SANSKARAM UNIVERSITY
JHAJJAR

Scheme of Examination and Syllabus for

B.Sc. Physics Hons.

Under Multiple Entry-Exit, Internships and CBCS-LOCF in accordance to NEP 2020

w.e.f. 2024-25

Programme Structure, B.Sc. Physics Hons., 2024

Semester	Discipline Specific Core Courses (4) #	Discipline SpecificElective (DSE) (4)#	Generic Elective (GE) (4)#	Ability Enhancement Course (AEC) (2)#	Skill Enhancement Course (SEC) (2)#	Internship/Apprenticeship/Project/Community Outreach (IAPC) (2)*	Value Addition Course (VAC) (2)#	Total Credits
I	Mechanics Mathematical Physics-I Waves & Oscillations	NA	Choose one GE from the pool of GE Courses of sem I	Choose one AEC from pool of courses	Choose one SEC from a pool of SEC of sem I	NA	Choose one VAC from apool of courses	**22**
II	Electricity & Magnetism Electrical Circuit Analysis Mathematical Physics-II	NA	Choose one GE from the pool of GE Courses of sem II	Choose one AEC from pool of courses	Choose one SEC from a pool of SEC of sem II	NA	Choose one VAC from apool of courses	**22**
Students on exit shall be awarded Undergraduate Certificate in Physics after securing the requisite 44 credits in Semesters I - II								
III	DSC- 7 DSC- 8 DSC- 9	Choose one DSE from the pool of DSE Courses of sem III Or Choose one GE from the pool of GE Courses of sem III		Choose one AEC from a pool of courses	Choose one SEC from a pool of SECs given for sem III OR Internship/Apprenticeship/Project/Community Outreach (IAPC) (2)*		Choose one VAC from apool of courses	**22**
IV	DSC- 10 DSC- 11 DSC- 12	Choose one DSE from the pool of DSE Courses of sem IV Or Choose one GE from the pool of GE Courses of sem IV		Choose one AEC from a pool of courses	Choose one SEC from a pool of SECs given for sem IV OR Internship/Apprenticeship/Project/Community Outreach (IAPC) (2)*		Choose one VAC from apool of courses	**22**
Students on exit shall be awarded Undergraduate Diploma in Physics after securing the requisite 88 credits after completion of Semesters I - IV								

Semester	Core Course (4) #	Discipline SpecificElective (DSE) (4) #	Generic Elective (GE) (4) #	Ability Enhancement Course (AEC) (2) #	Skill Enhancement Course (SEC) (2) #	Internship/Apprenticeship/Project/Community Outreach (IAPC) (2)*	Value Addition Course (VAC) (2)#	Total Credits
V	DSC- 13 DSC- 14 DSC- 15	Choose one DSE from the pool of DSE Courses of sem V	Choose one GE from the pool of GE Courses of sem V		Choose one SEC from a pool of SECs given for sem V OR Internship/Apprenticeship/Project/Community Outreach (IAPC) (2)*			**22**
VI	DSC- 16 DSC- 17 DSC- 18	Choose one DSE from the pool of DSE Courses of sem VI	Choose one GE from the pool of GE Courses of sem VI		Choose one SEC from a pool of SECs given for sem VI OR Internship/Apprenticeship/Project/Community Outreach (IAPC) (2)*			**22**
Students on exit shall be awarded Bachelor of Physics (Hons.) after securing the requisite 132 credits on completion of Semesters I - VI								
VII	DSC-19	Choose from a pool of DSE and GE courses given for semester VII in the combinations given below: • Choose three DSE courses OR • Choose two DSE and one GE courses OR • Choose one DSE and two GE courses ***				Dissertation on Major (4+2) OR Dissertation on Minor (4+2) OR • Academic project/ Entrepreneurship (4+2)		**22**
VIII	DSC-20	Choose from a pool of DSE and GE courses given for semester VIII in the combinations given below: • Choose three DSE courses OR • Choose two DSE and one GE courses OR • Choose one DSE and two GE *** courses				Dissertation on Major (4+2) OR Dissertation on Minor (4+2) OR • Academic project/ Entrepreneurship (4+2)		**22**
After securing the requisite 176 credits on completion of Semester VIII, students on exit shall be awarded • ***Bachelor of Physics (Hons. with Research / Internship/Apprenticeship/Project/Community Outreach)*** ***Or*** • ***Bachelor of Physics (Hons.) with Research in Physics (Major) and other Discipline (Minor)***								

Value inside parenthesis signifies credit of that course.
* There shall be choice in Semester III and IV to either choose a DSE (from a pool of Physics DSE courses) or a GE (from a pool of GE courses other than physics).
** ‘Research Methodology’ shall be offered as one of the DSE courses in VI and VII. If a student wishes to pursue four years Honours Degree with research, he/she shall compulsorily opt for a Research Methodology course in either VI Semester or VII Semester.
***The following choices will be available in VII and VIII semesters:
(i) to choose three DSEs of 4 credits each OR
(ii) to choose two DSEs and one GE of 4 credits each OR
(iii) to choose one DSE and two GEs of 4 credits each.

List of Discipline Specific Core (DSC) Courses

A student will study three Discipline Specific Core Courses each in Semesters I to VI and one core course each in semesters VII and VIII. The semester wise distribution of DSC courses over eight semesters as listed in Table.

Semester	Discipline Specific Core (DSC) Course	Course Code	Nomenclature	Credits		
				L	P	Total
I	DSC-1	020601001	Mechanics	3	1	4
	DSC-2	020601002	Mathematical Physics-I	2	2	4
	DSC-3	020601003	Waves & Oscillations	2	2	4
II	DSC-4	020602004	Electricity & Magnetism	3	1	4
	DSC-5	020602005	Electrical Circuit Analysis	2	2	4
	DSC-6	020602006	Mathematical Physics-II	2	2	4
III	DSC-7	020603007	Thermal Physics	3	1	4
	DSC-8	020603008	Electromagnetic Theory	3	1	4
	DSC-9	020603009	Analog Electronics	3	1	4
IV	DSC-10	020604010	Modern Physics	3	1	4
	DSC-11	020604011	Digital Electronics	3	1	4
	DSC-12	020604012	Light & Matter	3	1	4
V	DSC-13	020605013	Nuclear Physics	3	1	4
	DSC-14	020605014	Solid State Physics	4	0	4
	DSC-15	020605015	Atomic, Molecular and Nuclear Physics	3	1	4

VI	DSC-16	020606016	Statistical Mechanics	4	0	4
	DSC-17	020606017	Classical Mechanics	4	0	4
	DSC-18	020606018	Semiconductor Devices	3	1	4
VII	DSC-19	020607019	Quantum Mechanics	3	1	4
VIII	DSC-20	020608020	Nano Technology & Nano Sciences	3	1	4

List of Discipline Specific Elective (DSE) Courses

The Discipline Specific Electives (DSEs) are a pool of credit courses of Physics from which a student will choose to study based on his/ her interest. A student of B.Sc. Hons. Physics gets an option of choosing one DSE of Physics in each of the semesters III to VI, while the student has an option of choosing a maximum of three DSE courses of Physics in semesters VII and VIII. The semester wise distribution of DSE courses over six semesters is listed in Table. In addition to the proposed courses, students may select courses from the Swayam.org as MOOCs courses in semester VII & VIII up to the permissible limit.

Semester	Discipline Specific Elective (DSE) Course	Course Code	Nomenclature	Credits		
				L	P	Total
III	DSE 1		Biophysics	4	0	4
	DSE 2		Numerical	2	2	4
IV	DSE 3		Advanced Mathematical Physics I	4	0	4
	DSE 4		Physics of Devices	2	2	4
	DSE 5		Physics of Earth	4	0	4
V	DSE 6		Astronomy and Astrophysics	4	0	4
	DSE 7		Physics of Materials	2	2	4
	DSE 8		Communication System	2	2	4
VI	DSE 9		Advanced Mathematical Physics II	4	0	4

	DSE 10		Microprocessor	2	2	4
	DSE 11		Research Methodology	4	0	4
VII	DSE 12		Nano Science	2	2	4
	DSE 13		Plasma Physics	4	0	4
	DSE 14		Introduction to Particle Physics	4	0	4
	DSE 15		Group Theory and Applications	4	0	4
	DSE 16		Radiation and its Applications	2	2	4
	DSE 17		Advanced Mathematical Physics III	4	0	4
	DSE 18		Physics of Atmosphere and Climate Change	3	1	4
	DSE 19		Research Methodology	4	0	4
VIII	DSE 20		Applied Dynamics	4	0	4
	DSE 21		Applied Optics	2	2	4
	DSE 22		Introduction to Field Theory	4	0	4
	DSE 23		Nuclear and Particle Detectors	4	0	4
	DSE 24		Quantum Information	4	0	4
	DSE 25		General Theory of Relativity	4	0	4

List of Generic Elective (GE) Courses

Generic Elective courses provide multidisciplinary education to students.Various GE courses offered by the Physics Department are listed below in Table**.** In addition to the proposed courses, students may select courses from the Swayam.org as MOOCs courses semesters VII & VIII up to the permissible limit.

Semester	Generic Elective (GE) Course	Course Code	Nomenclature	Credits		
				T	P	Total
I	GE-1		Mechanics	3	1	4
	GE-2		Mathematical Physics	2	2	4
II	GE-3		Waves and Optics	2	2	4
	GE-4		Electricity & Magnetism	3	1	4
III	GE-5		Introduction to Electronics	2	2	4
	GE-6		Introductory Astronomy	2	2	4
IV	GE-7		Biological Physics	3	1	4
	GE-8		Numerical Analysis and Computational Physics	3	1	4
V	GE-9		Applied Dynamics	3	1	4
	GE-10		Quantum Information	3	1	4
VI	GE-11		Solid State Physics	3	1	4
	GE-12		Thermal Physics	3	1	4
VII	GE-13		Modern Physics	3	1	4
	GE-14		Introductory Astronomy	4	0	4
	GE-15		Quantum Mechanics	3	1	4
	GE-16		Introduction to Embedded System Design	4	0	4
VIII	GE-17		Nano Physics	4	0	4
	GE-18		Physics of Detectors	3	1	4
	GE-19			3	1	4

			Nuclear and Particle Physics			
	GE-20		Atomic and Molecular Physics	3	1	4

List of Skill Enhancement (SEC) Courses

To enhance the skills required for advanced studies, research and employability of studentsvarious Skill Enhancement Courses will be offered to students as listed in Table. In addition to the above proposed courses, students may select courses from the Swayam.org as MOOCs courses upto the permissible limit.

Semester	Skill Enhancement Course (SEC)	Course Code	Nomenclature	Credits		
				T	P	Total
I	SEC 1		Basic of Instruments	0	2	2
	SEC 2		Numerical Techniques	0	2	2
II	SEC 3		Introduction to Physics of Devices	0	2	2
	SEC 4		Radiation Safety	1	1	2
III	SEC 5		Sensors and Detection Technology	1	1	2
	SEC 6		Renewable Energy and Energy Harvesting	1	1	2
IV	SEC 7		Introduction to Laser and Fiber Optics	1	1	2
	SEC 8		Electric Circuits & Networks	1	1	2
V	SEC 9		Introduction to Scilab Programming	0	2	2
	SEC 10		Data Analysis and Statistical Methods	0	2	2
VI	SEC 11		Weather Forecasting	1	1	2
	SEC 12		Embedded System Programming	0	2	2

Detailed Syllabus

Course Code: DSC-1

Course Title: Mechanics

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Course Objectives: This course reviews the concepts of mechanics learnt at school from a more advanced perspective and goes on to build new concepts. It begins with Newton's Laws of Motion and ends with the Special Theory of Relativity. The students will learn the collisions in the center of mass frame, rotational motion and central forces. They will be able to apply the concepts learnt to several real world problems. In the laboratory part of thecourse, the students will learn to use various instruments, estimate the error for every experiment performed and report the result of experiment along with the uncertainty in the result up to correct significant figures.

Course Learning Outcomes: Upon completion of this course, students will be able to,

- Learn the Galilean invariance of Newton's laws of motion.
- Understand translational and rotational dynamics of a system of particles.
- Apply Kepler's laws to describe the motion of planets and satellite in circular orbit.
- Understand Einstein's postulates of special relativity.
- Apply Lorentz transformations to describe simultaneity, time dilation and length contraction.
- Use various instruments for measurements and perform experiments related to rotational dynamics, elastic properties, fluid dynamics, acceleration due to gravity, collisions, etc.
- Use propagation of errors to estimate uncertainty in the outcome of an experiment and perform the statistical analysis of the random errors in the observations.

THEORY (Credit: 03; 45 Hours)

Unit 1:

Fundamentals of Dynamics: Inertial and Non-inertial frames, Newton's Laws of Motion and their invariance under Galilean transformations. Momentum of variable mass system: motion of rocket. Dynamics of a system of particles, principle of conservation of momentum. Impulse. Determination of centre of mass of discrete and continuous objects having cylindrical and spherical symmetry, Differential Analysis of a static vertically hanging massive rope. **(7 Hours)Work and Energy:** Work and Kinetic Energy Theorem. Conservative forces and examples (Gravitational and electrostatic), non-conservative forces and examples (velocity dependent forces e.g. frictional force, magnetic force). Potential Energy. Energy diagram. Stable, unstable and neutral equilibrium. Force as gradient of the potential energy. Work done by non-conservative forces. **(4 Hours)**

Collisions: Elastic and inelastic collisions. Kinematics of $2 \rightarrow 2$ scattering in centre of mass and laboratory frames**.** **(3 Hours)**

Unit 2:

Rotational Dynamics: Angular momentum of a particle and system of particles. Torque. Principle of conservation of angular momentum. Rotation about a fixed axis. Determination of moment of inertia of symmetric rigid bodies (rectangular, cylindrical and spherical) using parallel and perpendicular axes theorems. Kinetic energy of rotation. Motion involving both translation and rotation. **(8 Hours)**

Non-Inertial Systems: Non-inertial frames and fictitious forces. Uniformly rotating frame. Centrifugal force. Coriolis force and its applications**.** **(4 Hours)**

Unit 3:

Central Force Motion: Central forces, Law of conservation of angular momentum for central forces, Two-body problem and its reduction to equivalent one-body problem and its solution. Concept of effective potential energy and stability of orbits for central potentials of the form kr^n for n = 2 and -1 using energy diagram, discussion on trajectories for $n = -2$. Solution of Kepler's problem, Kepler's laws for planetary motion, orbit for artificial satellites. **(7 Hours)**

Unit 4:

Relativity: Postulates of special theory of relativity, Lorentz transformations, simultaneity, length contraction, time dilation, proper length and proper time, Life time of a relativistic particle (for example muon decay time and decay length). Space-like, time-like and light-like separated events. Relativistic transformation of velocity and acceleration. Variation of mass with velocity, Mass-energy Equivalence. Transformation of Energy and Momentum.

(12 Hours)

References:

Essential Readings:

1) An Introduction to Mechanics (2/e), Daniel Kleppner and Robert Kolenkow, 2014, Cambridge University Press.

2) Mechanics Berkeley Physics Course, Vol. 1, 2/e: Charles Kittel, et. al., 2017, McGraw Hill Education

3) Theory and Problems of Theoretical Mechanics, Murray R. Spiegel, 1977, McGraw Hill Education.

4) Classical Mechanics by Peter Dourmashkin, 2013, John Wiley and Sons.

5) https://phys.libretexts.org/Bookshelves/Classical_Mechanics/classical_Mechanics_(Dourmashkin)/

6) Introduction to Classical Mechanics With Problems and Solutions, David Morin, 2008, Cambridge University Press.

7) Fundamentals of Physics, Resnick, Halliday and Walker 10/e, 2013, Wiley.

8) Introduction to Special Relativity, Robert Resnick, 2007, Wiley.

Additional Readings:

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

2) University Physics, H. D. Young, R. A. Freedman, 14/e, 2015, Pearson Education.

3) Classical Mechanics, H. Goldstein, C. P. Poole, J. L. Safko, 3/e, 2002, Pearson Education.

4) Newtonian Mechanics, A.P. French, 2017, Viva Books.

PRACTICAL (Credit: 01; 30 Hours)

Introductory Concepts and related activities (Mandatory)

Use of Basic Instruments:

Determination of least count and use of instruments like meter scale, vernier callipers, screw gauge and travelling microscope for measuring lengths.

Errors:

(a) Types of errors in measurements (instrumental limitations, systematic errors and random errors), Accuracy and Precision of observations, significant figures.

(b) Introduction to error estimation, propagation of errors and reporting of results along with uncertainties with correct number of significant figures.

(c) Statistical analysis of random errors, need for making multiple observations, standard error in the mean as estimate of the error.

Graph Plotting:

Pictorial visualisation of relation between two physical quantities, Points to be kept in mind while plotting a graph manually.

Data Analysis:

Principle of least square fitting (LSF) and its application in plotting linear relations. Estimation of LSF values of slope, intercept and uncertainties in slope and intercept.

Mandatory Activities:

- Determine the least count of meter scale, vernier callipers, screw gauge and travelling microscope, use these instruments to measure the length of various objects multiple time, find the mean and report the result along with the uncertainty up to appropriate number of significant digits.
- Take multiple observations of the quantities like length, radius etc. for some spherical, cylindrical and cubic objects, find mean of these observations and use them to determine the surface area and volume of these objects. Estimate the uncertainties in the outcome using law of propagation of errors. Report the result to appropriate number of significant figures.
- Given a data (x, y) corresponding to quantities x and y related by a relation y = f(x) that can be linearized. Plot the data points (manually) with appropriate choice of scale, perform least square fitting to determine the slope and intercept of the LSF line and use them to determine some unknown quantity in the relation. Determine the uncertainties in slope and intercept and use these to estimate the uncertainty in the value of unknown quantity.

Every student must perform at least 4 experiments from the following list.

1) To study the random errors in observations. It is advisable to keep observables of the order of least count of the instruments.
2) To determine the moment of inertia of a symmetric as well as asymmetric flywheel
3) To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
4) To determine g and velocity for a freely falling body using Digital Timing Technique.
5) To determine the Young's Modulus of a Wire by Optical Lever Method.
6) To determine the vertical distance between two given points using sextant.
7) To determine the coefficients of sliding and rolling friction experienced by a trolley on an inclined plane.
8) To verify the law of conservation of linear momentum in collisions on air track.

Suggested additional Activities:

1) Virtual lab collision experiments on two dimensional elastic and inelastic collisions (for example available on
   a) https://archive.cnx.org/specials/2c7acb3c-2fbd-11e5-b2d9-e7f92291703c/collision-lab/#sim-advanced-sim)
   b) https://phet.colorado.edu/en/simulations/collision-lab

2) Amrita Virtual Mechanics Lab : https://vlab.amrita.edu/?sub=1&brch=74

References (for Laboratory Work):

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worshnop, 1971, Asia Publishing House.

2) Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning India Pvt. Ltd.

3) Practical Physics, G. L. Squires, 2015, 4/e, Cambridge University Press.

4) A Text Book of Practical Physics, Vol I, Prakash and Ramakrishna, 11/e, 2011, Kitab Mahal.

5) An introduction to Error Analysis: The study of uncertainties in Physical Measurements, J. R. Taylor, 1997, University Science Books

Course Code: DSC-2

Course Title: MATHEMATICAL PHYSICS I

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Course Objectives: The emphasis of course is on applications in solving problems of interest to physicists. The course will teach the students to model a physics problem mathematically and then solve those numerically using computational methods. The course will expose the students to fundamental computational physics skills enabling them to solve a wide range of physics problems. The skills developed during course will prepare them not only for doing fundamental and applied research but also for a wide variety of careers.

Course Learning Outcomes: After completing this course, student will be able to,

- Draw and interpret graphs of various elementary functions and their combinations.
- Understand the vector quantities as entities with Cartesian components which satisfy appropriate rules of transformation under rotation of the axes.
- Use index notation to write the product of vectors in compact form easily applicable in computational work.
- Solve first and second order differential equations and apply these to physics problems.
- Understand the functions of more than one variable and concept of partial derivatives.
- Understand the concept of scalar field, vector field and gradient of scalar fields.
- Understand the properties of discrete and continuous distribution functions.

In the laboratory course, the students will learn to,

- Prepare algorithms and flowcharts for solving a problem.
- Design, code and test programs in Python in the process of solving various problems.
- Perform various operations of 1-d and 2-d arrays.
- Visualize data and functions graphically by use of Matplotlib
- Perform least square fitting of a given data
- Solve physics problems involving differentiation

THEORY (Credit: 02; 30 Hours)

Unit 1:

Functions: Plotting elementary functions and their combinations, Interpreting graphs of functions using the concepts of calculus, Taylor's series expansion for elementary functions.

(2 Hours)

Vector Algebra: Transformation of Cartesian components of vectors under rotation of the axes, Introduction to index notation and summation convention, Product of vectors – scalar and vector product of two, three and four vectors in index notation using $!_{ij}$ and s_{ijk} (as symbols only – no rigorous proof of properties), Invariance of scalar product under rotation transformation. **(5 Hours)**

Unit 2:

Ordinary Differential Equations: First order differential equations of degree one and those reducible to this form, Exact and Inexact equations, Integrating Factor, Applications to physics problems

(4 Hours)

Higher order linear homogeneous differential equations with constant coefficients, Wronskian and linearly independent functions. **(3 Hours)**

Unit 3:

Non-homogeneous second order linear differential equations with constant coefficients, complimentary function, particular integral and general solution, Determination of particular integral using method of undetermined coefficients and method of variation of parameters, Cauchy-Euler equation, Initial value problems. Applications to physics problems. **(8 Hours)**

Unit 4:

Multi-Variable Functions: Functions of more than one variable, Partial derivatives, chain rule for partial derivatives. Scalar and vector fields, concept of directional derivative, the vector differential operator $\vec{\$}$, gradient of a scalar field and its geometrical interpretation.

(3 Hours)

Probability Distributions: Discrete and continuous random variables, Probability distribution functions, Binomial, Poisson and Gaussian distributions, Mean and variance of these distributions. **(4 Hours)**

References:

Essential Readings:

1) An introduction to ordinary differential equations, E.A. Coddington, 2009, PHI learning.

2) Differential Equations, George F. Simmons, 2007, McGraw Hill.

3) Mathematical methods for Scientists and Engineers, D.A. McQuarrie, 2003, Viva Book.

4) Advanced Engineering Mathematics, D.G. Zill and W.S. Wright, 5 Ed., 2012, Jones and Bartlett Learning.

5) Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.

6) Probability and Statistics, Murray R Spiegel, John J Schiller and R Alu Srinivasan, 2018, McGraw Hill Education Private Limited.

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

8) Vector Analysis and Cartesian Tensors, D.E. Bourne and P.C. Kendall, 3 Ed. , 2017, CRC Press.

9) Vector Analysis, Murray Spiegel, 2 Ed., 2017, Schaum's outlines series.

10) John E. Freund's Mathematical Statistics with Applications, I. Miller and M. Miller, 7th Ed., 2003, Pearson Education, Asia.

Additional Readings:

1) Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 7 Ed., 2013, Elsevier.

2) Introduction to Electrodynamics, Chapter 1, David J. Griffiths, 4 Ed., 2017, Cambridge University Press.

3) The Feynman Lectures on Physics, Volume II, Feynman, Leighton and Sands, 2008, Narosa Publishing House.

4) Introduction to Vector Analysis, Davis and Snider, 6 Ed., 1990, McGraw Hill.

5) Differential Equations, R. Bronson and G.B. Costa, Schaum's outline series.

6) Mathematical Physics, A.K. Ghatak, I.C. Goyal and S.J. Chua, Laxmi Publications Private Limited (2017)

7) Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.

PRACTICAL (Credit: 02; 60 Hours)

The aim of this laboratory is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics. The course will consist of practical sessions and lectures on the related theoretical aspects of the laboratory. Assessment is to be done not only on the programming but also on the basis of formulating the problem.

At least 12 programs must be attempted covering each unit.

Basics of scientific computing (Mandatory):

(a) Binary and decimal arithmetic, Floating point numbers, single and double precision arithmetic, underflow and overflow, numerical errors of elementary floating point operations, round off and truncation errors with examples.

(b) Introduction to Algorithms and Flow charts. Branching with examples of conditional statements, for and while loops.

Unit 1:

Basic Elements of Python: The Python interpreter, the print statement, comments, Python as simple calculator, objects and expressions, variables (numeric, character and sequence types) and assignments, mathematical operators. Strings, Lists, Tuples and Dictionaries, type conversions, input statement, list methods. List mutability Formatting in the print statement.

Control Structures: Conditional operations, if, if-else, if-elif-else, while and for Loops, indentation, break and continue, List comprehension.

Functions: Inbuilt functions, user-defined functions, local and global variables, passing functions, modules, importing modules, math module, making new modules.

Recommended List of Programs (At least two)

(a) Make a python function that takes a number N as input and returns the value of factorial of N and compare with the output of math.factorial() method. Use this function to print the number of ways a set of m red and n blue balls can be arranged.

(b) Generate random numbers (integers and floats) in a given range and calculate area and volume of regular shapes with random dimensions.

(c) Generate data for coordinates of a projectile and plot the trajectory. Determine the range, maximum height and time of flight for a projectile motion.

Unit 2:

NumPy Fundamentals: Importing Numpy, Difference between List and NumPy array, Adding, removing and sorting elements, creating arrays using ones(), zeros(), random(), arange(), linspace(). Basic array operations (sum, max, min, mean, variance), 2-d and 3-d arrays, matrix operations, reshaping and transposing arrays, savetxt() and loadtxt(), create a Pandas dataframe from an array and then write the data frame to a csv file.

Plotting with Matplotlib: matplotlib.pyplot functions, Plotting of functions given in closed form as well as in the form of discrete data and making histograms.

Recommended List of Programs (At least two)

(a) Plot the displacement-time and velocity-time graph for the undamped, under damped critically damped and over damped oscillator using matplotlib

(b) Use recurrence relation for Legendre polynomials to generate and plot these polynomials for the first few orders using matplotlib.

(c) To generate array of N random numbers drawn from a given distribution (uniform, binomial, poisson and gaussian) and plot them using matplotlib for increasing N to verify the distribution. Verify the central limit theorem.

(d) To implement the transformation of physical observables under Galilean, Lorentz and Rotation transformation.

Unit 3:

Least Square fitting: Algorithm for least square fitting and its relation to maximumlikelihood for normally distributed data.

Make Python function for least square fitting, use it for fitting given data (*x*,*y*) and estimate the parameters *a*, *b* as well as uncertainties in the parameters for the following cases :

(a) Linear ($y = ax + b$)

(b) Power law ($y = ax^b$) and

(c) exponential ($y = ae^{bx}$).

Unit 4:

(a) To find value of π and to integrate a given function using acceptance-rejection method.

(b) Taylor's series expansion: To approximate the functions (e.g. exp(x), sin(x), cos(x),ln(1+x), etc.) by a finite number of terms of Taylor's series and discuss the truncation error.

Numerical Differentiation: Left, right and central approximations for derivative of a function

(a) Program to find the derivative of a function given in closed form. Plot both the function and derivative on the same graph. Plot the error as a function of step size on a log-log graph, study the behaviour of the plot as step size decreases and hence discuss the effect ofround off error.

(b) Applications e.g. determination of slope of tangent to a curve, points of extrema of a given function, etc.

References:

1) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).

2) Documentation of NumPy and Matplotlib : https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/

3) Computational Physics, Darren Walker, 1st Edn, Scientific International Pvt. Ltd (2015).

4) Elementary Numerical Analysis, K. E. Atkinson, 3rd Edn, 2007, Wiley India Edition.

5) An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).

6) Introduction to Numerical Analysis, S. S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.

7) Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India

(2007).

8) Numerical Recipes: The art of scientific computing, William H. Press, Saul A. Teukolsky and William Vetterling, Cambridge University Press; 3rd edition (2007), ISBN-13 : 978-0521880688

Course Code: DSC- 3

Course Title: Waves and Oscillations

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Course Objectives: This course reviews the concepts of waves and oscillations learnt at school from a more advanced perspective and goes on to build new concepts. It begins with explaining ideas of free oscillations and superposition of harmonic motion leading to physics of damped and forced oscillations. The course will also introduce students to coupled oscillators, normal modes of oscillations and free vibrations of stretched strings. Concurrently,in the laboratory component of the course students will perform experiments that expose themto different aspects of real oscillatory systems.

Course Learning Outcomes: On successful completion of this course, the students will have the skill and knowledge to,

- Understand travelling and standing waves, stretched strings
- Understand simple harmonic motion
- Understand superposition of N collinear harmonic oscillations
- Understand superposition of two perpendicular harmonic oscillations
- Understand free, damped and forced oscillations
- Understand coupled oscillators and normal modes of oscillations

THEORY (Credit: 02; 30 Hours)

Unit 1: Wave Motion

Types of waves: Longitudinal and Transverse (General idea). One dimensional plane wave, classical wave equation, standing wave on a stretched string (both ends fixed), normal modes. wave equation. Energy density. Standing waves in a string - modes of vibration. Phase velocity. Travelling wave solution **(10 Hours)**

Unit 2: Simple Harmonic Motion **(12 Hours)**

Differential equation of simple harmonic oscillator, its solution and characteristics, energy in simple harmonic motion, linearity and superposition principle, rotating vector representation of simple harmonic oscillation, motion of simple and compound pendulum (Bar and Kater's pendulum), loaded spring.

Superposition of N collinear harmonic oscillations with (1) equal phase differences and (2) equal frequency differences, Beats

Superposition of two perpendicular harmonic oscillations: Graphical and Analytical Methods. Lissajous Figures with equal and unequal frequencies, effect of variation of phase

Unit 3: Damped and Forced Oscillations (8 Hours)

Damped Oscillations: Equation of motion, dead beat motion, critically damped system, lightly damped system: relaxation time, logarithmic decrement, quality factor

Forced Oscillations: Equation of motion, complete solution, steady state solution, resonance, sharpness of resonance, power dissipation, quality factor.

Unit 4: Coupled Oscillations (6 Hours)

Coupled oscillators, normal coordinates and normal modes, energy relation and energy transfer, di-atomic molecules, representation of a general solution as a linear sum of normal modes, normal modes of N coupled oscillators.

References:

Essential Readings:

1) Vibrations and Waves by A. P. French. (CBS Pub. and Dist., 1987)

2) The Physics of Waves and Oscillations by N.K. Bajaj (Tata McGraw-Hill, 1988)

3) Fundamentals of Waves and Oscillations By K. Uno Ingard (Cambridge University Press, 1988)

4) An Introduction to Mechanics by Daniel Kleppner, Robert J. Kolenkow (McGraw-Hill, 1973)

5) Waves: BERKELEY PHYSICS COURSE by Franks Crawford (Tata McGrawHill, 2007).

6) Classical Mechanics by Peter Dourmashkin, John Wiley and Sons

7) https://phys.libretexts.org/Bookshelves/Classical_Mechanics/classical_Mechanics_(Dourmashkin)

Additional Readings:

1) Fundamentals of Physics, Resnick, Halliday and Walker 10/e, 2013, Wiley.

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

3) University Physics, H. D. Young, R. A. Freedman, 14/e, 2015, Pearson Education.

PRACTICAL (Credit: 02; 60 Hours)

Every student must perform at least 5 experiments

1) Experiments using bar pendulum:

  a) Estimate limits on angular displacement for SHM by measuring the time period at different angular displacements and compare it with the expected value of time period for SHM.

  b) Determine the value of g using bar pendulum.

  c) To study damped oscillations using bar pendulum

2) Study the effect of area of the damper on damped oscillations. Plot amplitude as a function of time and determine the damping coefficient and Q factor for different dampers.To determine the value of acceleration due to gravity using Kater's pendulum for both the cases (a) $T_1 \approx T_2$ and (b) $T_1 \neq T_2$ and discuss the relative merits of both cases by estimation of error in the two cases.

3) Understand the applications of CRO by measuring voltage and time period of a periodic waveform using CRO

4) Study the superposition of two simple harmonic oscillations using CRO: Study of Lissajous figures

5) Experiments with spring and mass system

  a) To calculate g, spring constant and mass of a spring using static and dynamic methods.

  b) To calculate spring constant of series and parallel combination of two springs.

6) To study normal modes and beats in coupled pendulums or coupled springs.

7) To determine the frequency of an electrically maintained tuning fork by Melde's experiment and to verify λ^2 – T Law.

References (For Laboratory Work):

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.

2) Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning India Pvt. Ltd.

3) Practical Physics, G. L. Squires, 2015, 4/e, Cambridge University Press.

4) A Text Book of Practical Physics, Vol I and II, Prakash and Ramakrishna, 11/e, 2011, Kitab Mahal.

5) An introduction to error analysis: The study of uncertainties in Physical Measurements, J. R. Taylor, 1997, University Science Books List of experiments

Course Code: DSC-4

Course Title: Electricity and Magnetism

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Course Objectives: This course reviews the concepts of electromagnetism learnt at school from a more advanced perspective and goes on to build new concepts. The course coversstatic and dynamic electric and magnetic fields due to continuous charge and current distributions respectively.

Course Learning Outcomes: After completing this course, student will be able to,

- Apply Coulomb's law to line, surface, and volume distributions of charges.
- Apply Gauss's law of electrostatics to distribution of charges
- Solve boundary value problems using method of images
- Comprehend the genesis of multipole effects in arbitrary distribution of charges
- Understand the effects of electric polarization and concepts of bound charges in dielectric materials
- Understand and calculate the vector potential and magnetic field of arbitrary current distribution
- Understand the concept of bound currents and ferromagnetism in magnetic materials.

THEORY (Credit: 03; 45 Hours)

Unit 1 **(12 Hours)**

Electric Field and Electric Potential for continuous charge distributions: Electric field due to a line charge, surface charge and volume charge. Divergence of electric field using Dirac Delta function, Curl of electric field, electric field vector as negative gradient of scalar potential, Ambiguities of Electric potential, Differential and integral forms of Gauss's Law, Applications of Gauss's Law to various charge distributions with spherical, cylindrical and planar symmetries.

Boundary Value Problems in Electrostatics: Formulation of Laplace's and Poisson equations. The first and second uniqueness theorems. Solutions of Laplace's and Poisson equations in one dimension using spherical and cylindrical coordinate systems and solutions in three-dimensional using Cartesian coordinates applying separable variable technique.

Unit 2 **(12 Hours)**

Special techniques for the calculation of Potential and Field: The Method of Images is applied to a system of a point charge and finite continuous charge distribution (line charge and surface charge) in the presence of (i) a Plane infinite sheet maintained at constant potential, and (ii) a Sphere maintained at constant potential.

Multipole Expansion: Monopole, dipole and quadrupole potentials at large distances due to an arbitrary charge distribution expressed in terms of Legendre polynomials, negative Gradient of Dipole potential in spherical coordinates.

Unit 3 **(13 Hours)**

Electric Field in Matter: Polarization in matter, Bound charges and their physical interpretation. Field inside a dielectric, Displacement vector D, Gauss' Law in the presence of dielectrics, Boundary conditions for D, Linear dielectrics, Electric Susceptibility and Dielectric Constant, idea of complex dielectric constant due to varying electric field. Boundary value problems with linear dielectrics.

Magnetic Field: Divergence and curl of magnetic field B, Magnetic field due to arbitrary current distribution using Biot-Savart law, Ampere's law, Integral and differential forms of Ampere's Law, Vector potential and its ambiguities, Coulomb gauge and possibility of making vector potential divergenceless, Vector potential due to line, surface and volume currents using Poisson equations for components of vector potential.

Unit 4 **(11 Hours)**

Magnetic Properties of Matter: Magnetization vector. Bound currents, Magnetic intensity. Differential and integral form of Ampere's Law in the presence of magnetised materials. Magnetic susceptibility and permeability. Ferromagnetism (Hund's rule).

Electrodynamics: Faraday's Law, Lenz's Law, inductance, electromotive force, Ohm's law ($\vec{J} = \sigma\vec{E}$), energy stored in a magnetic Field.

References:

Essential Readings:

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

2) Schaum's Outlines of Electromagnetics by J. A. Edminister and M. Nahvi

3) Fundamentals of Electricity and Magnetism, Arthur F. Kip, 2nd Edn.1981, McGraw-Hill.

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

5) Electricity and Magnetism, J. H. Fewkes and J. Yarwood, Vol. I, 1991, Oxford Univ. Press.

Additional Readings:

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

2) Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw

3) Electricity and Magnetism, J. H. Fewkes and J. Yarwood, Vol. I, 1991, Oxford Univ. Press.

4) Problems and Solutions in Electromagnetics (2015), Ajoy Ghatak, K Thyagarajan and Ravi Varshney.

PRACTICAL (Credit: 01; 30 Hours)

Every student must perform at least 06 experiments.

1) Measurement of current and charge sensitivity of ballistic galvanometer
2) Measurement of critical damping resistance of ballistic galvanometer
3) Determination of a high resistance by leakage method using ballistic galvanometer
4) Measurement of field strength B and its variation in a solenoid (determine dB/dx)
5) Determination of an unknown low resistance by Carey Foster's Bridge
6) Measurement of self-inductance of a coil by Anderson's Bridge.
7) Measurement of self-inductance of a coil by Owen's Bridge.
8) To determine the mutual inductance of two coils by the Absolute method.
9) Explore magnetic properties of matter using Arduino: To verify Faraday's law and Lenz's law by measuring the induced voltage across a coil subjected to the varying magnetic field. Also, estimate the dipole moment of the magnet.

References (for Laboratory Work):

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House

2) A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11th Ed., 2011, Kitab Mahal

3) Advanced Level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers

4) Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning

5) Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press

Course Code: DSC-5

Course Title: Electrical Circuit Analysis

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Course Objectives: This course covers the basic circuit concepts in a systematic manner which is suitable for analysis and design. It aims at study and analysis of electric circuits usingnetwork theorems and two-port parameters.

Course Learning Outcomes: At the end of the course the student will be able to,

- Understand the basic concepts, basic laws and methods of analysis of DC and ACnetworks and their difference
- Solve complex electric circuits using network theorems.
- Discuss resonance in series and parallel circuits and also the importance of initial conditions and their evaluation.
- Evaluate the performance of two port networks.

THEORY (Credit: 02; 30 Hours)

Unit 1: (10 Hours)

Circuit Analysis: Ideal voltage source, real voltage source, current source, Kirchhoff's current law, Kirchhoff's voltage law, node analysis, mesh analysis, Star and Delta conversion. **DC Transient Analysis:** Charging and discharging with initial charge in RC circuit, RL circuit with initial current, time constant, RL and RC Circuits with source.

Unit 2: (10 Hours)

AC Circuit Analysis: Sinusoidal voltage and current, Definitions of instantaneous, peak to peak, root mean square and average values, form factor and peak factor (for half-rectified and full-rectified sinusoidal wave, rectangular wave and triangular wave), voltage-current relationship in resistor, inductor and capacitor, phasor, complex impedance, power in AC circuits, sinusoidal circuit analysis for RL, RC and RLC Circuits, resonance in series and parallel RLC Circuits (Frequency Response, Bandwidth, Quality Factor), selectivity,application of resonant circuits.

Unit 3: (10 Hours)

Network Theorems: Principal of duality, Superposition theorem, Thevenin theorem, Norton theorem. Their applications in DC and AC circuits with more than one source, Maximum

Power Transfer theorem for AC circuits, Reciprocity Theorem, Millman's Theorem, Tellegen's theorem

Two Port Networks: Impedance (Z) Parameters, Admittance (Y) Parameters, Transmission Parameters, Impedance matching.

Unit 4: (10 Hours)

Electrical Circuit Analysis Using Laplace Transforms: Analysis of electrical circuits using Laplace Transform for standard inputs, convolution integral, Inverse Laplace transform, transformed network with initial conditions. Transfer function representation. Poles and Zeros. Frequency response (magnitude and phase plots), series and parallel resonances

References:

Essential Readings:

1) Electric Circuits, S. A. Nasar, Schaum's outline series, Tata McGraw Hill (2004)

2) Essentials of Circuit Analysis, Robert L. Boylestad, Pearson Education (2004)

3) Electrical Circuits, M. Nahvi and J. Edminister, Schaum's Outline Series, Tata McGraw-Hill (2005)

4) Fundamentals of Electric Circuits, C. Alexander and M. Sadiku, McGraw Hill (2008)

Additional Reading:

1) Network analysis, M. E. Van Valkenburg, Third edition, Prentice Hall

PRACTICAL (Credit: 02; 60 Hours)

Every student must perform at least seven experiments

1) Verification of Kirchoff's Law.
2) Verification of Norton's theorem.
3) Verification of Thevenin's Theorem.
4) Verification of Superposition Theorem.
5) Verification of Maximum Power Transfer Theorem.
6) Determination of time constant of RC and RL circuit
7) Study of frequency response of RC circuit
8) Study of frequency response of a series and parallel LCR Circuit and determination of its resonant frequency, impedance at resonance, quality factor and bandwidth.
9) Explore electrical properties of matter using Arduino:
   a. To study the characteristics of a series RC Circuit.
   b. To study the response curve of a Series LCR circuit and determine its resonant

frequency, impedance at resonance, quality factor and bandwidth

References (for Laboratory Work):

1) A Textbook of Electrical Technology, B. L. Thareja, A.K. Thareja, Volume II, S. Chand

2) Fundamentals of Electric Circuits, C. Alexander and M. Sadiku, McGraw Hill (2008)

3) Electric Circuits, S. A. Nasar, Schaum's outline series, Tata McGraw Hill (2004)

4) Electrical Circuits, K.A. Smith and R.E. Alley, 2014, Cambridge University Press

5) Electrical Circuit Analysis, K. Mahadevan and C. Chitran, 2nd Edition, 2018, PHI learning Pvt.Ltd.

Course Code: DSC-6

Course Title: Mathematical Physics II

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Course Objectives: The emphasis of course is on applications in solving problems of interest to physicists. The course will also expose students to fundamental computational physics skills enabling them to solve a wide range of physics problems. The skills developed during course will prepare them not only for doing fundamental and applied research but also for a wide variety of careers.

Course Learning Outcomes: After completing this course, student will be able to,

- Understand the concept of divergence and curl of vector fields.
- Perform line, surface and volume integration and apply Green's, Stokes' and Gauss's theorems to compute these integrals. The students will be also enabled to apply these to physics problems.
- Use curvilinear coordinates to problems with spherical and cylindrical symmetries.
- Represent a periodic function by a sum of harmonics using Fourier series

Pre-requisite: DSC course - Mathematical Physics I

THEORY (Credit: 02; 30 Hours)

Unit 1:

Vector Calculus: Divergence and curl of a vector field and their physical interpretation. Laplacian operator. Vector identities, Integrals of vector-valued functions of single scalar variable. **(7 Hours)**

Unit 2:

Multiple integrals, Jacobian. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of vector fields. Flux of a vector field. Gauss divergence theorem, Green's and Stokes' Theorems (no proofs) and their applications.

(8 Hours)

Unit 3:

Orthogonal Curvilinear Coordinates: Orthogonal Curvilinear Coordinates. Scale factors, element of area and volume in spherical and cylindrical coordinate Systems. Derivation of Gradient, Divergence, Curl and Laplacian in Spherical and Cylindrical Coordinate Systems

(6 Hours)

Some Special Integrals: Beta and Gamma Functions and relation between them, expression of integrals in terms of Gamma and Beta Functions. **(3 Hours)**

Unit 4:

Fourier Series: Periodic functions. Orthogonality of sine and cosine functions, Convergence of Fourier series and Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Even and odd functions and their Fourier expansions (Fourier Cosine Series and Fourier Sine Series). Parseval's Identity**.** **(6 Hours)**

References:

Essential Readings:

1) Mathematical methods for Scientists and Engineers, D. A. McQuarrie, 2003, Viva Book.

2) Advanced Engineering Mathematics, D. G. Zill and W. S. Wright, 5 Ed., 2012, Jones and Bartlett Learning.

3) Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.

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

5) Vector Analysis and Cartesian Tensors, D. E. Bourne and P. C. Kendall, 3 Ed., 2017, CRC Press.

6) Vector Analysis, Murray Spiegel, 2nd Ed., 2017, Schaum's outlines series.

7) Fourier analysis: With Applications to Boundary Value Problems, Murray Spiegel, 2017, McGraw Hill Education.

Additional Readings:

1) Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber, F. E. Harris, 7 Ed., 2013, Elsevier.

2) Introduction to Electrodynamics, Chapter 1, David J. Griffiths, 4 Ed., 2017, Cambridge University Presss.

3) The Feynman Lectures on Physics, Volume II, Feynman, Leighton and Sands, 2008, Narosa Publishing House.

4) Introduction to Vector Analysis, Davis and Snider, 6 Ed., 1990, McGraw Hill.

5) Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.

PRACTICAL (Credit: 02; 60 Hours)

The aim of this laboratory is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics. The course will consist of practical sessions and lectures on the related theoretical aspects of the laboratory. Assessment is to be done not only on the programming but also on the basis of formulating the problem. At least 12 programs must be attempted covering each unit. Although Python is recommended for implementation of the algorithms, however, anyprogramming language may use.

Unit 1: Root Finding: Bisection, Newton Raphson and Secant methods for solving roots of equations. Convergence analysis.

Recommended List of Programs (At least two):

a) Determine the depth up to which a spherical homogeneous object of given radius and density will sink into a fluid of given density.
b) Solve transcendental equations like $\alpha = \tan(\alpha)$.
c) To approximate nth root of a number up to a given number of significant digits.

Unit 2: Interpolation: Concept of Interpolation, Lagrange form of Interpolating polynomial. Error estimation, optimal points for interpolation.

Recommended List of Programs (At least one):

a) Write program to determine the unique polynomial of a degree n that agrees with a given set of $(n+1)$ data points (x_i, y_i) and use this polynomial to find the value of y at a value of x not included in the data.
b) Generate a tabulated data containing a given number of values $(x_i, f(x_i))$ of a function f(x) and use it to interpolate at a value of x not used in table.

Unit 3: Numerical Integration:

Newton Cotes Integration methods (Trapezoidal and Simpson rules) for definite integrals. Derivation of composite formulae for these methods and discussion of error estimation.

Gauss quadrature methods of integration with example of Legendre Gauss quadrature.

Recommended List of Programs (At least three):

a) Given acceleration at equidistant time values, calculate position and velocity and plot them.
b) Use integral definition of ln(x) to compute and plot ln(x) in a given range. Use Trapezoidal, Simpson and Gauss quadrature methods and compare the results.
c) Verify the rate of convergence of the composite Trapezoidal, Simpson and Gauss quadrature methods by approximating the value of a given definite integral.
d) Evaluate the Fourier coefficients of a given periodic function (e.g. square wave, triangle wave, half wave and full wave rectifier etc.)
e) Verify the Orthogonality of Legendre Polynomials.
f) Verify the properties of Dirac Delta function using its representation as a sequence of functions.

Unit 4: Solution of Linear system of equations: Solve system of linear equations using Gauss elimination method, need for pivoting. Iterative methods like Gauss Seidel method for solving system of equations

Numerical Solutions of Ordinary Differential Equations: Euler, modified Euler, and Runge-Kutta (RK) second and fourth order methods for solving first order initial value problems (IVP), System of first order differential equations and second order initial value problems. Discussion of errors involved in the approximate solutions obtained by these numerical methods.

Recommended List of Programs (At least two):

a) Solve given first order differential equation (Initial value problems) numerically using Euler RK2 and RK4 methods and apply to the following physics problems:
    a. Radioactive decay
    b. Current in RC and LR circuits with DC source
    c. Newton's law of cooling
b) Write a code to compare the errors in various numerical methods learnt by solving a first order IVP with known solution.
c) Solve a system of first order IVP numerically using Euler and Runge-Kutta methods.
d) Solve second order IVP numerically using Euler and Runge-Kutta methods. Study the solution of a free undamped, overdamped and critically damped harmonic oscillator with application to a mechanical oscillator or a LCR circuit.
e) Solve a forced oscillator problem and study the resonance.

References (for Laboratory work):

1) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).

2) Documentation of NumPy and Matplotlib: https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/

3) Computational Physics, Darren Walker, 1st Edn., Scientific International Pvt. Ltd (2015).

4) Elementary Numerical Analysis, K. E. Atkinson, 3rd Edn., 2007, Wiley India Edition.

5) An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).

6) Introduction to Numerical Analysis, S. S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.

7) Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India (2007).

8) Numerical Recipes: The art of scientific computing, William H. Press, Saul A. Teukolsky and William Vetterling, Cambridge University Press; 3rd Edition (2007)

9) Computational Problems for Physics, R.H. Landau and M.J. Paez, 2018, CRC Press.

GENERIC ELECTIVE (GE) COURSES

Course Code: GE 1 Course Title:

MECHANICS

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Course Objectives: This course reviews the concepts of mechanics learnt at school in a more advanced perspective and goes on to build new concepts. It begins with dynamics of a system of particles and ends with the special theory of relativity. Students will appreciate the concept of rotational motion, gravitation and oscillations. The students will be able to apply the concepts learnt to several real world problems. A brief recapitulation of vector algebra and differential equations is also done to familiarize students with basic mathematical concepts which are necessary for a course on mechanics.

Course Learning Outcomes: Upon completion of this course, students are expected to understand the following concepts.

- Laws of motion and their application to various dynamical situations. And their applications to conservation of momentum, angular momentum and energy.
- Motion of a simple and compound pendulum
- Application of Kepler's laws to describe the motion of satellites in circular orbit.
- The concept of geosynchronous orbits
- Concept of stress and strain and relation between elastic constants
- Postulates of Special Theory of Relativity, Lorentz transformation, relativistic effects on the mass and energy of a moving body.

In the laboratory course, after acquiring knowledge of how to handle measuring instruments (like vernier calliper, screw gauge and travelling microscope) student shall embark on verifying various principles and associated measurable quantities.

THEORY (Credit: 03; 45 Hours)

Unit 1: Recapitulation of Vectors and Ordinary Differential Equation Hours: 10

Vector algebra, scalar and vector product, gradient of a scalar field, divergence and curl of vectors field.

Ordinary Differential Equations: First order homogeneous differential equations, second order homogeneous differential equation with constant coefficients

Unit 2: Fundamentals of Dynamics Hours: 10

Review of Newton's laws of motion, dynamics of a system of particles, centre of mass, determination of centre of mass for discrete and continuous systems having spherical symmetry, Conservation of momentum and energy, Conservative and non-Conservative forces, work – energy theorem for conservative forces, force as a gradient of potential energy.

Unit 3: Rotational Dynamics and Oscillatory Motion **Hours: 12**

Angular velocity, angular momentum, torque, conservation of angular momentum, Moment of inertia, Theorem of parallel and perpendicular axes, Calculation of moment of inertia of discrete and continuous objects (1-D and 2-D).

Idea of simple harmonic motion, Differential equation of simple harmonic motion and its solution, Motion of a simple pendulum and compound pendulum

Unit 4: Gravitation **Hours: 14**

Newton's Law of Gravitation, Motion of a particle in a central force field, Kepler's Laws (statements only), Satellite in circular orbit and applications, geosynchronous orbits

Elasticity

Concept of stress and strain, Hooke's law, elastic moduli, twisting torque on a wire, tensile strength, relation between elastic constants, Poisson's ratio, rigidity modulus

Special Theory of Relativity

Postulates of Special Theory of Relativity, Lorentz transformation, length contraction, time dilation, relativistic transformation of velocity

References:

Essential Readings:

1) Vector Analysis – Schaum's Outline, M.R. Spiegel, S. Lipschutz, D. Spellman, 2nd Edn., 2009, McGraw- Hill Education.

2) An Introduction to Mechanics (2/e), Daniel Kleppner and Robert Kolenkow, 2014, Cambridge University Press.

3) Mechanics Berkeley Physics Course, Vol. 1, 2/e: Charles Kittel, et. al., 2017, McGraw Hill Education

4) Mechanics, D. S. Mathur, P. S. Hemne, 2012, S. Chand.

5) Fundamentals of Physics, Resnick, Halliday and Walker 10/e, 2013, Wiley.

Additional Readings:

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

2) University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.

3) University Physics, H. D. Young, R. A. Freedman, 14/e, 2015, Pearson Education.
4) Engineering Mechanics, Basudeb Bhattacharya, 2/e, 2015, Oxford University Press.
5) Physics for Scientists and Engineers, Randall D Knight, 3/e, 2016, Pearson Education.

PRACTICAL (Credit: 01; 30 Hours)

The teacher is expected to give basic idea and working of various apparatus and instruments related to different experiments. Students should also be given knowledge of recording and analyzing experimental data.

Every student should perform at least 06 experiments from the following list.

1) Measurement of length (or diameter) using vernier calliper, screw gauge and travelling microscope.
2) Study the random error in observations.
3) Determination of height of a building using a sextant.
4) Study of motion of the spring and calculate (a) spring constant and, (b) acceleration due to gravity (g)
5) Determination of moment of inertia of a flywheel.
6) Determination of g and velocity for a freely falling body using digital timing technique.
7) Determination of modulus of rigidity of a wire using Maxwell's needle.
8) Determination of elastic constants of a wire by Searle's method.
9) Determination of value of g using bar pendulum.
10) Determination of value of g using Kater's pendulum.

References (for Laboratory Work):

1) Advanced practical physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
2) Engineering practical physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning India Pvt. Ltd.
3) Practical physics, G. L. Squires, 2015, 4/e, Cambridge University Press.
4) A text book of practical physics, I. Prakash and Ramakrishna, 11/e, 2011, Kitab Mahal.
5) B. Sc. practical physics, Geeta Sanon, R. Chand and Co., 2016.

Course Code: GE 2

Course Title: MATHEMATICAL PHYSICS

Total Credits: 04 (Credits: Theory: 03, Tutorial: 01)

Total Hours: Theory: 45, Tutorial: 15

Course Objectives: The emphasis of course is to equip students with the mathematical tools required in solving problem of interest to physicists. The course will expose students to fundamental computational physics skills and hence enable them to solve a wide range of physics problems.

Course Learning Outcomes: At the end of this course, the students will be able to,

- Understand functions of several variables.
- Represent a periodic function by a sum of harmonics using Fourier series and their applications in physical problems such as vibrating strings etc.
- Obtain power series solution of differential equation of second order with variable coefficient using Frobenius method.
- Understand properties and applications of special functions like Legendre polynomials, Bessel functions and their differential equations and apply these to various physical problems such as in quantum mechanics.
- Learn about gamma and beta functions and their applications.
- Solve linear partial differential equations of second order with separation of variable method.
- Understand the basic concepts of complex analysis and integration.
- During the tutorial classes, students' skill will be developed to solve more problems related to the concerned topics.

Unit 1: (6 Hours)

Fourier series: Periodic functions. Orthogonality of sine and cosine functions, Convergence of Fourier series and Dirichlet Conditions (Statement only). Expansion of periodic functionsin a series of sine and cosine functions and determination of Fourier coefficients. Even andodd functions and their Fourier expansions (Fourier Cosine Series and Fourier Sine Series).

Unit 2: (10 Hours)

Frobenius Method and Special Functions: Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre and Bessel Differential Equations.

Unit 3: (14 Hours)

Some Special Integrals: Beta and Gamma Functions and Relation between them. Expression of integrals in terms of Gamma Functions.

(4 Hours)

Partial Differential Equations: Multivariable functions, Partial derivatives, Functions Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular geometry, Solution of 1D wave equation.

(10 Hours)

Unit 4: **(15 Hours)**

Complex Analysis: Functions of complex variable, limit, continuity, Analytic function, Cauchy-Riemann equations, singular points, Cauchy Goursat Theorem, Cauchy's Integral Formula, Residues, Cauchy's Residue Theorem.

References:

Essential Readings:

1) Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.

2) Complex Variables and Applications, J. W. Brown and R. V. Churchill, 7th Ed. 2003, Tata McGraw-Hill.

3) Advanced Mathematics for Engineers and Scientists: Schaum Outline Series, M. R Spiegel, 2009, McGraw Hill Education.

4) Applied Mathematics for Engineers and Physicists, L.A. Pipes and L.R. Harvill, 2014, Dover Publications.

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

Additional Readings:

1) Mathematical Physics, A.K. Ghatak, I.C. Goyal and S.J. Chua, 2017, Laxmi Publications Private Limited.

2) Advanced Engineering Mathematics, D. G. Zill and W.S.Wright, 5 Ed., 2012, Jones and Bartlett Learning.

3) An introduction to ordinary differential equations, E.A.Coddington, 2009, PHI Learning.

4) Differential Equations, George F. Simmons, 2007, McGraw Hill.

5) Mathematical methods for Scientists and Engineers, D.A.Mc Quarrie, 2003, Viva Books.

Course Code: GE 3

Course Title: WAVES AND OPTICS

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Course Objectives: This coursework reviews the concept of waves and optics learnt at school level from a more advanced perspective and builds new concepts. This course is divided into two main parts. The first part deals with vibrations and waves. The second part pertains to optics and provides the details of interference, diffraction and polarization.

Course Learning Outcomes: After the completion of this course, the students will have learnt the following.

- Simple harmonic motion, superposition principle and its application to find the resultant of superposition of harmonic oscillations.
- Concepts of vibrations in strings.
- Interference as superposition of waves from coherent sources.
- Basic concepts of Diffraction: Fraunhoffer and Fresnel Diffraction.
- Elementary concepts of the polarization of light.

THEORY (Credit: 03; 45 Hours)

Unit 1: (10 Hours)

Superposition of Harmonic Oscillations: Simple harmonic motion (SHM). Linearity and Superposition Principle. Superposition of two collinear harmonic oscillations having (1) equal frequencies and (2) different frequencies (Beats). Superposition of two perpendicular harmonic oscillations: Graphical and Analytical Methods. Lissajous Figures (1:1 and 1:2) and their uses.

Unit 2: (8 Hours)

Waves Motion: Types of waves: Longitudinal and Transverse (General idea).One dimensional plane wave, classical wave equation . Travelling waves in a string, wave equation. Energy density. Standing waves in a string - modes of vibration. Phase velocity.

Unit 3: (12 Hours)

Interference of Light: Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle. Interference: Division of amplitude and division of wave front. Young's Double Slit experiment. Fresnel's Biprism. Phase change on reflection: Stoke's treatment. Interference in Thin Films: parallel and wedge-shaped films. Newton's Rings: measurement of wavelength and refractive index.

Unit 4: (14 Hours)

Diffraction: Fraunhofer diffraction - Single slit, Double slit and Diffraction grating. Fresnel Diffraction - Half-period zones, Zone plate.

Polarization: Transverse nature of light waves. Plane polarized light. Production and detection of linearly polarized light. Malus's Law. Idea of circular and elliptical polarization.

References:

Essential Readings:

1) The Physics of Waves and Oscillations: N K Bajaj, Tata Mcgraw Hill
2) Optics: Ajoy Ghatak, Seventh edition, Mcgraw Hill
3) Principle of Optics: B. K. Mathur and T. P. Pandya, Gopal Printing Press
4) Optics: Brij Lal and N. Subramanyam, S. Chand
5) The Fundamentals of Optics: A. Kumar, H. R. Gulati and D. R. Khanna, R. Chand

Additional Readings:

1) Vibrations and Waves: A. P. French, CRC
2) The physics of Vibrations and Waves: H. J. Pain, Wiley
3) Fundamentals of Optics: Jenkins and White, McGraw Hill
4) Optics: E. Hecht and A R. Ganesan, Pearson, India
5) Introduction to Optics: F. Pedrotti, L. M. Pedrotti and L. S. Pedrotti, Pearson, India

PRACTICAL (Credit: 01; 30 Hours)

Every student must perform at least 05 experiments out of the list following experiments.

1) To determine the frequency of an electrically maintained tuning fork by Melde's experiment and to verify λ^2 – T Law.
2) To study Lissajous Figures.
3) Familiarization with Schuster`s focusing and determination of the angle of prism.
4) To determine the refractive index of the material of a prism using sodium light.
5) To determine the dispersive power of a prism using mercury light.
6) To determine wavelength of sodium light using Newton's rings.
7) To determine wavelength of sodium light using a plane diffraction grating.
8) To verify Malus's Law.
9) To determine the wavelength of Laser light using single slit diffraction. (Due care should be taken not to see Laser light source directly as it may cause injury to eyes.)

References (for Laboratory Work):

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, Asia Publishing House
2) A Text Book of Practical Physics, Indu Prakash and Ramakrishna, Kitab Mahal
3) An advanced course in practical physics, D. Chattopadhyay and P. C. Rakshit, New Central Book Agency

Course Code: GE 4

Course Title: ELECTRICITY AND MAGNETISM

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Course Objectives: This course begins with theorems of network analysis which are required to perform the associated experiments in the laboratory. Then course delves into the elementary vector analysis, an essential mathematical tool for understanding static electric field and magnetic field. By the end of the course student should appreciate Maxwell'sequations.

Course Learning Outcomes (Theory): At the end of this course the student will be able to,

- Apply Coulomb's law to line, surface, and volume distributions of charges.
- Apply Gauss's law of electrostatics to distribution of charges
- Understand the effects of electric polarization and concepts of bound charges in dielectric materials
- Understand and calculate the vector potential and magnetic field of arbitrary current distribution
- Understand the concept of bound currents and ferromagnetism in magnetic materials

THEORY (Credit: 03; 45 Hours)

Unit 1:

Network Analysis: Superposition, Thevenin, Norton theorems and their applications in DC and AC circuits with more than one sources. Maximum Power Transfer theorem for AC circuits

(6 Hours)

Mathematical Preliminaries:

Concept of scalar and vector fields, Gradient of a scalar field, Divergence and curl of vector fields and their physical interpretation, Conservative forces and Laplace and Poisson equations.

(4 Hours)

Unit 2:

Concept of a line integral of a scalar and vector field, surface integral of vector fields and volume integral. Gauss's theorem, Stoke's theorem.

(5 Hours)

Electric Field and Electric Potential for continuous charge distributions: Electric field due to a line charge, surface charge and volume charge distributions, Electric field vector as negative gradient of scalar potential, Ambiguities of Electric potential, Differential and integral forms of Gauss's Law, Applications of Gauss's Law to various charge distributions with spherical, cylindrical and planar symmetries. Uniqueness theorem.

(7 Hours)

Unit 3:

Electric Field in Matter: Bound charges due to polarization and their physical interpretation. Average electric field inside a dielectric, Electric Field in spherical and cylindrical cavities of a dielectric, Displacement vector and its boundary conditions, Gauss' Law in the presence of dielectrics, Linear dielectrics: electric susceptibility and dielectric constant, Boundary value problems with linear dielectrics.

(8 Hours)

Magnetic Field: Divergence and curl of magnetic field B, Magnetic field due to arbitrary current distribution using Biot-Savart law, Ampere's law, integral and differential forms of Ampere's Law, Vector potential and its ambiguities.

(4 Hours)

Unit 4:

Magnetic Properties of Matter: Magnetization vector. Bound Currents, Magnetic Intensity. Differential and integral form of Ampere's Law in the presence of magnetised materials. Magnetic susceptibility and permeability. Ferromagnetism (Hund's rule).

(6 hours)

Electrodynamics: Faraday's Law, Lenz's Law, inductance. Electromotive force, Ohm's Law ($\vec{J} = \sigma\vec{E}$). Energy stored in a Magnetic Field. Charge Conservation, Continuity equation, Differential and integral forms of Maxwell's equations in matter.

(5 hours)

References:

Essential Readings:

1) Introduction to Electrodynamics, D. J. Griffiths, 4th Edn., 2015, Pearson Education India Learning Private Limited.

2) Schaum's Outlines of Electromagnetics, M. Nahvi and J. A. Edminister, 2019, McGraw-Hill Education.

3) Electromagnetic Fields and Waves, Paul Lorrain and Dale Corson, 1991, W. H. Freeman.

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

5) Network, Lines and Fields, John D. Ryder, 2nd Edn., 2015, Pearson.

6) Introductory circuit analysis, R. Boylestead, 2016, Pearson.

7) Electricity and Magnetism, Tom Weideman, University of California Davis. [url: https://zhu.physics.ucdavis.edu/Physics9C-C_2021/Physics%209C_EM%20by%20Tom%20Weideman.pdf]

Additional Readings:

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

2) Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw

3) Fundamentals of Physics, Resnick, Halliday and Walker 10/e, 2013, Wiley

PRACTICAL (Credit: 01; 30 Hours)

Course Learning Outcome (Practical):

- To understand working of Arduino Microcontroller System
- To use Arduino to measure time, count events and time between events
- To use Arduino to measure voltage/current/resistance
- To use Arduino to measure various physical parameters like magnetic field

Unit I (Mandatory)

Arduino Programming

Introduction to Arduino Microcontroller platform. Getting acquainted with the Arduino IDE and Basic Sketch structure. Digital Input and output. Measuring time and events. Measuring analog voltage. Generating analog voltage using Pulse Width Modulation. Serial communication and serial monitor. Programming using Interrupts.

Unit II Exploring electrical properties of matter using Arduino (at least one experiment)

1) To study the characteristics of a series RC Circuit.
2) To study response curve of a Series LCR circuit and determine its (a) Resonant frequency, Impedance at resonance, (c) Quality factor Q, and (d) Band width.
3) Diode Charateristics:
    a) To study characteristics of diode and estimate Boltzman constant.
    b) To study characteristics of LED and estimate Planck's constant

Unit III Exploring magnetic properties of matter using Arduino

To verify Faraday's law and Lenz's law by measuring induced voltage across a coil subjected to varying magnetic field. Also, estimate dipole moment of the magnet.

Unit IV DC and AC Bridges (at least one experiment)

1) To compare capacitances using De Sauty's Bridge
2) To determine a Low Resistance by Carey - Foster Bridge

References (for Laboratory Work):

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.

2) Engineering Practical Physics, S. Panigrahi and B.Mallick, 2015, Cengage Learning India Pvt. Ltd.

3) A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11th Ed.2011, Kitab Mahal

4) Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press

SKILL ENHANCEMENT COURSE (SEC)

Course Code: SEC 1

Course Title: BASIC OF INSTRUMENTS

Total Credits: 02 (Credits: Theory: 00, Practical: 02)

Total Hours: Theory: 00, Practical: 60

Course Objectives: To expose the students to various aspects of instruments and their usage through hands-on mode. To provide them a thorough understanding of basics of measurement, measurement devices such as electronic voltmeter, oscilloscope, signal and pulse generators, impedance bridges, digital instruments etc.

Course Learning Outcomes: At the end of this course the students will learn the following.

- The student is expected to have the necessary working knowledge on accuracy, precision, resolution, range and errors/uncertainty in measurements.
- Course learning begins with the basic understanding of the measurement and errors in measurement. It then familiarizes about each and every specification of a multimeter, multivibrators, rectifiers, amplifiers, oscillators and high voltage probes and their significance with hands on mode.
- Explanation of CRO and their significance. Complete explanation of CRT.
- Students learn the use of CRO for the measurement of voltage (DC and AC), frequency and time period. Covers the Digital Storage Oscilloscope and its principle of working.
- Students learn principles of voltage measurement. Students should be able to understand the advantages of electronic voltmeter over conventional multimeter in terms of sensitivityetc. Types of AC millivoltmeter should be covered.
- Covers the explanation and specifications of Signal and pulse Generators: low frequency signal generator and pulse generator. Students should be familiarized with testing and specifications.
- Students learn about the working principles and specifications of basic LCR Bridge.
- Hands on ability to use digital multimeter and frequency counter.

PRACTICAL (Credit: 02; 60 Hours)

The list of experiments for this course is based on the following topics.

- **Basics of Measurement:** Instruments accuracy, precision, sensitivity, resolution range etc. Errors in measurements and loading effects. Working principle of time interval, frequency and period measurement, time-base stability, accuracy and resolution.
- **Multimeter:** Measurement of dc voltage and dc current, ac voltage, ac current and

resistance. Specifications of electronic voltmeter/multimeter and their significance. AC milli-voltmeter, working of a digital multimeter.

- **Cathode Ray Oscilloscope:** Specifications of CRO with block diagram and their significance. Measurement of voltage (dc and ac), frequency and time period. Special features of dual trace. Digital storage Oscilloscope: principle of working.
- **Signal and Pulse Generators:** Block diagram and specifications of low frequency signal and pulse generators. Distortion factor meter, wave analysis.
- **Impedance Bridges:** Block diagram, working principles of RLC Bridge. Specifications of RLC Bridge. Block diagram and working principles of a Q-Meter. Digital LCR bridges.

List of Experiments:

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

Open Ended Experiments:

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

It is further suggested that students may be motivated to pursue semester long dissertation wherein he/she may do a hands-on extensive project based on the extension of the experiments enumerated above.

References:

Essential Readings:

1) Logic circuit design, Shimon P. Vingron, 2012, Springer.
2) Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.
3) Electronic Devices and circuits, S. Salivahanan and N. S. Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill
4) Digital Circuits and Systems, Venugopal, 2011, Tata McGraw Hill.
5) Electronic Instrumentation, H.S. Kalsi, 3rd Ed. Tata McGraw Hill.

Additional Readings:

1) A text book in Electrical Technology - B L Theraja - S Chand and Co.
2) Performance and design of AC machines - M G Say ELBS Edn.

Course Code: SEC 2

Course Title: NUMERICAL TECHNIQUES

Total Credits: 02 (Credits: Theory: 00, Practical: 02)

Total Hours: Theory: 00, Practical: 60

Course Objectives: The emphasis of course is to equip students with the mathematical tools required in solving problem of interest to physicists and to expose them to fundamental computational physics skills and hence enable them to solve a wide range of physics problems. To help students develop critical skills and knowledge that will prepare them not only for doing fundamental and applied research but also prepare them for a wide variety of careers.

Course Learning Outcomes: The numerical methods given below will be implemented using C/C++ or Python programming language, and hence a basic knowledge of the programming language is desirable. The course will consist of practical sessions including relevant lectures on the following theoretical aspects of the laboratory.

- Errors and iterative methods: Truncation and Round-off Errors. Floating Point Computation, Overflow and underflow. Single and Double Precision Arithmetic
- Solutions of Algebraic and Transcendental Equations: Fixed point iteration method, Bisection method, Secant Method, Newton Raphson method
- Interpolation, Numerical Differentiation, and Integration: Forward and Backward Differences. Symbolic Relation, Newton's Forward and Backward Interpolation Formulas, Integration using Trapezoidal Rule, and Simpson's 1/3 and 3/8 Rules.
- Solution of Ordinary Differential Equations: First Order ODE's: solution of Initial Value problems: Euler's Method, Modified Euler's method, Runge-Kutta method
- Least Square fitting: Linear least square fit on data points, Linearization of exponential function fitting, Fitting using Polynomial of *n*th degree.

PRACTICAL (Credit: 02; 60 Hours)

Every student must perform at least 08 programs from the following list.

1. Algebraic and transcendental equation:

a. To find the roots of an algebraic equation by Bisection method.
b. To find the roots of an algebraic equation by Secant method.

c. To find the roots of an algebraic equation by Newton-Raphson method.
d. To find the roots of a transcendental equation by Bisection method.

2. Interpolation
a. To find the forward difference table from a given set of data values.
b. To find a backward difference table from a given set of data values.

3. 4Differentiation
a. To find the first and second derivatives near the beginning of the table of values of (x,y).
b. To find the first and second derivatives near the end of the table of values of (x,y).

4. Integration
a. To evaluate a definite integral by trapezoidal rule.
b. To evaluate a definite integral by Simpson 1/3 rule.
c. To evaluate a definite integral by Simpson 3/8 rule.

5. Differential Equations
a. To solve differential equations by Euler's method
b. To solve differential equations by modified Euler's method
c. To solve differential equations by Runge-Kutta method

6. Curve fitting
a. To fit a straight line to a given set of data values.
b. To fit a polynomial to a given set of data values.
c. To fit an exponential function to a given set of data values.

References:

1) Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition.
2) Introduction to Numerical Analysis, S.S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
3) Schaum's Outline of Programming with C++. J. Hubbard, 2000, McGraw Hill Pub.
4) Numerical Recipes in C++: The Art of Scientific Computing, W.H. Press et.al., 2nd Edn., 2013, Cambridge University Press.
5) An introduction to Numerical methods in C++, Brian H. Flowers, 2009, Oxford University Press.
6) C++ How to Program', Paul J. Deitel and Harvey Deitel, Pearson (2016).
7) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).

Course Code: SEC 3

Course Title: INTRODUCTION TO PHYSICS OF DEVICES

Total Credits: 02 (Credits: Theory: 01, Practical: 01)

Total Hours: Theory: 15, Practical: 30

Course Objectives: This paper is based on basic electrical and electronics instruments which cover the devices such as diode, photodiode, solar cell, electromagnet etc. This course also covers working of ideal and constant current source; ideal and constant voltage source; and dependent and independent current and voltage source.

Course Learning Outcomes: At the end of this course, students will be able to,

- Develop the basic knowledge of semiconductor device physics and electronic circuits along with the practical technological considerations and applications.
- Understand the operation of devices such as multimeter, current source and voltage source etc.

THEORY (Credit: 01; 15 Hours)

Unit 1: **Hours: 4**

Measurement of Voltage and current: Working of ideal and constant current source, Ideal and constant voltage source, Dependent and independent current and voltage source. Working of moving coil galvanometer, its use as Voltmeter and Ammeter, Use of digital multimeter for measurement of R, L, C, ac and dc voltage and current, type of transistor etc.

Unit 2: **Hours: 4**

Two layered devices: Working principle and I-V characteristics of p-n junction diode, Zener diode, LED, photo-diode and solar cell.

Unit 3: **Hours: 4**

Centre-tapped and Bridge Full-wave Rectifiers,Calculation of ripple factor and rectification efficiency, basic idea about capacitor filter, Working of regulator IC 7805.

Unit 4: **Hours: 5**

Electrical Appliances: Use of capacitor/condenser in electrical motor, Uses of electrical fuses, MCBs, difference between power, neutral and ground in electrical circuits, Use of ground terminal in electrical circuits, Working of IR remote control, microwave oven and water purifier

PRACTICAL (Credit: 01; 30 Hours)

Every student must perform at least 06 experiments for the following list.

1) To examine the performance of a constant current source and constant voltage source.
2) Making voltmeter and ammeter using galvanometer.
3) I-V characteristics of LED
4) Zener diode as voltage regulator.
5) Measurement of efficiency and fill factor of solar cell.
6) Measurement of photocurrent using photodiode with variation in intensity of incident light.
7) To design a regulated power supply (adapter) using bridge rectifier and regulator IC (7805).
8) Design an electrical switch board with fuse and power indicator.
9) The basic idea of First Aid for Electrical Emergencies.

References (For Theory):

Essential Readings:

1) Physics of Semiconductor Devices, S. M. Sze and K. K. Ng, 3rd Edition 2008, John Wiley and Sons

2) Electronic Devices and Circuits, A. Mottershead, 1998, PHI Learning Pvt. Ltd.

3) H. S. Kalsi, Electronic Instrumentation, TMH (2006).

References (For Laboratory Work):

1) PC based instrumentation; Concepts and Practice, N. Mathivanan, 2007, Prentice-Hall of India

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

3) Electrical Wiring Components and Accessories and First Aid for Electrical Emergencies kvdl103.pdf (ncert.nic.in)

Course Code: SEC 4

Course Title: RADIATION SAFETY

Total Credits: 02 (Credits: Theory: 01, Practical: 01)

Total Hours: Theory: 15, Practical: 30

Course Objectives: This course focuses on the applications of nuclear techniques and radiation protection. It will not only enhance the skills towards the basic understanding of the radiation but will also provide the knowledge about the protective measures against radiation exposure. It imparts all the skills required by a radiation safety officer or any job dealing with radiation such as X-ray operators, jobs dealing with nuclear medicine: chemotherapists, operators of PET, MRI, CT scan, gamma camera etc.

Course Learning Outcomes: This course will help students in the following ways.

- Awareness and understanding the hazards of radiation and the safety measures to guard against these hazards.
- Having a comprehensive knowledge about the nature of interaction of matter with radiations like gamma, beta, alpha rays, neutrons etc. and radiation shielding by appropriate materials.
- Knowing about the units of radiations and their safety limits, the devices to detect and measure radiation.
- Learning radiation safety management, biological effects of ionizing radiation, operational limits and basics of radiation hazards evaluation and control, radiation protection standards,
- Learning about the devices which apply radiations in medical sciences, such as X-ray, MRI, PET, CT-scan

THEORY (Credit: 01; 15 Hours)

Unit 1: **Hours: 6**

Radiation and its interaction with matter: Basic idea of different types of radiation electromagnetic (X-ray, gamma rays, cosmic rays etc.), nuclear radiation and their origin.

Nuclear Radiation: Basic idea of Alpha, Beta, Gamma neutron radiation and their sources (sealed and unsealed sources).

Interaction of Charged Particles (including alpha particles): Heavy charged particles (e.g. accelerated ions) - Beth-Bloch Formula, Scaling laws, Mass Stopping Power, Range, Straggling.

Interaction of Beta Particles: Collision and Radiation loss (Bremsstrahlung).
Interaction of Photons: Linear and Mass Attenuation Coefficients.
Interaction of Neutrons: Collision, slowing down and Moderation.

Unit 2: **Hours: 4**

Radiation detection and monitoring devices: Basic concepts and working principle of gas detectors, Scintillation Detectors, Solid State Detectors and Neutron Detectors, Thermo-luminescent Dosimetry.
Radiation Quantities and Units:
Basic idea of different units of activity, KERMA, exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, annual limit of intake (ALI) and derived air concentration (DAC).

Unit 3: **Hours: 2**

Radiation Units, dosage and safety management*:*
Basic idea of different units of activity, KERMA, exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, annual limit of intake (ALI) and Derived air concentration (DAC).
Radiation safety management: Biological effects of ionizing radiation, Operational limits and basics of radiation hazards, its evaluation and control: radiation protection standards.

Unit 4: **Hours: 3**

Application of radiation as a technique: Application in medical science (e.g., basic principles of X-rays, MRI, PET, CT scan, Projection Imaging Gamma Camera, Radiation therapy), Archaeology, Art, Crime detection, Mining and oil. Industrial Uses: Tracing, Gauging, Material Modification, Sterilization, Food preservation.

PRACTICAL (Credit: 01; 30 Hours)

Minimum five experiments need to be performed from the following, graphs to be plotted using any graphical plotting software

1) Estimate the energy loss of different projectiles/ions in Water and carbon, using SRIM/TRIM etc. simulation software, (different projectiles/ions to be used by different students).
2) Simulation study (using SRIM/TRIM or any other software) of radiation depth in materials (Carbon, Silver, Gold, Lead) using H as projectile/ion.
3) Comparison of interaction of projectiles with Z_P = 1 to 92 (where Z_P is atomic number of projectile/ion) in a given medium (Mylar, Carbon, Water) using simulation software(SRIM etc).
4) SRIM/TRIM based experiments to study ion-matter interaction of heavy projectiles on heavy atoms. The range of investigations will be Z_P = 6 to 92 on Z_A = 16 to 92 (where Z_P and Z_A are atomic numbers of projectile and atoms respectively). Draw and infer

appropriate Bragg Curves.

5) Calculation of absorption/transmission of X-rays, γ-rays through Mylar, Be, C, Al, Fe and Z_A = 47 to 92 (where Z_A is atomic number of atoms to be investigated as targets) using XCOM, NIST (https://physics.nist.gov/PhysRefData/Xcom/html/xcom1.html).

6) Study the background radiation in different places and identify the source material from gamma ray energy spectrum. (Gamma ray energies are available in the website http://www.nndc.bnl.gov/nudat2/).

7) Study the background radiation levels using Radiation meter.

8) Study of characteristics of GM tube and determination of operating voltage and plateau length using background radiation as source (without commercial source).

9) Study of counting statistics using background radiation using GM counter.

10) Study of radiation in various materials (e.g. KSO_4 etc.). Investigation of possible radiation in different routine materials by operating GM counter at operating voltage.

11) Study of absorption of beta particles in Aluminum using GM counter.

12) Measurement of gamma ray attenuation co-efficient of aluminium using GM counter.

13) Estimation of half thickness for aluminium using GM Counter.

References:

Essential Readings:

1) Basic ideas and concepts in Nuclear Physics: An introductory approach by K Heyde, third edition, IOP Publication, 1999.

2) Nuclear Physics by S N Ghoshal, First edition, S. Chand Publication, 2010.

3) Nuclear Physics: Principles and Applications by J Lilley, Wiley Publication, 2006.

4) Fundamental Physics of Radiology by W J Meredith and B Massey, John Wright and Sons, UK, 1989.

5) An Introduction to Radiation Protection by A Martin and S A Harbisor , John Willey and Sons, Inc. NewYork, 1981.

Additional Readings:

1) Radiation detection and measurement by G F Knoll, 4th Edition, Wiley Publications, 2010.

2) Techniques for Nuclear and Particle Physics experiments by W R Leo, Springer, 1994.

3) Thermoluminescence dosimetry by A F Mcknlay, Bristol, Adam Hilger (Medical Physics Hand book 5

4) Medical Radiation Physics by W R Hendee, Year book Medical Publishers, Inc., London, 1981.

5) Physics and Engineering of Radiation Detection by S N Ahmed, Academic Press Elsevier, 2007.

6) IAEA Publications: (a) General safety requirements Part 1, No. GSR Part 1 (2010), Part 3 No. GSR Part 3 (Interium) (2010); (b) Safety Standards Series No. RS-G-1.5 (2002), Rs-G-1.9 (2005), Safety Series No. 120 (1996); (c) Safety Guide GS-G-2.1 (2007).

References (for Laboratory Work):

1) Schaum's Outline of Modern Physics, McGraw-Hill, 1999.

2) Schaum's Outline of College Physics, by E. Hecht, 11th edition, McGraw Hill, 2009.

3) Modern Physics by K Sivaprasath and R Murugeshan, S Chand Publication, 2010.

4) AERB Safety Guide (Guide No. AERB/RF-RS/SG-1), Security of radioactive sources inradiation facilities, 2011

5) AERB Safety Standard No. AERB/SS/3 (Rev. 1), Testing and Classification of sealedRadioactivity Sources., 2007.