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
I[st] – VI[th]semester

Department of Physics
Panjab University, Chandigarh

Academic Session (2025-2026)

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, 2025-2026

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

1. Teaching assignments
2. Scientific assignments
3. Instrument development including scientist, medical device, laser detectors and electronics.
4. Research and Development in the industries.
5. Simulation techniques development.
6. Career in renewable energy resources.
7. Astronomer, career in nuclear and particle physics.

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)	
PHY-DSC -1	Mechanics Credits- 4(T) + 2(P) Marks – 100 (T) + 50 (P)	**PHY-DSC -2**	Electricity and Magnetism Credits – 4(T) + 2(P) Marks - 100 (T) + 50 (P)
PHY-SEC-1	Mathematical Physics & Computational Technique -1 Credits -3, Marks-75 (50 (T) + 25 (P)	**PHY- SEC -2**	Waves and Optics Credits-3, Marks -75 (50 (T) + 25 (P))
PHY-M-1	Mechanics Credits- 4(T) + 2(P) Marks – 100 (T) + 50 (P)	**PHY-M- 2**	Electricity and Magnetism Credits – 4(T) + 2(P) Marks –150 (100 (T) + 50 (P))
PHY-IDC-1	Electricity & Magnetism Credits – 3 (2(T) + 1 (P)) Marks – 75 (50 (T) +25 (P))	**PHY-IDC- 2**	Elements of Modern Physics Credits – 3 Marks – 75 (50 (T) +25 (P))
PHY- VAC -1	Renewable energy &Energy Harvesting Credit -2 (T) Marks - 50	**PHY- VAC -2**	Introduction to material science Credit -2 (T) Marks - 50
PHY-AEC- 1	English/ Environmental Science Credits -2, Marks -50	**PHY-AEC- 3**	PHY-AECC2: English/ Environmental Science Credits -2, Marks -50
PHY-AEC - 2	MIL Credit-2, Marks -50	**PHY-AEC - 4**	MIL Credit-2, Marks -50

Important Notes:

1. The minor and major subjects opted by a student will remain same for two consecutive semesters (i.e Sem I and II; Sem III and IV; Sem V and Sem VI and Sem VII and Sem VIII). The change in these subjects during a running session will not be allowed.
2. IDC shall be different from the DSC and Minor courses.
3. * The contact hours of AEC ourses are doubled in order to meet the conditions of the syllabi for teaching and improving writing skills.
4. #Only those students will be allowed to do research who will have more than 75% CGPA till 6th semester. For Sem VII, a theory paper of 4 credits will be taught to the project holders on ‘Research Methodology and basics of research’. The student will submit a report on the literature survey and synopsis of the proposed research work, that will fulfil 2 credits. For semester VIII, the student will be engaged in the research work and will submit a dissertation/project report (6 credits) for the same.
5. ** This paper is meantfor those students who have less than 75% CGPA till 6th Semester and are not allowed to opt for research project.
6. See Nomenclature tables for codes
7. The codes for IDC and VAC courses will be assigned later.

Criteria for the award of certificate/degree

1. Students exiting the programme after securing 48 credits will be awarded UG certificate in the relevant discipline/subject provided they secure 4 credits in work based vocational courses offered during summer term or internship/apprenticeship in addition to 6 credits from skill-based courses earned during first and second semester
2. Students exiting the programme after securing 96 credits will be awarded UG diploma in the relevant discipline/subject provided they secure additional 4 credits in skill-based vocational courses offered during lastr year or second year summer term.
3. Students who want to undertake 3-year UG programme will be awarded UG degree in the relevant discipline/subject upon securing 144 credits. Subject to minimum credit requirement in respective subject.
4. Students will be awarded UG degree (Honours) with Research in the relevant discipline/subject upon securing 192 credits subject to minimum credit requirement in respective subject.

2nd 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 III (Credits = 24, Marks = 600)		**SEMESTER IV (Credits = 24, Marks = 600)**	
PHY- DSC -3	Elements of Modern Physics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))	**PHY- DSC -5**	Mathematical & Computational Physics - III Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))
PHY- DSC -4	Thermal Physics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))	**PHY- DSC -6**	Quantum Mechanics and Applications Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))
PHY- SEC -3	Mathematical & Computational Physics - II Credits -3, Marks-75 (50 (T) + 25 (P)	**PHY- DSC -7**	Analog Systems and Applications Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))
PHY- IDC -3	Waves & Optics Credits – 3 (2(T) + 1 (P)) Marks – 75 (50 (T) +25 (P))		
PHY– M- 3	Waves and Optics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))	**PHY– M- 4**	Elements of Modern Physics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))

3rd 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 V (Credits = 24, Marks = 600)		SEMESTER VI (Credits = 24, Marks = 600)	
PHY- DSC -8	Electromagnetic Theory Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))	**PHY- DSC -11**	Nuclear Physics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))
PHY- DSC -9	Statistical Mechanics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))	**PHY- DSC -12**	Particle Physics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))
PHY- DSC -10	Atomic and Molecular Physics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))	**PHY- DSC -13**	Solid State Physics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))
PHY– M- 5	Analog Electronics and Applications Credits- 3(T) + 1(P) Marks – 100 (75 (T) + 25 (P))	**PHY– M- 6**	Basics of Quantum Mechanics Credits- 3(T) + 1(P) Marks – 100 (75 (T) + 25(P))
PHY- VAC -3	Basic Instrumentation Skill for Science Students Credit -2 (T) Marks - 50	**Internship PHY- INT- 1**	*Operational Procedure to be defined by physics department Credits -2, Marks -50

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 Practicalsfor the 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 IDC and VAC courses: -** 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 Dissertation/ Projects / 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 evaluation 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.

Semester I

PHY-DSC-1: 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.*

Fundamentals of Dynamics: Reference frames. Inertial frames; Review of Newton'sLaws 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 Liquidthrough a Capillary Tube. **(2 Lectures)**

Gravitation and Central Force Motion: Law of gravitation. Gravitational potentialenergy. 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 itssolution. 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 rotatingframe. 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.

PHY- DSC- 1: MECHANICS (Practical)

Credits – 02
Marks -50

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 equipment.*

Note: *The experiments listed in the Practical Part of the Core Papers, i.e., PHY-DSC-1:Mechanics, PHY-SEC-1: Mathematical Physics -1 , PHY-DSC-2: Electricity and Magnetism and PHY- SEC-2: 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/Torsionalpendulum; (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, 11thEdn, 2011, Kitab Mahal
4.Engineering Practical Physics, S. Panigrahi &B.Mallick, 2015, Cengage Learning India Pvt. Ltd.

PHY- SEC-1: MATHEMATICAL PHYSICS& COMPUTATIONAL TECHNIQUE -1

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, 7thEdn., 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- SEC-1: MATHEMATICAL PHYSICS & COMPUTATIONAL TECHNIQUE -1

PRACTICAL

Total Lectures: 45 **Credits: 2**

Max. Marks: 50

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-DSC-1:Mechanics, PHY-SEC-1: Mathematical Physics -1, PHY-DSC-2: Electricity and Magnetism and PHY- SEC-2: 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. *$\sin\theta$, $\cos\theta$, $\tan\theta$ 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 θ'(0) = 0. Solve the equation for α= 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 θ = θ)

Suggested Reading

1. Introduction to Numerical Analysis, S.S. Sastry, 5thEdn. , 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, 3rdEdn. , 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, 3rdEdn . , 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, 2ndEdn. , 2006,Cambridge Univ. Press
8. Computational Physics, Darren Walker, 1stEdn., 2015, Scientific International Pvt. Ltd.

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

MINOR -1

PHY-M- 1: MECHANICS

THEORY

Total Lectures: 60Credits: 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.

(4 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. **(4 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. **(4 Lectures)**

Fundamentals of Dynamics: Reference frames. Inertial frames; Review of Newton'sLaws 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.

(5 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 Liquidthrough a Capillary Tube. **(2 Lectures)**

Gravitation and Central Force Motion: Law of gravitation. Gravitational potentialenergy. 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). **(3 Lectures)**

Oscillations: SHM: Simple Harmonic Oscillations. Differential equation of SHM and itssolution. 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. **(3 Lectures)**

Non-Inertial Systems: Non-inertial frames and fictitious forces. Uniformly rotatingframe. 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.
(3 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.

(7 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

8.Mechanics, D.S. Mathur, S. Chand and Company Limited, 2000

9.University Physics. F.W Sears, M.W Zemansky, H.D Young 13/e, 1986, Addison Wesley

10. Physics for scientists and Engineers with Modern Phys., J.W. Jewett, R.A. Serway, 2010, Cengage Learning

11. Theoretical Mechanics, M.R. Spiegel, 2006, Tata McGraw Hill.

MECHANICS PHY-M-1 (P) -- Credit -02, Marks -50

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/Torsionalpendulum; (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, 11thEdn, 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.

PHY- VAC -1 RENEWABLE ENERGY AND ENERGY HARVESTING

Total Lectures : 30 **Credits: 2**

Max. Marks : 50

Objective :*The aim of this course is not just to impart theoretical knowledge to the students but to provide them with exposure and hands-on learning wherever possible*

Note: *The students in the class will be divided in to groups. There will be regular teaching of the theoretical aspects (8 hours) along with the Practical training of the students in various skill Development Subjects. Students shall submit a report of nearly 20 pages about the work done (giving details, highlighting innovation and future prospectus) by the end-semester. General evaluation procedure has been defined under the heading “Evaluation” in the beginning of the syllabus.*

Fossil fuels and Alternate Sources of energy: Fossil fuels and nuclear energy, theirlimitation, need of renewable energy, non-conventional energy sources. An overview of developments in Offshore Wind Energy, Tidal Energy, Wave energy systems, Ocean

Thermal Energy Conversion, solar energy, biomass, biochemical conversion, biogas generation, geothermal energy tidal energy, Hydroelectricity. **(3 Lectures)**

Solar energy: Solar energy, its importance, storage of solar energy, solar pond, nonconvective solar pond, applications of solar pond and solar energy, solar water heater, flat plate collector, solar distillation, solar cooker, solar green houses, solar cell, absorption air conditioning. Need and characteristics of photovoltaic (PV) systems, PV models and equivalent circuits, and sun tracking systems. **(6 Lectures)**

Wind Energy harvesting: Fundamentals of Wind energy, Wind Turbines and differentelectrical machines in wind turbines, Power electronic interfaces, and grid interconnection topologies. **(3 Lectures)**

Ocean Energy: Ocean Energy Potential against Wind and Solar, Wave Characteristicsand Statistics, Wave Energy Devices.

Tide characteristics and Statistics, Tide Energy Technologies, Ocean Thermal Energy,Osmotic Power, Ocean Bio-mass.

(2 Lectures)

Geothermal Energy: Geothermal Resources, Geothermal Technologies. **(2 Lectures)**

Hydro Energy: Hydropower resources, hydropower technologies, environmental impactof hydro power sources. **(2 Lectures)**

Piezoelectric Energy harvesting: Introduction, Physics and characteristics ofpiezoelectric effect, materials and mathematical description of piezoelectricity, Piezoelectric parameters and modeling piezoelectric generators, Piezoelectric energy harvesting applications, Human power

(4 Lectures)

Electromagnetic Energy Harvesting: Linear generators, physics mathematical models, recent applications. **(2 Lectures)**

Carbon captured technologies, cell, batteries, power consumption **(2 Lectures)**

Environmental issues and Renewable sources of energy, sustainability. **(1 Lecture)**

Demonstrations and Experiments

1. Demonstration of Training modules on Solar energy, wind energy, etc.

2. Conversion of vibration to voltage using piezoelectric materials

3. Conversion of thermal energy into voltage using thermoelectric modules.

Reference Books:

1. Non-conventional energy sources - G.D Rai - Khanna Publishers, New Delhi

2. Solar energy - M P Agarwal - S Chand and Co. Ltd.

3. Solar energy - Suhas P Sukhative Tata McGraw - Hill Publishing Company Ltd.

4. Godfrey Boyle, "Renewable Energy, Power for a sustainable future", 2004, Oxford University Press, in association with The Open University.

5. Dr. P Jayakumar, Solar Energy: Resource Assesment Handbook, 2009

6. J.Balfour, M.Shaw and S. Jarosek, Photovoltaics, Lawrence J Goodrich (USA).

7. http://en.wikipedia.org/wiki/Renewable_energy

PHY- IDC -1 : 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 MagneticField**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 Reactanceand 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: Currentand 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- DSC-1 (P): ELECTRICITY AND MAGNETISM (PRACTICALS)

Total Lectures: 30 **Credits: 1**

Max. Marks:25

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-DSC-1:Mechanics, PHY-SEC-1: Mathematical Physics -1, PHY-DSC-2: Electricity and Magnetism and PHY- SEC-2: 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-upcoil/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 thermoe.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.

Semester II

PHY- DSE-2: 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 Alternatingcurrent 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**. **(6Lectures)**

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 MagneticField**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 Reactanceand 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: Currentand 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- DSC-2 (P): ELECTRICITY AND MAGNETISM (PRACTICALS)

Total Lectures: 45 **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.*

Note: The experiments listed in the Practical Part of the Core Papers, i.e., PHY-DSC-1:Mechanics, PHY-SEC-1: Mathematical Physics -1, PHY-DSC-2: Electricity and Magnetism and PHY- SEC-2: 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.*

27. Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances, and (e) Checking electrical fuses.
28. To determine an unknown Low Resistance using Potentiometer.
29. To determine an unknown Low Resistance using Carey Foster's Bridge.
30. Measurement of field strength B and its variation in a solenoid (determine dB/dx)
31. 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.
32. To verify the Thevenin and Norton theorems.

33. To verify the Superposition, and Maximum power transfer theorems.
34. To determine selfinductance of a coil by Anderson's bridge.
35. 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.
36. To study the response curve of a parallel LCR circuit and determine its (a) Anti-resonant frequency and (b) Quality factor Q.
37. Measurement of charge and current sensitivity and CDR of Ballistic Galvanometer.
38. Determine a high resistance by leakage method using Ballistic Galvanometer.
39. To determine self-inductance of a coil by Rayleigh's method.
40. To determine the mutual inductance of two coils by Absolute method.
41. Determination of E.C.E. of hydrogen and evaluation of Faraday and Avogadro constants.
42. To study the magnetic field produced by a current carrying solenoid using a pick-upcoil/Hall sensor and to find the value of permeability of air.
43. To determine the frequency of A.C. mains using sonometer.
44. To determine the resistance of an electrolyte for A.C current and study its concentration dependence. Also to study temperature dependence.
45. Study of temperature dependence resistivity of Cu conductor, Manganin/constantin alloy and semiconductor (FET channel).
46. To measure thermoe.m.f. of a thermocouple as a function of temperature and find inversion temperature.
47. 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.
48. To plot the Lissajous figures and determine the phase angle by C.R.O.
49. To study B-H curves for different ferromagnetic materials using C.R.O.
50. Determination of low inductance by Maxwell-Wein bridge.
51. Study of R.C. circuit with a low frequency a.c. source.
52. 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.

PHY-SEC-2: 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 SuperpositionPrinciple. 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 AnalyticalMethods. 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.

PlaneProgressive (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 ofLongitudinal 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 theoryrequired), (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 PlaneWave. 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. Theoryof 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, 7thEdn., 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- SEC -2 (P): WAVES AND OPTICS (PRACTICAL)

Credits – 02

Marks – 50

Note: The experiments listed in the Practical Part of the Core Papers, i.e., PHY-DSC-1:Mechanics, PHY-SEC-1: Mathematical Physics -1, PHY-DSC-2: Electricity and Magnetism and PHY- SEC-2: 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.*

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 highlighted.*

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, 11^{th} Ed., 2011, Kitab Mahal
3. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4^{th} 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

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 MagneticField**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 Reactanceand 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: Currentand Charge Sensitivity. Electromagnetic damping. Logarithmic damping. CDR. **(3 Lectures)**

Suggested Reading

15. Electricity and Magnetism (Berkley, Phys. Course 2), Edward M. Purcell, 1986 McGraw-Hill Education

16. Electricity and Magnetism: A.S. Mahajan & A.A. Rangwala (Tata- McGraw Hill), 1988.
17. Electricity, Magnetism & Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw
18. Introduction to Electrodynamics, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.
19. Feynman Lectures Vol.2, R.P. Feynman, R.B. Leighton, M. Sands, 2008, Pearson Education
20. Elements of Electromagnetics, M.N.O. Sadiku, 2010, Oxford University Press.
21. Electricity and Magnetism, J.H.Fewkes&J.Yarwood. Vol. I, 1991, Oxford Univ. Press.

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

Total Lectures: 45 **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-upcoil/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 thermoe.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-IMD-2 (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-IDC-2 (P): ELEMENTS OF MODERN PHYSICS
PRACTICAL

Total Lectures: 30 **Credits: 1**
Max. Marks: 25

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

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.

PHY- VAC -2

BASICS OF MATERIALS SCIENCE

Total Lectures : 30 **Credits : 2**
Max. Marks : 50

Objective: The aim of the course is to provide students the understanding of crystal structure, band theory of solid, semiconductors, dielectric and magnetic properties of solids.

Unit-I **(10 Lectures)**

Review of Atomic Stucture: Rutherford atom model, Bohr model of atom, Somerfield's Extension of Bohr's theory, Pauli's Exclusion principle , Wave mechanical model of the atom ; Properties of crystalline and amorphous solids, crystal lattice, symmetry considerations, space lattice of cubic system, lattice planes and miller indices, Bragg's law, reciprocal lattice ; Imperfection in crystals, point defects, dislocations, surface imperfections ; Bonding in solids : Ionics bonding, covalent bonding, metallic bonding, van der Waal's bonding, Hydrogen bonding, Cohesive energy.

Unit-II **(10 Lectures)**

Classical free electron theory of metals, Electrical conductivity, thermal conductivity, Wiedemann- Franz law, Quantum theory of free electrons, Fermi level, Fermi energy, Fermi sphere, Density of states, Bloch theorem, Kronig-Penny model for the band formation ; Semiconductors : Direct and indirect semiconductors, Drift velocity, mobility, Carrier concentration in n-and p-type semiconductors, Hall effect, Carrier transport in semiconductors, Techniques for formation of p-n junction, characteristics of a p-n junction.

Unit-III **(10 Lectures)**

Properties of solids : Dielectric properties : Polar and non-polar solids, concept of dielectric polarization, Dielectric constant and polarizability polarization processes, Dielectric loss, Applications of dielectric materials, Ferroelectricity, Antiferroelectricity, pyroelectricity, piezoelectricity ; Magnetic properties of solids : Definition of magnetism, origin of magnetic moment, Diamagnetism, paramagnetism, Ferromagnetism, Antiferromagnetic and Ferrimagnetism.

Reference Books :

1. Introduction to Solid State Physics, Charles Kittel, 8th Edition 2004. Wiley India Pvt. Ltd.
2. Elements of Solid State Physics, J.P. Srivastava, 4th Edition, 2015, Prentice-Hall of India
3. Introduction to Solids, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill
4. Solid State Physics, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning
5. Essentials of Solid State Physics, S.P. Kuila, 2016, NCBA Ltd.
6. Elementary Solid State Physics, 1/e M. Ali Omar, 1999, Pearson India
7. Solid State Physics, M.A. Wahab, 2011, Narosa Publications

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2nd 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 III (Credits = 24, Marks = 600)		SEMESTER IV (Credits = 24, Marks = 600)	
PHY- DSC - 3	Elements of Modern Physics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))	**PHY- DSC - 5**	Mathematical & Computational Physics - III Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))
PHY- DSC - 4	Thermal Physics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))	**PHY- DSC - 6**	Quantum Mechanics and Applications Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))
PHY- SEC - 3	Mathematical & Computational Physics - II Credits -3, Marks-75 (50 (T) + 25 (P)	**PHY- DSC - 7**	Analog Systems and Applications Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))

PHY- IDC -3	Waves & Optics Credits – 3 (2(T) + 1 (P)) Marks – 75 (50 (T) +25 (P))		
PHY– M- 3	Waves and Optics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))	**PHY– M- 4**	Elements of Modern Physics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))

Semester III

PHY-DSC-3: (THEORY)

ELEMENTS OF MODERN PHYSICS

Total Lectures: 60Credits: 4

Max. Marks:100

Objective: *The course content covers foundations of modern physics, experiments forming basis of quantum mechanics, Schrodinger equation and applications, uncertainty principle, nature of nuclear force, nuclear models, fission and fusion, nuclear reactors, stellar energy Spontaneous and Stimulated emissions and Lasers.*

Planck's quantum, Planck's constant and light as a collection of photons; Blackbody Radiation: Quantum theory of Light; Photo-electric effect and Compton scattering. De Broglie wavelength and matter waves; Davisson-Germer experiment. Wave description of particles by wave packets. Group and Phase velocities and relation between them. Two-Slit experiment with electrons. Probability. Wave amplitude and wave functions.

Gravitational Red-shift of photons. **(10 Lectures)**

Position measurement- gamma ray microscope thought experiment; Wave-particle duality, Heisenberg uncertainty principle (Uncertainty relations involving Canonical pair of variables): Derivation from Wave Packets impossibility of a particle following a trajectory; Estimating minimum energy of a confined particle using uncertainty principle; Energy-time uncertainty principle- application to virtual particles and range of an interaction. **(5 Lectures)**

Two slit interference experiment with photons, atoms and 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 a wave function, probabilities and normalization; Probability and probability current densities in one dimension. **(8 Lectures)**

One dimensional infinitely rigid box- energy eigenvalues and eigenfunctions, normalization; Quantum dot as example; Quantum mechanical scattering and tunnelling in one dimension-across a step potential & rectangular potential barrier. **(8 Lectures)**

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

Radioactivity: stability of the nucleus; Law of radioactive decay; Mean life and half-life; Alpha decay; Beta decay- energy released, spectrum and Pauli's prediction of neutrino; Gamma ray emission, energy-momentum conservation: electron-positron pair creation by gamma photons in the vicinity of a nucleus.
(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 driving stellar energy (brief qualitative discussions). **(3 Lectures)**

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

(3 Lectures)

Reference Books:

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

Additional Books for Reference

7. Modern Physics, J.R. Taylor, C.D. Zafiratos, M.A. Dubson, 2004, PHI Learning.
8. Theory and Problems of Modern Physics, Schaum`s outline, R. Gautreau and W. Savin, 2ndEdn, Tata McGraw-Hill Publishing Co. Ltd.
9. Quantum Physics, Berkeley Physics, Vol.4. E.H.Wichman, 1971, Tata McGraw-Hill Co.
10. Basic ideas and concepts in Nuclear Physics, K.Heyde, 3rdEdn., Institute of Physics Pub.
11. Six Ideas that Shaped Physics: Particle Behave like Waves, T.A.Moore, 2003, McGraw Hill

PHY-DSC- 4 (THEORY)

THERMAL PHYSICS

Total Lectures:60Credits: 4

Max. Marks: 100

Objective: *The covers laws of thermodynamics and applications, Thermodynamic Potentials, Maxwell's Thermodynamic Relations, Kinetic theory of gases, molecular collisions and real gas behaviour, Equation of State for Real Gases, Joule-Thomson Effect for Real and Van der Waal Gases.*

Introduction to Thermodynamics

Zeroth and First Law of Thermodynamics: Extensive and intensive ThermodynamicVariables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics & Concept of Temperature, Concept of Work & Heat, State Functions, First Law of Thermodynamics and its differential form, Internal Energy, First Law & various processes, Applications of First Law: General Relation between C_P and C_V, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient. **(5 Lectures)**

Second Law of Thermodynamics: Reversible and Irreversible process with examples.Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine & efficiency. Refrigerator & coefficient of performance, 2^{nd} Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence. Carnot's Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale. **(8 Lectures)**

Entropy: Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law ofThermodynamics in terms of Entropy. Entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Temperature–Entropy diagrams for Carnot's Cycle. Third Law of Thermodynamics. Unattainability of Absolute Zero. **(5 Lectures)**

Thermodynamic Potentials: Thermodynamic Potentials: Internal Energy, Enthalpy,Helmholtz Free Energy, Gibb's Free Energy. Their Definitions, Properties and Applications. Surface Films and Variation of Surface Tension with Temperature. Magnetic Work, Cooling due to adiabatic demagnetization, First and second order Phase Transitions with examples, Clausius Clapeyron Equation and Ehrenfest equations. **(5 Lectures)**

Maxwell's Thermodynamic Relations: Derivations and applications of Maxwell'sRelations, Maxwell's Relations:(1) Clausius Clapeyron equation, (2) Values of C_p-C_V, (3) TdS Equations, (4) Joule-Kelvin coefficient for Ideal and Van der Waal Gases, (5) Energy equations, (6) Change of Temperature during Adiabatic Process. **(5 Lectures)**

Kinetic Theory of Gases

Distribution of Velocities: Maxwell-Boltzmann Law of Distribution of Velocities in anIdeal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases. **(5 Lectures)**

Molecular Collisions: Mean Free Path. Collision Probability. Estimates of Mean FreePath. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance. **(4 Lectures)**

Real Gases: Behavior of Real Gases: Deviations from the Ideal Gas Equation. TheVirial Equation. Andrew's Experiments on CO_2 Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapour and Gas. Boyle Temperature. Van der Waal's Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States. Comparison with Experimental Curves. P-V Diagrams. Joule's Experiment. Free Adiabatic Expansion of a Perfect Gas. Joule-Thomson Porous Plug Experiment. Joule-Thomson Effect for Real and Van der Waal Gases. Temperature of Inversion. Joule-Thomson Cooling. **(8 Lectures)**

Reference Books:

1. Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill.
2. A Treatise on Heat, Meghnad Saha, and B.N.Srivastava, 1958, Indian Press
3. Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition, 1993, Tata McGraw-Hill
4. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer.
5. Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa.
6. Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Ed., 2012, Oxford University Press
7. Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. Chand Publications.

PHY- SEC-3 (THEORY)

MATHEMATICAL & COMPUTATIONA PHYSICS PHYSICS-II

Total Lectures: 45 **Credits: 3**

Max. Marks: 75

Objective: *The emphasis of the course is on applications in solving problems of interest to physicists. Students are to be examined on the basis of problems, seen and unseen.*

Fourier Series: Periodic functions. Orthogonality of sine and cosine functions, DirichletConditions(Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Complex representation of Fourier series. Expansion of functions with arbitrary period. Expansion of non-periodic functions over an interval. Even and odd functions and their Fourier expansions. Application.

Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity. **(10 Lectures)**

Frobenius Method and Special Functions: Singular Points of Second Order LinearDifferential Equations and their importance. Frobenius method and its applications to differential equations. Legendre, Bessel, Hermite and Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. Expansion of function in a series of Legendre Polynomials. Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions ($J_o(x)$ and $J_1(x)$)and Orthogonality.

(20 Lectures)

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

Theory of Errors: Systematic and Random Errors. Propagation of Errors. Normal Lawof Errors. Standard and Probable Error. Least-squares fit. Error on the slope and intercept of a fitted line. **(6 Lectures)**

Partial Differential Equations: Solutions to partial differential equations, usingseparation of variables: Laplace's Equation in problems of rectangular, cylindrical and
spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes. Diffusion Equation.

(12 Lectures)

Reference Books:

1. Mathematical Methods for Physicists: Arfken, Weber, 2005, Harris, Elsevier.
2. Fourier Analysis by M.R. Spiegel, 2004, Tata McGraw-Hill.
3. Mathematics for Physicists, Susan M. Lea, 2004, Thomson Brooks/Cole.
4. Differential Equations, George F. Simmons, 2006, Tata McGraw-Hill.
5. Partial Differential Equations for Scientists & Engineers, S.J. Farlow, 1993, Dover Pub.
6. Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press
7. Mathematical methods for Scientists & Engineers, D.A. McQuarrie, 2003, Viva Books

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(PRACTICAL)

For PHY- DSC -3, PHY -DSC -4, SEC 3, PHY-DSC -5, PHY-DSC-6 and PHY-DSC-7

Credits and marks are defined at the beginning of the syllabus

Note: *The experiments listed are the Practical Part of the DSC and SEC Papers, are to be clubbed together and will be performed by the students during the Semesters III and IV. Basic experiments of these core papers will be covered in Semester III and the rest will be done in Semester IV.* ***(10+10)*** *experiments are to be performed in each Semester without any repetition. General evaluation procedure has been defined under the heading "Evaluation" in the beginning of the syllabus.*

Experiments involving thermal physics:

Objective: *The laboratory exercises have been designed on the measurements of thermal conductivity, Temperature Coefficient of Resistance,and use of various temperature transducers.*

1. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
2. To measure the coefficient of linear expansion for different metals and alloys.
3. To determine the value of Stefan's Constant of radiation.
4. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
5. To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.
6. To measure the thermal conductivity and thermal diffusivity of a conductor.
7. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.
8. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT).
9. To study the variation of Thermo-Emf of a Thermocouple with Difference of Temperature of its Two Junctions. To calibrate a thermocouple to measure temperature in a specified Range using (i) Null Method, (ii) Direct measurement using Op-Amp difference amplifier and to determine Neutral Temperature.
10. To determine thermal conductivity of a bad conductor disc using Advance kit involving constant current source for heating and thermocouples for temperature measurements.

Reference Books

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.

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Experiments involvinganalog systems and applications:

1. To study I-V characteristics of different diodes - Ge, Si, LED and Zener. Use constant current source for Zener.
2. To study voltage regulation and ripple factor for a half-wave and a full-wave rectifier without and with different filters. Use of Zener diode and IC regulators.
3. To study common emitter characteristics of a given transistor and to determine various parameters.
4. Study of I-V & power curves of solar cells, and find maximum power point & efficiency.
5. To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
6. To study the frequency response of voltage gain of a RC-coupled transistor amplifier.
7. To design a Wien bridge oscillator for given frequency using an op-amp.
8. To design a phase shift oscillator of given specifications using BJT.
9. To study the Colpitt`s oscillator.
10. To design a digital to analog converter (DAC) of given specifications.
11. To study the analog to digital convertor (ADC) IC.
12. To design an inverting amplifier using Op-amp (741,351) for dc voltage of given gain
13. To design inverting amplifier using Op-amp (741,351) and study its frequency response
14. To design non-inverting amplifier using Op-amp (741,351) & study its frequency response
15. To study the zero-crossing detector and comparator
16. To add two dc voltages using Op-amp in inverting and non-inverting mode
17. To design a precision Differential amplifier of given I/O specification using Op-amp.
18. To investigate the use of an op-amp as an Integrator.
19. To investigate the use of an op-amp as a Differentiator.
20. To design a circuit to simulate the solution of a $1^{st}/2^{nd}$ order differential equation. \
21. To draw the characteristics of a given triode and to determine the tube parameters.
22. Calibration of a Si diode, a thermistor and thermocouple for temperature measurements.
23. To measure low resistance by Kelvin's double bridge/ Carey Foster's bridge.

Reference Books:

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

Experiments involving modern physics:

Objective :*The laboratory experiments forming basis of quantum mechanics photoelectric effect – photoelectric effect, ionization potential, measurement of absorption and emission spectra, diffraction, diffraction of light, charge on electron, and tunneling effect.*

1. Measurement of Planck's constant using black body radiation and photo-detector
2. Photo-electric effect: photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light
3. To determine work function of material of filament of directly heated vacuum diode.
4. To determine the 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 ionization potential of mercury.
7. To determine the absorption lines in the rotational spectrum of Iodine vapour.
8. To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
9. To setup the Millikan oil drop apparatus and determine the charge of an electron.
10. To show the tunneling effect in tunnel diode using I-V characteristics.
11. To determine (i) wavelength and (ii) angular spread of He-Ne laser using plane diffraction grating
12. Dependence of scattering angle on kinetic energy and impact parameter in Rutherford scattering (mechanical analogue).
13. Measurement of the electrical and thermal conductivity of copper to determine its Lorentz number.
14. To determine energy band gap of a given semiconductor.
15. Verification of laws of probability and radioactivity (mechanical analogue).

Reference Books

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

Experiments in Computer Lab:

Objective: *The aim of this Lab is to use the computational methods to solve physical problems. Course will consist of lectures (both theory and practical) in the Lab. Evaluation will be performed both on the programming and also the basis of formulating the problem.*

Scilab/C++ based simulations experiments based on Mathematical Physics problems like

1. Solve differential equations:

dy/dx = e^{-x} with y = 0 for x = 0
dy/dx + e^{-x}y = x^2
d^2y/dt^2 + 2 dy/dt = -y
d^2y/dt^2 + e^{-t} dy/dt = -y

2. Dirac Delta Function : Evaluate $\frac{1}{\sqrt{2\pi\sigma^2}}\int e^{\frac{-(x-2)^2}{2\sigma^2}}(x+3)dx$, for σ = 1, 0.1, 0.01 and show it tends to 5.

3. Fourier Series:

Program to sum $\sum_{n=1}^{\infty}(0.2)^n$
Evaluate the Fourier coefficients of a given periodic function (square wave)

4. Frobenius method and Special functions:

$$\int_{-1}^{+1} P_n(\mu)P_m(\mu)d\mu = \delta_{n,m}$$

Plot $P_n(x)$, $j_v(x)$.
Show recursion relations.

5. Calculation of error for each data point of observations recorded in experiments done in previous semesters (choose any two).

6. Calculation of least square fitting manually without giving weightage to error. Confirmation of least square fitting of data through computer program.
7. Evaluation of trigonometric functions e.g. *sinθ,* Given Bessel's function at N points find its value at an intermediate point. Complex analysis: Integrate $1/(x^2+2)$ numerically and check with computer integration.
8. Compute the n^{th} roots of unity for n = 2, 3, and 4.
9. Find the two square roots of −5+12*j*.
10. Integral transform: FFT of given functions
11. Solve Kirchoff's Current law for any node of an arbitrary circuit using Laplace's transform.
12. Solve Kirchoff's Voltage law for any loop of an arbitrary circuit using Laplace's transform.
13. Perform circuit analysis of a general LCR circuit using Laplace's transform.

Reference Books:

- Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
- Mathematics for Physicists, P. Dennery and A. Krzywicki, 1967, Dover Publications
- Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer ISBN: 978-3319067896
- A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press
- Scilab by example: M. Affouf, 2012. ISBN: 978-1479203444
- Scilab (A free software to Matlab): H.Ramchandran, A.S.Nair. 2011 S.Chand& Company
- Scilab Image Processing: Lambert M. Surhone. 2010 Betascript Publishing
- https://web.stanford.edu/~boyd/ee102/**laplace**_ckts.pdf
- ocw.nthu.edu.tw/ocw/upload/12/244/12handout.pdf

Minor-Physics: For students of other department

PHY-M- 3

WAVES AND OPTICS

THEORY

Total Lectures: 60 **Credits: 4**

Max. Marks : 100

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.*

Superposition of Two Collinear Harmonic oscillations: Linearity &SuperpositionPrinciple. (1) Oscillations having equal frequencies and (2) Oscillations having different frequencies (Beats). **(4 Lectures)**

Superposition of Two Perpendicular Harmonic Oscillations: Graphical andAnalytical Methods. Lissajous Figures with equal an unequal frequency and their uses. **(2 Lectures)**

Waves Motion- General: Transverse waves on a string. Travelling and standingwaves on a string. Normal Modes of a string. Group velocity, Phase velocity. Plane waves. Spherical waves, Wave intensity. **(7 Lectures)**

Fluids: Surface Tension: Synclastic and anticlastic surface - Excess of pressure -Application to spherical and cylindrical drops and bubbles - variation of surface tension with temperature - Jaegar's method. Viscosity - Rate flow of liquid in a capillary tube - Poiseuille's formula - Determination of coefficient of viscosity of a liquid - Variations of viscosity of liquid with temperature- lubrication. **(6 Lectures)**

Sound: Simple harmonic motion - forced vibrations and resonance - Fourier'sTheorem - Application to saw tooth wave and square wave - Intensity and loudness of sound - Decibels - Intensity levels - musical notes - musical scale. Acoustics of buildings: Reverberation and time of reverberation - Absorption coefficient - Sabine's formula - measurement of reverberation time - Acoustic aspects of halls and auditoria. **(6 Lectures)**

Wave Optics: Electromagnetic nature of light. Definition and Properties of wavefront. Huygens Principle. **(3 Lectures)**

Interference: Interference: Division of amplitude and division of wavefront. Young'sDouble 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.

(10 Lectures)

Michelson's Interferometer: Idea of form of fringes (no theory needed),Determination of wavelength, Wavelength difference, Refractive index, and Visibility of fringes.

(3 Lectures)

Diffraction: Fraunhofer diffraction- Single slit; Double Slit. Multiple slits andDiffraction grating. Fresnel Diffraction: Half-period zones. Zone plate. Fresnel Diffraction pattern of a straight edge, a slit and a wire using half-period zone analysis. **(14 Lectures)**

Polarization: Transverse nature of light waves. Plane polarized light – productionand analysis. Circular and elliptical polarization. **(5 Lectures)**

Reference Books:

1. Fundamentals of Optics, F.A Jenkins and H.E White, 1976, McGraw-Hill
2. Principles of Optics, B.K. Mathur, 1995, Gopal Printing
3. Fundamentals of Optics, H.R. Gulati and D.R. Khanna, 1991, R. Chand Publications
4. University Physics. F.W. Sears, M.W. Zemansky and H.D. Young. 13/e, 1986. Addison-Wesley

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PHY-M- 303
WAVES AND OPTICS
PRACTICAL

Total Lectures : 60 **Credits: 2**

Max. Marks : 50

Objective *:* The aim of the laboratory exercises is to train the students in handling the equipments, verifying some laws they study in theory and making them confident to perform precise measurements.

Note: *The experiments listed in the Practical Part of the Generic Elective Papers, i.e.,* ***PHY-GE5P (B) :Waves and Optics, PHY-GE6P (B):Mathematical Physics II, PHY-GE7P (B): Digital, Analog Circuits and Instrumentation, PHY-GE8P (B): Thermal Physics and Statistical Mechanics,*** *are to be clubbed together and will be performed by the students during the Semesters III and IV. Basic experiments of these Generic Elective papers will be covered in Semester III and the rest will be done in Semester IV.* ***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 investigate the motion of coupled oscillators
2. To determine the Frequency of an Electrically Maintained Tuning Fork by Melde's Experiment and to verify λ^2 – T Law.
3. To study Lissajous Figures
4. Familiarization with Schuster`s focussing; determination of angle of prism.

5. To determine the Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
6. To determine the Refractive Index of the Material of a Prism using Sodium Light.
7. To determine Dispersive Power of the Material of a Prism using Mercury Light
8. Determination of refractive index of prism for different wave-lengths using Spectrometer and deterrmine the value of Cauchy Constants.
9. To determine the Resolving Power of a Prism.
10. To determine wavelength of sodium light using Fresnel Biprism.
11. To determine wavelength of sodium light using Newton's Rings.
12. To determine the wavelength of Laser light using Diffraction of Single Slit.
13. To determine wavelength of (1) Sodium and (2) Spectral lines of the Mercury light using plane diffraction Grating
14. To determine the Resolving Power of a Plane Diffraction Grating.
15. To measure the intensity using photosensor and laser in diffraction patterns of single and double slits.
16. Determination of focal length of convex mirror by beam compass method.
17. Determination of magnifying power of a telescope by slit method.
18. Determination of resolving power of a telescope.
19. To determine the wave-length of laser light using a plane diffraction grating.
20. Determination of wave-length of sodium light by Newton's rings method.
21. Determination of specific rotation of sugar using a Polarimeter.
22. Determination of frequency of A.C. mains by using electrical vibrator.
23. Determination of velocity of ultrasonic waves in a given liquid

Reference Books:

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, 4^{th} Edition, reprinted 1985, Heinemann Educational Publishers
3. A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11^{th} Edition, 2011, Kitab Mahal, New Delhi.

PHY-IDC-3 (Theory)

WAVES AND OPTICS

THEORY

Total Lectures: 30 **Credits: 2**

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.*

Superposition of Two Collinear Harmonic oscillations: Linearity &SuperpositionPrinciple. (1) Oscillations having equal frequencies and (2) Oscillations having different frequencies (Beats). **(4 Lectures)**

Superposition of Two Perpendicular Harmonic Oscillations: Graphical andAnalytical Methods. Lissajous Figures with equal an unequal frequency and their uses. **(2 Lectures)**

Waves Motion- General: Transverse waves on a string. Travelling and standingwaves on a string. Normal Modes of a string. Group velocity, Phase velocity. Plane waves. Spherical waves, Wave intensity. **(7 Lectures)**

Fluids: Surface Tension: Synclastic and anticlastic surface - Excess of pressure -Application to spherical and cylindrical drops and bubbles - variation of surface tension with temperature - Jaegar's method. Viscosity - Rate flow of liquid in a capillary tube - Poiseuille's formula - Determination of coefficient of viscosity of a liquid - Variations of viscosity of liquid with temperature- lubrication. **(6 Lectures)**

Sound: Simple harmonic motion - forced vibrations and resonance - Fourier'sTheorem - Application to saw tooth wave and square wave - Intensity and loudness of sound - Decibels - Intensity levels - musical notes - musical scale. Acoustics of buildings: Reverberation and time of reverberation - Absorption coefficient - Sabine's formula - measurement of reverberation time - Acoustic aspects of halls and auditoria. **(6 Lectures)**

Wave Optics: Electromagnetic nature of light. Definition and Properties of wavefront. Huygens Principle. **(3 Lectures)**

Interference: Interference: Division of amplitude and division of wavefront. Young'sDouble 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.

(10 Lectures)

Michelson's Interferometer: Idea of form of fringes (no theory needed),Determination of wavelength, Wavelength difference, Refractive index, and Visibility of fringes.

(3 Lectures)

Diffraction: Fraunhofer diffraction- Single slit; Double Slit. Multiple slits andDiffractiongrating. Fresnel Diffraction: Half-period zones. Zone plate. Fresnel Diffraction pattern of a straight edge, a slit and a wire using half-period zone analysis. **(14 Lectures)**

Polarization: Transverse nature of light waves. Plane polarized light – productionand analysis. Circular and elliptical polarization. **(5 Lectures)**

Reference Books:

5. Fundamentals of Optics, F.A Jenkins and H.E White, 1976, McGraw-Hill
6. Principles of Optics, B.K. Mathur, 1995, Gopal Printing
7. Fundamentals of Optics, H.R. Gulati and D.R. Khanna, 1991, R. Chand Publications
8. University Physics. F.W. Sears, M.W. Zemansky and H.D. Young. 13/e, 1986. Addison-Wesley

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WAVES AND OPTICS (IDC -3)

PRACTICAL

Total Lectures : 45 Credits: 1

Max. Marks : 25

Objective *:* The aim of the laboratory exercises is to train the students in handling the equipments, verifying some laws they study in theory and making them confident to perform precise measurements.

Note: *The experiments listed in the Practical Part of the Generic Elective Papers, i.e.,* ***PHY-GE5P (B) :Waves and Optics, PHY-GE6P (B):Mathematical Physics II, PHY-GE7P (B): Digital, Analog Circuits and Instrumentation, PHY-GE8P (B): Thermal Physics and Statistical Mechanics,*** *are to be clubbed together and will be performed by the students during the Semesters III and IV. Basic experiments of these Generic Elective papers will be covered in Semester III and the rest will be done in Semester IV.* ***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.*

24. To investigate the motion of coupled oscillators
25. To determine the Frequency of an Electrically Maintained Tuning Fork by Melde's Experiment and to verify λ^2 – T Law.
26. To study Lissajous Figures
27. Familiarization with Schuster`s focussing; determination of angle of prism.
28. To determine the Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
29. To determine the Refractive Index of the Material of a Prism using Sodium Light.

30. To determine Dispersive Power of the Material of a Prism using Mercury Light
31. Determination of refractive index of prism for different wave-lengths using Spectrometer and deterrmine the value of Cauchy Constants.
32. To determine the Resolving Power of a Prism.
33. To determine wavelength of sodium light using Fresnel Biprism.
34. To determine wavelength of sodium light using Newton's Rings.
35. To determine the wavelength of Laser light using Diffraction of Single Slit.
36. To determine wavelength of (1) Sodium and (2) Spectral lines of the Mercury light using plane diffraction Grating
37. To determine the Resolving Power of a Plane Diffraction Grating.
38. To measure the intensity using photosensor and laser in diffraction patterns of single and double slits.
39. Determination of focal length of convex mirror by beam compass method.
40. Determination of magnifying power of a telescope by slit method.
41. Determination of resolving power of a telescope.
42. To determine the wave-length of laser light using a plane diffraction grating.
43. Determination of wave-length of sodium light by Newton's rings method.
44. Determination of specific rotation of sugar using a Polarimeter.
45. Determination of frequency of A.C. mains by using electrical vibrator.
46. Determination of velocity of ultrasonic waves in a given liquid

Reference Books:

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, 4^{th} Edition, reprinted 1985, Heinemann Educational Publishers
3. A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11^{th} Edition, 2011, Kitab Mahal, New Delhi.

Semester IV

PHY-DSC-5

MATHEMATICAL & COMPUTATIONAL PHYSICS-III
(THEORY)

Total Lectures: 60 **Credits: 4**

Max. Marks : 100

Objective: *The emphasis of the course is on applications in solving problems of interest to physicists. Students are to be examined on the basis of problems, seen and unseen.*

Complex Analysis: Brief Revision of Complex Numbers and their GraphicalRepresentation. Euler's formula, De Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity, branch cuts. Integration of a function of a complex variable. Cauchy's Inequality. Cauchy's Integral formula. Simply and multiply connected region. Laurent and Taylor's expansion. Residues and Residue Theorem. Application in solving Definite Integrals. **(30 Lectures)**

Integrals Transforms:

Fourier Transforms: Fourier Integral theorem. Fourier Transform. Examples. Fourier transform of trigonometric, Gaussian, finite wave train & other functions. Representation of Dirac delta function as a Fourier Integral. Fourier transform of derivatives, Inverse Fourier transform, Convolution theorem. Properties of Fourier transforms (translation, change of scale, complex conjugation, etc.). Three dimensional Fourier transforms with examples. Application of Fourier Transforms to differential equations: One dimensional Wave and Diffusion/Heat Flow Equations.

(15 Lectures)

Laplace Transforms: Laplace Transform (LT) of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of 1^{st} and 2^{nd} order Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. LT of Unit Step function, Dirac Delta function, Periodic Functions. Convolution Theorem. Inverse LT. Application of Laplace Transforms to 2^{nd} order Differential Equations: Damped Harmonic Oscillator, Simple Electrical Circuits, Coupled differential equations of 1^{st} order. Solution of heat flow along infinite bar using Laplace transform. **(15 Lectures)**

Reference Books:

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

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PHY-DSC-6

QUANTUM MECHANICS AND APPLICATIONS

THEORY

Total Lectures: 60 **Credits: 4**

Max. Marks : 100

Objective:*The course content covers basis of quantum mechanics, Time dependent and time independent Schrodinger equations and their solutions with different potentials, applications of quantum mechanics for hydrogen-like and many electron atoms and atoms in electric and magnetic fields.*

Time dependent Schrodinger equation: Time dependent Schrodinger equation and dynamical evolution of a quantum state; Properties of Wave Function. Interpretation of Wave Function Probability and probability current densities in three dimensions; Conditions for Physical Acceptability of Wave Functions. Normalization. Linearity and Superposition Principles. Eigenvalues and Eigenfunctions. Position, momentum and Energy operators; commutator of position and momentum operators; Expectation values of position and momentum. Wave Function of a Free Particle. **(6 Lectures)**

Time independent Schrodinger equation-Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wavefunction as a linear combination of energy eigenfunctions; General solution of the time dependent Schrodinger equation in terms of linear combinations of stationary states; Application to spread of Gaussian wave-packet for a free particle in one dimension; wave packets, Fourier transforms and momentum space wavefunction; Position-momentum uncertainty principle. **(10 Lectures)**

General discussion of bound states in an arbitrary potential- continuity of wave function, boundary condition and emergence of discrete energy levels; application to one-dimensional problem-square well potential; Quantum mechanics of simple harmonic oscillator-energy levels and energy eigenfunctions using Frobenius method; Hermite polynomials; ground state, zero point energy & uncertainty principle. **(12 Lectures)**

Quantum theory of hydrogen-like atoms: time independent Schrodinger equation in spherical polar coordinates; separation of variables for second order partial differential equation; angular momentum operator & quantum numbers; Radial wavefunctions from Frobenius method; shapes of the probability densities for ground & first excited states; Orbital angular momentum quantum numbers l and m; s, p, d,.. shells. **(10 Lectures)**

Atoms in Electric & Magnetic Fields: Electron angular momentum. Space quantization. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Zeeman Effect: Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton. **(8 Lectures)**

Atoms in External Magnetic Fields: Normal and Anomalous Zeeman Effect. Paschen Back and Stark Effect (Qualitative Discussion only). **(4 Lectures)**

Many electron atoms: Pauli's Exclusion Principle. Symmetric & Antisymmetric Wave Functions. Periodic table. Fine structure. Spin orbit coupling. Spectral Notations for Atomic States. Total angular momentum. Vector Model. Spin-orbit coupling in atoms-L-S and J-J couplings. Hund's Rule. Term symbols. Spectra of Hydrogen and Alkali Atoms (Na etc.). **(10 Lectures)**

Reference Books:

1. A Text book of Quantum Mechanics, P.M.Mathews and K.Venkatesan, 2nd Ed., 2010, McGraw Hill
2. Quantum Mechanics, Robert Eisberg and Robert Resnick, 2nd Edn., 2002, Wiley.
3. Quantum Mechanics, Leonard I. Schiff, 3rd Edn. 2010, Tata McGraw Hill.
4. Quantum Mechanics, G. Aruldhas, 2nd Edn. 2002, PHI Learning of India.
5. Quantum Mechanics, Bruce Cameron Reed, 2008, Jones and Bartlett Learning.
6. Quantum Mechanics: Foundations & Applications, Arno Bohm, 3rd Edn., 1993, Springer
7. Quantum Mechanics for Scientists & Engineers, D.A.B. Miller, 2008, Cambridge University Press

Additional Books for Reference

1. Quantum Mechanics, Eugen Merzbacher, 2004, John Wiley and Sons, Inc.
2. Introduction to Quantum Mechanics, D.J. Griffith, 2nd Ed. 2005, Pearson Education
3. Quantum Mechanics, Walter Greiner, 4th Edn., 2001, Springer

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PHY-DSC- 7

ANALOG SYSTEMS AND APPLICATIONS

THEORY

Total Lectures: 60 **Credits: 4**

Max. Marks: 100

Objective: *The course content covers basic network theorems for circuit analysis, semiconductor physics and devices, diodes and applications, bipolar junction transistors, amplifiers, feedback concepts, Operation amplifiers and applications.*

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

(4 Lectures)

Semiconductor Diodes: P and N type semiconductors. Energy Level Diagram.Conductivity and Mobility, Concept of Drift velocity. PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. Static and Dynamic Resistance. Current Flow Mechanism in Forward and Reverse Biased Diode. Drift Velocity. Derivation for Barrier Potential, Barrier Width and Current for Step Junction. Current Flow Mechanism in Forward and Reverse Biased Diode. **(10 Lectures)**

Two-terminal Devices and their Applications: (1) Rectifier Diode: Half-waveRectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter (2) Zener Diode and Voltage Regulation. Principle and structure of (1) LEDs, (2) Photodiode and (3) Solar Cell. **(6 Lectures)**

Bipolar Junction transistors: n-p-n and p-n-p Transistors. Characteristics of CB, CEand CC Configurations. Current gains α and β Relations between α and β. Load Line analysis of Transistors. DC Load line and Q-point. Physical Mechanism of Current Flow. Active, Cutoff and Saturation Regions. **(6 Lectures)**

Amplifiers: Transistor Biasing and Stabilization Circuits. Fixed Bias and VoltageDivider Bias. Transistor as 2-port Network. h-parameter Equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model. Input and Output Impedance. Current, Voltage and Power Gains. Classification of Class A, B & C Amplifiers. **(10 Lectures)**

Coupled Amplifier: Two stage RC-coupled amplifier and its frequency response. **(4 Lectures)**

Feedback in Amplifiers: Effects of Positive and Negative Feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise.**(4 Lectures)**

Sinusoidal Oscillators: Barkhausen's Criterion for self-sustained oscillations. RC Phaseshift oscillator, determination of Frequency. Hartley & Colpitts oscillators.

(4 Lectures)

Operational Amplifiers (Black Box approach): Characteristics of an Ideal andPractical Op-Amp. (IC 741) Open-loop and Closed-loop Gain. Frequency Response. CMRR. Slew Rate and concept of Virtual ground.

(4 Lectures)

Applications of Op-Amps: (1) Inverting and non-inverting amplifiers, (2) Adder, (3)Subtractor, (4) Differentiator, (5) Integrator, (6) Log amplifier, (7) Zero crossing detector (8) Wein bridge oscillator. **(9 Lectures)**

Conversion: Resistive network (Weighted and R-2R Ladder). Accuracy and Resolution. A/D Conversion (successive approximation) **(3 Lectures)**

Reference Books:

1. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
2. Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
3. Solid State Electronic Devices, B.G.Streetman&S.K.Banerjee, 6th Edn.,2009, PHI Learning
4. Electronic Devices & circuits, S.Salivahanan&N.S.Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill
5. OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
6. Microelectronic circuits, A.S. Sedra, K.C. Smith, A.N. Chandorkar, 2014, 6thEdn., Oxford University Press.
7. Electronic circuits: Handbook of design & applications, U.Tietze, C.Schenk,2008, Springer
8. Semiconductor Devices: Physics and Technology, S.M. Sze, 2nd Ed., 2002, Wiley India

9. Microelectronic Circuits, M.H. Rashid, 2nd Edition, Cengage Learning
10. Electronic Devices, 7/e Thomas L. Floyd, 2008, Pearson India

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(PRACTICAL)

For PHY- DSC -3, PHY -DSC -4, SEC 3, PHY-DSC -5, PHY-DSC-6 and PHY-DSC-7

Credits and marks are defined at the beginning of the syllabus

Note: *The experiments listed are the Practical Part of the DSC and SEC Papers, are to be clubbed together and will be performed by the students during the Semesters III and IV. Basic experiments of these core papers will be covered in Semester III and the rest will be done in Semester IV.* ***(10+10)*** *experiments are to be performed in each Semester without any repetition. General evaluation procedure has been defined under the heading "Evaluation" in the beginning of the syllabus.*

Experiments involving thermal physics:

Objective: *The laboratory exercises have been designed on the measurements of thermal conductivity, Temperature Coefficient of Resistance, and use of various temperature transducers.*

11. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
12. To measure the coefficient of linear expansion for different metals and alloys.
13. To determine the value of Stefan's Constant of radiation.
14. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
15. To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.
16. To measure the thermal conductivity and thermal diffusivity of a conductor.
17. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.
18. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT).
19. To study the variation of Thermo-Emf of a Thermocouple with Difference of Temperature of its Two Junctions. To calibrate a thermocouple to measure temperature in a specified Range using (i) Null Method, (ii) Direct measurement using Op-Amp difference amplifier and to determine Neutral Temperature.
20. To determine thermal conductivity of a bad conductor disc using Advance kit involving constant current source for heating and thermocouples for temperature measurements.

Reference Books

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.

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Experiments involving analog systems and applications:

1. To study I-V characteristics of different diodes - Ge, Si, LED and Zener. Use constant current source for Zener.
2. To study voltage regulation and ripple factor for a half-wave and a full-wave rectifier without and with different filters. Use of Zener diode and IC regulators.
3. To study common emitter characteristics of a given transistor and to determine various parameters.
4. Study of I-V & power curves of solar cells, and find maximum power point & efficiency.
5. To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
6. To study the frequency response of voltage gain of a RC-coupled transistor amplifier.
7. To design a Wien bridge oscillator for given frequency using an op-amp.
8. To design a phase shift oscillator of given specifications using BJT.
9. To study the Colpitt`s oscillator.
10. To design a digital to analog converter (DAC) of given specifications.
11. To study the analog to digital convertor (ADC) IC.
12. To design an inverting amplifier using Op-amp (741,351) for dc voltage of given gain
13. To design inverting amplifier using Op-amp (741,351) and study its frequency response
14. To design non-inverting amplifier using Op-amp (741,351) & study its frequency response
15. To study the zero-crossing detector and comparator
16. To add two dc voltages using Op-amp in inverting and non-inverting mode
17. To design a precision Differential amplifier of given I/O specification using Op-amp.

18. To investigate the use of an op-amp as an Integrator.
19. To investigate the use of an op-amp as a Differentiator.
20. To design a circuit to simulate the solution of a $1^{st}/2^{nd}$ order differential equation. \
21. To draw the characteristics of a given triode and to determine the tube parameters.
22. Calibration of a Si diode, a thermistor and thermocouple for temperature measurements.
23. To measure low resistance by Kelvin's double bridge/ Carey Foster's bridge.

Reference Books:

5. Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, Mc-Graw Hill.
6. OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4^{th} edition, 2000, Prentice Hall.
7. Electronic Principle, Albert Malvino, 2008, Tata Mc-Graw Hill.
8. Electronic Devices & circuit Theory, R.L. Boylestad& L.D. Nashelsky, 2009, Pearson

Experiments involving modern physics:

Objective :*The laboratory experiments forming basis of quantum mechanics photoelectric effect – photoelectric effect, ionization potential, measurement of absorption and emission spectra, diffraction, diffraction of light, charge on electron, and tunneling effect.*

16. Measurement of Planck's constant using black body radiation and photo-detector
17. Photo-electric effect: photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light
18. To determine work function of material of filament of directly heated vacuum diode.
19. To determine the Planck's constant using LEDs of at least 4 different colours.
20. To determine the wavelength of H-alpha emission line of Hydrogen atom.
21. To determine the ionization potential of mercury.
22. To determine the absorption lines in the rotational spectrum of Iodine vapour.
23. To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
24. To setup the Millikan oil drop apparatus and determine the charge of an electron.
25. To show the tunneling effect in tunnel diode using I-V characteristics.
26. To determine (i) wavelength and (ii) angular spread of He-Ne laser using plane diffraction grating

27. Dependence of scattering angle on kinetic energy and impact parameter in Rutherford scattering (mechanical analogue).
28. Measurement of the electrical and thermal conductivity of copper to determine its Lorentz number.
29. To determine energy band gap of a given semiconductor.
30. Verification of laws of probability and radioactivity (mechanical analogue).

Reference Books

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, 4^{th} Edition, reprinted 1985, Heinemann Educational Publishers
3. A Text Book of Practical Physics, I.Prakash& Ramakrishna, 11^{th}Edn, 2011, Kitab Mahal

Experiments in Computer Lab:

Objective: *The aim of this Lab is to use the computational methods to solve physical problems. Course will consist of lectures (both theory and practical) in the Lab. Evaluation will be performed both on the programming and also the basis of formulating the problem.*

Scilab/C^{++} based simulations experiments based on Mathematical Physics problems like

1. Solve differential equations:

$dy/dx = e^{-x}$ with $y = 0$ for $x = 0$
$dy/dx + e^{-x}y = x^2$
$d^2y/dt^2 + 2\, dy/dt = -y$
$d^2y/dt^2 + e^{-t}\, dy/dt = -y$

2. Dirac Delta Function : Evaluate $\frac{1}{\sqrt{2\pi\sigma^2}}\int e^{\frac{-(x-2)^2}{2\sigma^2}}(x+3)dx,$ for σ = 1, 0.1, 0.01 and show it tends to 5.
3. Fourier Series:

Program to sum $\sum_{n=1}^{\infty}(0.2)^n$
Evaluate the Fourier coefficients of a given periodic function (square wave)

4. Frobenius method and Special functions:

$$\int_{-1}^{+1} P_n(\mu) P_m(\mu) d\mu = \delta_{n,m}$$

Plot $P_n(x)$, $j_\nu(x)$.

Show recursion relations.

14. Calculation of error for each data point of observations recorded in experiments done in previous semesters (choose any two).
15. Calculation of least square fitting manually without giving weightage to error. Confirmation of least square fitting of data through computer program.
16. Evaluation of trigonometric functions e.g. *sinθ,* Given Bessel's function at N points find its value at an intermediate point. Complex analysis: Integrate $1/(x^2+2)$ numerically and check with computer integration.
17. Compute the n^{th} roots of unity for $n = 2, 3$, and 4.
18. Find the two square roots of $-5+12j$.
19. Integral transform: FFT of given functions
20. Solve Kirchoff's Current law for any node of an arbitrary circuit using Laplace's transform.
21. Solve Kirchoff's Voltage law for any loop of an arbitrary circuit using Laplace's transform.
22. Perform circuit analysis of a general LCR circuit using Laplace's transform.

Reference Books:

- Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
- Mathematics for Physicists, P. Dennery and A. Krzywicki, 1967, Dover Publications
- Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer ISBN: 978-3319067896
- A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press
- Scilab by example: M. Affouf, 2012. ISBN: 978-1479203444
- Scilab (A free software to Matlab): H.Ramchandran, A.S.Nair. 2011 S.Chand& Company

- Scilab Image Processing: Lambert M. Surhone. 2010 Betascript Publishing
- https://web.stanford.edu/~boyd/ee102/**laplace**_ckts.pdf
- ocw.nthu.edu.tw/ocw/upload/12/244/12handout.pdf

Minor-Physics: For students of other department

PHY-M-4

ELEMENTS OF MODERN PHYSICS

THEORY

Total Lectures: 60 **Credits: 4**

Max. Marks: 100

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 physics*

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. **(8 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. **(4 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. **(4 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. **(11 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. **(12 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. **(6 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. **(11 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. **(4 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-M-4
ELEMENTS OF MODERN PHYSICS
PRACTICAL

Total Lectures : 60 **Credits: 2**

Max. Marks : 50

Objective*: This course aims to impart practical knowledge to students related to the Minor Physics subjects with in particular emphasis on Modern Physics.*

Note: *The experiments listed in the Practical Part of the Generic Elective Physics subject, i.e.,* ***Electricity and Magnetism, Mechanics, Thermal Physics, Elements of Modern Physics.*** *The experiments will be performed by the students during the Semesters I and II. Basic experiments of these papers will be covered in Semester III and the rest will be done in Semester IV. Atleast 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.*

SECTION-I

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.
16. To study the variation of the resistance of filament of bulb with its temperature.
17. Study of B-H curves of various materials using C.R.O, and determination of various parameters.

SECTION-II

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. Determination of height (of inaccessible structure) using sextant.
3. To determine the Moment of Inertia of a Flywheel.
4. 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.

5. Determination of coefficient of viscosity of a given liquid by Stoke's method. Study its temperature dependence.
6. To determine the Young's modulus by bending of beam using traveling microscope/laser.
7. Determination of modulus of rigidity by (i) dynamic method Maxwell's needle/Torsional pendulum; (ii) Forced torsional oscillations excited using electromagnet.

SECTION-III

1. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
2. Measurement of Planck's constant using black body radiation.
3. Determination of coefficient of linear expansion
4. To determine Stefan's Constant.
5. To determine the coefficient of thermal conductivity of Cu by Searle's Apparatus.
6. To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.
7. To determine the coefficient of thermal conductivity of a bad conductor by Lee and Charlton's disc method.
8. To determine the temperature co-efficient of resistance by Platinum resistance thermometer.
9. To study the variation of thermo emf across two junctions of a thermocouple with temperature.
10. To record and analyze the cooling temperature of an hot object as a function of time using a thermocouple and suitable data acquisition system
11. To calibrate Resistance Temperature Device (RTD) using Null Method/Off-Balance Bridge

SECTION-IV

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&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.
5. A Laboratory Manual of Physics for Undergraduate Classes, D.P. Khandelwal, 1985, Vani Publication.
6. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press.

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3rd 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 V (Credits = 24, Marks = 600)		SEMESTER VI (Credits = 24, Marks = 600)	
PHY- DSC -8	Electromagnetic Theory Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))	**PHY- DSC -11**	Nuclear Physics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))
PHY- DSC -9	Statistical Mechanics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))	**PHY- DSC -12**	Particle Physics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))
PHY- DSC -10	Atomic and Molecular Physics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))	**PHY- DSC -13**	Solid State Physics Credits- 4(T) + 2(P) Marks – 150 (100 (T) + 50 (P))
PHY– M- 5	Analog Electronics and Applications Credits- 3(T) + 1(P) Marks – 100 (75 (T) + 25 (P))	**PHY– M- 6**	Basics of Quantum Mechanics Credits- 3(T) + 1(P) Marks – 100 (75 (T) + 25 (P))
PHY- VAC -3	Basic Instrumentation Skill for Science Students Credit -2 (T) Marks - 50	**Internship** **PHY- INT- 1**	*Operational Procedure to be defined by physics department Credits -2, Marks -50

SEMESTER- V

PHY-DSC- 8 (T): ELECTROMAGNETIC THEORY

THEORY

Total Lectures: 60 **Credits: 4**

Max. Marks : 100

Objective :*The students are exposed to Maxwell equations and their applications, EM wave propagation in unbounded and bounded media,wave guides and optical fibers, polarization properties of em waves.*

Maxwell Equations: Review of Maxwell's equations. Displacement Current. Vector and Scalar Potentials. Gauge Transformations: Lorentz and Coulomb Gauge. Boundary Conditions at Interface between Different Media. Wave Equations. Plane Waves in Dielectric Media. Poynting Theorem and Poynting Vector. Electromagnetic (EM) Energy Density. Physical Concept of Electromagnetic Field Energy Density, Momentum Density and Angular Momentum Density. **(12 Lectures)**

EM Wave Propagation in Unbounded Media: Plane EM waves through vacuum and isotropic dielectric medium, transverse nature of plane EM waves, refractive index and dielectric constant, wave impedance. Propagation through conducting media, relaxation time, skin depth. Wave propagation through dilute plasma, electrical conductivity of ionized gases, plasma frequency, refractive index, skin depth, application to propagation through ionosphere. **(10 Lectures)**

EM Wave in Bounded Media: Boundary conditions at a plane interface between two media. Reflection & Refraction of plane waves at plane interface between two dielectric media-Laws of Reflection & Refraction. Fresnel's Formulae for perpendicular & parallel polarization cases, Brewster's law. Reflection & Transmission coefficients. Total internal reflection, evanescent waves. Metallic reflection (normal Incidence) **(10 Lectures)**

Polarization of Electromagnetic Waves: Description of Linear, Circular and Elliptical Polarization. Propagation of E.M. Waves in Anisotropic Media. Symmetric Nature of Dielectric Tensor. Fresnel's Formula. Uniaxial and Biaxial Crystals. Light Propagation in Uniaxial Crystal. Double Refraction. Polarization by Double Refraction. Nicol Prism. Ordinary & extraordinary refractive indices. Production & detection of Plane, Circularly and Elliptically Polarized Light.

Phase Retardation Plates: Quarter-Wave and Half-Wave Plates. Babinet Compensator and its Uses. Analysis of Polarized Light

(12 Lectures)

Rotatory Polarization: Optical Rotation. Biot's Laws for Rotatory Polarization. Fresnel's Theory of optical rotation. Calculation of angle of rotation. Experimental verification of Fresnel's theory. Specific rotation. Laurent's half-shade polarimeter. **(5 Lectures)**

Wave Guides: Planar optical wave guides. Planar dielectric wave guide. Condition of continuity at interface. Phase shift on total reflection. Eigenvalue equations. Phase and group velocity of guided waves. Field energy and Power transmission. **(8 Lectures)**

Optical Fibers: -Numerical Aperture. Step and Graded Indices (Definitions Only). Single and Multiple Mode Fibers (Concept and Definition Only). **(3 Lectures)**

Reference Books:

1. Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.
2. Elements of Electromagnetics, M.N.O. Sadiku, 2001, Oxford University Press.
3. Introduction to Electromagnetic Theory, T.L. Chow, 2006, Jones & Bartlett Learning
4. Fundamentals of Electromagnetics, M.A.W. Miah, 1982, Tata McGraw Hill
5. Electromagnetic field Theory, R.S. Kshetrimayun, 2012, Cengage Learning
6. Engineering Electromagnetic, Willian H. Hayt, 8th Edition, 2012, McGraw Hill.
7. Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer

Additional Books for Reference

1. Electromagnetic Fields & Waves, P.Lorrain&D.Corson, 1970, W.H.Freeman& Co.
2. Electromagnetics, J.A. Edminster, Schaum Series, 2006, Tata McGraw Hill.
3. Electromagnetic field theory fundamentals, B. Guru and H. Hiziroglu, 2004, Cambridge University Press

PHY-DSC-8 (P): ELECTROMAGNETIC THEORY PRACTICALS

Total Lectures : 60 **Credits: 2**

Max. Marks : 50

Objective :*The laboratory experiments based on refraction, polarization, diffraction properties of e.m. waves.*

Note: *The experiments listed in the Practical Part of the Core Papers are to be clubbed together and will be performed by the students during the Semesters V and VI. General evaluation procedure has been defined under the heading "Evaluation" in the beginning of the syllabus.*

To verify the law of Malus for plane polarized light.

1. To determine the specific rotation of sugar solution using Polarimeter.
2. To analyze elliptically polarized Light by using a Babinet's compensator.
3. To study dependence of radiation on angle for a simple Dipole antenna.
4. To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene, etc.) by studying the diffraction through ultrasonic grating.
5. To study the reflection, refraction of microwaves
6. To study Polarization and double slit interference in microwaves.
7. To determine the refractive index of liquid by total internal reflection using Wollaston's air-film.
8. To determine the refractive Index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.
9. To study the polarization of light by reflection and determine the polarizing angle for air-glass interface.
10. To verify the Stefan`s law of radiation and to determine Stefan's constant.

11. To determine the Boltzmann constant using V-I characteristics of PN junction diode.

12. To study transmission line modeled as LC ladder and find out its propagation constant.

13. To measure the Numerical Aperture of Optical Fiber and study Propagation Loss and Bending Losses.

14. Refractive index of air using Jamin's Interferometer.

15. To study the Michelson interferometer and its application.

16. To study the intensity profile of the diffraction pattern of single slit and verify the uncertainty principle by using LASER.

Reference Books

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 Ed., 2011, Kitab Mahal

4. Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer

PHY-DSC -9 (T): STATISTICAL MECHANICS

THEORY

Total Lectures: 60 **Credits: 4**

Max. Marks : 100

Objective :*The students are exposed to Classical statistics, Classical and quantum theory of radiation, Bose-Einstein and Fermi-Dirac statistics and their applications.*

Classical Statistics: Macrostate& Microstate, Elementary Concept of Ensemble, Phase Space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law, Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox, Sackur Tetrode equation, Law of Equipartition of Energy (with proof) – Applications to

Specific Heat and its Limitations, Thermodynamic Functions of a Two-Energy Levels System, Negative Temperature.

(18 Lectures)

Classical Theory of Radiation: Properties of Thermal Radiation. Blackbody Radiation. Pure temperature dependence. Kirchhoff's law. Stefan-Boltzmann law: Thermodynamic proof. Radiation Pressure. Wien's Displacement law. Wien's Distribution Law. Saha's Ionization Formula. Rayleigh-Jean's Law. Ultraviolet Catastrophe. **(9 Lectures)**

Quantum Theory of Radiation: Spectral Distribution of Black Body Radiation. Planck's Quantum Postulates. Planck's Law of Blackbody Radiation: Experimental Verification. Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law. **(5 Lectures)**

Bose-Einstein Statistics: B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and Thermodynamic functions of photon gas. Bose derivation of Planck's law.

(13 Lectures)

Fermi-Dirac Statistics: Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit. **(15 Lectures)**

Reference Books:

1. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.

2. Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill

3. Statistical and Thermal Physics, S. Lokanathan and R.S. Gambhir. 1991, Prentice Hall

4. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.

5. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer

6. An Introduction to Statistical Mechanics & Thermodynamics, R.H. Swendsen, 2012, Oxford Univ. Press

PHY- DSC-9 : STATISTICAL MECHANICS
PRACTICALS

Total Lectures: 60 **Credits: 2**

Max. Marks : 50

Objective :*The computer based numerical simulations involving use of C/C^{++}/Scilab for handling the problems based on Statistical Mechanics.*

Use C/C^{++}/Scilab/other numerical simulations for solving the problems based on Statistical Mechanics like

1. Computational analysis of the behavior of a collection of particles in a box that satisfy Newtonian mechanics and interact via the Lennard-Jones potential, varying the total number of particles N and the initial conditions:
   a) Study of local number density in the equilibrium state (i) average; (ii) fluctuations
   b) Study of transient behavior of the system (approach to equilibrium)
   c) Relationship of large N and the arrow of time
   d) Computation of the velocity distribution of particles for the system and comparison with the Maxwell velocity distribution
   e) Computation and study of mean molecular speed and its dependence on particle mass
   f) Computation of fraction of molecules in an ideal gas having speed near the most probable speed

2. Computation of the partition function $Z(\beta)$ for examples of systems with a finite number of single particle levels (e.g., 2 level, 3 level, etc.) and a finite number of non-interacting particles N under Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein statistics:
   a) Study of how $Z(\beta)$, average energy $\langle E \rangle$, energy fluctuation ΔE, specific heat at constant volume C_v, depend upon the temperature, total number of particles N and the spectrum of single particle states.
   b) Ratios of occupation numbers of various states for the systems considered above
   c) Computation of physical quantities at large and small temperature T and comparison of various statistics at large and small temperature T.

3 Plot Planck's law for Black Body radiation and compare it with Raleigh-Jeans Law at high temperature and low temperature.

4 Plot Specific Heat of Solids (a) Dulong-Petit law, (b) Einstein distribution function, (c) Debye distribution function for high temperature and low temperature and compare them for these two cases.

5 Plot the following functions with energy at different temperatures

a) Maxwell-Boltzmann distribution
b) Fermi-Dirac distribution
c) Bose-Einstein distribution

Reference Books:

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

2 Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.

3 Introduction to Modern Statistical Mechanics, D. Chandler, Oxford University Press, 1987

4 Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.

5 Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer

6 Statistical and Thermal Physics with computer applications, Harvey Gould and Jan Tobochnik, Princeton University Press, 2010.

7 Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer ISBN: 978-3319067896

8 Scilab by example: M. Affouf, 2012. ISBN: 978-1479203444

9 Scilab Image Processing: L.M.Surhone. 2010, Betascript Pub., ISBN: 9786133459274

PHY-DSC-10: ATOMIC AND MOLECULAR PHYSICS

Total Lectures: 75 **Credits: 6**

Max. Marks : 150

Objective: *The course contents covers the hydrogen and alkali spectra, coupling schemes, atoms in magnetic fields, Infrared and Raman spectroscopy, andelectron spectra, line broadening mechanisms and Lasers.*

UNIT I

Hydrogen and Alkai Spectra: Series in hydrogen, nuclear mass effect, elliptical orbits, Sommerfeld model, spin-orbit coupling, relativistic correction and Lamb shift (qualitative). Alkali Spectra and intensity ratios in doublets

Complex Spectra: LS-Coupling scheme, normal triplets, basic assumptions of the theory, identification of terms, selection rules, jj- coupling, Lande's interval rule, Selection rules, intensity ratios, regularities in complex spectra. Normal and anomalous Zeeman and Paschen Back effects, intensity rules. **(15 Lectures)**

UNIT II

Infrared and Raman Spectra: Rigid rotator, energy levels, spectrum, intensity of rotational lines, Harmonic oscillator: energy levels, eigenfunctions, spectrum, Raman effect, Quantum theory of Raman effect, Rotational and Vibrational Raman spectrum. Anharmonic oscillator: energy levels, Infrared and Raman Spectrum, Vibrational frequency and force constants, Dissociation of molecules.

Non-rigid rotator including symmetric top: energy levels, spectrum, Vibrating-rotator energy levels, Infrared and Raman spectrum, Symmetry properties of rotational levels, influence of nuclear spin, isotope effect on rotational spectra.

Electronic Spectra: Classification of electronic states: Orbital angular momentum, Electronic energy and potential curves, resolution of total energy, Vibrational Structure of Electronic transitions. Vibrational analysis, Rotational Structure of Electronic bands: General relations, branches of a band, band-head formation, Intensity distribution in a vibrational band system. Franck-Condon Principle and its wave mechanical formulation. **(40 Lectures)**

UNIT III

Lasers : Temporal and spatial coherence, shape and width of spectral lines, line broadening mechanism, natural, collision and Doppler broadening.

II. Laser Pumping and Resonators: Resonators, modes of a resonator, number of modes per unit volume, quality factor, threshold condition.

III. Dynamics of the Laser Processes: Rate equations for two, three and four level systems, production of a giant pulse – Q switching, mode-locking.

IV. Types of Lasers: He-Ne gas laser, Nitrogen Laser, CO_2 laser, Ruby laser, Semiconductor lasers, dye lasers.

V. Applications: Holography, non-linear optics: harmonic generation, second harmonic generation, phase matching and optical mixing. **(20 Lectures)**

TUTORIALS: Problems pertaining to the topics covered in the course.

Recommended Books:

1. Atomic Spectra: H. Kuhn (Longman Green) 1969.
2. Molecular Spectra and Molecular Structure I: G. Herzberg (Van-Nostrand Rein-hold), 1950.
3. Atomic Spectra: H.E. White (McGraw Hill) 1934.
4. Fundamentals of Molecular spectroscopy: Banwell and McCash (Tata McGraw Hill), 1994.
5. Molecular Spectroscopy: S. Chandra (Narosa), 2009.
6. Atomic, Molecular and Photons, Wolfgang Damtrodes (Springer), 2010.
7. Lasers and Non-linear Optics: B.B. Laud. (Wiley Eastern), 1991.
8. Principles of Lasers: O. Svelto (Plenum Press), 4^{th} edition, 1998.
9. An Introduction to Lasers and their applications: D.C.O'Shea, W. Russell and W.T. Rhodes (Addition –Wesley), 1977.
10. Laser Theory and Applications : Thyagarajan and A. Ghatak (Plenum) 1981 (reprint : MacMillan)

PHY-DSC-10 (P): ATOMIC AND MOLECULAR PHYSICS

Total Lectures: 50 Credits: 2

Max. Marks :50

Experiments are clubbed together with PHY-DSC- 8 and PHY-DC -9

MINOR PHYSICS

PHY- M- 5

ANALOG SYSTEMS AND APPLICATIONS

THEORY

Total Lectures: 45 **Credits: 3**

Max. Marks: 75

Objective: *The course content covers basic network theorems for circuit analysis, semiconductor physics and devices, diodes and applications, bipolar junction transistors, amplifiers, feedback concepts, Operation amplifiers and applications.*

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

(4 Lectures)

Semiconductor Diodes: P and N type semiconductors. Energy Level Diagram.Conductivity and Mobility, Concept of Drift velocity. PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. Static and Dynamic Resistance. Current Flow Mechanism in Forward and Reverse Biased Diode. Drift Velocity. Derivation for Barrier Potential, Barrier Width and Current for Step Junction. Current Flow Mechanism in Forward and Reverse Biased Diode. **(10 Lectures)**

Two-terminal Devices and their Applications: (1) Rectifier Diode: Half-waveRectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter (2) Zener Diode and Voltage Regulation. Principle and structure of (1) LEDs, (2) Photodiode and (3) Solar Cell. **(6 Lectures)**

Bipolar Junction transistors: n-p-n and p-n-p Transistors. Characteristics of CB, CEand CC Configurations. Current gains α and β Relations between α and β. Load Line analysis of Transistors. DC Load line and Q-point. Physical Mechanism of Current Flow. Active, Cutoff and Saturation Regions. **(6 Lectures)**

Amplifiers: Transistor Biasing and Stabilization Circuits. Fixed Bias and VoltageDivider Bias. Transistor as 2-port Network. h-parameter Equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model. Input and Output Impedance. Current, Voltage and Power Gains. Classification of Class A, B & C Amplifiers.

(10 Lectures)

Coupled Amplifier: Two stage RC-coupled amplifier and its frequency response.

(4 Lectures)

Feedback in Amplifiers: Effects of Positive and Negative Feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise.**(4 Lectures)**

Sinusoidal Oscillators: Barkhausen's Criterion for self-sustained oscillations. RC Phaseshift oscillator, determination of Frequency. Hartley & Colpitts oscillators.

(4 Lectures)

Operational Amplifiers (Black Box approach): Characteristics of an Ideal andPractical Op-Amp. (IC 741) Open-loop and Closed-loop Gain. Frequency Response. CMRR. Slew Rate and concept of Virtual ground.

(4 Lectures)

Applications of Op-Amps: (1) Inverting and non-inverting amplifiers, (2) Adder, (3)Subtractor, (4) Differentiator, (5) Integrator, (6) Log amplifier, (7) Zero crossing detector (8) Wein bridge oscillator. **(9 Lectures)**

Conversion: Resistive network (Weighted and R-2R Ladder). Accuracy and Resolution.
A/D Conversion (successive approximation) **(3 Lectures)**

Reference Books:

11. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
12. Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
13. Solid State Electronic Devices, B.G.Streetman&S.K.Banerjee, 6th Edn.,2009, PHI Learning
14. Electronic Devices & circuits, S.Salivahanan&N.S.Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill
15. OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
16. Microelectronic circuits, A.S. Sedra, K.C. Smith, A.N. Chandorkar, 2014, 6thEdn., Oxford University Press.
17. Electronic circuits: Handbook of design & applications, U.Tietze, C.Schenk,2008, Springer
18. Semiconductor Devices: Physics and Technology, S.M. Sze, 2nd Ed., 2002, Wiley India
19. Microelectronic Circuits, M.H. Rashid, 2nd Edition, Cengage Learning

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

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(PRACTICAL)

Credit - 1
Marks – 25 Total Lectures -30

Experiments involving analog systems and applications:

1. To study I-V characteristics of different diodes - Ge, Si, LED and Zener. Use constant current source for Zener.
2. To study voltage regulation and ripple factor for a half-wave and a full-wave rectifier without and with different filters. Use of Zener diode and IC regulators.
3. To study common emitter characteristics of a given transistor and to determine various parameters.
4. Study of I-V & power curves of solar cells, and find maximum power point & efficiency.
5. To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
6. To study the frequency response of voltage gain of a RC-coupled transistor amplifier.
7. To design a Wien bridge oscillator for given frequency using an op-amp.
8. To design a phase shift oscillator of given specifications using BJT.
9. To study the Colpitt`s oscillator.
10. To design a digital to analog converter (DAC) of given specifications.
11. To study the analog to digital convertor (ADC) IC.
12. To design an inverting amplifier using Op-amp (741,351) for dc voltage of given gain
13. To design inverting amplifier using Op-amp (741,351) and study its frequency response
14. To design non-inverting amplifier using Op-amp (741,351) & study its frequency response
15. To study the zero-crossing detector and comparator
16. To add two dc voltages using Op-amp in inverting and non-inverting mode
17. To design a precision Differential amplifier of given I/O specification using Op-amp.
18. To investigate the use of an op-amp as an Integrator.
19. To investigate the use of an op-amp as a Differentiator.
20. To design a circuit to simulate the solution of a 1st/2nd order differential equation. \
21. To draw the characteristics of a given triode and to determine the tube parameters.

22. Calibration of a Si diode, a thermistor and thermocouple for temperature measurements.
23. To measure low resistance by Kelvin's double bridge/ Carey Foster's bridge.

Reference Books:

9. Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A. Miller, 1994, Mc-Graw Hill.
10. OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall.
11. Electronic Principle, Albert Malvino, 2008, Tata Mc-Graw Hill.
12. Electronic Devices & circuit Theory, R.L. Boylestad& L.D. Nashelsky, 2009, Pearson

PHY- VAC - 3: BASIC INSTRUMENTATION SKILLS FOR SCIENCE STUDENTS

Total Lectures : 30 **Credits: 2**

Max. Marks : 50

Objective: *This course is to get exposure with various aspects of instruments and their usage through hands-on mode. Experiments listed below are to be done in continuation of the topics.*

Note: *The students in the class will be divided in to groups. There will be regular teaching of the theoretical aspects (8 hours) along with the Practical training of the students in various skill Development Subjects. Students shall submit a report of nearly 20 pages about the work done (giving details, highlighting innovation and future prospectus) by the end-semester. General evaluation procedure has been defined under the heading "Evaluation" in the beginning of the syllabus.*

Basic of Measurement: Instruments accuracy, precision, sensitivity, resolution rangeetc. Errors in measurements and loading effects. **Multimeter:** Principles of measurement of dc voltage and dc current, ac voltage, ac current and resistance. Specifications of a multimeter and their significance. **(4 Lectures)**

Electronic Voltmeter: Advantage over conventional multimeter for voltagemeasurement with respect to input impedance and sensitivity. Principles of voltage, measurement (block diagram only). Specifications of an electronic Voltmeter/ Multimeter and their significance.

AC millivoltmeter: Type of AC millivoltmeters: Amplifier- rectifier, and rectifier-amplifier. Block diagram ac millivoltmeter**,** specifications and their significance. **(4 Lectures)**

Cathode Ray Oscilloscope: Block diagram of basic CRO. Construction of CRT,Electron gun, electrostatic focusing and acceleration (Explanation only-no mathematical treatment), brief discussion on screen phosphor, visual persistence &chemical composition. Time base operation, synchronization. Front panel controls. Specifications of a CRO and their significance. **(6 Lectures)**

Use of CRO for the measurement of voltage (dc and ac frequency, time period. Special features of dual trace, introduction to digital oscilloscope, probes. Digital storage Oscilloscope: Block diagram and principle of working. **(3 Lectures)**

Signal Generators and Analysis Instruments: Block diagram, explanation andspecifications of low frequency signal generators. pulse generator, and function generator. Brief idea for testing, specifications. Distortion factor meter, wave analysis.**(4 Lectures)**

Impedance Bridges & Q-Meters: Block diagram of bridge. working principles of basic(balancing type) RLC bridge. Specifications of RLC bridge. Block diagram & working principles of a Q- Meter. Digital LCR bridges. **(3 Lectures)**

Digital Instruments: Principle and working of digital meters. Comparison of analog &digital instruments. Characteristics of a digital meter. Working principles of digital voltmeter.
(3 Lectures)

Digital Multimeter: Block diagram and working of a digital multimeter. Workingprinciple of time interval, frequency and period measurement using universal counter/ frequency counter, time- base stability, accuracy and resolution. **(3 Lectures)**

The test of lab skills will be of the following test items:

1. Use of an oscilloscope.
2. CRO as a versatile measuring device.
3. Circuit tracing of Laboratory electronic equipment,

4. Use of Digital multimeter/VTVM for measuring voltages

5. Circuit tracing of Laboratory electronic equipment

6. Winding a coil / transformer.

7. Study the layout of receiver circuit.

8. Trouble shooting a circuit

9. Balancing of bridges

Laboratory Exercises:

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

Open Ended Experiments:

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

Reference Books:

1. A text book in Electrical Technology - B L Theraja - S Chand and Co.

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

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SEMESTER -VI

PHY-DSC- 11: NUCLEAR PHYSICS

Theory

Total Lectures: 60 Credits: 4

Max. Marks : 100

Objective: *The course contents covers general properties of nuclei, nuclear models, radioactive decays, Nuclear reactions, fission and fusion processes and applications,interaction of gamma ray, charged particles and neutrons radiation with matter and respective detectors.*

General Properties of Nuclei: Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excites states. **(10 Lectures)**

Nuclear Models: Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas), evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force, Meson theory of nuclear forces. **(12 Lectures)**

Radioactivity decay: (a) Alpha decay: basics of α-decay processes, radioactive series, tunnel theory of α emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy. (b) β-decay: β^-, β^+, EC decays, beta energy spectrum, end point energy, Gamma decay: Gamma rays emission & kinematics, internal conversion. **(12 Lectures)**

Nuclear Reactions: Types of Reactions, Coulomb scattering (Rutherford scattering), Coulomb barrier, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct Reaction, resonance reaction. **(10 Lectures)**

Fission and Fusion: Nuclear reactors, Breeder reactors, Nuclear fusion in stars, formation of heavier elements, Nuclear reactor accidents – Chernobyl and Fukushima, Nuclear weapons, Fusion reactors, Inetrantional thermonuclear experimental reactor (ITER). **(9 Lectures)**

Interaction of radiation and charged particles with matter : Interaction of gamma rays with matter - photoelectric effect, Compton scattering, pair production, Energy loss of electrons and positrons, Positron annihilation in condensed media, Stopping power and range of heavier charged particles, derivation of Bethe-Bloch formula, neutron interaction with matter. **(12 Lectures)**

Detector for Nuclear Radiations: Gas-filled detectors: ionization chamber, proportional counter and GM Counter. Basic principle of Organic and Inorganic scintillation detectors for gamma and electron radiation, photo-multiplier tube, Semiconductor detectors, Solid state nuclear track detectors, Neutron detector, Cherenkov detector, radiation monitoring devices.

(10 Lectures)

Reference Books:

1 Introductory Nuclear Physics by Kenneth S. Krane (Wiley India Pvt. Ltd., 2008).

2 Concepts of Nuclear Physics by Bernard L. Cohen. (Tata Mcgraw Hill, 1998).

3. Concepts of Modern Physics by Arthur Beiser, Shobit Mahajan and S. Rai Choudhury (Tata Mcgraw Hill, 2006).
4. Modern Physics by J. Bernstein, Paul M..Fishbane, S. G. Gasiorowicz (Pearson, 2000).
5. Introduction to the physics of Nuclei & Particles, R.A. Dunlap. (Thomson Asia, 2004).
6. Basic ideas and concepts in Nuclear Physics - An Introductory Approach by K. Heyde (IOP-Institute of Physics Publishing, 2004).
7. Radiation detection and measurement, G.F. Knoll (John Wiley & Sons, 2000).
8. Physics and Engineering of Radiation Detection, Syed Naeem Ahmed (Academic Press, Elsevier, 2007).
9. Theoretical Nuclear Physics, J.M. Blatt &V.F.Weisskopf (Dover Pub.Inc., 1991).

PHY-DSC -12: PARTICLE PHYSICS

Total Lectures:60 **Credits: 4**

Max. Marks : 100

Objective :*The course contents covers the elementary particles, cosmic rays, particle properties and their reactions, evolution of universe, Partcle accelerators, colliding beams, and detectors for high energy physics.*

Elementary Particles : Historical introduction, fermions and bosons, particles and antiparticles, Classification of elementary particles and their interactions - electromagnetic, weak, strong and gravitational interactions. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, Discovery of quarks, concept of quark flavor, color quantum number, Interactions among quarks, Yukawa theory, Field bosons, Standard model and beyond, Higgs boson. **(18 Lectures)**

Cosmic Connection: Cosmic rays, sources of cosmic rays and production of secondary cosmic rays in atmosphere, Van allen radiation belt, Carbon-14 and other isotopic datings, soft and hard cosmic rays, cosmic ray experiments: discovery of particles, Brief about ground based experiments – GRAPES. **(12 Lectures)**

Particle Properties and their reactions: Properties and life time of muon, pions: Determination of mass, spin and parity. Lifetime of neutral pion and isotopic spin. Strange particles: V particles, charged K-mesons, mass and life time for charged K-mesons. Observations of different strange particles ($\Lambda°$, $\Sigma°$, $\Sigma\pm$, $\Xi°$, $\Xi+$, Ω), strange particle production and decay.Strangeness and Hypercharge. **(15 Lectures)**

VIII. Particles and evolution of Universe: Big bang expansion: size, time and temperature, formation of particles, relic radiation. Source of energy in Stars: fusion reactions, solar and atmospheric neutrinos, Black holes, Neutron stars, Concept of dark matter and dark energy.

(12 Lectures)

Particle Accelerators: Acceleartors, Ion sources, Introduction to beam optics, beamline components – magnets and vacuum systems.Linear accelerator, Cockroft accelerator, Van-de Graaff generator, Tandem accelerator, Cyclotron, Electron synchrotron, Accelerator facilities in India. Introduction to colliding beam machines CERN LHC facility.

(10 Lectures)

Detectors: Nuclear emulsions, Bubble chamber, Cloud chamber, Position-sensitive gas-filled and scintillator detectors, electromagnetic calorimeter and hadron calorimeter.

(8 Lectures)

Reference Books:

1. Introduction to High Energy Physics, D.H. Perkins, Cambridge Univ. Press
2. Introduction to Elementary Particles, D. Griffith, John Wiley & Sons
3. Quarks and Leptons, F. Halzen and A.D. Martin, Wiley India, New Delhi
4. Radiation detection and measurement, G.F. Knoll (John Wiley & Sons, 2000).
5. Physics and Engineering of Radiation Detection, Syed Naeem Ahmed (Academic Press, Elsevier, 2007).
6. Concepts of Modern Physics by Arthur Beiser, Shobit Mahajan and S. Rai Choudhury (Tata Mcgraw Hill, 2006).
7. Modern Physics by J. Bernstein, Paul M..Fishbane, S. G. Gasiorowicz (Pearson, 2000).

PHY-DSC-13 (T): SOLID STATE PHYSICS

THEORY

Total Lectures: 60 **Credits: 4**

Max. Marks: 100

Objective: *The course content covers understanding of crystal structure, band theory of solid, lattice dynamics, magnetic and dielectric properties of matter, ferroelectric materials, and superconductivity phenomenon.*

Crystal Structure: Solids: Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis – Central and Non-Central Elements. Unit Cell. Miller Indices. Reciprocal Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law. Atomic and Geometrical Factor. **(12 Lectures)**

Elementary Lattice Dynamics: Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T^3 law **(10 Lectures)**

Magnetic Properties of Matter: Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of dia– and Paramagnetic Domains. Quantum Mechanical Treatment of Paramagnetism. Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains. Discussion of B-H Curve. Hysteresis and Energy Loss. **(8 Lectures)**

Dielectric Properties of Materials: Polarization. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability. Clausius Mosotti Equation. Classical Theory of Electric Polarizability. Normal and Anomalous Dispersion. Cauchy and Sellmeir relations. Langevin-Debye equation. Complex Dielectric Constant. Optical Phenomena. Application: Plasma Oscillations, Plasma Frequency, Plasmons, TO modes. **(8 Lectures)**

Ferroelectric Properties of Materials: Structural phase transition, Classification of crystals, Piezoelectric effect, Pyroelectric effect, Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop. **(6 lectures)**

Elementary band theory: Kronig Penny model. Band Gap. Conductor, Semiconductor (P and N type) and insulator. Conductivity of Semiconductor, mobility, Hall Effect. Measurement of conductivity (04 probe method) & Hall coefficient. **(10 Lectures)**

Superconductivity: Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth. Isotope effect. Idea of BCS theory (No derivation) **(6 Lectures)**

Reference Books:

1. Introduction to Solid State Physics, Charles Kittel, 8th Edition, 2004, Wiley India Pvt. Ltd.
2. Elements of Solid State Physics, J.P. Srivastava, 4th Edition, 2015, Prentice-Hall of India
3. Introduction to Solids, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill
4. Solid State Physics, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning
5. Solid-state Physics, H. Ibach and H. Luth, 2009, Springer
6. Solid State Physics, Rita John, 2014, McGraw Hill
7. Elementary Solid State Physics, 1/e M. Ali Omar, 1999, Pearson India
8. Solid State Physics, M.A. Wahab, 2011, Narosa Publications

PRACTICALS FOR DSC- 11, DSC -12 and DSC-13

Practicals for the above DSE courses will be taken both in Physics and Computer lab meant for B.Sc. V and VI *The experiments listed in the Practical Part of the Core Papers are to be clubbed together and will be performed by the students during the Semesters V and VI. General evaluation procedure has been defined under the heading "Evaluation" in the beginning of the syllabus.*

Note: Few representative experiments are listed below. Students will perform other experiments available in B.Sc. 3rd year laboratory of old CBCS class.

1 To measure magnetic volume susceptibility of liquid - $FeCl_2/MnSo_4$solution by Quincke's method.

2 To measure the Magnetic susceptibility of Solids.

3 To determine the Coupling Coefficient of a Piezoelectric crystal.

4 To measure the Dielectric Constant of a dielectric Materials with frequency

5 To determine the complex dielectric constant and plasma frequency of metal usingSurface Plasmon resonance (SPR)

6 To determine the refractive index of a dielectric layer using SPR

7 To study the PE Hysteresis loop of a Ferroelectric Crystal.

8 To draw the BH curve of Fe using Solenoid & determine energy loss from Hysteresis.

9 To measure the resistivity of a semiconductor (Ge) with temperature by four-probe method (room temperature to 150 ^{o}C) and to determine its band gap.

10. To measure dielectric constant of a non-polar liquid and its applications.

11. To determine the Hall coefficient and mobility of given semiconductors.

12. To find conductivity of given semiconductor crystal using four probe method.

Reference Books

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 Ed., 2011, Kitab Mahal
4. Elements of Solid State Physics, J.P. Srivastava, 2nd Ed., 2006, Prentice-Hall of India.

Minor course for students of other departments

PHY-M-6

Basics of Quantum Mechanics

THEORY

Total Lectures: 45 **Credits: 3**

Max. Marks : 75

Objective :*The course content covers basis of quantum mechanics, Time dependent and time independent Schrodinger equations and their solutions with different potentials, applications of quantum mechanics for hydrogen-like and many electron atoms and atoms in electric and magnetic fields.*

Time dependent Schrodinger equation: Time dependent Schrodinger equation and dynamical evolution of a quantum state; Properties of Wave Function. Interpretation of Wave Function Probability and probability current densities in three dimensions; Conditions for Physical Acceptability of Wave Functions. Normalization. Linearity and Superposition Principles. Eigenvalues and Eigenfunctions. Position, momentum and Energy operators; commutator of position and momentum operators; Expectation values of position and momentum. Wave Function of a Free Particle.

Time independent Schrodinger equation-Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wavefunction as a linear combination of energy eigenfunctions; General solution of the time dependent Schrodinger equation in terms of linear combinations of stationary states; Application to spread of Gaussian wave-packet for a free particle in one dimension; wave packets, Fourier transforms and momentum space wavefunction; Position-momentum uncertainty principle.

General discussion of bound states in an arbitrary potential- continuity of wave function, boundary condition and emergence of discrete energy levels; application to one-dimensional problem-square well potential; Quantum mechanics of simple harmonic oscillator-energy levels and energy eigenfunctions using Frobenius method; Hermite polynomials; ground state, zero point energy & uncertainty principle.

Quantum theory of hydrogen-like atoms: time independent Schrodinger equation in spherical polar coordinates; separation of variables for second order partial differential equation; angular momentum operator & quantum numbers; Radial wavefunctions from Frobenius method; shapes of the probability densities for ground & first excited states; Orbital angular momentum quantum numbers l and m; s, p, d,.. shells.

Atoms in Electric & Magnetic Fields: Electron angular momentum. Space quantization. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Zeeman Effect: Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton.

Atoms in External Magnetic Fields: Normal and Anomalous Zeeman Effect. Paschen Back and Stark Effect (Qualitative Discussion only).

Many electron atoms: Pauli's Exclusion Principle. Symmetric & Antisymmetric Wave Functions. Periodic table. Fine structure. Spin orbit coupling. Spectral Notations for Atomic States. Total angular momentum. Vector Model. Spin-orbit coupling in atoms-L-S and J-J couplings. Hund's Rule. Term symbols. Spectra of Hydrogen and Alkali Atoms (Na etc.).

Reference Books:

8. A Text book of Quantum Mechanics, P.M.Mathews and K.Venkatesan, 2nd Ed., 2010, McGraw Hill
9. Quantum Mechanics, Robert Eisberg and Robert Resnick, 2nd Edn., 2002, Wiley.
10. Quantum Mechanics, Leonard I. Schiff, 3rd Edn. 2010, Tata McGraw Hill.
11. Quantum Mechanics, G. Aruldhas, 2nd Edn. 2002, PHI Learning of India.
12. Quantum Mechanics, Bruce Cameron Reed, 2008, Jones and Bartlett Learning.
13. Quantum Mechanics: Foundations & Applications, Arno Bohm, 3rd Edn., 1993, Springer
14. Quantum Mechanics for Scientists & Engineers, D.A.B. Miller, 2008, Cambridge University Press

Additional Books for Reference

4. Quantum Mechanics, Eugen Merzbacher, 2004, John Wiley and Sons, Inc.
5. Introduction to Quantum Mechanics, D.J. Griffith, 2nd Ed. 2005, Pearson Education
6. Quantum Mechanics, Walter Greiner, 4th Edn., 2001, Springer

PHY- M- 6 - Practical

Credits -01

Marks – 25 Total Lectures – 30

Relevant Practicalswill be performed in the

B.Sc. Subsidiary laboratory)

Internship

PHY- INT- 1

*Operational Procedure to be
defined by physics department
Credits -2, Marks -50