conditions; Eigenfunction expansion of Green's function. Green's function for the Laplacian in 2-D and 3-D; Green's function for quantum mechanical scattering.

5. **Integral transforms (3) •**
   Laplace and inverse Laplace transforms, Bromwich integral [use of partial fractions in calculating inverse Laplace transforms]; Transform of derivative and integral of a function; Solution of differential equations using Laplace and Fourier transforms.

6. **Statistics (6) •**
   Bayes' theorem; Parameter estimation in frequentist approach — maximum likelihood and χ^2 estimation; Linear least square fit.

Tutorial [1 Credit]

Students must be given at least one assignment or a small set of problems. On the basis of regularity of submission and evaluation of assignment by the respective teacher, credits should be awarded to the students.

Recommended reading

1. G. Arfken, H. Weber, and F. Harris: Mathematical Methods for Physicists
2. J. Mathews and R.L. Walker: Mathematical Methods of Physics
3. P.B. Pal: A Physicist's Introduction to Algebraic Structures
4. P. Dennery and A. Krzywicki: Mathematics for Physicists

5. R.V. Churchill and J.W. Brown: Complex variables and Applications
6. M.R. Spiegel: Theory and Problems of Complex Variables
7. W.W. Bell: Special Functions for Scientists and Engineers
8. A.W. Joshi: Elements of Group Theory for Physicists
9. M. Tinkham: Group Theory and Quantum Mechanics
10. S.L. Ross: Differential Equations
11. A. Zee : Group Theory in a Nutshell for Physicists.

PHS-DSCC-7-2 : Advanced Classical Mechanics

Theory [3 Credits]

1. **Lagrangian formulation (4) •**
   Application of Lagrange's formalism for some cases, *e.g.*, (i) double pendulum, (ii) pendulum with moving support, (iii) particles connected by massive chain moving under gravity, (iv) point particle slipping off a sphere, (v) charged particle in electromagnetic field. Noether's theorem in particle mechanics.
2. **Small oscillations (3) •**
   Normal modes and frequencies for small oscillation.
3. **Canonical transformations (6) •**
   Generating functions; Canonical transformations—examples and group property; Poisson brackets; Infinitesimal canonical transformations; Conservation theorem in Poisson bracket formalism; Jacobi's identity; Angular momentum Poisson bracket relations.
4. **Rigid bodies (4) •**
   Euler's equations; Heavy symmetrical top with precession and nutation.
5. **Fluid dynamics (5) •**
   Different types of derivatives; Equation of continuity and equation of motion for an ideal fluid; Bernoulli's theorem; Concept of streamlines and vortex lines; Gravity waves and shallow waves; Non-ideal fluids and Navier-Stokes equation.
6. **Classical fields (5) •**
   Fields as generalised coordinates; Euler-Lagrange equation for the fields from extremisation of $S = \int \mathscr{L}\, d^4x$; Conjugate momentum and Hamiltonian density; Symmetries and Noether's theorem with Schrödinger field as example.
7. **Nonlinear dynamics (8) •**
   Dynamical systems, Idea of Autonomous and non-autonomous system through examples: free, forced and damped oscillators. Idea of fixed points in one dimensional problem. Flows. Linear stability analysis. Classification of fixed points in 1-D and 2-D through simple examples. x-p phase diagrams, with physical examples for simple 1-D potentials.
8. **Special theory of relativity (15) •**
   Lorentz transformations; vectors and tensors in Minkowski space-time, Transformation properties, Metric tensor, Raising and lowering of indices, Contraction, Symmetric and antisymmetric tensors; 4-velocity and 4-momentum; Covariant equations of motion; Relativistic kinematics ($1 \to 2$ decay, elastic scattering and Mandelstam variables, inelastic scattering and threshold energy); Lagrangian of a free relativistic particle.

Tutorial [1 Credit]

Students must be given at least one assignment or a small set of problems. On the basis of regularity of submission and evaluation of assignment by the respective teacher, credits should be awarded to the students.

Recommended reading

1. H. Goldstein: Classical Mechanics
2. A.K. Raychaudhuri: Classical Mechanics — A Course of Lectures
3. N.C. Rana and P.S. Joag: Classical Mechanics
4. D. Strauch : Classical Mechanics
5. E.N. Moore : Theoretical Mechanics
6. S. Weinberg: Gravitation and Cosmology
7. A.P. French: Special Relativity

PHS-DSCC-7-3 : Advanced Quantum Mechanics I

Theory [3 Credits]

1. **Basic concepts (6) •**
   (i) Wave packet: Fourier Transforms of δ, sine, and gaussian functions.
   (ii) Eigenvalues and eigenfunctions: Momentum and parity operators; Commutativity and simultaneous eigenfunctions; Complete set of eigenfunctions; expansion of wave function in terms of a complete set.
   (iii) Generalised uncertainty principle.
2. **One-dimensional problems (5) •**
   Delta function potential; double-δ potential; Multiple well potential, Kronig-Penney model.
3. **Quantum theory of measurement and time evolution (7) •**
   Double Stern-Gerlach experiment for spin-$\frac{1}{2}$ system; Schrödinger, Heisenberg and interaction pictures. Time evolution of a two state system, spin-$\frac{1}{2}$ particle in magnetic field, Larmor's precession.
4. **Approximation methods: (i) Time independent perturbation theory (12) •**
   First and second order corrections to the energy eigenvalues; First order correction to the eigenvector; Convergence of the non-degenerate perturbation theory; Degenerate perturbation theory; Application to one-electron system – Stark Effect.
5. **Approximation methods: (ii) Variational method (6) •**
   Estimation of the ground state energy by variational method, Particle in a box and Helium atom as examples; First order perturbation; Exchange degeneracy; Ritz principle for excited states for Helium atom.
6. **Addition of angular momenta (6) •**
   Introduction to direct product space, Addition of two angular momenta — Clebsch-Gordan coefficients and their properties. Explicit calculation of Clebsch-Gordan coefficients (for $j_1, j_2 \leq 1$). Recursion relation for Clebsch-Gordan coefficients.

7. **Quantum entanglement and foundational issues (4) •**
   Entanglement in pure bipartite states; EPR argument; Bell's theorem: statement and relation to the Copenhagen interpretation; Impossibility of superluminal communication by entanglement; Mixed states and density matrix; Reduced density matrix of (one) part of a Bell state.

8. **Introduction to quantum computation (4) •**
   Scope and purview of quantum computation; Bits versus qubits; Quantum gates: single-qubit and two-qubit (only CNOT) gates; No-cloning theorem; Quantum circuit for generating the Bell states; Quantum teleportation; Deutsch algorithm.

(The vector space formalism, with bra-ket notations, should be used as much as possible.)

Tutorial [1 Credit]

Students must be given at least one assignment or a small set of problems. On the basis of regularity of submission and evaluation of assignment by the respective teacher, credits should be awarded to the students.

Recommended reading

1. D.J. Griffiths : Introduction to Quantum Mechanics
2. P.M. Mathews, K. Venkatesan: A Text Book of Quantum Mechanics
3. J.J. Sakurai : Modern Quantum Mechanics
4. K. Sengupta and P.B. Pal : Introduction to Quantum Mechanics
5. N. Zettili : Quantum Mechanics: Concepts and Applications
6. M. Nielsen and I. Chuang : Quantum Computation and Quantum Information
7. A. Chatterjee, Introduction to Quantum Computation (arXiv:quant-ph/0312111)

PHS-DSCC-7-4 : Classical Electrodynamics

Theory [3 Credits]

1. **Electrostatics and magnetostatics (8) •**
   Gauge transformations; Multipole expansion of vector potential due to a linear stationary current distribution. Electrostatic and magnetostatic energy. Poynting's theorem. Maxwell's stress tensor.

2. **Radiation from time dependent sources of charges and currents (5) •**
   Inhomogeneous wave equations and their solutions using time-dependent Green's function; Radiation from a localised electric dipole.

3. **Maxwell's equations and covariant formulation (10) •**
   Maxwell's equations in covariant form, Electromagnetic field tensor, Lorentz transformation law for the electromagnetic fields and the fields due to a point charge in uniform motion; Field invariants; Covariance of Lorentz force equation and the equation of motion of a charged particle in an electromagnetic field; The generalised momentum; Energy-momentum tensor and the conservation laws for the electromagnetic field; Relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field.

4. **Radiation from moving point charges (15) •**
   Lienard-Wiechert potentials; Fields due to a charge moving with uniform velocity; Qualitative discussion of radiation from a uniformly moving charge through a medium: Čerenkov radiation (qualitative treatment only); Fields due to an accelerated charge; Radiation at low velocity; Larmor's formula and its relativistic generalisation; Radiation when velocity (relativistic) and acceleration are parallel, Bremsstrahlung; Radiation when velocity and acceleration are perpendicular, Synchrotron radiation. Thomson scattering.

5. **Radiation reaction (6) •**
   Radiation reaction from energy conservation; Problem with Abraham-Lorentz formula; Limitations of Classical Electrodynamics.

6. **Introduction to Plasma Physics (6) •**
   Definition of plasma, occurrence in nature, plasma parameters (density, temperature, Debye length, plasma frequency), criteria for being a plasma (Debye shielding, collective behavior, plasma parameter $N_D \gg 1$). Motion of charged particles in uniform electric and magnetic fields, drift velocity. Fluid description of plasmas: fluid equations — continuity equation, momentum equation, pressure closure (rigorous derivation not needed), Poisson's equation, electrostatic Langmuir waves in unmagnetised plasma. Thermonuclear fusion, overview of magnetic confinement, MHD instabilities (sausage and kink), basic idea of ITER.

Tutorial [1 Credit]

Students must be given at least one assignment or a small set of problems. On the basis of regularity of submission and evaluation of assignment by the respective teacher, credits should be awarded to the students.

Recommended reading

1. J.D. Jackson: Classical Electrodynamics
2. W.K.H. Panofsky and M. Phillips: Classical Electricity and Magnetism
3. K. Bhattacharya and S. Mukhopadhyay : Introduction to Advanced Electrodynamics
4. J.R. Reitz, F.J. Milford and R.W. Christy: Foundations of Electromagnetic theory
5. D.J. Griffiths: Introduction to Electrodynamics
6. L.D. Landau and E.M. Lifshitz: (i) Electrodynamics of Continuous Media (ii) Classical theory of fields
7. C.A. Brau, Modern Problems in Classical Electrodynamics
8. J.A. Bittencourt, Fundamentals of Plasma Physics

PHS-DSCC-7-5 : General Laboratory I

Practical [4 Credits]

Part I (50 marks)

1. Molecular absorption spectroscopy using iodine vapour.

2. Acousto-optical effect using piezo-electric crystal and determination of the velocity of ultrasonic wave in liquids.

3. Verification of Bohr's atomic theory by Franck-Hertz Experiment.

4. Determination of wavelength of light using Michelson interferometer.

Part II (50 marks)

1. Study of amplitude modulation and demodulation.

2. Fabrication of Notch filter circuit; Tuned band pass filter.

3. To determine Fourier spectrum of (i) square, (ii) triangular and (iii) half sinusoidal waveform by cathode ray oscilloscope.

4. Static characteristics study of SCR.

8 Semester 8 (For 4-year Honours)

PHS-DSCC-8-1 : Advanced Quantum Mechanics II

Theory [3 Credits]

1. **Approximation methods: (iii) WKB approximation (4) •**
   Quantisation rule, tunnelling through a barrier, connection formulae, quantitative discussion of α-decay (Gamow's theory).

2. **Time-dependent perturbation theory (15) •**
   Interaction picture and Dyson series; Constant perturbation — Fermi's Golden rule; harmonic perturbation; Application for two-level systems with sinusoidal perturbation. Resonance phenomenon. Sudden and adiabatic approximations. Interaction of an atom with electromagnetic wave: The interaction Hamiltonian — Selection rules; Nonresonant excitation — Comparison with the elastically bound electron model; Resonant excitation — Induced absorption and emission. Einstein's A and B coefficients.

3. **Scattering theory (16) •**
   Laboratory and centre of mass frames, differential and total scattering cross-sections, scattering amplitude; Scattering by spherically symmetric potentials; Partial wave analysis and phase shifts; Optical theorem; Significance of the sign of phase shift; Scattering by a rigid sphere and square well. Formal theory of scattering — Green's function in scattering theory; Lippman-Schwinger equation; Born approximation with Yukawa and δ-function potentials; Born series (physical interpretation). Scattering of identical particles.

4. **Symmetries in quantum mechanics (15) •**
   Conservation laws and degeneracy associated with symmetries.
   Continuous symmetries — space and time translations, rotations; Construction of representations; Rotation group, homomorphism between SO(3) and SU(2); Explicit matrix representation of generators for $j = \frac{1}{2}$ and $j = 1$. Rotation matrices; Irreducible spherical tensor operators, Wigner-Eckart theorem; Simple examples of Wigner-Eckart theorem; Selection rules for atomic transitions.
   Discrete symmetries — parity and time reversal. Idea of antiunitary operators. Applications like (i) selection rules for atomic transitions, (ii) real wavefunctions for nondegenerate states if $[H, T] = 0$, (iii) Kramers degeneracy, (iv) vanishing of electric dipole moment of charged point particles.

Tutorial [1 Credit]

Students must be given at least one assignment or a small set of problems. On the basis of regularity of submission and evaluation of assignment by the respective teacher, credits should be awarded to the students.

Recommended reading

1. D.J. Griffiths : Introduction to Quantum Mechanics
2. P.M. Mathews, K. Venkatesan: A Text Book of Quantum Mechanics
3. J.J. Sakurai : Modern Quantum Mechanics

4. J.J. Sakurai : Advanced Quantum Mechanics
5. K. Sengupta and P.B. Pal : Introduction to Quantum Mechanics
6. N. Zettili : Quantum Mechanics: Concepts and Applications
7. B. H. Bransden and C. J. Joachain : Quantum Mechanics

PHS-DSCC-8-2 : Advanced Statistical Mechanics

Theory [3 Credits]

1. **Canonical and Grand Canonical ensemble (6) •**
   System in contact with a heat reservoir; expression of entropy; canonical partition function; Helmholtz free energy; fluctuation of internal energy.
   System in contact with a particle reservoir; chemical potential; grand canonical partition function and grand potential; fluctuation of internal energy and particle number; Chemical potential of ideal gas; Chemical equilibrium and Saha ionisation equation.
2. **Classical non-ideal gas (4) •**
   Mean field theory and Van der Wall's equation of state; Cluster integrals and Mayer-Ursell expansion.
3. **Quantum statistical mechanics (5) •**
   Density Matrix; Quantum Liouville theorem; Density matrices for microcanonical, canonical and grand canonical systems; Simple examples of density matrices — one electron in a magnetic field, particle in a box; Identical and indistinguishable particles — B-E and F-D distributions.
4. **Ideal quantum gas (7) •**
   Ideal quantum gas in microcanonical ensemble; grand partition function; statistics of occupation numbers; pressure of a quantum ideal gas. Ideal Bose gas: equation of state; Bose condensation. Ideal Fermi gas: equation of state; statistical properties. Specific heat of Bose and Fermi gases.
5. **Phase transition and critical phenomena (12) •**
   Liquid gas and magnetic phase transitions; classification of phase transitions; response functions and fluctuation-dissipation theorem. Critical phenomena: critical exponents, universality and scaling relations. Ising model: exact solution in one dimension by transfer matrix method; Calculation of critical exponents (α, β, γ and δ) using mean field theory (Weiss) and Landau theory. Validity of mean field theory (qualitative discussion).
6. **Magnetic properties of solids (8) •**
   Origin of magnetism; Diamagnetism: quantum theory of atomic diamagnetism; Landau diamagnetism (qualitative discussion); Paramagnetism: quantum theory of paramagnetism; case of rare-earth and iron-group ions; quenching of orbital angular momentum; Van Vleck paramagnetism and Pauli paramagnetism; Ferromagnetism: Curie-Weiss law, temperature dependence of saturated magnetisation, Heisenberg's exchange interaction; Ferrimagnetism and Antiferromagnetism.
7. **Elementary discussions on stochastic processes (8) •**
   Probability distributions and central limit theorem; Markov processes; Random walk: derivation of the Gaussian probability distribution, Brownian motion, Langevin equation

and calculation of velocity autocorrelation function; Master equation for the 1-d random walk.

Tutorial [1 Credit]

Students must be given at least one assignment or a small set of problems. On the basis of regularity of submission and evaluation of assignment by the respective teacher, credits should be awarded to the students.

Recommended reading

1. M. Plischke and B. Bergersen: Equilibrium Statistical Physics.
2. J.M. Yeomans: Statistical Mechanics of Phase Transitions.
3. L.D. Landau and E.M. Lifshitz: Statistical Physics, Vol. 5 in Course in Theoretical Physics.
4. P.M. Chaikin, T.C. Lubensky: Principles of Condensed Matter Physics.
5. D. Chandler: Introduction to Modern Statistical Mechanics.
6. R.K. Pathria: Statistical Mechanics
7. K. Huang: Statistical Mechanics
8. F. Mandl: Statistical Physics
9. H.B. Callen: Thermodynamics and an Introduction to Thermostatics

PHS-DSCC-8-3 : Electronics and Instrumentation

Theory [3 Credits]

1. **Electronic filters (8) •**
   Laplace Transform, s-domain analysis, Sallen-Key network, Butterworth filter, low pass and high pass filters upto 3rd order; Transfer function, Poles and zeros of transfer function, Butterworth polynomials; Location of poles in s-plane; RC bandpass filter; Band reject Filter; Twin-T network; Delay equaliser.

2. **Digital MOS circuits (6) •**
   NMOS and CMOS gates (AND, NAND and NOT), Dynamic MOS circuits, MOS shift register, Memory Devices; Random access memory (RAM), Static and dynamic random access memories (SRAM and DRAM)

3. **Physics of semiconductor (8) •**
   Charge carrier concentration in non-degenerate and degenerate semiconductors; Position of Fermi level, band gap calculation, Extrinsic semiconductors, Compensated semiconductors, law of mass action, Drift and diffusion of carriers; Einstein relation; Invariance of the Fermi level at the equilibrium; development of continuity equation in n-type and p-type semiconductor, Minority carrier injection and diffusion length.

4. **Semiconductor devices I (12) •**
   p-n junction diode; Doping profile — step junction, Linearly graded and hyper-abrupt junction; Depletion width; Built-in potential; Calculation of electric field across the junction; Depletion capacitance; Varactor diode, Shockley equation; Dynamic diffusion capacitance of p-n junction; Charge storage phenomenon; Reverse Recovery Transient; Ebers-Moll model of p-n-p transistor.

5. **Semiconductor devices II (16) •**
   Semiconductor heterojunction and its band structure; Metal semiconductor junctions: Schottky barriers; Rectifying contacts; Ohmic contacts; Typical Schottky barriers; Optoelectronic devices — LED, Junction Laser; Negative resistance devices — Tunnel diode, IMPATT diode, Gunn diode; Power devices — p-n-p-n diode, Semiconductor controlled rectifier (SCR), TRIAC.

Tutorial [1 Credit]

Students must be given at least one assignment (theoretical/practical) or a small set of problems. On the basis of regularity of submission and evaluation of assignment by the respective teacher, credits should be awarded to the students.

Recommended reading

1. J. Millman and C. Halkias: Integrated Electronics
2. B.G. Streetman, S. Banerjee: Solid State Electronic Devices
3. H. Taub and D. Schilling: Digital Integrated Electronics
4. P. Bhattacharyya: Semiconductor Optoelectronic Devices
5. S.M. Sze: Physics of Semiconductor Devices
6. J.D. Ryder: Electronic Fundamental and Applications
7. J. Millman and A. Grabel: Microelectronics
8. A. Sedra, K. Smith, T. Carusone, V. Gaudet: Microelectronic Devices
9. R. Boylestad and L. Nashelski: Electronic Devices and Circuit Theory

PHS-DSCC-8-4 : Advanced Solid State Physics

Theory [3 Credits]

1. **Structure of solids (10) •**
   Bravais lattice, Wigner-Seitz cell; Symmetry operations and classification of 2- and 3-dimensional Bravais lattices; NaCl and CsCl structure, HCP structure, Zinc blende and Wurtzite structure, Bonding of solids, atomic and geometric structure factors; Friedel's law; Reciprocal lattice and Brillouin zone; Ewald construction; Electron and neutron scattering by crystals.
2. **Band theory of solids (12) •**
   Bloch theorem; Empty lattice band; Number of states in a band; Effective mass of an electron in a band: concept of holes; Electronic band structures in solids — reduced, extended and periodic zone schemes, Nearly free electron bands; Tight binding method — application to simple cubic, FCC and BCC lattices; Band structures in copper, GaAs and silicon;
3. **Lattice dynamics (9) •**
   Classical and quantum theory of lattice vibration in three dimensions under harmonic approximation; Lattice vibrations in a monatomic simple cubic lattice; Symmetry consideration of eigenvectors; Inelastic scattering of neutron by phonon and experimental observation of dispersion relation; Debye-Waller factor; Anharmonic effects in crystals.

4. **Dielectric properties of solids (8) •**
   Dipolar polarisation; Langevin function, interaction with medium, Complex dielectric constant and dielectric losses, Relaxation time, Debye equations; ideas of distribution of relaxation time,

5. **Magnetic resonances (5) •**
   Nuclear magnetic resonances, Paramagnetic resonance, Bloch equation, Longitudinal and transverse relaxation time; Spin echo; Motional narrowing in line width; Absorption and dispersion; Hyperfine field; Electron-spin resonance.

6. **Superconductivity (6) •**
   Phenomenological description of superconductivity; Outlines of the BCS theory, Instability of Fermi Sea, Cooper pair; Giaver tunnelling (qualitative discussion only); Flux quantisation; a.c. and d.c. Josephson effect.

Tutorial [1 Credit]

Students must be given at least one assignment or a small set of problems. On the basis of regularity of submission and evaluation of assignment by the respective teacher, credits should be awarded to the students.

Recommended reading

1. N.W. Ashcroft and N.D. Mermin: Solid State Physics
2. J.R. Christman: Fundamentals of Solid State Physics
3. A.J. Dekker: Solid State Physics
4. C. Kittel: Introduction to Solid State Physics
5. H. Ibach and H. Luth: Solid State Physics: An Introduction to Theory and Experiment
6. J.P. Srivastava: Elements of Solid State Physics
7. J.P. McKelvey: Solid State and Semiconductor Physics

PHS-DSCC-8-5 : General Laboratory II

Practical [4 Credits]

Part I (50 marks)

General practical

1. Analysis of X-ray diffraction pattern using open-source software.
2. Study of lattice dispersion relation of monatomic and diatomic lattice with the help of a periodic electrical LC circuit.
3. Determination of Lande g-factor by ESR spectroscopy.
4. Measurement of magnetic susceptibility of solids (Gouy's method).
5. Study of Characteristics of LDR and Photodiode.

Part II (50 marks)

Computer practical

1. Simulation of nearest neighbour Ising model in 1-D and 2-D square lattice using Glauber/Metropolis Monte Carlo algorithm and estimate magnetisation, susceptibility and specific heat as a function of temperature.

2. Time evolution of quantum mechanical wave packet using Crank-Nicolson algorithm:
   a) Time evolution of a gaussian wave packet moving in free space;
   b) Study of rectangular barrier penetration and tunnelling for an initially gaussian wave packet;
   c) Time evolution of a gaussian wave packet in a 1-D linear harmonic oscillator.

3. Random Walk in 1-D and in 2-D (Square grid):
   a) Plot of r.m.s. value of end-to-end distance as a function of time step;
   b) Fitting and finding of exponent.

4. Monte Carlo Integration:
   a) Estimation of the area of a circle/ellipse;
   b) Estimation of overlap of two distributions, *e.g.*, two gaussian distributions with the same width but different mean values and vice versa.

5. Nonlinear dynamics simulations:
   a) Logistic map $x_{n+1} = r x_n (1 - x_n)$, $0 < x < 1$, $r \leq 4$. Study of fixed points and chaotic behaviour. Plots for different r values;
   b) Bifurcation diagram, *e.g.*, of $dx/dt = r + x^2$ $(r < 0)$;
   c) Nonlinear simple pendulum: phase portrait.

9 Semester 8 (For 4-year Honours with Research)

PHS-DSCC-8-1R : Research Methodology I

Theory [3 Credits]

1. **Research in Physics (18) •**
   Nature and scope of physics research. Inductive vs deductive reasoning. The character of physical laws, including universality, falsifiability, and reproducibility (with examples). Typical traits of pseudoscience.
   Role of symmetry, conservation laws, and invariance principles. Paradigm shifts in physics (examples from quantum mechanics, relativity, cosmology, scale invariance).

2. **Types of Research in Physics (8) •**
   Theoretical, experimental, computational, and phenomenological research. Fundamental vs applied research. Interdisciplinary research (physics with biology, data science, AI, etc.). Use and misuse of AI in research.

3. **Literature Survey and Information Retrieval (8) •**
   Structure of a research paper. Review articles vs research articles. Preprints and peer-reviewed journals. Impact factor and h-index (limitations and misuse). Research Databases: arXiv, INSPIRE-HEP, ADS, Web of Science, Scopus, Google Scholar.

4. **Mathematical Logic (16) •**
   Need for mathematical logic. Sentences and truth values. Negation of a sentence. Binary relations on sentences using truth tables. Tautology and contradiction. Binary connectives like AND, OR.
   Propositional logic: Different types of logical equivalence. Implication ($P \Rightarrow Q$) and its truth table with two and three propositions.
   Predicate logic: Universal ($\forall$) and existential ($\exists$) quantifiers. Rules of inference (also involving quantifiers: universal and existential instantiation and generalisation). Various techniques of proof: direct, by contradiction (reductio ad absurdum), by contrapositive. Proofs using sequences: methods of induction and descent.
   (Both truth tables and actual examples are to be used.)

Viva [1 Credit]

Recommended reading

1. C.R. Kothari : Research Methodology, Methods and Techniques, New Age International Publication.

2. R. Kumar : Research Methodology, Pearson Education.

3. B.L. Garg, R. Karadia, F. Agarwal, and U.K. Agarwal : An introduction to Research Methodology, RBSA Publishers.

4. J.W. Creswell and J.D. Creswell : Research design: Qualitative, Quantitative, and Mixed Methods Approach, Sage publications.

5. P.B. Pal : A Physicist's Introduction to Algebraic Structures, Cambridge (Chapter 1).

6. J. Beall : Predatory publishers are corrupting open access, Nature 489, 179 (2012).

PHS-DSCC-8-2R : Research Methodology II

Theory [3 Credits]

1. **Scientific Writing and Communication (15) •**
   Writing a research proposal. Thesis structure and formatting. Writing abstracts and introductions. Figures, tables, and captions. Use of LaTeX (including online LaTeX editors) for scientific writing with examples.
   Oral and visual presentation: Conference presentations and posters. Preparation of slides (PowerPoint and LaTeX based softwares like Beamer). Defending results and handling questions. Outreach and communicating physics to non-experts.

2. **Research Ethics and Professional Conduct (15) •**
   (i) Ethics in Research. Data fabrication and falsification. Plagiarism and self-plagiarism. Authorship and collaboration ethics. Conflict of interest.
   (ii) Publication Ethics: Peer review process. Open access vs subscription journals. Predatory journals. Retractions. Ethics of collaboration.
   (iii) Gender issues and gender bias. Other types of discrimination.
   (iv) Problems faced by researchers: Compromise, job uncertainty, lack of funds, etc. Need for psychological counseling.
   (v) Intellectual property rights.

3. **Statistics (20) •**
   Population and sample, sampling methods.
   Analysis of time series data.
   Parameter estimation: Estimates for mean, variance, and median. The method of maximum likelihood. Method of least squares. Parameter estimation with constraints. Bayesian approach and priors. Treatment of nuisance parameters: frequentist vs Bayesian.
   Statistical tests: Hypothesis testing, significance and p-values. Look-elsewhere effect. Goodness of fit with χ^2 or likelihood ratio.
   Role of AI and ML in data handling and processing.

Viva [1 Credit]

(The questions for PHS-DSCC-8-1R and PHS-DSCC-8-2R will be of essay type. The theory examination will be of 75 marks for each paper, and the students have to answer 15 questions, each of 5 marks.)

Recommended reading

1. K. Muralidhar, A. Ghosh, A.K. Singhvi ed. : Ethics in Science Education, Research, and Governance, Indian National Science Academy.

2. D. Resnick : The Ethics of Science, An Introduction, Taylor and Francis.

3. Particle Data Group : The Review of Particle Physics, https://pdg.lbl.gov, Review on Statistics.

4. J.R. Taylor : An Introduction to Error Analysis, University Science Books (California).

5. N.K. Acharya : Textbook on intellectual property rights, Asia Law House.

6. J. Beall : Predatory publishers are corrupting open access, Nature 489, 179 (2012).

PHS-DSCC-8-3R : Research Internship

[4 Credits]

PHS-DSCC-8-4R : Research Project

[8 Credits]

There is no clear demarcation between PHS-DSCC-8-3R and PHS-DSCC-8-4R. A part of the research project will go in PHS-DSCC-8-3R, and the rest in PHS-DSCC-8-4R. In the latter, the student has to present his/her work in front of a board, necessarily including the project mentor and an external examiner. He/she also has to submit a written report as part of the evaluation. The detailed guideline will be made available later.

Syllabus for the Undergraduate (B.Sc.) course in Physics (Multidisciplinary)

The structure of the revised syllabus for the B.Sc. course in Physics (Semesters 1 to 6) is as follows.

Each paper carries 4 Credits, equivalent to 100 marks.

Th: Theory, Pr: Practical, Tut: Tutorial

For students opting for Multidisciplinary Degree

Semester	Paper code	Paper name	Credit
Semester 1	PHS-CC-1-1 [MDC (Core)]	Basic Physics - I	Th: 3, Pr: 1
Semester 2	PHS-CC-2-1 [MDC (Core)]	Basic Physics - II	Th: 3, Pr: 1
Semester 3	PHS-CC-3-1 [MDC (Core)]	Waves and Optics	Th: 3, Pr: 1
	PHS-Minor3-3-1 [MDC (Minor)]	Basic Physics - I	Th: 3, Pr: 1
Semester 4	PHS-CC-4-1 [MDC (Core)]	Modern Physics	Th: 3, Pr: 1
	PHS-CC-4-2 [MDC (Core)]	Electromagnetism	Th: 3, Pr: 1
	PHS-Minor3-4-1 [MDC (Minor)]	Basic Physics - II	Th: 3, Pr: 1
Semester 5	PHS-CC-5-1 [MDC (Core)]	Electronics I	Th: 3, Pr: 1
	PHS-CC-5-2 [MDC (Core)]	Nuclear and Particle Physics	Th: 3, Tut: 1
	PHS-Minor3-5-1 [MDC (Minor)]	Waves and Optics	Th: 3, Pr: 1
	PHS-Minor3-5-2 [MDC (Minor)]	Electronics I	Th: 3, Pr: 1
Semester 6	PHS-CC-6-1 [MDC (Core)]	Nuclear and Particle Physics	Th: 3, Tut: 1
	PHS-CC-6-2 [MDC (Core)]	Electronics II	Th: 3, Pr: 1
	PHS-Minor3-6-1 [MDC (Minor)]	Modern Physics	Th: 3, Pr: 1
	PHS-Minor3-6-2 [MDC (Minor)]	Electromagnetism	Th: 3, Pr: 1

This table needs some explanation. A student opting for Multidisciplinary Course (MDC) degree may take Physics as a Core subject, with 8 papers, or as a Minor subject, with 6 papers. The MDC Core papers are coded as PHS-CC- and the MDC Minor papers as PHS-Minor3-.

Students taking Physics as MDC Core-1 must take PHS-CC-5-1 and PHS-CC-5-2 in Semester 5 and PHS-CC-6-2 in Semester 6. Students taking Physics as MDC Core-2 must take PHS-CC-5-1 in Semester 5, and PHS-CC-6-1 and PHS-CC-6-2 in Semester 6.

An MDC Physics Minor student has to take 1 course in each of the Semesters 3 and 4, and 2 courses in each of the Semesters 5 and 6.

10 Multidisciplinary Core Papers

PHS-CC-1-1 : Basic Physics - I

[1st Semester, MDC (Core)]
The syllabus is identical to PHS-DSCC-1-1 for Physics (Major).

PHS-CC-2-1 : Basic Physics - II

[2nd Semester, MDC (Core)]
The syllabus is identical to PHS-DSCC-2-1 for Physics (Major).

PHS-CC-3-1 : Waves and Optics

[3rd Semester, MDC (Core)]

(Identical content with PHS-Minor4/1-5-1, PHS-Minor4/2-5-1, PHS-Minor3-5-1)

Theory [3 Credits]

1. **Oscillations (6) •**
   Differential equation of simple harmonic oscillation and its solution. Kinetic energy, potential energy, total energy and their time average values. Damped and forced oscillations: Transient and steady states; Resonance, sharpness of resonance; power dissipation and Quality Factor.

2. **Superposition of harmonic oscillations (3) •**
   Superposition of two collinear harmonic oscillations having equal frequencies and different frequencies (beats), Superposition of two perpendicular harmonic oscillation for phase difference $\delta = 0, \pi, 2\pi$.

3. **Wave motion (8) •**
   Plane progressive (traveling) waves. Wave equation for travelling waves . Particle and wave velocities. Velocity of transverse vibrations of stretched strings, standing (stationary) waves in a string. Phase and group velocities. Doppler effect.

4. **Geometrical optics (5) •**
   Fermat's principle. Laws of reflection and refraction at a plane surface, refraction at a spherical surface, lens formula. Combination of thin lenses — equivalent focal length. Dispersion and dispersive power.

5. **Interference (12) •**
   Huygens' principle: explanation of the laws of reflection and refraction. Division of amplitude and wavefront. Young's double slit experiment. Intensity distribution, conditions of interference, Interference in thin films: parallel and wedge shaped films. Fringes of equal inclination (Haidinger fringes); Fringes of equal thickness (Fizeau fringes). Newton's rings: Measurement of wavelength and refractive index.

6. **Diffraction (8) •**
   Fraunhofer diffraction: Single slit, double slit and diffraction grating. Resolving power of grating. Circular aperture (qualitative discussion only)
   Fresnel diffraction: Fresnel's half-period zones for plane waves. Theory of a Zone Plate: Multiple foci of a Zone Plate.

7. **Polarization (8) •**
   Description of linear, circular and elliptical polarization. Propagation of electromagnetic waves in birefringent medium, polarization in uniaxial crystals. Double refraction. Polarization by double refraction. Ordinary and extraordinary refractive indices. Phase Retardation plates: Quarter-wave and Half-wave plates. Rotatory polarization, Biot's laws for rotatory polarization. Specific rotation.

Recommended reading

1. Advanced Acoustics, D. P. Roychowdhury, 1981, Chayan Publisher
2. Waves and Oscillations, N. K. Bajaj, 2017, Tata McGraw-Hill
3. A textbook of Optics, N Subramanyam, B. Lal and M.N.Avadhanulu, 2006, S. Chand Publishing
4. Optics, B. Ghosh, Sreedhar Publications

Practical [1 Credit]

1. Measurement of focal length of a concave lens by combination method.
2. Determination of unknown frequency of a tuning fork by Sonometer.
3. To determine wavelength of sodium light/radius of plano convex lens using Newton's Rings.
4. Measurement of thickness of paper by interference pattern created by a Wedge shaped film.
5. To study the specific rotation of optically active solution using polarimeter.

Recommended reading

1. B.Sc. Practical Physics, C.L. Arora, S Chand and Company Limited
2. Advanced Practical Physics, Vol 1, B. Ghosh, K.G.Majumdar, Shreedhar Publishers
3. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency (P) Ltd

PHS-CC-4-1 : Modern Physics

[4th Semester, MDC (Core)]

(Identical content with PHS-Minor4/1-6-1, PHS-Minor4/2-6-1, PHS-Minor3-6-1)

Theory [3 Credits]

1. **Special Theory of Relativity (8) •**
   Postulates of STR, Lorentz transformation (derivation not required). Derivation of (i) length contraction (ii) time dilation (iii) velocity addition for velocities in the same direction. Energy-momentum dispersion relation. Mass-energy equivalence.

2. **Quantum theory of radiation (8) •**
   Planck's concept, radiation formula (statement only). Photo-electric effect. Bohr's theory. Effect of finite nuclear mass. Compton effect.

3. **Basic Quantum Mechanics (15) •**
   Wave nature of material particles, wave-particle duality, wavelength of de Broglie waves, Heisenberg uncertainty principle, Schrödinger equation, time dependent and independent Schrödinger wavefunction and its probabilistic interpretation. Normalization. Introduction to linear operators. Calculation of various commutation relations. Particle in a one dimensional infinite well: energy eigenvalues. Schrödinger equation for one-dimensional harmonic oscillator. Energy eigenvalues and wavefunctions (only first three wavefunctions, no need to introduce Hermite polynomials, and no detailed derivation required).

4. **Crystal structure (7) •**
   Crystal Structure : Crystalline nature of solid, Miller indices, lattice planes, simple cubic, FCC and BCC lattices. Diffraction of X-ray, Bragg's law; Moseley's law: explanation from Bohr's theory. Continuous and characteristic X-ray.

5. **Structure of solids (6) •**
   Different types of bonding: ionic, covalent, metallic, Van der Waals and hydrogen. Elementary ideas about band structure in conductors, direct and indirect semiconductors and insulators (qualitative discussions).

6. **Magnetic properties of materials (6) •**
   Dia, para and ferro-magnetic properties of solids. Origin of diamagnetism. Langevin theory of paramagnetism and Curie's Law. Domain structure of ferromagnetic materials. B-H loop and hysteresis.

Recommended reading

1. Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill
2. Modern Physics, R.Murugeshan & K.Sivaprasath, 2019, S. Chand Publishing
3. Atomic and Nuclear Physics Volume 1, S.N. Ghoshal, 2010, S. Chand Publishing

4. Theory and Problems of Modern Physics, Schaum's outline, R. Gautreau and W. Savin, 2nd Edn, 2020, Tata McGraw-Hill

Practical [1 Credit]]

1. Measurement of Planck's constant using LED.
2. Determination of e/m of electrons by using bar magnet.
3. To study the photoelectric effect: variation of photocurrent versus intensity and wavelength of light.
4. To show the tunneling effect in tunnel diode using I-V characteristics.
5. Verification of Stefan's law by using a glowing tungsten filament of a torch bulb.

Recommended reading

1. B.Sc. Practical Physics, C.L. Arora, 2010, S. Chand
2. Practical Physics Vol 1 and Vol 2, B. Ghosh, K. G. Majumder, Sreedhar Publishers

PHS-CC-4-2 : Electromagnetism

[4th Semester, MDC (Core)]

(Identical content with PHS-Minor3-6-2)

Theory [3 Credits]

1. **Electrostatics (10) •**
   Method of Images and its application to plane Infinite metal sheet. Electric fields inside matter. Electric polarisation, bound charges (no derivation required), displacement density vector, linear dielectric medium, electric susceptibility and permittivity.

2. **Magnetostatics (12) •**
   Divergence and curl of magnetostatic field using Biot-Savart law; Magnetic vector potential for uniform magnetic field. Magnetic fields inside matter, magnetization, bound currents (no derivation required). $\boldsymbol{H}$ and $\boldsymbol{B}$ field. Linear media.

3. **Electromagnetic induction (10) •**
   Non-conservative nature of electric field. Faraday's law of induction: simple examples (eg: motional emf, Faraday disc); Lenz's law. Self and mutual inductances in simple cases, L of single coil, M of two coils. Energy stored in inductors.

4. **Electrodynamics (8) •**
   Maxwell's equations and EM waves: Maxwell's equations, Equation of continuity of current, displacement current, electromagnetic wave propagation through vacuum and isotropic dielectric medium, transverse nature of EM waves, Poynting vector, decay of charge in conducting medium.

5. **Varying currents (4) •**
   Growth and decay of currents in L-R circuit; charging and discharging of capacitor in C-R circuit.

6. **Alternating current (6) •**
   Mean and r.m.s. values of current and emf with sinusoidal wave form; LR, CR and series LCR circuits, reactance, impedance, power factor, vector diagram, resonance in a series LCR circuit, Q-factor.

Recommended reading

1. Foundations of Electricity and Magnetism, B. Ghosh, 2008, Books & Allied Ltd; 3rd Revised edition
2. Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education
3. Electricity and Magnetism, D C Tayal, 1988, Himalaya Publishing House
4. Electricity and Magnetism, R.Murugeshan, 2019, S. Chand
5. Electricity and Magnetism, Chattopadhyay and Rakshit, 2011, New Central Book Agency

Practical [1 Credit]

1. To draw the resonance curve of a series LCR circuit.
2. Determination of horizontal component of Earth's magnetic field using magnetometer.
3. To study the ac characteristics of a series RC circuit and calculation of capacitance from current reactance graph.
4. Construction of one ohm coil by measuring resistivity of a sample wire using Carey Foster bridge.
5. To study the variation (with current) of the magnetic field between pole pieces for different distances of an electromagnet using Gaussmeter.

Recommended reading

1. Advanced Practical Physics (Vol 1 and Vol 2), B. Ghosh, K. G. Majumder, Sreedhar Publication.

PHS-CC-5-1 : Electronics I

[5th Semester, MDC (Core)]
Theory [3 Credits]

(A) Basic Analog Electronics (30)

1. **Circuits and network (6) •**
   Discrete components, active and passive components, ideal constant voltage and constant current sources. Network analysis: Kirchhoff's laws, Thevenin's and Norton's theorems, Reciprocity theorem, Superposition theorem. Maximum power transfer theorem.

2. **Semiconductor diodes and applications (15) •**
   (a) Semiconductor diodes: P and N type semiconductors. Barrier formation in PN junction diode. Qualitative idea of current flow mechanism in forward and reverse biased diodes. PN junction and its characteristics. Static and dynamic resistance. Principle and structure of LED, Photodiode, Solar cell.
   (b) Application of diodes: Half-wave rectifiers. Centre-tapped and bridge full-wave rectifiers, Ripple factor and Rectification efficiency. Basic idea about capacitor filter. Zener diode and voltage regulation.
   (c) Bipolar junction transistors: n-p-n and p-n-p transistors. Characteristics of CB, CE and CC configurations. Active, cut-off and saturation regions. Current gains α and β, relations between them. Load line analysis of transistors. DC load line and Q-point. Concept of biasing.

3. **Power supply (3) •**
   Difference between regulated and unregulated power supplies. Load regulation and line regulation. Zener as voltage regulator. Principle of series regulated power supply, IC controlled regulated power supply.

4. **Field Effect transistors (6) •**
   JFET and MOSFET (both depletion and enhancement type) as a part of MISFET. Basic structure and principle of operations and their characteristics. Pinch off, threshold voltage and short channel effect. Comparison of JFET and MOSFET.

(B) Basic Digital Electronics (20)

1. **Number system (10) •**
   Binary numbers, decimal to binary and reverse conversions. Binary addition and subtraction (1's Complement and 2's complement method), signed and unsigned number representation of binary system; representation of negative numbers. OR, AND, NOT, NOR, NAND, XOR and XNOR gates — Truth tables. Statement of de Morgan's theorem. Realization of OR, AND, NOT using diodes and transistors.

2. **Digital circuits (10) •**
   Difference between analog and digital circuits. XOR and XNOR gates and application as parity checkers. Product term and sum term in logical expression; SOP, POS and mixed expression. Minterm and Maxterm in the expressions. Conversion between truth table and logical expression. Simplification of logical expression using Karnaugh maps (4 variables).

Recommended reading

1. Electronic Principle, Albert Malvino, 2008, Tata McGraw-Hill.

2. Electronics: Fundamentals and Applications, D. Chattopadhyay, P.C. Rakshit, New Age Publication.

Practical [1 Credit]

1. Verification of Thevenin's and Norton's theorems, superposition theorem and maximum power transfer theorem for resistive network fed by D.C. power supply.

2. To draw the output characteristics of a transistor in CE-mode and calculate current gain.

3. I-V curve for reversed bias Zener diode. Voltage regulation characteristics using a variable load.

4. Construction of OR AND and NOT gates using diode and transistors.

5. To verify the truth tables of basic gates and De-Morgan's theorem using IC-chips.

Recommended reading

1. Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, McGraw-Hill

2. Advanced Practical Physics (volume II), B. Ghosh , Shreedhar Publication

3. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency

PHS-CC-5-2 : Nuclear and Particle Physics

[5th Semester, MDC (Core), for Physics as Core-1]

AND

PHS-CC-6-1 : Nuclear and Particle Physics

[6th Semester, MDC (Core), for Physics as Core-2]
Theory [3 Credits]

1. **Atomic spectra (12) •**
   Bohr-Sommerfeld model of hydrogen-like atoms. Fine structure. Stern-Gerlach experiment and spin as an intrinsic quantum number. Vector atom model; Magnetic moment of the electron, Lande g-factor. Space quantization. Zeeman effect. Explanation from vector atom model.

2. **Molecular spectroscopy (4) •**
   Diatomic molecules: rotational and vibrational energy levels. Basic ideas about molecular spectra. Raman effect and its application to molecular spectroscopy (qualitative discussion only).

3. **Atomic nucleus (10) •**
   Nuclear mass, charge, size, binding energy, spin and magnetic moment. Isobars, isotopes and isotones. Radioactivity, successive disintegration, radioactive equilibrium, radioactive dating. Nature of forces between nucleons, nuclear stability and nuclear binding, the liquid drop model (descriptive) and the Bethe-Weizsäcker mass formula. Fission and fusion.

4. **Unstable nuclei (8) •**
   α-decay: α particle spectra – velocity and energy of α particles. Geiger-Nuttall law. β-decay: nature of β- ray spectra, the neutrino, positron emission and electron capture. γ-decay: γ-ray spectra and nuclear energy levels.

5. **Particle accelerators (4) •**
   LINAC, cyclotron.

6. **Particle physics (6) •**
   Fundamental particles and their families. Fundamental particle interactions and their basic features. Symmetries and conservation laws, baryon number, lepton number, isospin, strangeness and charm. Quark model, quark structure of hadrons.

7. **Nuclear Astrophysics (6) •**
   Primordial nucleosynthesis, energy production in stars, p-p chain, CNO cycle. Production of elements (qualitative discussion only).

Recommended reading

1. Nuclear Physics, D. C. Tayal, 2011, Himalayan Publisher.

2. Nuclear and Particle Physics, S. Bhattacharyya, 2020, Universities Press.

3. Introduction to Nuclear and Particle Physics, Mittal, Verma, Gupta, 2016, Prentice Hall India Learning

4. Atomic and and Nuclear Physics Vol 1, S.N. Ghoshal, 2010, S. Chand

5. Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.

6. Solid State Physics, Puri, Babbar, 2010, S. Chand

Tutorial [1 Credit]
Students must be given at least one assignment or a small set of problems. On the basis of regularity of submission and evaluation of assignment by the respective teacher, credits should be awarded to the students.

PHS-CC-6-2 : Electronics II

[6th Semester, MDC (Core)]
Theory [3 Credits]

(A) Advanced Analog Electronics (20)

1. **Operational Amplifiers (10) •**
   OP-AMP (black box approach): Characteristics of ideal and practical (IC 741) OP-AMPs. Concept of negative and positive feedback. Open-loop and closed-loop voltage Gain. Concept of virtual ground. Application of OP-AMP: Inverting and non-inverting amplifiers, inverting and non-inverting adders, differentiator as subtractor.

2. **Communication systems (10) •**
   Propagation of electromagnetic waves in atmosphere, various layers of atmosphere, ground and sky waves; Transmission of electromagnetic waves: Amplitude and frequency modulation. Optical fiber, core and cladding, numerical aperture, step index and graded index fiber. Satellite communication, microwave link — modem and internet.

(B) Applied Digital Electronics (30)

1. **Implementation of different circuits (5) •**
   Half and full adders; subtractors; 4-bit binary adder/subtractor.; use of IC 7483 as adder and subtractor.

2. **Data processing circuits (5) •**
   Basic idea of multiplexers, de-multiplexers, decoders, encoders.

3. **Sequential circuits (10) •**
   Introduction to next state–present state table and excitation table for sequential circuits. Basic ideas of SR, D, JK and T Flip-Flops. Clocked (level and edge triggered) Flip-Flops. Preset and Clear operations; Race condition in SR and race-around conditions in JK Flip-Flop. Master-slave JK Flip-Flop (basic ideas only).

4. **Registers and counters (10) •**
   Storing of data, registers (up to 4 bits only), parallel and serial loading. Concept of shift register with loading from LSB.

Recommended reading

1. Digital Principles and Applications, A.P. Malvino, D.P. Leach and Saha, 7th Ed., 2011, Tata McGraw-Hill

2. Electronic devices & circuits, S. Salivahanan & N.S. Kumar, 2012, Tata McGraw-Hill

3. Electronics: Fundamentals and Applications, D. Chattopadhyay, P.C. Rakshit, 2022, New Age Publication

Practical [1 Credit]

1. To construct Half and Full Adder using IC-chips.

2. Construction of SR and D Flip Flop circuits using NAND gates.

3. Construction of 4×1 Multiplexer using IC 74151.

4. To use OP-AMP as inverting, non-inverting amplifier.

5. To use OP-AMP as differentiator and as an adder.

Recommended reading

1. Advanced Practical Physics, B. Ghosh, K. G. Majumder, Sreedhar Publication

2. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency (P) Limited

3. Laboratory Manual for Operational Amplifiers and Linear ICs, David A. Bell, 2006, Prentice Hall of India

11 Multidisciplinary Minor Papers

PHS-Minor3-3-1 : Basic Physics - I

[3rd Semester, MDC (Minor)]
The syllabus is identical to PHS-DSCC-1-1 for Physics (Major).

PHS-Minor3-4-1 : Basic Physics - II

[4th Semester, MDC (Minor)]
The syllabus is identical to PHS-DSCC-2-1 for Physics (Major).

PHS-Minor3-5-1 : Waves and Optics

[5th Semester, MDC (Minor)]
The syllabus is identical to PHS-CC-3-1 for Multidisciplinary Physics (Core).

PHS-Minor3-5-2 : Electronics I

[5th Semester, MDC (Minor)]

Theory [3 Credits]

(A) Basic Analog Electronics (25)

1. **Circuits and network (6) •**
   Discrete components, active and passive components, ideal constant voltage and constant current sources. Network analysis: Kirchhoff's laws, Thevenin's and Norton's theorems, Reciprocity theorem, Superposition theorem. Maximum power transfer theorem.

2. **Semiconductor diodes and applications (15) •**
   (a) Semiconductor diodes: P and N type semiconductors. Barrier formation in PN junction diode. Qualitative idea of current flow mechanism in forward and reverse biased diodes. PN junction and its characteristics. Static and dynamic resistance. Principle and structure of LED, Photodiode, Solar cell.
   (b) Application of diodes: Half-wave rectifiers. Centre-tapped and bridge full-wave rectifiers, Ripple factor and Rectification efficiency. Basic idea about capacitor filter. Zener diode and voltage regulation.
   (c) Bipolar junction transistors: n-p-n and p-n-p transistors. Characteristics of CB, CE and CC configurations. Active, cut-off and saturation regions. Current gains α and β, relations between them. Load line analysis of transistors. DC load line and Q-point. Concept of biasing.

3. **Power supply (4) •**
   Difference between regulated and unregulated power supplies. Load regulation and line regulation. Zener as voltage regulator.

(B) Basic Digital Electronics (25)

1. **Number system (12) •**
   Binary numbers, decimal to binary and reverse conversions. Binary addition and subtraction (1's Complement and 2's complement method), signed and unsigned number representation of binary system; representation of negative numbers. OR, AND, NOT, NOR, NAND, XOR and XNOR gates — Truth tables. Statement of de Morgan's theorem. Realization of OR, AND, NOT using diodes and transistors.

2. **Digital circuits (13) •**
   Difference between analog and digital circuits. XOR and XNOR gates and application as parity checkers. Product term and sum term in logical expression; SOP, POS and mixed expression. Minterm and Maxterm in the expressions. Conversion between truth table and logical expression. Simplification of logical expression using Karnaugh maps (4 variables).

Recommended reading

1. Electronic Principle, Albert Malvino, 2008, Tata McGraw-Hill.

2. Electronics: Fundamentals and Applications, D. Chattopadhyay, P.C. Rakshit, New Age Publication.

Practical [1 Credit]

1. Verification of Thevenin's and Norton's theorems, superposition theorem and maximum power transfer theorem for resistive network fed by D.C. power supply.

2. To draw the output characteristics of a transistor in CE-mode and calculate current gain.

3. I-V curve for reversed bias Zener diode. Voltage regulation characteristics using a variable load.

4. Construction of OR AND and NOT gates using diode and transistors.

5. To verify the truth tables of basic gates and De-Morgan's theorem using IC-chips.

Recommended reading

1. Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, McGraw-Hill

2. Advanced Practical Physics (volume II), B. Ghosh , Shreedhar Publication

3. An Advanced Course in Practical Physics, D. Chattopadhyay, P.C. Rakshit, New Central Book Agency

PHS-Minor3-6-1 : Modern Physics

[6th Semester, MDC (Minor)]
The syllabus is identical to PHS-CC-4-1 for Multidisciplinary Physics (Core).

PHS-Minor3-6-2 : Electromagnetism

[5th Semester, MDC (Minor)]
The syllabus is identical to PHS-CC-4-2 for Multidisciplinary Physics (Core).

12 SEC for Multidisciplinary Courses

PHS-CC-SEC-1-1 : Introduction to Computer Programming and Graph Plotting

[To be taught in 1st Semester for Physics as First Major, in 2nd Semester for Physics as Second Major, and in 3rd Semester for Physics as Minor, or as per the University regulations]

The syllabus is identical to PHS-SEC-1-1 for Physics Major.

Syllabus for the Undergraduate (B.Sc.) course in Physics (4-year Minor)

The structure of the revised syllabus for the B.Sc. course in Physics (Semesters 1 to 6) is as follows.

Each paper carries 4 Credits, equivalent to 100 marks.

Th: Theory, Pr: Practical

For students with other Majors and Physics as a Minor subject

Semester	Paper code	Paper name	Credit
Semester 1	PHS-Minor4/1-1-1	Basic Physics - I	Th: 3, Pr: 1
	If Physics is taken as First Minor		
Semester 2	PHS-Minor4/1-2-1	Basic Physics - II	Th: 3, Pr: 1
	If Physics is taken as First Minor		
Semester 3	PHS-Minor4/2-3-1	Basic Physics - I	Th: 3, Pr: 1
	If Physics is taken as Second Minor		
Semester 4	PHS-Minor4/2-4-1	Basic Physics - II	Th: 3, Pr: 1
	If Physics is taken as Second Minor		
Semester 5	PHS-Minor4/1-5-1	Waves and Optics	Th: 3, Pr: 1
	PHS-Minor4/1-5-2	Modern Physics	Th: 3, Pr: 1
Semester 6	PHS-Minor4/2-6-1	Waves and Optics	Th: 3, Pr: 1
	PHS-Minor4/2-6-2	Modern Physics	Th: 3, Pr: 1

Students with some other Major can take Physics as one of the two Minor subjects. If it is chosen as the first Minor paper (PHS-Minor4/1-), they have to take PHS-Minor4/1-1-1 and PHS-Minor4/1-2-1 in the first and second semesters respectively. If it is chosen as the second Minor paper (PHS-Minor4/2-), they need to take the identical courses in semesters 3 and 4, called PHS-Minor4/2-3-1 and PHS-Minor4/2-4-1 respectively. Students with Physics as first Minor will study two papers in Semester 5, while the students with Physics as the second Minor will study those two papers in Semester 6.

13 Minor papers

PHS-Minor4/1-1-1 : Basic Physics - I

[1st Semester for Physics as First Minor]

AND

PHS-Minor4/2-3-1 : Basic Physics - I

[3rd Semester for Physics as Second Minor]

The syllabus is identical to PHS-DSCC-1-1 for Physics (Major).

PHS-Minor4/1-2-1 : Basic Physics - II

[2nd Semester for Physics as First Minor]

AND

PHS-Minor4/2-4-1 : Basic Physics - II

[4th Semester for Physics as Second Minor]

The syllabus is identical to PHS-DSCC-2-1 for Physics (Major).

PHS-Minor4/1-5-1 : Waves and Optics

[5th Semester for Physics as First Minor]

AND

PHS-Minor4/2-6-1 : Waves and Optics

[6th Semester for Physics as Second Minor]
The syllabus is identical to PHS-CC-3-1 for Multidisciplinary Core papers.

PHS-Minor4/1-5-2 : Modern Physics

[5th Semester for Physics as First Minor]

AND

PHS-Minor4/2-6-2 : Modern Physics

[6th Semester for Physics as Second Minor]
The syllabus is identical to PHS-CC-4-1 for Multidisciplinary Core papers.

Syllabus for the Interdisciplinary (IDC) Physics course

The structure of the Interdisciplinary (IDC) course in Physics is as follows. This course is to be offered to only those students who do not have Physics as Major, Minor, or Multidisciplinary subject. The paper may be taken in the first, second, or third semester.

The paper carries 3 Credits (Th: 2, Tut: 1), equivalent to 75 marks.

14 Interdisciplinary paper

PHS-IDC : Frontiers in Physics

[1st, 2nd, or 3rd Semester for students with no Physics Major/Minor/Multidisciplinary]
Theory [2 Credits]

1. **Nature of Science •**
   Role of proper reasoning and experiments, with examples. Inductive and deductive logic. The character of physical laws, including universality. Difference between science and pseudoscience.

2. **Universe •**
   The Copernican revolution, Kepler's laws and the Solar system, Galileo and birth of Telescopic Astronomy, Modern observations: Stars and galaxies, Life cycle of stars. Birth of the Universe, Big Bang and Hubble expansion, Dark matter and dark energy. Origin of life and exoplanets.

3. **Matter •**
   Atoms and molecules: The physical basis of the Periodic table.
   Heat and Thermodynamics: Basic idea about the kinetic theory of gases; Distinction between ideal and real gases; The three laws of thermodynamics. Concept of Entropy.
   Radioactivity: α, β, and γ decay; X-Rays: Properties.
   Structure of the atom: Electron, nucleus, proton and neutron. Mention of the Standard Model of particles and interactions.

4. **Forces •**
   Laws of falling bodies, Inertia, Gravitation, Electricity and Magnetism, Light and its dual property.
   The microscopic world of Quantum Mechanics.
   Special and General Theory of Relativity (brief and qualitative ideas only).

(No Mathematical derivation beyond simple algebra should be used)

Recommended reading

1. Six Easy Pieces: Richard P. Feynman
2. The first three minutes: Steven Weinberg
3. The character of physical laws: Richard P. Feynman

4. Introduction to Astronomy: From Darkness to Blazing Glory: J.W. Scott, JAS Educational Publications

5. *Adhunik bijnaner kromobikash*, ed. Sushanta Majumdar, Bhupati Chakraborty, Anushtup Prakashani (in Bengali)

Tutorial [1 Credit]
Students may be asked to give either a short presentation with a writeup on some topic relevant to this course (as suggested by the concerned teacher), or to appear for an internal examination.

Programme Educational Objective (PEO) and Outcome

- **PEO1 •**
  The Physics syllabus framed under the National Education Policy (NEP) 2020 is designed to promote conceptual understanding, critical thinking, and analytical skills while reducing reliance on rote memorisation. The curriculum emphasises experiential learning through laboratory work, problem-based learning, projects, and interdisciplinary approaches. It encourages students to explore fundamental principles of Physics alongside emerging areas such as computational physics, materials science, and other various topics.

- **PEO2 •**
  In alignment with NEP 2020, the Physics programme supports flexibility, multiple exit options, and skill-oriented learning, enabling students to pursue Physics at varying levels of depth according to their interests and career goals. The syllabus integrates theoretical knowledge with practical applications, mathematical modelling, and technological tools, fostering curiosity, innovation, and scientific temper. Overall, the NEP-aligned Physics syllabus aims at the holistic development of learners by strengthening intellectual, ethical, and professional competencies, preparing them for higher education, research, industry, and societal contributions. Under the framework of the National Education Policy (NEP) 2020, **Course Outcomes (COs)** define the specific and measurable competencies that students are expected to attain at the completion of an individual course. **Programme Outcomes (POs)**, on the other hand, represent the broader knowledge, skills, and abilities that learners should possess upon successful completion of an academic programme. The attainment of these Programme Outcomes is achieved through the successful fulfilment of the Course Outcomes, as each course contributes cumulatively to the overall goals of the programme. The syllabus of Physics Major and Minor has been designed in a way the student gets a strong foundation in the subject and gains an in-depth knowledge.

Programme Outcome

- **PO1 •**
  Graduates will acquire a strong foundation in core areas of Physics such as classical mechanics, electromagnetism, quantum mechanics, and statistical physics. They will be able to critically analyse physical concepts, principles, and theoretical frameworks. The programme enables students to interpret physical phenomena using appropriate laws and models. This analytical understanding supports further learning, research, and interdisciplinary applications of Physics.

- **PO2 •**
  Students will be trained to identify and analyse real-world physical problems using fundamental principles of Physics. They will develop the ability to formulate mathematical models and equations to represent physical systems. The programme emphasises logical reasoning, approximation techniques, and solution methods. These skills enable students to arrive at meaningful and acceptable solutions applicable to science, engineering, and technology.

- **PO3 •**
  The programme provides hands-on laboratory training to develop experimental, observational, and analytical skills. Students will learn to design experiments, collect data, and analyse results using scientific reasoning. Emphasis is placed on error analysis, instrumentation, and safety practices. These laboratory skills enhance problem-solving ability and promote a research-oriented mindset.

- **PO4 •**
  Graduates will develop effective written and oral communication skills through laboratory reports, seminars, presentations, and group discussions. They will be able to communicate scientific ideas, experimental results, and technical information clearly and logically. The programme encourages interaction with peers, teachers, and interdisciplinary audiences. These skills prepare students for academic, professional, and societal engagement.

- **PO5 •**
  Students will gain exposure to emerging areas in Physics along with mathematical and computational tools. The programme promotes collaborative learning and interdisciplinary problem-solving. Learners will apply modern techniques such as data analysis, simulations, and computational methods to physical problems. This prepares graduates to contribute innovative solutions in industry, research institutions, and academia.

- **PO6 •**
  The curriculum is designed to strengthen conceptual understanding and problem-solving skills required for competitive examinations. Students are prepared for national and international exams such as JAM, NET, GATE, and other entrance or recruitment tests. This enables graduates to pursue higher studies and secure employment in scientific and technical fields.

- **PO7 •**
  Promotes research aptitude through projects, internships, and inquiry-based learning. Encourages continuous learning to keep pace with advancements in Physics and allied disciplines.

- **PO8** •
  Apply Physics knowledge in interdisciplinary and applied domains. Enables students to apply Physics principles in interdisciplinary areas.

Program Specific Outcomes (PSO) are detailed below.

Programme: One year Certificate course with Physics Major

Participants: Students of Semester one and semester two

Programme details: One year Certificate course with Physics major consists of two semesters, each of 21 credits. In each of the semesters students study one core course of Physics Major having credit 4, One Skill enhancement course of Physics Major having credit 4, one core course of one Minor paper having credit 4, one interdisciplinary course of credit 3, one language course of credit 2 and two value added course each of credit 2.

Courses taught in Physics Major:

Semester 1: (a) Core course:- Ordinary differential equation, Vector algebra, vector calculus, Gravitation and central force, Fluids.
(b) Skill enhancement Course (SEC1): Basic programming with Python, Graph plotting with Gnuplot.
Semester 2: (a) Core course:- Electrostatics, Magnetostatics, Kinetic theory of gas, Laws of Thermodynamics, Entropy.
(b) Skill enhancement Course (SEC2): Scientific writing using LaTeX .

Program Specific Outcome:

After completion of the course,

PSO1: Students will learn how to solve differential equations and how to use vector algebra and vector calculus, which are essential for further studies. They will gain a deep understanding of dynamics of particle or system of particles under different potentials, central forces, Gravitation etc. Students will be also able to apply the laws of electrostatics and magnetostatics for the symmetric system. They will also get familiar with the microscopic descriptions as well as the macroscopic description of gases. This one year certificate course helps the students to grow a strong understanding of the basics of the subject.

PSO2: Students will develop the proficiency in using precision instruments, and handle errors in measured data, learn to determine physical properties of matter, able to safely handle electrical components and circuits and to do experiments related to thermal physics.

PSO3: Students will acquire knowledge of basic programming skill using Python and gnuPlot for data visualisation which are necessary to solve problems numerically, scientific writing using LaTeX . This will help them to learn advance computation in future.

Programme: Two year Diploma course with Physics Major

Participants: Students of Semester Three and Semester Four after successful completion of one year certificate course

Programme details: Two year Diploma course with Physics major consists of four semesters where the courses of first two semesters are identical with one year Certificate course with Physics Major. In the third semester (21 credits) students will study two core courses of Physics Major having credit 4, One Skill enhancement course of Physics Major having credit 4, one core course of the second Minor paper having credit 4, one interdisciplinary course of credit 3 and one language course of credit 2. In the fourth semester (22 credits) they should study four core courses each of credit 4, one core course of the second Minor paper having credit 4 and one language course of credit 2.

Courses taught in Physics Major:

Courses taught in the semester 1 and the semester 2 are identical with the one year certificate course with Physics Major.
Semester 3: (a) Core courses: (i) Harmonic oscillations: damped and forced, superposition of oscillations, wave equation, solution with given boundary conditions, interference, diffraction and polarisation. (ii) Convergence of infinite series, Fourier series and transforms, partial differential equations, special integrals, probability distribution function.
(b) Skill Enhancement course: Arduino / data analysis.
Semester 4: (i) Radiation, basic quantum mechanics and its 1d applications, quantum harmonic oscillator. (ii) Alternating current, electrostatics and magnetostatics, electromagnetic induction, Maxwell's equations, EM wave. (iii) 2nd order differential equations, Linear vector space, orthogonal curvilinear coordinates and rotational transformation, tensors, matrices, numerical methods to solve PDEs (iv) non inertial frame and rotational dynamics, formulation of Lagrangian and Hamiltonian, special theory of relativity.

Program Specific Outcome:

Program outcome after the completion of the first year is identical with one year Certificate course with Physics Major (PSO1-PSO3). After the completion of the second year,

PSO4: Students will gain profound knowledge in solving differential equations (including damped and forced oscillation, wave equations with boundary conditions), series expansion of functions, LVS, matrices and tensors, probability distribution function.

PSO5: Students will learn fundamentals of wave optics, basic quantum mechanics and its 1d applications, electrostatics and magnetostatics, em wave propagation, mechanics in noninertial frame, rotational dynamics, lagrangian and hamiltonian formulation and special theory of relativity.

PSO6: Students will develop the skill of doing numerical methods using numPy and matplotlib. Further they will learn to do basic projects using Arduino / data analysis and visualization using Pandas and seaborn. This will help them to explore areas like machine learning, AI or microcontroller prototyping.

PSO7: Students will develop the skill of handling optical instruments, electrical circuits, designing experimental set ups related to em induction, tunnel diode, determination of e/m, Planck's constant, determination of elastic constants etc.

Programme: Three year Degree course with Physics Major

Participants: Students of Semester five and Semester six after successful completion of two year diploma course.

Programme details: Three year Degree course with Physics Major consists of six semesters where the courses of the first four semesters are identical with two year Diploma course with Physics Major. In the fifth semester (total 24 credits) there are four core courses each of credit 4, one core course of the first Minor paper having credit 4 and one core course of the second Minor paper having credit 4. In the sixth semester (23 credits) there are three core courses each of credit 4, one core course of the first Minor paper having credit 4 and one core course of the second Minor paper having credit 4 and summer internship programme of credit 3.

Courses taught in Physics Major:
Courses taught in the first two years (semester 1 to semester 4) are identical with the two year Diploma course with Physics Major.
Semester 5: (i)Electronics of semiconductors, transistors, amplifiers, OPAMP and their applications. (ii) Nuclear properties and structure, radioactive decays, nuclear reactions, elementary particles and their families and features, quark structure, energy production in stars. (iii) Quantum mechanics in vector space language, applications in 2d and 3d, angular momentum, H-like atoms, quantum statistical mechanics. (iv) Transport phenomena, conduction of heat, real gas, thermodynamic potentials and thermodynamic relations, phase transition, radiation and classical statistical mechanics.
Semester 6: (i) Digital electronics including number system, truth tables, logic gates and its implications in different circuits, data processing circuits, sequential circuits, registers and counters, data conversion. (ii) Crystal structure, lattice dynamics, band theory, dielectric and magnetic properties of matter, superconductivity. (iii) Generalised momenta and spin, atoms in external magnetic field, splitting of spectral lines, many electron atoms, molecular spectroscopy and laser.

Program Specific Outcome:
Program outcome after the completion of the first two years is identical with two year Diploma course with Physics Major (PSO1-PSO7). After the completion of the third year,

PSO8: Students will develop detailed knowledge of electrical components like diodes, transistors, amplifiers, OPAMP and their applications in different circuits as well as digital circuits including data processing circuits, sequential circuits, registers, counters etc.

PSO9: Students will learn quantum mechanics in vector space notation, angular momentum algebra, H-like atoms, many electron atoms and fundamentals of atomic, nuclear and particle physics including nuclear reactions, radioactive decay, molecular spectroscopy, splitting of spectral lines, elementary particles and quark structure.

PSO10: Students will acquire knowledge of kinetic theory of gas including transport phenomena, conduction of heat, thermodynamic potentials and thermodynamic relations, phase transitions, classical and quantum statistical mechanics, fundamentals of solid state physics.

PSO11: Students will develop the skill of doing basic experiments related to design electrical circuits using analog and digital components, experiments related to thermal physics and solid state physics. Further they will also learn to solve 2nd order ODEs and transient equations numerically using scipy.

Thus they will be familiar with all the basic branches of physics which is essential for advanced courses of physics.

Programme: Four year Degree course (Honours) with Physics Major

Participants: Students of Semester five and Semester six after successful completion of three year Degree course, and admitted to the four-year course following the rules and regulations of the University.

Programme details: Four year Degree course (Honours) with Physics Major consists of eight semesters where the courses of the first six semesters are identical with three year Degree course with Physics Major. In the 7th semester (total 20 credits) there are five core courses each of credit 4. In the 8th semester (20 credits) there are again five core courses each of credit 4.

Courses taught in Physics Major:
Courses taught in the first three years (semester 1 to semester 6) are identical with the three year Degree course with Physics Major.
Semester 7: (i) Mathematical methods including Group theory, Complex analysis, Green's function, Integral transforms, Statistics; (ii) Advanced classical mechanics including Lagrangian formulation, small oscillations, canonical transformations, rigid bodies, fluid dynamics, classical fields, nonlinear dynamics, and special theory of relativity; (iii) Advanced quantum mechanics including quantum theory of measurements, approximation methods, angular momentum algebra, and quantum computation; (iv) Classical electrodynamics including covariant formulation of Maxwell's equations, radiation, radiation reaction, and plasma physics; (v) A set of eight advanced level experiments.
Semester 8: (i) Advanced quantum mechanics including scattering theory, time-dependent perturbation, and application of symmetries; (ii) Advanced statistical mechanics including canonical and grand canonical ensembles, classical non-ideal gas, quantum statistical mechanics, ideal quantum gas, phase transition and critical phenomena, magnetic properties of solids, and stochastic processes; (iii) Electronics and instrumentation including filters, digital MOS circuits, and physics of semiconductor devices; (iv) Advanced solid state physics including structure of solids, band theory, lattice dynamics, dielectric properties, magnetic resonances, and superconductivity; (v) A set of five advanced level experiments and a set of five advanced computational problems.

Program Specific Outcome:
Program outcome after the completion of the first three years is identical with three year Degree course with Physics Major (PSO1-PSO11). After the completion of the fourth year,

PSO12: Students will learn the use of advanced level mathematics in physics.

PSO13: Students will learn advanced level of classical mechanics, including the covariant formulation of special theory of relativity.

PSO14: Students will acquire a comprehensive knowledge of advanced quantum mechanics, including approximation methods and scattering.

PSO15: Students will learn the covariant formulation of electrodynamics, and plasma physics.

PSO16: Students will acquire a very substantial amount of knowledge on statistical mechanics and solid state physics, right at the level of joining a Ph.D. programme.

PSO17: Students will learn the physics of semiconductor devices and advanced electronics, which will be helpful for those going into experimental research.

PSO18: Students will get acquainted with enough advanced level practicals.

Thus they will be ready to enter the one-year PG programme of any reputed university.

Programme: Four year Degree course (Honours with Research) with Physics Major

Participants: Students of Semester five and Semester six after successful completion of three year Degree course, and admitted to the four-year course following the rules and regulations of the University.

Programme details: Four year Degree course (Honours with Research) with Physics Major consists of eight semesters where the courses of the first six semesters are identical with three year Degree course with Physics Major, and the courses of the 7th semester are identical with those of the 7th semester for four-year Degree (Honours) course, as outlined above. In the 8th semester (total 20 credits) there are two core courses on research methodology (8 credits), one course on research internship (4 credits), and one course on project/dissertation (8 credits).

Courses taught in Physics Major:

Courses taught in the first three years (semester 1 to semester 6) are identical with the three year Degree course with Physics Major.
Semester 7: (i) Mathematical methods including Group theory, Complex analysis, Green's function, Integral transforms, Statistics; (ii) Advanced classical mechanics including Lagrangian formulation, small oscillations, canonical transformations, rigid bodies, fluid dynamics, classical fields, nonlinear dynamics, and special theory of relativity; (iii) Advanced quantum mechanics including quantum theory of measurements, approximation methods, angular momentum algebra, and quantum computation; (iv) Classical electrodynamics including covariant formulation of Maxwell's equations, radiation, radiation reaction, and plasma physics; (v) A set of eight advanced level experiments.
Semester 8: (i) Research methodology, including scientific writing and communication, mathematical logic, statistics, and ethical practice. (ii) Research internship and project/dissertation, where the student will be introduced to research.

Program Specific Outcome:

Program outcome after the completion of the first three years is identical with three year Degree course with Physics Major (PSO1-PSO11), and identical with the 7th semester of the four year Degree (Honours) course (PSO12-PSO15). After the completion of the 8th semester,

PSO16: Students will have a proper understanding of research methodology and ethical norms, which are an absolute must if they go for research.

PSO17: Students will be introduced to some proper research, including writing and presenting the results.

Thus they will be ready to enter the Ph.D. programme of any reputed university/institute. They may also opt for one-year PG courses.

Course Outcome

Major courses

PHS-DSCC-1-1 : Basic Physics - I

CO1: to learn plotting and series expansion of functions, basic ideas of calculus (limit, continuity and differentiability of functions, finding extremes), partial derivatives.

CO2: to learn how to solve first order linear and second order linear homogeneous (with constant coefficients) differential equations.

CO3: to recapitulate basic vector algebra and to learn vector calculus (gradient, divergence, curl, surface and volume integration), divergence theorem and Stoke's theorem.

CO4: to have the idea of various orthogonal coordinates (plane polar, spherical polar, cylindrical), to learn to deal with vector calculus in different coordinate system and to solve particle dynamics in different coordinate systems.

CO5: to recapitulate the basics of classical mechanics (Galilean frame and its invariance, Newton's laws, rotational motion, conservation of linear and angular momentum), to solve the simple problems of classical mechanics.

CO6: to learn about the conservative forces, force as a gradient of scalar potential, to gain insight on the one dimensional motion from the potential energy curve.

CO7: to learn about the dynamics of a system of particles, concept of the reduced mass for two body problem, the centre of mass, momentum and energy of the system of particles.

CO8: to learn about the properties of the central force field, equations of motion and trajectories of the particle moving under the central force field, Gravitation as an example of central force field, Kepler's law, to learn how to find gravitational potential for different cases using Gauss' law.

CO9: to learn two body collision and scattering.

CO10: to acquire knowledge of compressible and incompressible fluids, continuity equations, Stoke's law and Euler's equation, Bernoulli's theorem

CO11: to learn basic measurement techniques using slide calipers, screw gauge, sextant etc., to determine moment of inertia, modulus of rigidity and viscosity, estimation of errors.

PHS-SEC-1-1 : Introduction to Computer Programming and Graph Plotting

CO1: to learn plotting of functions in 2d, polar and parametric plots, data fittings using GNUplot.

CO2: to learn basic programming using Python (Basic mathematical and logical operations, conditional statements, loops, data types)

PHS-DSCC-2-1: Basic Physics - II

CO1: to learn about electrostatic fields, potential, flux and charge distributions, integral form of Gauss' law and its applications, electric dipoles, electrostatic energy of charged system, conductors and capacitance, dynamics of charged particles in simultaneous electric field and magnetic field.

CO2: to acquire knowledge of magnetostatics, Biot-Savart's law and its applications, Ampere's circuital law with applications, magnetic dipoles.

CO3: to learn molecular kinetic theory of ideal gas, relation between the macroscopic and the microscopic variables, Maxwell's velocity distribution.

CO4: to acquire knowledge of thermodynamic variables, thermodynamic equilibrium, state functions, concept of work and energy, thermodynamic process, specific heats, laws of thermodynamics, entropy.

CO5: to learn to handle electrical apparatus and components, to measure current and resistances in the circuit, to measure expansion coefficients etc.

PHS-SEC-2-1 : Scientific Writing Skills (LaTeX)

CO1: to learn to prepare various types of LATEX documents containing lists, tables, figures, mathematical expressions etc.

PHS-DSCC-3-1 : Waves and Optics

CO1: to learn to construct and solve differential equations of harmonic oscillators (damped and forced),calculate their energies, to learn resonance, power dissipation and quality factor, superposition of harmonic oscillators and Lissajous' figure.

CO2: to gain knowledge of wave equation, traveling and standing waves, solution of vibrating strings, modes of vibration, energy of the vibrating string, plucked and struck string.

CO3: to learn the laws of reflection and refraction of light at plane and curved surfaces, Interference of light, division of amplitude and division of wavefront, fringes of equal width and equal inclination, Newton's ring, Michelson interferometer and Fabry-Perot interferometer, Diffraction using single slit, double slit and grating, resolving power, Fresnel's half plate zone and zone plate.

CO4: to build the concept of polarisation of electromagnetic waves, double refraction, ordinary and extra ordinary ray, phase retardation plates, production and analysis of polarised light.

CO5: to learn to deal with optical instruments, to study the variation of refractive index, to determine the wavelength of sodium light, to study grating, specific rotation using polarimeter, Melde's experiment.

PHS-DSCC-3-2 : Mathematical Physics I

CO1: to get the idea of convergence of power series, different types of convergent tests.

CO2: to learn Fourier series expansion and its complex representation, Fourier integral theorem, Fourier transform with examples and applications.

CO3: to learn to solve partial differential equation using the method of separation of variables, Laplace equation, wave equation and diffusion equation.

CO4: to acquire the knowledge of probability of discrete events and uncorrelated events, Probability Distribution Function, Binomial, Gaussian and Poisson distribution, 1-d random walk.

CO5: to learn Dirac-delta function, beta and gamma functions, error functions.

CO6: to learn approximation in numerical computation, numerical solution in algebraic equation, numerical integration and solution of ordinary differential equations, to solve system of algebraic equations, curve fitting.

CO7: to learn to use NumPy and its applications in matrix operations and numerical computations, to use matplotlib for graph plotting.

PHS-SEC-3-1 : Arduino

CO1: to gain the skill of handling Arduino and do some basic projects

PHS-SEC-3-2 : Introductory Data Analysis

CO1: to get an overview on data analysis and data analytics including data structure, cleaning and reshaping using Pandas, numerical computing using NumPy, data visualisation using matplotlib and Seaborn.

PHS-DSCC-4-1 : Modern Physics

CO1: To learn the development of Quantum mechanics starting from the problems of classical framework.

CO2: To learn the basics of Quantum mechanics.

CO3 : To learn the Schrödinger equation and applications to simple problems.

PHS-DSCC-4-2 : Electromagnetism

CO1: To learn about the image method used in electrostatics.

CO2 : To learn about the properties of magnetic field inside matter.

CO3: To learn the development of Maxwell's equation.

PHS-DSCC-4-3 : Mathematical Physics II

CO1 : To learn the basics of Linear vector space.

CO2 : To learn the techniques of solving 2nd order differential equations using power series.

CO3 : To learn the properties of matrices and solving eigenvalue problems.
CO4 : To acquire the basic knowledge of cartesian tensors.

PHS-DSCC-4-4 : Classical Mechanics and Special theory of Relativity
CO1 : To learn the variational calculus.
CO2 : To learn the Lagrangian and Hamiltonian formulation.
CO3 : To learn the foundation of Special Relativity.

PHS-DSCC-5-1 : Electronics I CO1 : To learn the basics of circuits and network.
CO2 : To acquire the knowledge of diodes, transistors and FETs.
CO3 : To learn the properties of Operational amplifiers.
CO4 : To learn the basic properties of Oscillators.

PHS-DSCC-5-2 : Nuclear and Particle Physics CO1 : to learn the basic properties of Nucleus.
CO2 : to learn the details of nuclear reactions.
CO3 : to learn the basic idea of fundamental particles and their interactions.
CO4 : to acquire a basic knowledge about nuclear fusion in stars.

PHS-DSCC-5-3 : Quantum Mechanics
CO1 : to learn the Dirac's bracket formulation of QM.
CO2 : to learn the application of Schrodinger equation in 2 and 3 dimensions.
CO3 : to acquire the idea of bosons and fermions and their statistics.

PHS-DSCC-5-4 : Thermal Physics and Statistical Mechanics
CO1 : to learn about the thermodynamic potentials and Maxwell's relations.
CO2 : to learn the thermodynamics of phase transition and Black body radiation.
CO3 : to gain the basic formalism of classical statistical mechanics.

PHS-DSCC-6-1 : Electronics II
CO1 : to learn the Number System , binary algebra and their application to different logic gates.
CO2 : to acquire a knowledge of Sequential circuits , Registers and Counters.

PHS-DSCC-6-2 : Solid State Physics
CO1 : to learn the basic formalism of crystal structure. CO2 : to gain a basic understanding of band structure of solids.
CO3 : to learn the dielectric and magnetic properties of solids.

PHS-DSCC-6-3 : Atomic, Molecular, and Laser Physics
CO1 : to learn the characteristics of Zeeman effect.
CO2 : to learn the properties of many-electron atoms.
CO3 : to learn the basic properties of molecular spectra.
CO4 : to learn the properties of Lasers ; idea of spontaneous and stimulated emission and derivation of Einstein's A and B coefficients.
CO5 : to learn the basics of optical fibres and its different properties.

PHS-DSCC-7-1 : Mathematical Methods III
CO1: To learn about the application of Group Theory in physics.
CO2: To learn about the complex analysis technique.
CO3: To learn about homogeneous and inhomogeneous differential equations and integral transforms.
CO4: To learn about some statistical tools necessary for physics.

PHS-DSCC-7-2 : Advanced Classical Mechanics
CO1: To learn about the Lagrangian formulation and small oscillation.
CO2: To learn about the canonical transformations.
CO3: To learn about fluid dynamics and classical fields.
CO4: To learn the 4-vector notation of Special Relativity.
CO5: To have an introductory idea about nonlinear dynamics.

PHS-DSCC-7-3 : Advanced Quantum Mechanics I
CO1: To learn about the solution of one-dimensional problems.
CO2: To learn various approximation methods used in quantum mechanics.
CO3: To have an introductory idea on quantum computation and foundations of quantum mechanics.

PHS-DSCC-7-4 : Classical Electrodynamics
CO1: To learn about Maxwell's equations and their solutions.
CO2: To learn about accelerated charges and radiation, including radiation reaction.

CO3: To have an elementary idea on Plasma Physics and its applications.

PHS-DSCC-7-5 : General Laboratory I

CO1: To perform some advanced level experiments in physics.

PHS-DSCC-8-1 : Advanced Quantum Mechanics II

CO1: To learn about scattering thery.
CO2: To learn about the role of symmetries in quantum mechanics.
CO3: To learn time-dependent perturbation theory.

PHS-DSCC-8-2 : Advanced Statistical Mechanics

CO1: To learn about canonical and grand canonical ensem, and classical non-ideal gas.
CO2: To learn about quantum statistical mechanics.
CO3: To learn about phse transition and critical phenomena.
CO4: To learn about magnetism in solids.
CO5: To learn about stochastic processes.

PHS-DSCC-8-3 : Electronics and Instrumentation

CO1: To learn about filters and digital MOS circuits.
CO2: To learn about physics of semiconductors.
CO3: To get acquainted with several semiconductor-based devices needed in cutting-edge research.

PHS-DSCC-8-4 : Advanced Solid State Physics

CO1: To learn about crystal structure, band theory of solids, and lattice dynamics.
CO2: To learn about dielectric properties of solids.
CO3: To learn about magnetic resonances.
CO4: To have an introductory notion about superconductivity.

PHS-DSCC-8-5 : General Laboratory II

CO1: To perform some advanced level experiments in physics.
CO2: To perform high-level computer simulations of some interesting physics problems.

PHS-DSCC-8-1R and PHS-DSCC-8-2R : Research Methodology I and II

CO1: To have an idea of research in physics, and different types of research.
CO2: To learn about literature survey, information retrieval, scientific writing, and communication.
CO3: To learn about ethics in research and possible malpractices.
CO4: To learn some important statistical tools necessary for data handling and processing.

PHS-DSCC-8-3R and PHS-DSCC-8-4R :

CO1: To have an experience of actual research, including data collection, analysis, presentation of results, and writing dissertations.

MDC courses

PHS-CC-1-1 : Basic Physics - I

Identical to that of PHS-DSCC-1-1.

PHS-CC-2-1 : Basic Physics - II

Identical to that of PHS-DSCC-2-1.

PHS-CC-3-1 : Waves and Optics

CO1 : to learn the basics of simple harmonic oscillations and superposition of vibrations.
CO2 : to learn the properties of travelling and standing waves.
CO3: to acquire the basics of Geometrical optics and formulation of Fermat's principle.
CO4 : to learn the various characteristics of Interference, diffraction and polarisation.

PHS-CC-4-1 : Modern Physics

CO1 : to gain a basic idea of Special theory of Relativity.
CO2: to learn the basics of old quantum theory.
CO3 : to learn the formulation of Schrödinger equation and its different applications. CO4 : to learn the basics of crystal structure, idea of metals, semiconductors and insulators.

PHS-CC-4-2 : Electromagnetism

CO1 : to learn the basic idea of electrostatics and magnetostatics.
CO2 : to learn the EM induction and Maxwell's equations.
CO3 : to learn about the L-R and C-R circuit and also properties of alternating current (AC).

PHS-CC-5-1 : Electronics I

CO1 : to learn the basics of analog electronics : electric circuits, diodes, transistors and FETs.
CO2 : to learn the basics of digital electronics : boolean algebra, different logic gates and their properties.

PHS-CC-6-1 : Nuclear and Particle Physics

CO1 : to learn the idea of properties of nucleus, properties of alpha, beta and gamma rays.
CO2 : to learn about the accelerators with a special consideration to cyclotron.
CO3 : to learn the fundamental properties of subatomic particles and their interactions.

PHS-CC-6-2 : Electronics II

CO1 : to learn the Number System , binary algebra and their application to different logic gates
CO2 : to acquire a knowledge of Sequential circuits , Registers and Counters.

Minor courses

COs are the same as those of corresponding MDC papers, as mentioned in the syllabus.

PHS-IDC : Frontiers in Physics

CO1 : To learn about the role of scientific reasoning , difference between science and pseudoscience.
CO2 : To learn the historical development of theory of Gravity from Copernicus to Einstein.
CO3 : To learn the development of theories of atom and molecules in a pedagogic fashion.
CO4 : To learn about the basic building blocks of astronomy and astrophysics.

Question Pattern

Physics (Major)

All Major papers starting with PHS-DSCC- with 3 credits for theory (which means all the Major papers except PHS-DSCC-7-5, PHS-DSCC-8-5, and PHS-DSCC-8-1R to PHS-DSCC-8-5R) will have the following structure:
Theory:
Full Marks: 75, students have to answer 5 questions (out of 8) each of 3 marks, and 5 questions (out of 8) each of 12 marks. $[5 \times 3 + 5 \times 12 = 75]$
For the following papers, where the different modules are explicitly displayed, the 12-mark questions will be divided as follows:
PHS-DSCC-1-1: Mathematical Physics 3-4, Classical Mechanics 4-5;
PHS-DSCC-2-1: Basic Electricity and Magnetism 3-4, Introduction to Thermodynamics 4-5;
PHS-DSCC-5-3: Quantum Mechanics 5-6, Quantum Statistical Mechanics 2-3;
PHS-DSCC-5-4: Kinetic Theory of Gases 1-2, Thermodynamics 3-5, Classical Statistical Mechanics 2-3.
Practical
For all Major papers with a 1 credit (25 marks) Practical (laboratory) component, the division of marks will be as follows:
Laboratory notebook: 5, Viva: 5, Experiment: 15.
For the papers with a Computer Practical component, the division pf marks will be:
Laboratory notebook: 5, Viva: 5, Programming (in Python): 15.
Tutorial
For all Major papers with a 1 credit (25 marks) Tutorial component, the evaluation will be based on assignment or a small set of problems, as mentioned in the syllabus.
PHS-DSCC-7-5
Students have to perform two experiments in the final examination, taking one from each group. The division of marks will be as follows:
Laboratory notebook: 20, Viva: 20, Experiment: $30 + 30$.
PHS-DSCC-8-5
Students have to perform one experiment from Part I, and one programming from Part II, in the final examination. The division of marks will be as follows:
Part I: Laboratory notebook: 10, Viva: 10, Experiment: 30
Part II: Laboratory notebook: 10, Viva: 10, Programming (in Python): 30.
PHS-DSCC-8-1R and PHS-DSCC-8-2R
The questions for PHS-DSCC-8-1R and PHS-DSCC-8-2R will be of essay type. The theory examination will be of 75 marks for each paper, and the students have to answer 15 questions, each of 5 marks. 1 credit (25 marks) in each paper will be on viva.
PHS-DSCC-8-3R and PHS-DSCC-8-4R
The detailed guideline on the division of marks will be made available later.

Physics (SEC)

SEC papers

PHS-SEC-1-1: Laboratory notebook: 20, Viva: 20, Programming: 60 [Gnuplot: 20, Python program: 40]
PHS-SEC-2-1: Project: 60, Document writing: 40.
PHS-SEC-3-1 and PHS-SEC-3-2: Theory; 25 [5 questions, each of 5 marks, are to be answered out of 8], Practical: 75 [Laboratory notebook: 25, Viva: 10, Experiment/Programming: 40]

Physics (Multidisciplinary, Minor, IDC)

Physics Multidisciplinary Core, Multidisciplinary Minor, and Minor (for other Majors) papers

All papers with a 75 marks (3 credits) theory component will have the same pattern as the similar Major papers:
5 questions (out of 8) of 3 marks each + 5 questions (out of 8) of 12 marks each.
For the papers with an explicit division of modules, the number of questions for each module will be the same as the corresponding Major papers.
All papers with a 25 marks (1 credit) practical component will have the following division:
Laboratory notebook: 5, Viva: 5, Experiment: 15.
For papers with a 25 marks (1 credit) tutorial component, the guidelines are the same as the similar Major papers.
PHS-CC-SEC-1-1 will have the identical division of marks as **PHS-SEC-1-1**.

Physics Interdisciplinary, PHS-IDC

Theory (50 marks/2 credits): 10 (out of 12) MCQ type (1×10), 10 (out of 12) fill-in-the-blanks type (1×10), 6 (out of 9) short answer type questions (5×6).
Tutorial (25 marks/1 credit): Students may be asked to give either a short presentation with a writeup on some topic relevant to this course (as suggested by the concerned teacher), or to appear for an internal examination.