PANJAB UNIVERSITY, CHANDIGARH (INDIA)

(Established under the Panjab University Act VII of 1947 enacted by the Govt. of India)

FACULTY OF SCIENCE

SYLLABI

FOR

B. Sc. (Honours) in Physics
(4 Years Programme as per NEP-2020)
Under the Framework of Honours School System

and

Syllabi of B. Sc. (Honours) in Physics
Ist & IInd semester

Department of Physics
Panjab University, Chandigarh

Academic Session (2023-2024)

PANJAB UNIVERSITY, CHANDIGARH

OUTLINES OF TESTS, SYLLABI AND COURSES OF READING FOR B.Sc. (HONOURS) IN PHYSICS UNDER THE FRAMEWORK OF HONOURS SCHOOL SYSTEM
(NEP 2020) EXAMINATION, 2023-2024

About the Programme:

Integrated B.Sc.- M.Sc. (Physics) under Honors School system is a five-year regular programme. There are ten semester in this programme each of sixteen week duration. Teaching and learning process of this programme involes theory and practical classes along with seminar presentations and research project work.

The curriculum will be taught throgh formal lectures with the aid of audio and video tools, and other teaching aids as and when required. Emphasis will be given to problem solving, laboratory work and visits to national laboratories/industries to give hands-on experience to students. The aim of the programme are as follows:
The syllabus will opted by the student. The syllabus contents are in accordance with NEP 2020 for B.Sc. (Hons.) in Physics.

1. To teach the fundamental concepts of Physics and their applications.
2. Provide comprehensive knowledge, and improve theoretical and practical skills of Physics subject and other Science subjects
3. Introduce advanced ideas and techniques that are applicable in respective field.
4. Develop the ability of students to perform, observe, analyse and report experiments.
5. Develop the ability of students to deal with physical models and formulas mathematically.
6. Equip the students with different practical, intellectual and transferable skills to aplly these in real world
7. Provide the students with computational tools and mathematical models to be used in solving professional problems.
8. Improve the inter-disciplinary skills of the students.
9. Prepare the students for career in academia, self employment and industry.

Qualification Descriptors:

Upon sucessful completion of the course, students will receive a degree/diploma/certificate based on the credits acquired. The sstudents will be able to demonstrate their knowledge in advanced braches of Physics and to persue higher studies. The possible carear paths are:

1. Teaching assignments
2. Scientific assignments
3. Istrument development including scientic, medical device, laser detectors and electronics.
4. Research and Development in the industries.
5. Simulation techniques development.
6. Carear in renewable energy resources.
7. Astronomer

Programme Outcomes (PO):

Students will have opportunity to learn and master the following components in addition to attaining essential skills and abilities:

PO	Component	Outcomes
PO-1	Basic knowledge	Capable of delivering basic disciplinary knowlwdge gained during the programme
PO-2	In-depth knowledge	Capable of delivering advanced knowledge gained during the programme
PO-3	Critical thinking and problem solving ability	Capable of analysing the results critically and apply acquired knowledge to solve the problems
PO-4	Creativity and innovation	Capable to identify, formulate, investigate, and analyze scientific problems and innovatively design, creat products and solve real-life problems.
PO-5	Research aptitude and global competency	Ability to develop a research aptitude and apply knowledge to find research problems in the concerned and associated fields at the national and international level.
PO-6	Holistic and multidisciplinary education	Ability to gain knowledge with the holistic and multidisciplinary approach across the fields.
PO-7	Skills enhancement	Learn disciplinary or multidisciplinary skills and advanced techniques and apply them for the betterment of the society.
PO-8	Leadership and teamwork abilities	Ability to learn and work in groups and capable of leading a team.
PO-9	Environmental and human health awareness	Learn important aspects associated with environmental and human health. Ability to develop eco-friendly technologies.
PO-10	Ethical thinking and social awareness	Inculcate the professional and ethical attitude and ability to relate to social problems.
PO-11	lifelong learning skills and Entrepreneurship	Ability to develop lifelong learning skills which are important to provide better opportunities and improve quality of life. Capable to establish an independent startup/innovation center etc.

PROGRAMME SPECIFIC OUTCOMES (PSOs):

The students shall be able to realize the following specific outcomes by the end of program:

Number	Programme Specific Outcomes
PSO-1	Identify, formulate, and solve Physics problems
PSO-2	Design and conduct experiments, analyze results and interpret data
PSO-3	Apply knowledge of Physics in a different stream of science and to communicate effectively.
PSO-4	Ability to use the techniques, skills, and modern physical tools in a real-world application. Ability to use sophisticated instruments.
PSO-5	Engage in life-long learning.
PSO-6	Develop research oriented skills

Graduate Attributes:

Some of the characteristic attributes of a graduate in Physics are:

1. Disciplinary knowledge and skills: Capable of demonstrating a good knowledge and understanding of major concepts, theoretical principles and experimental findings in Physics and its different fields like Condesed Matter Physics, Nuclear and Particle Physics, Space science and other related fields of study, including broader interdisciplinary subfields like Chemistry, Mathematics, Life sciences, Environmental sciences, Atmospheric Physics, Computer science, Information Technology, etc. Ability to use modern instrumentation and laboratory techniques to design and perform experiments is highly desirable in almost all the fields of Physics.

2. Skilled communicator: Ability to transmit complex technical information relating to various areas of Physics in a clear and concise manner in writing and oral ability to present complex and technical concepts in a simple language for better understanding.

3. Critical thinker and problem solver: Ability to employ critical thinking and efficient problem-solving skills in the basic areas of Physics.

4. Sense of inquiry: Capability for asking relevant/appropriate questions relating to the issues and problems in the field of the subject; and planning, executing, and reporting the results of a theoretical or experimental investigation.

5. Team player/worker: Capable of working effectively in diverse teams in both classroom, laboratory, workshop, and in industry and field-based situations.

6. Skilled project manager: Capable of identifying/mobilizing appropriate resources required for a project, and managing a project till the end, while observing responsible and ethical scientific conduct; and safety and laboratory hygiene regulations and practices.

7. Digitally efficient: Capable of using computers for simulation studies in Physics and computation. Capable to use appropriate software for numerical and statistical analysis of data, and employing modern e-library search tools like Inflibnet, various websites of the renowned Physics labs in countries like the USA, Europe, Japan, etc. to locate, retrieve, and evaluate Physics information.

8. Ethical awareness/reasoning: capable of demonstrating the ability to think and analyze rationally with a modern and scientific outlook and identify ethical issues related to one's work, avoid unethical behavior such as fabrication, falsification data or committing plagiarism, not adhering to intellectual property rights.

9 National and international perspective: Able to develop a national as well as international perspective for their career in the chosen field of the academic/professional activities. They should prepare themselves during their most formative years for their appropriate role in contributing toward the national development and projecting our national priorities at the international level pertaining to their field of interest and future expertise.

10. Lifelong learners: Capable of self-paced and self-directed learning aimed at personal development and for improving knowledge/skill development and reskilling in all areas of Physics.

1st Year Course Structure, B.Sc. (Hons.) in Physics under the Frame Work of Honours School System of Panjab University & in Accordance with NEP-2020

SEMESTER I (Credits = 24, Marks = 600)		SEMESTER II (Credits = 24, Marks = 600)	
C1	PHY-DSC-101: Mathematical Physics Credits -3, Marks-75	**C3**	PHY-DSC-203: Electricity and Magnetis Credits -3, Marks -75
C2	PHY-DSC-102: Mechanics Credits-3, Marks-75	**C4**	PHY-DSC-204: Waves and Optics Credits-3, Marks -75
SEC1	PHY-SEC-101: Laboratory Credits-3, Marks -75	**SEC2**	PHY-SEC-202: Laboratory Credits-3, Marks -75
AECC1*	PHY-AECC1: English/ Environmental Science Credits -2, Marks -50	**AECC3***	PHY-AECC2: English/ Environmental Science Credits -2, Marks -50
AECC2*	MIL Credit-2, Marks -50	**AECC4***	MIL Credit-2, Marks -50
M1*	PHY-M-101 Credits- 4+2** Theory Marks – 100, Lab Marks -50	**M2***	PHY-M-202 Credits- 4+2** Theory Marks – 100, Lab Marks - 50
IMD1*	PHY-IMD-101 Credits-2+1, Marks -75	**IMD2***	PHY-IMD-202 Credits – 2+1, Marks - 75
CVAC1*	Credits -2 , Marks -50	**CVAC2***	Credits -2, Marks -50

C/DSC: Core Courses/ Discipline Specific Courses; GE: General Elective; AECC: Ability Enhancement Course; SEC: Skill Enhancement Course; CVAC: Common Value Added Course; IMD1 and IMD2: Inter or Multi Disciplinary Course,*Courses to be taken at other departments;** Credit Structure for Minors Offered at Physics Department.

Note 1:

M1* and M2*, IMD1*, IMD2*, CVAC1* and CVAC2* are courses to be taken by physics students in other departments. M1*, M2*, IMD1* and IMD2* offered at physics department for students of other department

Note2:

Minimum Credits Required to get Certificate Course in Physics = 40 + 4 #

Exit 1: Certificate Course - Student can Exit after completion of 1st year having secured 40 Credits and will be awarded a UG Certificate provided they complete a vocational course/internship of 4 credits during the summer vacation of the first year, in addition to the 6 credits from skill based courses earned during first and second semester

Note3: (M1*, M2*) and (IMD1*, IMD2*) to be taken in different departments and will be governed by the common central rules of the Panjab University.

Semester I
MAJOR COURSE (PHYSICS)

Theory Papers:

Major Course-1 (C1): Mathematical Physics – I 75 Marks (3 credits)

PHY-DSC-101
Major Course-2 (C2): Mechanics 75 Marks (3 credits)
PHY-DSC-102

Skill Enhancement Course:
Work shop practices
Major Course-1 Practical (C1 Lab): Mathematical Physics – I 75 Marks (3 credits)
PHY-SEC-101
Major Course-2 Practical (C2 Lab): Mechanics
PHY-SEC-101

ABILITY ENHANCEMENT COURSE

Each student has to opt one Ability Enhancement Compulsory Course of the following:

1. English 50 Marks (2 credits)
2. Environmental Science 50 Marks (2 credits)

MINOR

Each student may opt for one of the generic electives (M1, M2) offered by the other Departments of Panjab University out of following:
(i) Mathematics
(ii) Chemistry
(iii) Economics
(iv) Computer Science
(v) Statistics
(vi) Geology

Minor -1 (M1) 150 Marks (6 credits)

Inter or Multi Disciplinary Course

Each student may opt for one of the Inter or Multi Disciplinary course (IMD1) offered by the other Departments of Panjab University out of the following:

(i) Mathematics
(ii) Chemistry
(iii) Economics
(iv) Computer Science
(v) Statistics
(vi) Geology

IMD1- 75 Marks (3 credits)

Common Value Added Course

Each student may opt for one of the common value added course offered by the other Departments of Panjab University from the list given by central time table.

CVAC 50 marks (2 credits)

Semester II
MAJOR COURSE (PHYSICS)
Theory Papers:

Major Course-3 (C3): PHY-DSC-203	Electricity and Magnetism	75 Marks (3 credits)
Major Course- 4 (C4): PHY-DSE-204	Waves and Optics	75 Marks (3 credits)

Skill Enhancement Course:
Work shop practices (PHY-SEC-202)

Major Course-3 Practical (C3 Lab):	Electricity and Magnetism	75 Marks (3 credits)
Major Course-4 Practical (C4 Lab):	Waves and Optics	

ABILITY ENHANCEMENT COURSE

Each student has to opt one Ability Enhancement Course (other than selected in first semester) of the following :

English	50 Marks (2 credits)
Environmental Science	50 Marks (2 credits)

MINOR

Each student may opt for one of the generic electives (M1, M2) offered by the other Departments of Panjab University out of following:

(i) Mathematics
(ii) Chemistry
(iii) Economics
(iv) Computer Science
(v) Statistics
(vi) Geology

Minor -1 (M1) 150 Marks (6 credits)

Inter or Multi Disciplinary Course

Each student may opt for one of the Inter or Multi Disciplinary course (IMD1) offered by the other Departments of Panjab University out of the following:

(i) Mathematics
(ii) Chemistry
(iii) Economics
(iv) Computer Science
(v) Statistics

(vi) Geology

IMD1- 75 Marks (3 credits)

Common Value Added Course

Each student may opt for one of the common value added course offered by the other Departments of Panjab University from the list given by central time table.

CVAC 50 marks (2 credits)

EVALUATION

1. There shall be one Mid Term Examination of 20% Marks (20 marks) for theory papers in each semester. End-semester examination will be of 80% of total marks (80 marks).

2. **Evaluation of Practicals for Core Subjects** - The practical examination of all the core/DSE courses in a particular semester will be held together. There shall be internal assessment component for practicals of all the core courses having weightage of 20% of the allocated marks. It will be based on performance of the students in the laboratory, viva voice of each experiment, regularity (attendance) in the class and number of experiments performed. The final end-semester examination of all the core courses will be of 80% of the total marks and 4 (3+1) hours duration. The evaluation will be based on the following components for each of the Core courses:

   (i) There may be a written comprehensive test of 60 minutes duration containing short answer questions
   and covering all the experiments. It will be consisting of various sections corresponding to the core
   courses. The test will have a weightage of 20 % of the total allocated marks and will be jointly set by
   the teachers involved in the examination.
   (ii) Viva voce by the external examiner (weightage - 20%) related to the practicals core courses.
   (iii) Performance in the experiments done during the Practical examination (weightage - 40 %)

3. **Evaluation of Practicals for Generic Elective Subjects** - There shall be internal assessment for practicals having weightage of 20% marks of the total marks. It will be based on performance of the students in the laboratory, viva voice of each experiment, regularity (attendance) in the class and number of experiments performed. The final end-semester examination will be of 80% marks and 3 hours duration. The evaluation will be based on the following components with equal weightage:

(i) performance in the allotted Experiment and,
(ii) evaluation by the External examiner in the end-semester examination.

   4.Evaluation in Skill Development Courses : Projects/Jobs will be allocated to the students and will
   be evaluated by a Committee during
   (i) the midterm interaction with weightage 30 %,
   (ii) end-semester evaltion based on the presentation and project report, and innovation will be given
   extra credits.

3. To qualify a Course consisting of Theory and Practical parts, the student has to obtain minimum of 40% marks in each of the examinations held for the Theory and Practical parts. Failing in one component (Theory/Practical), the candidate has to reappear in that component only.

EXIT OPTION: Certificate in Physics

Minimum Credits Required to get Certificate Course in Physics = 40 + 4 #

Exit 1: Certificate Course - Student can Exit after completion of 1st year having secured 40 Credits and will be awarded a UG Certificate provided they complete a vocational course/internship of 4 credits during the summer vacation of the first year, in addition to the 6 credits from skill based courses earned during first and second semester

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Semester I

PHY-DSC-101: MATHEMATICAL PHYSICS-I

THEORY

Total Lectures: 45 **Credits: 3**

Max. Marks: 75

Objective*: The emphasis of course is on applications in solving problems of interest to physicists. The objective of the course is to equip the student with the mathematical techniques that are required for understanding theoretical treatment in different Physics subjects being taught.*

Calculus:

Recapitulation: Limits, continuity, average and instantaneous quantities, differentiation. Plotting functions. Intuitive ideas of continuous, differentiable, etc. functions and plotting of curves. Approximation: Taylor and binomial series (statements only). **(2 Lectures)**

First Order and Second Order Differential equations: First Order Differential Equations and Integrating Factor. Homogeneous Equations with constant coefficients. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems. Particular Integral. **(10 Lectures)**

Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers. **(5 Lectures)**

Vector Calculus: Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields.

(5 Lectures)

Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities. **(5 Lectures)**

Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes

Theorems and their applications (no rigorous proofs). **(8 Lectures)**

Orthogonal Curvilinear Coordinates: Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems. **(4 Lectures)**

Introduction to probability:

Independent random variables: Probability distribution functions; binomial, Gaussian, and Poisson, with examples. Mean and variance.

Dependent events: Conditional Probability. Bayes' Theorem and the idea of hypothesis testing. **(4 Lectures)**

Dirac Delta function and its properties:

Definition of Dirac delta function. Representation as limit of a Gaussian function and rectangular function. Properties of Dirac delta function. **(2 Lectures)**

Suggested Reading

1. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 2013, 7th Edn., Elsevier.
2. An introduction to ordinary differential equations, E.A. Coddington, 2009, PHI learning
3. Differential Equations, George F. Simmons, 2007, McGraw Hill.
4. Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.
5. Mathematical methods for Scientists and Engineers, D.A. McQuarrie, 2003, Viva Book
6. Advanced Engineering Mathematics, D.G. Zill and W.S. Wright, 5 Ed., 2012, Jones and Bartlett Learning
7. Mathematical Physics, Goswami, 1st edition, Cengage Learning
8. Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press
9. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
10. Essential Mathematical Methods, K.F.Riley & M.P.Hobson, 2011, Cambridge Univ. Press

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PHY-DSC-102: MECHANICS

THEORY

Total Lectures: 45 **Credits: 3**

Max. Marks: 75

Objective: *The purpose of the course is to train the students in the Newtonian Mechanics*

and Special Theory of Relativity formalisms to an extent that they can use these in the modern branches of Physics.

Fundamentals of Dynamics: Reference frames. Inertial frames; Review of Newton's Laws of Motion. Galilean transformations; Galilean invariance. Momentum of variable-mass system: motion of rocket. Motion of a projectile in Uniform gravitational field. Conservation of Energy, Conservative forces, Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum. Impulse. Angular Momentum about the Centre of mass, Rotational invariance, Shape of Galaxy. **(4 Lectures)**

Work and Energy: Work and Kinetic Energy Theorem. Conservative and non-conservative forces. Potential Energy. Energy diagram. Stable and unstable equilibrium. Elastic potential energy. Force as gradient of potential energy. Work & Potential energy. Work done by non-conservative forces. Law of conservation of Energy. **(4 Lectures)**

Elastic and Inelastic Scattering : Types of scattering and conservation laws, Laboratory and centre of mass systems, collision of particles which stick together, General elastic collision of particles of different mass, Cross-section of elastic scattering, Rutherford scattering. **(3 Lectures)**

Rotational Dynamics: Angular momentum of a particle and system of particles.
Torque. Principle of conservation of angular momentum. Rotation about a fixed axis. Moment of Inertia. Calculation of moment of inertia for rectangular, cylindrical and spherical bodies. Kinetic energy of rotation. Motion involving both translation and rotation. Cylinder on an accelerated rough plane, Behaviour of angular momentum vector, Principal axes and Euler's equations, Elementary Gyroscope, Symmetrical Top. **(7 Lectures)**

Elasticity: Relation between Elastic constants. Twisting torque on a Cylinder or Wire. **(3 Lectures)**

Fluid Motion: Kinematics of Moving Fluids: Poiseuille's Equation for Flow of a Liquid through a Capillary Tube. **(2 Lectures)**

Gravitation and Central Force Motion: Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere. Force between a Point Mass and Spherical shell. Force between a Point Mass and Solid Sphere, Gravitational and Electrostatic self-energy. Gravitational energy of the Galaxy and of uniform sphere. **(3 Lectures)**

Motion of a particle under a central force field. Two-body problem and its reduction to one-body problem and its solution. The energy equation and energy diagram. Kepler's Laws. Satellite in circular orbit and applications. Geosynchronous orbits. Weightlessness. Basic idea of global positioning system (GPS). **(4 Lectures)**

Oscillations: SHM: Simple Harmonic Oscillations. Differential equation of SHM and its solution. Kinetic energy, potential energy, total energy and their time-average values. Damped oscillation. Forced oscillations: Transient and steady states; Resonance, sharpness of resonance; power dissipation and Quality Factor. **(4 Lectures)**

Non-Inertial Systems: Non-inertial frames and fictitious forces. Uniformly rotating frame. Laws of Physics in rotating coordinate systems. Centrifugal force. Coriolis force and its applications. Components of Velocity and Acceleration in Cylindrical and Spherical Coordinate Systems. **(4 Lectures)**

Special Theory of Relativity: Michelson-Morley Experiment and its outcome. Postulates of Special Theory of Relativity. Lorentz Transformations. Simultaneity and order of events. Lorentz contraction. Time dilation. Relativistic transformation of velocity, frequency and wave number. Relativistic addition of velocities. Variation of mass with velocity. Massless Particles. Mass-energy Equivalence. Relativistic Doppler effect. Relativistic Kinematics. Transformation of Energy and Momentum, Transformation of Force, Four vectors. Problems of Relativistic Dynamics: Acceleration of charged particle by constant electric field, transverse Electric field.

(8 Lectures)

Suggested Reading

1.An introduction to mechanics, D. Kleppner, R.J. Kolenkow, 1973, McGraw-Hill.
2.Mechanics, Berkeley Physics, vol.1, C.Kittel, W.Knight, et.al. 2007, Tata McGraw-Hill.
3.Physics, Resnick, Halliday and Walker 8/e. 2008, Wiley.
4.Analytical Mechanics, G.R. Fowles and G.L. Cassiday. 2005, Cengage Learning.
5.Feynman Lectures, Vol. I, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education
6.Introduction to Special Relativity, R. Resnick, 2005, John Wiley and Sons.
7.University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.

Additional Suggested Reading

1.Mechanics, D.S. Mathur, S. Chand and Company Limited, 2000
2.University Physics. F.W Sears, M.W Zemansky, H.D Young 13/e, 1986, Addison Wesley
3.Physics for scientists and Engineers with Modern Phys., J.W. Jewett, R.A. Serway, 2010,

Cengage Learning
4.Theoretical Mechanics, M.R. Spiegel, 2006, Tata McGraw Hill.

Skill Enhancement Course:
Work shop practices
Major Course-1 Practical (C1 Lab): Mathematical Physics – 175 Marks (3 credits)
Major Course-2 Practical (C2 Lab): Mechanics

Total Lectures / Class: 90 hrs **Credits:3 Max. Marks: 75**

PHY-SEC-101: MATHEMATICAL PHYSICS-I

PRACTICALS

***Objective**: The aim of this Lab is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics.*

- *Highlights the use of computational methods to solve physical problems*
- *The course will consist of lectures (both theory and practical) in the Lab*
- *Evaluation done not on the programming but on the basis of formulating the problem*
- *Aim at teaching students to construct the computational problem to be solved*
- *Students can use any one operating system Linux or Microsoft Windows*

***Note:** The experiments listed in the Practical Part of the Core Papers, i.e., PHY-C1P: Mathematical Physics–I, PHY-C2P: Mechanics, PHY-C3P: Electricity and Magnetism and PHY-C4P: Waves and Optics, are to be clubbed together and will be performed by the students during the Semesters I and II. Basic experiments of these core papers will be covered in Semester I and the rest will be done in Semester II. **15** experiments are to be performed in each Semester without repetition. General evaluation procedure has been defined under the heading "Evaluation" in the beginning of the syllabus.*

Topics	**Description with Applications**
Introduction and Overview	Computer architecture and organization, memory and Input/output devices
Basics of scientific computing	Binary and decimal arithmetic, Floating point numbers, algorithms, Sequence, Selection and Repetition, single and double precision arithmetic, underflow & overflow- emphasize the importance of making equations in terms of dimensionless variables, Iterative methods
Errors and error Analysis	Truncation and round off errors, Absolute and relative errors, Floating point computations.
Review of C & C++ Programming fundamentals	Introduction to Programming, constants, variables and data types, operators and Expressions, I/O statements, scanf and printf, c in and c out, Manipulators for data formatting, Control statements (decision making and looping statements) (*If statement. If else Statement. Nested if Structure. Else-if Statement. Ternary*

	Operator. Goto Statement. Switch Statement. Unconditional and Conditional Looping. While Loop. Do-While Loop. FOR Loop. Break and Continue Statements. Nested Loops), Arrays (*1D & 2D*) and strings, user defined functions, Structures and Unions, Idea of classes and objects.
Programs:	Sum & average of a list of numbers, largest of a given list of numbers and its location in the list, sorting of numbers in ascending descending order, Binary search
Random number generation	Area of circle, area of square, volume of sphere, value of pi (**π**)
Solution of Algebraic and Transcendental equations by Bisection, Newton Raphson and Secant methods	Solution of linear and quadratic equation, solving $\alpha = \tan\alpha$; $I = I_o \left[\frac{\sin\alpha}{\alpha}\right]^2$ in optics
Interpolation by Newton Gregory Forward and Backward difference formula, Error estimation of linear interpolation	Evaluation of trigonometric functions e.g. *sin θ, cos θ, tan θ etc.*
Numerical differentiation (Forward and Backward difference formula) and Integration (Trapezoidal and Simpson rules), Monte Carlo method	Given Position with equidistant time data to calculate velocity and acceleration and vice versa. Find the area of B-H Hysteresis loop
Solution of Ordinary Differential Equations (ODE) First order Differential equation Euler, modified Euler and Runge-Kutta (RK) second and fourth order methods	First order differential equation □ Radioactive decay □ Current in RC, LC circuits with DC source □ Newton's law of cooling □ Classical equations of motion Attempt following problems using RK 4 order method: Solve the coupled differential equations

	$\frac{dx}{dt} = y + x - \frac{x^3}{3}; \ \frac{dy}{dt} = -x$ for four initial conditions x(0) = 0, y(0) = -1, -2, -3, -4. Plot x vs y for each of the four initial conditions on the same screen for $0 \le t \le 15$ The differential equation describing the motion of a pendulum is $\frac{d^2\theta}{dt^2} = -\sin\theta$. The pendulum is released from rest at an angular displacement α and $\theta'(0) = 0$. Solve the equation for $\alpha = 0.1, 0.5$ and 1.0 and plot θ as a function of time in the range $0 \le t \le 8\pi$. Also plot the analytic solution valid for small θ ($\sin\theta = \theta$)

Suggested Reading

1. Introduction to Numerical Analysis, S.S. Sastry, 5th Edn. , 2012, PHI Learning Pvt. Ltd.
2. Schaum's Outline of Programming with C++. J. Hubbard, 2000, McGraw-Hill Pub.
3. Numerical Recipes in C: The Art of Scientific Computing, W.H. Pressetal, 3rd Edn. , 2007, Cambridge University Press.
4. A first course in Numerical Methods, U.M. Ascher & C. Greif, 2012, PHI Learning.
5. Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn . , 2007 , Wiley India Edition.
6. Numerical Methods for Scientists & Engineers, R.W. Hamming, 1973, Courier Dover Pub.
7. An Introduction to computational Physics, T.Pang, 2nd Edn. , 2006,Cambridge Univ. Press
8. Computational Physics, Darren Walker, 1st Edn., 2015, Scientific International Pvt. Ltd.

PHY-SEC-102: MECHANICS

PRACTICAL

Objective*: The laboratory exercises have been so designed that the students learn to verify some of the concepts learnt in the theory courses. They are trained in carrying out precise measurements and handling sensitive equipments.*

Note: *The experiments listed in the Practical Part of the Core Papers, i.e., PHY-C1P: Mathematical Physics–I, PHY-C2P: Mechanics, PHY-C3P: Electricity and Magnetism and PHY-C4P: Waves and Optics, are to be clubbed together and will be performed by the students during the Semesters I and II. Basic experiments of these core papers will be covered in Semester I and the rest will be done in Semester II.* ***15*** *experiments are to be*

performed in each Semester without repetition. General evaluation procedure has been defined under the heading "Evaluation" in the beginning of the syllabus.

1. Use of Vernier callipers, Screw gauge, Spherometer, Barometer, Sphygmomanometer, Lightmeter, dry and wet thermometers, TDS/conductivity meter and other measuringinstruments based on applications of the experiments. Use of Plumb line and Spirit level.
2. To study the random error in observations.
3. Determination of height (of inaccessible structure) using sextant.
4. To study the Motion of Spring and calculate (a) Spring constant, (b) g and (c) Modulus of rigidity.
5. To determine the Moment of Inertia of a Flywheel.
6. To determine g and velocity for a freely falling body using Digital Timing Technique
7. To determine the value of g using Kater's Pendulum.
8. To study the variation of time period with distance between centre of suspension and centre of gravity for a bar pendulum and to determine: (i) Radius of gyration of the bar about an axis through its C.G. and perpendicular to its length. (ii) The value of g in the laboratory.
9. Determination of coefficient of viscosity of a given liquid by Stoke's method. Study its temperature dependence.
10. To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
11. To determine the Young's Modulus of a Wire by Optical Lever Method.
12. To determine the Young's modulus by (i) bending of beam using traveling microscope/laser, (ii) Flexural vibrations of a bar.
13. Determination of modulus of rigidity by (i) dynamic method Maxwell's needle/Torsional pendulum; (ii) Forced torsional oscillations excited using electromagnet.
14. To determine the elastic Constants of a wire by Searle's method.
15. To study one dimensional collision using two hanging spheres of different materials.

Suggested Reading

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

2.Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers

3.A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Edn, 2011, Kitab Mahal

4.Engineering Practical Physics, S. Panigrahi & B.Mallick, 2015, Cengage Learning India Pvt. Ltd.

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

MINOR -1 M1 COURSE

PHY-M-101: MECHANICS

PHY- M1 (T): MECHANICS

THEORY

Total Lectures: 60 **Credits: 4**

Max. Marks: 100

Objective: *The purpose of the course is to train the students in the Newtonian Mechanics and Special Theory of Relativity formalisms to an extent that they can use these in the modern branches of Physics.*

Vector Calculus: Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields.

(5 Lectures)

Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities. **(5 Lectures)**

Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. **(5 Lectures)**

Fundamentals of Dynamics: Reference frames. Inertial frames; Review of Newton's Laws of Motion. Galilean transformations; Galilean invariance. Momentum of variable-mass system: motion of rocket. Motion of a projectile in Uniform gravitational field. Conservation of Energy, Conservative forces, Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum. Impulse. Angular Momentum about the Centre of mass, Rotational invariance, Shape of Galaxy. **(4 Lectures)**

Work and Energy: Work and Kinetic Energy Theorem. Conservative and non-conservative forces. Potential Energy. Energy diagram. Stable and unstable equilibrium. Elastic potential energy. Force as gradient of potential energy. Work & Potential energy. Work done by non-conservative forces. Law of conservation of Energy. **(4 Lectures)**

Elastic and Inelastic Scattering : Types of scattering and conservation laws, Laboratory and centre of mass systems, collision of particles which stick together, General elastic collision of particles of different mass, Cross-section of elastic scattering, Rutherford scattering. **(3 Lectures)**

Rotational Dynamics: Angular momentum of a particle and system of particles.

Torque. Principle of conservation of angular momentum. Rotation about a fixed axis. Moment of Inertia. Calculation of moment of inertia for rectangular, cylindrical and spherical bodies. Kinetic energy of rotation. Motion involving both translation and rotation. Cylinder on an accelerated rough plane, Behaviour of angular momentum vector, Principal axes and Euler's equations, Elementary Gyroscope, Symmetrical Top. **(7 Lectures)**

Elasticity: Relation between Elastic constants. Twisting torque on a Cylinder or Wire. **(3 Lectures)**

Fluid Motion: Kinematics of Moving Fluids: Poiseuille's Equation for Flow of a Liquid through a Capillary Tube. **(2 Lectures)**

Gravitation and Central Force Motion: Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere. Force between a Point Mass and Spherical shell. Force between a Point Mass and Solid Sphere, Gravitational and Electrostatic self-energy. Gravitational energy of the Galaxy and of uniform sphere. **(3 Lectures)**

Motion of a particle under a central force field. Two-body problem and its reduction to one-body problem and its solution. The energy equation and energy diagram. Kepler's Laws. Satellite in circular orbit and applications. Geosynchronous orbits. Weightlessness. Basic idea of global positioning system (GPS). **(4 Lectures)**

Oscillations: SHM: Simple Harmonic Oscillations. Differential equation of SHM and its solution. Kinetic energy, potential energy, total energy and their time-average values. Damped oscillation. Forced oscillations: Transient and steady states; Resonance, sharpness of resonance; power dissipation and Quality Factor. **(4 Lectures)**

Non-Inertial Systems: Non-inertial frames and fictitious forces. Uniformly rotating frame. Laws of Physics in rotating coordinate systems. Centrifugal force. Coriolis force and its applications. Components of Velocity and Acceleration in Cylindrical and

Spherical Coordinate Systems. **(4 Lectures)**

Special Theory of Relativity: Michelson-Morley Experiment and its outcome. Postulates of Special Theory of Relativity. Lorentz Transformations. Simultaneity and order of events. Lorentz contraction. Time dilation. Relativistic transformation of velocity, frequency and wave number. Relativistic addition of velocities. Variation of mass with velocity. Massless Particles. Mass-energy Equivalence. Relativistic Doppler effect. Relativistic Kinematics. Transformation of Energy and Momentum, Transformation of Force, Four vectors. Problems of Relativistic Dynamics: Acceleration of charged particle by constant electric field, transverse Electric field.

(8 Lectures)

Suggested Reading

8.An introduction to mechanics, D. Kleppner, R.J. Kolenkow, 1973, McGraw-Hill.
9.Mechanics, Berkeley Physics, vol.1, C.Kittel, W.Knight, et.al. 2007, Tata McGraw-Hill.
10. Physics, Resnick, Halliday and Walker 8/e. 2008, Wiley.
11. Analytical Mechanics, G.R. Fowles and G.L. Cassiday. 2005, Cengage Learning.
12. Feynman Lectures, Vol. I, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education
13. Introduction to Special Relativity, R. Resnick, 2005, John Wiley and Sons.
14. University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.

Additional Suggested Reading

5.Mechanics, D.S. Mathur, S. Chand and Company Limited, 2000
6.University Physics. F.W Sears, M.W Zemansky, H.D Young 13/e, 1986, Addison Wesley
7.Physics for scientists and Engineers with Modern Phys., J.W. Jewett, R.A. Serway, 2010, Cengage Learning
8.Theoretical Mechanics, M.R. Spiegel, 2006, Tata McGraw Hill.

PHY-M1 (P): MECHANICS (PHY-M-101 (P) -- Credit -02

PRACTICAL

Objective*: The laboratory exercises have been so designed that the students learn to verify some of the concepts learnt in the theory courses. They are trained in carrying out precise measurements and handling sensitive equipments.*

1. Use of Vernier callipers, Screw gauge, Spherometer, Barometer, Sphygmomanometer, Lightmeter, dry and wet thermometers, TDS/conductivity meter and other measuringinstruments based on applications of the experiments. Use of Plumb line and Spirit level.

2. To study the random error in observations.
3. Determination of height (of inaccessible structure) using sextant.
4. To study the Motion of Spring and calculate (a) Spring constant, (b) g and (c) Modulus of rigidity.
5. To determine the Moment of Inertia of a Flywheel.
6. To determine g and velocity for a freely falling body using Digital Timing Technique
7. To determine the value of g using Kater's Pendulum.
8. To study the variation of time period with distance between centre of suspension and centre of gravity for a bar pendulum and to determine: (i) Radius of gyration of the bar about an axis through its C.G. and perpendicular to its length. (ii) The value of g in the laboratory.
9. Determination of coefficient of viscosity of a given liquid by Stoke's method. Study its temperature dependence.
10. To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
11. To determine the Young's Modulus of a Wire by Optical Lever Method.
12. To determine the Young's modulus by (i) bending of beam using traveling microscope/laser, (ii) Flexural vibrations of a bar.
13. Determination of modulus of rigidity by (i) dynamic method Maxwell's needle/Torsional pendulum; (ii) Forced torsional oscillations excited using electromagnet.
14. To determine the elastic Constants of a wire by Searle's method.
15. To study one dimensional collision using two hanging spheres of different materials.

Suggested Reading

6. Advanced Practical Physics for students, B. L. Flint and H.T. Worsnop, 1971, Asia Publishing House
7. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
8. A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Edn, 2011, Kitab Mahal
9. Engineering Practical Physics, S. Panigrahi & B.Mallick, 2015, Cengage Learning India Pvt. Ltd.
10. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press.

Semester II

PHY-C3: ELECTRICITY AND MAGNETISM

PHY-C3 (T): ELECTRICITY AND MAGNETISM

THEORY

Total Lectures : 45 **Credits: 3 Max. Marks: 75**

Objective *: The student is exposed to Electrostatics and Magnetostatics including Boundary value problems, Maxwell equations and their applications and analysis of Alternating current circuits.*

Electric Charges and Fields : Conservation and quantization of charge, Coulomb's Law, Energy of a system of charges. Electric field lines, Electric flux, Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry. **(5 Lectures)**

Conservative nature of Electrostatic Field. Electrostatic Potential. Potential as line integral of field, potential difference, Gradient of a scalar function, Derivation of the field from the potential, potential of a charge distribution, Uniformly charged disc. Force on a surface charge, energy associated with an electric field, Gauss's theorem and differential form of Gauss's law, Laplacian and Laplace's equation, Poisson's equation. Force and Torque on a dipole. **(5 Lectures)**

Electric Fields Around Conductors : Conductors and insulators, General electrostatic problem. Boundary conditions, Uniqueness theorem, Electrostatic energy of system of charges. Electrostatic energy of a charged sphere. Conductors in an electrostatic Field. Surface charge and force on a conductor. Capacitance of a system of charged conductors. Parallel-plate capacitor. Capacitance of an isolated conductor. Method of Images and its application to: Plane Infinite Sheet and Sphere. **(8 Lectures)**

Dielectric Properties of Matter: Dielectrics, Moments of a charge distribution, Potential and field of a dipole, Atomic and molecular dipoles, Induced dipole moments, Permanent dipole moments, electric field caused by polarized matter, field of a polarized sphere, dielectric sphere in a uniform field, Gauss's law in a dielectric medium, Electrical susceptibility and atomic polarizability, Energy changes in polarization, Polarization in

changing fields. Displacement vector **D**. Relations between **E**, **P** and **D**.

(6 Lectures)

The Fields of Moving Charges : Magnetic forces, Measurement of a charge in motion, invariance of charge, Electric field measured in different frames of reference, Field of a point charge moving with constant velocity, Field of a charge that starts or stops, Force on a moving charge, Interaction between a moving charge and other moving charges. **(4 Lectures)**

Magnetic Field: Magnetic force between current elements and definition of Magnetic Field **B**. Biot-Savart's Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with Electric Dipole). Ampere's Circuital Law and its application to (1) Solenoid and (2) Toroid. Properties of **B**: curl and divergence. Vector Potential. Magnetic Force on (1) point charge (2) current carrying wire (3) between current elements. Torque on a current loop in a uniform Magnetic Field. Change in **B** at a current sheet; Transformations of electric and magnetic fields. Rowland's experiment, Hall effect. **(6 Lectures)**

Magnetic Properties of Matter: Response of various substances to magnetic field, Force on a dipole in an external field, Electric currents in Atoms, Electron spin and Magnetic moment, types of magnetic materials, Magnetization vector (**M).** Magnetic Intensity (**H).** Magnetic Susceptibility and permeability. Relation between **B, H, M**. Ferromagnetism. B-H curve and hysteresis. **(4 Lectures)**

Electromagnetic Induction : Universal law of induction, Mutual inductance, Reciprocity theorem, Self inductance, Energy stored in a Magnetic field. A circuit containing self inductance, Displacement current and Maxwell's equations. **(4 Lectures)**

Alternating Current Circuits: A resonance circuit, , Kirchhoff's laws for A.C. networks. Phasor, Complex Reactance and Impedance. Skin effect, Power and Energy in A.C. circuits, Anderson's Bridge, Instantaneous Power, Average Power, Reactive Power, Power Factor. Sinusoidal Circuit Analysis for RL, RC and RLC Circuits. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and (3) Quality Factor, and (4) Band Width. Parallel LCR Circuit.

(3 Lectures)

Ballistic Galvanometer: Torque on a current Loop. Ballistic Galvanometer: Current and Charge Sensitivity. Electromagnetic damping. Logarithmic damping. CDR. **(3 Lectures)**

Suggested Reading

1. Electricity and Magnetism (Berkley, Phys. Course 2), Edward M. Purcell, 1986 McGraw-Hill Education
2. Electricity and Magnetism: A.S. Mahajan & A.A. Rangwala (Tata- McGraw Hill), 1988.
3. Electricity, Magnetism & Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw
4. Introduction to Electrodynamics, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.
5. Feynman Lectures Vol.2, R.P. Feynman, R.B. Leighton, M. Sands, 2008, Pearson Education
6. Elements of Electromagnetics, M.N.O. Sadiku, 2010, Oxford University Press.
7. Electricity and Magnetism, J.H.Fewkes & J.Yarwood. Vol. I, 1991, Oxford Univ. Press.

PHY-C4 : WAVES AND OPTICS

PHY-C4 (T) : WAVES AND OPTICS

THEORY

Total Lectures : 45 **Credits: 3**

Max. Marks : 75

Objective *: The course covers Harmonic oscillations and coupled oscillations, wave motion in damped, driven media. It also covers the Interference, diffraction and polarisation of light and their applications with emphasis on Holography.*

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

Superposition of two perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures with equal an unequal frequency and their uses. **(4 Lectures)**

Coupled oscillations : Stiffness coupled oscillations, normal coordinates and modes of vibrations. Normal frequencies, Forced vibrations and resonance of coupled oscillators, masses on string-coupled oscillators. **(3 Lectures)**

Wave Motion: Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Particle and Wave Velocities. Differential Equation. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Wave. Water Waves: Ripple and Gravity Waves. **(4 Lectures)**

Velocity of Waves: Velocity of Transverse Vibrations of Stretched Strings. longitudinal waves on a rod, Velocity of Longitudinal Waves in a Fluid in a Pipe. Newton's Formula for Velocity of Sound. Laplace's Correction. Reflection and transmission of transverse waves on a string at the discontinuity. Impedance matching, eigen frequencies and eigen functions for stationary waves ona string. **(4 Lectures)**

Superposition of Two Harmonic Waves: Standing (Stationary) Waves in a String: Fixed and Free Ends. Analytical Treatment. Phase and Group Velocities. Changes with respect to Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Plucked and Struck Strings. Melde's Experiment. Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes. Superposition of N Harmonic Waves.

(5 Lectures)

Wave Optics: Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle. Temporal and Spatial Coherence. **(2 Lectures)**

Interference: Division of amplitude and wavefront. Young's double slit experiment. Lloyd's Mirror and Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fizeau Fringes). Newton's Rings: Measurement of wavelength and refractive index. **(5 Lectures)**

Interferometer: Michelson Interferometer-(1) Idea of form of fringes (No theory required), (2) Determination of Wavelength, (3) Wavelength Difference, (4) Refractive Index, and (5) Visibility of Fringes. Fabry-Perot interferometer. **(4 Lectures)**

Diffraction: Kirchhoff's Integral Theorem, Fresnel-Kirchhoff's Integral formula. (Qualitative discussion only) **(2**

Lectures)

Fraunhofer diffraction: Single slit. Circular aperture, Resolving Power of a telescope. Double slit. Multiple slits. Diffraction grating. Resolving power of grating. **(5 Lectures)**

Fresnel Diffraction: Fresnel's Assumptions. Fresnel's Half-Period Zones for Plane Wave. Explanation of Rectilinear Propagation of Light. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Fresnel's Integral, Fresnel diffraction pattern of a straight edge, a slit and a wire.

(5 Lectures)

Holography: Principle of Holography. Recording and Reconstruction Method. Theory of Holography as Interference between two Plane Waves. Point source holograms.

(3 Lectures)

Suggested Reading

1. Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.
2. Fundamentals of Optics, F.A. Jenkins and H.E. White, 1981, McGraw-Hill
3. Principles of Optics, Max Born and Emil Wolf, 7th Edn., 1999, Pergamon Press.
4. Optics, Ajoy Ghatak, 2008, Tata McGraw Hill
5. The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.
6. The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.
7. Fundamental of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications.

PHY-C3 (P): ELECTRICITY AND MAGNETISM (PRACTICALS)

PHY-C4 (P) : WAVES AND OPTICS (PRACTICAL)

Total Lectures : 90 **Credits: 3**

Max. Marks : 75

PHY-C3 (P): ELECTRICITY AND MAGNETISM (PRACTICALS)

Objective: *The aim of this course is to build an understanding about various components of an electrical circuit and to develop skill to measure the related physical quantities.*

Note: *The experiments listed in the Practical Part of the Core Papers, i.e., PHY-C1P: Mathematical Physics–I, PHY-C2P: Mechanics, PHY-C3P: Electricity and Magnetism and PHY-C4P: Waves and Optics, are to be clubbed together and will be performed by the students during the Semesters I and II. Basic experiments of these core papers will be covered in Semester I and the rest will be done in Semester II.* ***15*** *experiments are to be performed in each Semester without repetition. General evaluation procedure has been defined under the heading "Evaluation" in the beginning of the syllabus.*

1. Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances, and (e) Checking electrical fuses.
2. To determine an unknown Low Resistance using Potentiometer.
3. To determine an unknown Low Resistance using Carey Foster's Bridge.
4. Measurement of field strength B and its variation in a solenoid (determine dB/dx)
5. To determine the value of an air capacitance by de-Sauty Method and to find permittivity of air. Also to determine the dielectric constant of a liquid.
6. To verify the Thevenin and Norton theorems.
7. To verify the Superposition, and Maximum power transfer theorems.
8. To determine self inductance of a coil by Anderson's bridge.
9. To study response curve of a Series LCR circuit and determine its (a) Resonant frequency, (b) Impedance at resonance, (c) Quality factor Q, and (d) Band width.
10. To study the response curve of a parallel LCR circuit and determine its (a) Anti-resonant frequency and (b) Quality factor Q.
11. Measurement of charge and current sensitivity and CDR of Ballistic Galvanometer.
12. Determine a high resistance by leakage method using Ballistic Galvanometer.
13. To determine self-inductance of a coil by Rayleigh's method.
14. To determine the mutual inductance of two coils by Absolute method.
15. Determination of E.C.E. of hydrogen and evaluation of Faraday and Avogadro constants.
16. To study the magnetic field produced by a current carrying solenoid using a pick-up coil/Hall sensor and to find the value of permeability of air.
17. To determine the frequency of A.C. mains using sonometer.
18. To determine the resistance of an electrolyte for A.C current and study its concentration dependence. Also to study temperature dependence.
19. Study of temperature dependence resistivity of Cu conductor, Manganin/constantin

alloy and semiconductor (FET channel).

20. To measure thermo e.m.f. of a thermocouple as a function of temperature and find inversion temperature.
21. To study C.R.O. as display and measuring device by recording sines and square waves, output from a rectifier, verification (qualitative) of law of electromagnetic induction and frequency of A.C. mains.
22. To plot the Lissajous figures and determine the phase angle by C.R.O.
23. To study B-H curves for different ferromagnetic materials using C.R.O.
24. Determination of low inductance by Maxwell-Wein bridge.
25. Study of R.C. circuit with a low frequency a.c. source.
26. Studies based on LCR Board: Impedance of LCR circuit and the phase and between voltage and current.
27. To study the induced emf as a function of the velocity of magnet and to study the phenomenon of electromagnetic damping.
28. To study the variation of magnetic field with distance along axis of a circular coil – realization of Helmholtz's coils.

Suggested Reading

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

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

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

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

5.A Laboratory Manual of Physics for undergraduate classes, D.P. Khandelwal, 1985, Vani Pub.

PHY-C4 (P) : WAVES AND OPTICS (PRACTICAL)

Objective: *The course covers experiments related to damped, driven and forced oscillations, wave motion in media. Properties and Characteristics of light through experiments related to interference and diffraction phenomenon are high lighted.*

Note: *The experiments listed in the Practical Part of the Core Papers, i.e., PHY-C1P: Mathematical Physics–I, PHY-C2P: Mechanics, PHY-C3P: Electricity and Magnetism and PHY-C4P: Waves and Optics, are to be clubbed together and will be performed by the*

students during the Semesters I and II. Basic experiments of these core papers will be covered in Semester I and the rest will be done in Semester II. ***15*** *experiments are to be performed in each Semester without repetition. General evaluation procedure has been defined under the heading "Evaluation" in the beginning of the syllabus.*

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify λ^2 –T law.
2. To investigate the motion of coupled oscillators.
3. To study Lissajous Figures.
4. Familiarization with: Schuster`s focusing; determination of angle of prism.
5. To determine refractive index of the Material/liquid of a prism using sodium source.
6. To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
7. To determine the wavelength of sodium source using Michelson's interferometer.
8. To determine wavelength of sodium light using Fresnel Biprism.
9. To determine wavelength of sodium light using Newton's Rings.
10. To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.
11. To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
12. To determine dispersive power and resolving power of a plane diffraction grating.
13. To study Malus's law of polarization.
14. To find the resolving power and magnification of a telescope.
15. To find the resolving power and magnification of a diffraction grating.
16. To study hydrogen/Neon gas discharge tube spectrum using diffraction grating.
17. To study temperature dependence of refractive index of organic liquid using Abbe's refractometer.
18. To study the variation of specific rotation of sugar solution with concentration.
19. To measure power distribution and divergence parameters of He-Ne and Semiconductor lasers.
20. To study Moire's fringe patterns and applications to measure small distance and angle.

Suggested Reading

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

Publishing House
2. A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal
3. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
4. A Laboratory Manual of Physics for undergraduate classes, D.P. Khandelwal, 1985, Vani Pub.

MINOR –M2

PHY-M2: ELECTRICITY AND MAGNETISM

PHY-M2 (T): ELECTRICITY AND MAGNETISM

THEORY

Total Lectures : 60 **Credits: 4 Max. Marks: 100**

Objective *: The student is exposed to Electrostatics and Magnetostatics including Boundary value problems, Maxwell equations and their applications and analysis of Alternating current circuits.*

Electric Charges and Fields : Conservation and quantization of charge, Coulomb's Law, Energy of a system of charges. Electric field lines, Electric flux, Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry. **(5 Lectures)**

Conservative nature of Electrostatic Field. Electrostatic Potential. Potential as line integral of field, potential difference, Gradient of a scalar function, Derivation of the field from the potential, potential of a charge distribution, Uniformly charged disc. Force on a surface charge, energy associated with an electric field, Gauss's theorem and differential form of Gauss's law, Laplacian and Laplace's equation, Poisson's equation. Force and Torque on a dipole. **(5 Lectures)**

Electric Fields Around Conductors : Conductors and insulators, General electrostatic problem. Boundary conditions, Uniqueness theorem, Electrostatic energy of system of charges. Electrostatic energy of a charged sphere. Conductors in an electrostatic Field. Surface charge and force on a conductor. Capacitance of a system of charged conductors. Parallel-plate capacitor. Capacitance of an isolated conductor. Method of Images and its

application to: Plane Infinite Sheet and Sphere. **(8 Lectures)**

Dielectric Properties of Matter: Dielectrics, Moments of a charge distribution, Potential and field of a dipole, Atomic and molecular dipoles, Induced dipole moments, Permanent dipole moments, electric field caused by polarized matter, field of a polarized sphere, dielectric sphere in a uniform field, Gauss's law in a dielectric medium, Electrical susceptibility and atomic polarizability, Energy changes in polarization, Polarization in changing fields. Displacement vector **D**. Relations between **E**, **P** and **D**.

(6 Lectures)

The Fields of Moving Charges : Magnetic forces, Measurement of a charge in motion, invariance of charge, Electric field measured in different frames of reference, Field of a point charge moving with constant velocity, Field of a charge that starts or stops, Force on a moving charge, Interaction between a moving charge and other moving charges. **(4 Lectures)**

Magnetic Field: Magnetic force between current elements and definition of Magnetic Field **B**. Biot-Savart's Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with Electric Dipole). Ampere's Circuital Law and its application to (1) Solenoid and (2) Toroid. Properties of **B**: curl and divergence. Vector Potential. Magnetic Force on (1) point charge (2) current carrying wire (3) between current elements. Torque on a current loop in a uniform Magnetic Field. Change in **B** at a current sheet; Transformations of electric and magnetic fields. Rowland's experiment, Hall effect. **(6 Lectures)**

Magnetic Properties of Matter: Response of various substances to magnetic field, Force on a dipole in an external field, Electric currents in Atoms, Electron spin and Magnetic moment, types of magnetic materials, Magnetization vector (**M).** Magnetic Intensity (**H).** Magnetic Susceptibility and permeability. Relation between **B, H, M**. Ferromagnetism. B-H curve and hysteresis. **(4 Lectures)**

Electromagnetic Induction : Universal law of induction, Mutual inductance, Reciprocity theorem, Self inductance, Energy stored in a Magnetic field. A circuit containing self inductance, Displacement current and Maxwell's equations. **(4 Lectures)**

Alternating Current Circuits: A resonance circuit, , Kirchhoff's laws for A.C. networks. Phasor, Complex Reactance and Impedance. Skin effect, Power and Energy in A.C. circuits, Anderson's Bridge, Instantaneous Power, Average Power, Reactive Power, Power Factor. Sinusoidal Circuit Analysis for RL, RC and RLC Circuits. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and (3) Quality Factor, and (4) Band Width. Parallel LCR Circuit.

(3 Lectures)

Ballistic Galvanometer: Torque on a current Loop. Ballistic Galvanometer: Current and Charge Sensitivity. Electromagnetic damping. Logarithmic damping. CDR. **(3 Lectures)**

Suggested Reading

8. Electricity and Magnetism (Berkley, Phys. Course 2), Edward M. Purcell, 1986 McGraw-Hill Education
9. Electricity and Magnetism: A.S. Mahajan & A.A. Rangwala (Tata- McGraw Hill), 1988.
10. Electricity, Magnetism & Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw
11. Introduction to Electrodynamics, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.
12. Feynman Lectures Vol.2, R.P. Feynman, R.B. Leighton, M. Sands, 2008, Pearson Education
13. Elements of Electromagnetics, M.N.O. Sadiku, 2010, Oxford University Press.
14. Electricity and Magnetism, J.H.Fewkes & J.Yarwood. Vol. I, 1991, Oxford Univ. Press.

PHY-M2 (P): ELECTRICITY AND MAGNETISM (PRACTICALS)

Total Lectures : 30 **Credits: 2**

Max. Marks : 50

Objective: *The aim of this course is to build an understanding about various components of an electrical circuit and to develop skill to measure the related physical quantities.*

1. Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances, and (e) Checking electrical fuses.

2. To determine an unknown Low Resistance using Potentiometer.
3. To determine an unknown Low Resistance using Carey Foster's Bridge.
4. Measurement of field strength B and its variation in a solenoid (determine dB/dx)
5. To determine the value of an air capacitance by de-Sauty Method and to find permittivity of air. Also to determine the dielectric constant of a liquid.
6. To verify the Thevenin and Norton theorems.
7. To verify the Superposition, and Maximum power transfer theorems.
8. To determine self inductance of a coil by Anderson's bridge.
9. To study response curve of a Series LCR circuit and determine its (a) Resonant frequency, (b) Impedance at resonance, (c) Quality factor Q, and (d) Band width.
10. To study the response curve of a parallel LCR circuit and determine its (a) Anti-resonant frequency and (b) Quality factor Q.
11. Measurement of charge and current sensitivity and CDR of Ballistic Galvanometer.
12. Determine a high resistance by leakage method using Ballistic Galvanometer.
13. To determine self-inductance of a coil by Rayleigh's method.
14. To determine the mutual inductance of two coils by Absolute method.
15. Determination of E.C.E. of hydrogen and evaluation of Faraday and Avogadro constants.
16. To study the magnetic field produced by a current carrying solenoid using a pick-up coil/Hall sensor and to find the value of permeability of air.
17. To determine the frequency of A.C. mains using sonometer.
18. To determine the resistance of an electrolyte for A.C current and study its concentration dependence. Also to study temperature dependence.
19. Study of temperature dependence resistivity of Cu conductor, Manganin/constantin alloy and semiconductor (FET channel).
20. To measure thermo e.m.f. of a thermocouple as a function of temperature and find inversion temperature.
21. To study C.R.O. as display and measuring device by recording sines and square waves, output from a rectifier, verification (qualitative) of law of electromagnetic induction and frequency of A.C. mains.
22. To plot the Lissajous figures and determine the phase angle by C.R.O.
23. To study B-H curves for different ferromagnetic materials using C.R.O.
24. Determination of low inductance by Maxwell-Wein bridge.

25. Study of R.C. circuit with a low frequency a.c. source.

26. Studies based on LCR Board: Impedance of LCR circuit and the phase and between voltage and current.

27. To study the induced emf as a function of the velocity of magnet and to study the phenomenon of electromagnetic damping.

28. To study the variation of magnetic field with distance along axis of a circular coil – realization of Helmholtz's coils.

Suggested Reading

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

7.A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal

8.Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers

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

10. A Laboratory Manual of Physics for undergraduate classes, D.P. Khandelwal, 1985, Vani Pub.

INTER / MULTI-DISCIPLINARY SUBJECTS for Students of other Departments/Disciplines

IMD1 ELECTRICITY AND MAGNETISM

PHY-IMD-101 (T): ELECTRICITY AND MAGNETISM
THEORY

Total Lectures : 30 **Credits: 2**

Max. Marks : 50

Objective *: This course focuses on essentials of electrostatics and magnetostatics along with Maxwell's mathematical formulation of electric and magnetic fields.*

Vector Analysis: Scalar and Vector product, gradient, divergence, Curl and their significance, Vector Integration, Line, surface and volume integrals of Vector fields, Gauss-divergence theorem and Stoke's theorem of vectors (statement only).

(8 Lectures)

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

(12 Lectures)

Magnetism:

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

(5 Lectures)

Electromagnetic Induction: Faraday's laws of electromagnetic induction, Lenz's law, self and mutual inductance, L of single coil, M of two coils. Energy stored in magnetic field. **(4 Lectures)**

Maxwell`s equations and Electromagnetic wave propagation: Equation of continuity of current, Displacement current, Maxwell's equations, Poynting vector, energy density in electromagnetic field, electromagnetic wave propagation through vacuum and isotropic dielectric medium, transverse nature of EM waves, polarization. **(8 Lectures)**

Suggested Reading

1. Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education
2. Electricity & Magnetism, J.H. Fewkes & J.Yarwood. Vol. I, 1991, Oxford Univ. Press
3. Electricity and Magnetism, D C Tayal, 1988, Himalaya Publishing House.
4. University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.
5. D.J.Griffiths, Introduction to Electrodynamics, 3rd Edn, 1998, Benjamin Cummings.

PHY-IMD-101 (P) : ELECTRICITY AND MAGNETISM

PRACTICAL

Total Lectures: 30 **Credits: 1**

Max. Marks : 25

Objective *: This course aims to impart practical knowledge to students related to electricity and magnetism.*

Note: *The experiments listed in the Practical Part of the Generic Elective Papers, i.e.,* ***PHY-GE1(P): Electricity and Magnetism, PHY-GE2(P): Mathematical Physics–I, PHY-GE3(P): Elements of Modern Physics, PHY-GE4(P): Mechanics*** *are to be clubbed together and will be performed by the students during the Semesters I and II. Basic experiments of these core papers will be covered in Semester I and the rest will be done in Semester II.* ***8*** *experiments are to be performed in each Semester without repetition. General evaluation procedure has been defined under the heading "Evaluation" in the beginning of the syllabus.*

1. To use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages,

(b) DC Current, and (d) checking electrical fuses.

2. Ballistic Galvanometer: (a) Measurement of charge and current sensitivity

(b) Measurement of CDR, (c) Determine a high resistance by Leakage Method, (d) To

determine Self Inductance of a Coil by Rayleigh's Method.

3. To compare capacitances using De'Sauty's bridge.
4. Measurement of field strength B and its variation in a Solenoid (Determine dB/dx)
5. To study the Characteristics of a Series RC Circuit.
6. To study a series LCR circuit LCR circuit and determine its (a) Resonant frequency, (b) Quality factor
7. To study a parallel LCR circuit and determine its (a) Anti-resonant frequency and (b) Quality factor Q
8. To calibrate the wire of Carey Foster bridge and hence determine Low Resistance of two turns of a tangent galvanometer.
9. To verify the Thevenin and Norton theorems
10. To verify the Superposition, and Maximum Power Transfer Theorems
11. Self-inductance by Anderson's bridge.
12. Verification of laws of electromagnetic induction.
13. Verification of maximum power theorem.
14. To study the concentration dependence of the resistance electrolyte
15. To study dependence of magnetic field in a solenoid on various parameters and hence to evaluate μ_0.
17. To study the variation of the resistance of filament of bulb with its temperature.
18. Study of B-H curves of various materials using C.R.O, and determination of various parameters.

Suggested reading

1. Advanced Practical Physics for students, B.L.Flint & H.T.Worsnop, 1971, Asia Publishing House.
2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
3. A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Ed.2011, Kitab Mahal
4. Engineering Practical Physics, S.Panigrahi & B.Mallick,2015, Cengage Learning India Pvt. Ltd.

IMD2 ELEMENTS OF MODERN PHYSICS

PHY-IMD-202 (T) : ELEMENTS OF MODERN PHYSICS

THEORY

Total Lectures: 30 **Credits: 2**

Max. Marks: 50

Objective*: The aim of the course is to provide students with insight of the exciting results and reasoning of the physical phenomena on the basis of modern physcs.*

Planck's quantum, Planck's constant and light as a collection of photons; Photo-electric effect and Compton scattering. De Broglie wavelength and matter waves; Davisson-Germer experiment. **(5 Lectures)**

Problems with Rutherford model- instability of atoms and observation of discrete atomic spectra; Bohr's quantization rule and atomic stability; calculation of energy levels for hydrogen like atoms and their spectra. **(3 Lectures)**

Position measurement- gamma ray microscope thought experiment; Wave-particle duality, Heisenberg uncertainty principle- impossibility of a particle following a trajectory; Estimating minimum energy of a confined particle using uncertainty principle; Energy-time uncertainty principle. **(3 Lectures)**

Two slit interference experiment with photons, atoms & particles; linear superposition principle as a consequence; Matter waves and wave amplitude; Schrodinger equation for non-relativistic particles; Momentum and Energy operators; stationary states; physical interpretation of wavefunction, probabilities and normalization; Probability and probability current densities in one dimension. **(5 Lectures)**

One dimensional infinitely rigid box- energy eigenvalues and eigenfunctions, normalization; Quantum dot as an example; Quantum mechanical scattering and tunnelling in one dimension - across a step potential and across a rectangular potential barrier. **(5 Lectures)**

Size and structure of atomic nucleus and its relation with atomic weight; Impossibility of an electron being in nucleus as a consequence of the uncertainty principle. Nature of nuclear force, NZ graph, semi-empirical mass formula and binding energy. **(5 Lectures)**

Radioactivity: stability of nucleus; Law of radioactive decay; Mean life and half-life; α decay; β decay - energy released, spectrum and Pauli's prediction of neutrino; γ-ray emission. **(5 Lectures)**

Fission and fusion - mass deficit, relativity and generation of energy; Fission - nature of fragments and emission of neutrons. Nuclear reactor: slow neutrons interacting with Uranium 235; Fusion and thermonuclear reactions. **(3 Lectures)**

Suggested Reading

1. Concepts of Modern Physics, Arthur Beiser, 2009, McGraw-Hill.\
2. Modern Physics, J.R. Taylor, C.D. Zafiratos, M.A. Dubson,2009, PHI Learning
3. Six Ideas that Shaped Physics:Particle Behave like Waves, Thomas A. Moore, 2003, McGraw Hill
4. Quantum Physics, Berkeley Physics,Vol.4. E.H. Wichman, 2008, Tata McGraw-Hill Co.
5. Modern Physics, R.A. Serway, C.J. Moses, and C.A.Moyer, 2005, Cengage Learning
6. Modern Physics, G. Kaur and G.R. Pickrell, 2014, McGraw Hill

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PHY-IMD-202 (P) : ELEMENTS OF MODERN PHYSICS PRACTICAL

Total Lectures : 30 **Credits: 1**

Max. Marks : 25

Objective : *This course is eastablish for practical understanding of the results obtained from modern physics.*

Note: *The experiments listed in the Practical Part of the Generic Elective Papers, i.e.,* ***PHY-GE1(P): Electricity and Magnetism, PHY-GE2(P): Mathematical Physics–I, PHY-GE3(P): Elements of Modern Physics, PHY-GE4(P): Mechanics*** *are to be clubbed together and will be performed by the students during the Semesters I and II. Basic experiments of these core papers will be covered in Semester I and the rest will be done in Semester II.* ***8*** *experiments are to be performed in each Semester without repetition. General evaluation procedure has been defined under the heading "Evaluation" in the beginning of the syllabus.*

1. To determine value of Boltzmann constant using V-I characteristic of PN diode.
2. To determine work function of material of filament of directly heated vacuum diode.
3. To determine the ionization potential of mercury.

4. To determine value of Planck's constant using LEDs of at least 4 different colours.
5. To determine the wavelength of H-alpha emission line of Hydrogen atom.
6. To determine the absorption lines in the rotational spectrum of Iodine vapour.
7. To study the diffraction patterns of single and double slits using laser and measure its intensity variation using Photosensor & compare with incoherent source – Na.
8. Photo-electric effect: photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light.
9. To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
10. To setup the Millikan oil drop apparatus and determine the charge of an electron.
11. Determination of Eg in Si and Ge.
12. Determination of Planck's constant using photocell.
13. Dependence of scattering angle on kinetic energy and impact parameter in Rutherford scattering (mechanical analogue).
14. Verification of Rutherford- Soddy nuclear decay formula - mechanical analogue.
15. To find half-life period of a given radio-active substance using GM counter/ Charterctisitcs of GM Counter

Suggested Reading

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