Department of Physics & Mathematics

Faculty of Science

M.Sc. Program in Physics

Under UGC-LOCF & CBCS

SRI SRI UNIVERSITY

24-08-19

24.8.2019

Surjeet 24/08/19

24.08.2019.

Susanta Das 24/8/19

Program Objectives, Outcomes, and General Rules & Regulations

Background: Over the years, a paradigm shift has been observed in the landscape of science. This is attributed to the enormous amount of new challenges encountered by scientists such as new discoveries, employability, cutting edge research, and ever increasing demands of this rapidly changing modern society. Henceforth, a more pragmatic approach has been felt, necessitated, and implemented in today's science education and research to counter these challenges. Consequently, cross-, inter-, and multi-disciplinary research fields have emerged, leading to a convergence of ideas, knowledge, and expertise. Physics has been an integral part of these vibrant fields - astrophysics, biophysics, nanophysics, geophysics/earth science, medical physics, chemical physics, radiation physics, environmental science, pollution control, waste management, smart materials, smart cities, engineering physics, and renewable/non-conventional energy to name a few. Therefore, a strong foundation in Physics and computational and soft skills are absolutely necessary at post-graduate level to prepare students to thrive in this highly competitive and complicated environment.

Outlines and Features of the Program: It is in response to this background, this program is proposed. It is tailored to incorporate the essential ingredients of multifaceted education and research for this rapidly changing world. This program will (i) provide the much needed and strong foundation in Physics so that students can develop the ability to apply the knowledge of Physics in any allied fields, (ii) help students to develop programming proficiency with high end software for both computation and automation (*Mathematica/Matlab* software/Programming language and *LabVIEW*), (iii) give students an opportunity to use advanced laboratory equipment to get acquainted with them, (iv) present a platform to students for training in both mechanical and electronic hardware (mechanical engineering drawing and workshop, and PCB) for basic and applied research, and (vi) offer necessary soft skills to students to build their professional careers.

Program Objectives: The objectives of this program are to cater and to meet the needs and aspirations of contemporary post-graduate Physics students. This program aims to

1. Provide
   (i) Pedagogical and content knowledge of Physics.
   (ii) Advanced knowledge.
   (iii) Technical and soft skills.
2. Create thinking abilities.
3. Train to 'Read-to-Learn' and 'Learn-to-Read'.
4. Make 'Learning-while-Doing' a realistic process.
5. Develop 'Problem Solving Skills' (PSK).
6. Develop proficiency in computer programming.
7. Connect science and technology with society.
8. Prepare for higher studies and various national/international level competitive/entrance exams (NET, GATE, JAM, & Subject GRE).
9. Improve self-efficacy.

Program Outcomes: After completion of the program, students will

1. Have
   (i) Conceptual understanding of Physics.

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(ii) Broader view of the world of science and technology
(iii) critical thinking & analytical ability.

2. Be able to
   (i) Understand other physics related topics.
   (ii) Answer & solve basic & conceptual questions and problems.
   (iii) Handle/tackle challenging problems.
   (iv) Apply the concepts in daily life.
   (v) Communicate scientific results effectively and fluently.
   (vi) Connect science and technology with society.
   (vii) Apply concepts of physics in society – sociophysics and econophysics.
   (viii) Study & understand research related articles.
   (ix) Handle sophisticated instruments.
   (x) Develop code for DAQ and theoretical physics.
   (xi) Trouble-shoot various components/devices and experimental set-up.
   (xii) Design & develop low-cost as well as high-end instruments.
   (xiii) Get involved easily with research lab.
   (xiv) Pursue higher studies in physics and other allied branches.

Academic Session: Semester system. 02 semesters (July - December and January - May).

Medium of Instruction of the Program: The medium of instruction and examination shall be English for M.Sc. Physics Program.

Conduct of the Program: A student of the M.Sc. Physics Program shall not be permitted to seek admission concurrently to any other equivalent or higher degree or diploma examination in this University or any other University, subject to rules/regulations of UGC or equivalent body in this regard and adoption of the same by the University.

Paper/Course Code: Each course offered by the Department of Physics and Mathematics is identified by a unique course code comprising of **six letters / numbers** indicating Program / level of Program [first letter in uppercase, i.e., **B** for Bachelor (Under Graduate) and **M** for **M**aster (Post Graduate)], Discipline / Subject (Next two letters in uppercase, i.e., **PH** for **PH**ysics), Semester (next digit starting from 1), Course Number (next two digits starting from 01 for each semester).
For example, the course code of the M.Sc. Physics Program in the Third semester in the Department will be **MPH 302**.
Every time when a new course is prepared by the Board of Studies (BoS) of the Department it shall be assigned a new course code. However, the University may decide a different course codification pattern for any Program in future as per the demand of the situation.

Attendance Rules: A student is required to attend 100% of the classes held in a course in the specific semester in order to be eligible to appear in the End-semester examination of that particular course. Waiving of attendance-deficit up to a maximum of 25% is permissible to accommodate following situations: (a) Representing the University in any inter-collegiate, inter-University, local, national or international events; (b) Participating in an activity of the University with prior permission of the Competent Authority; (c) Participation in NCC/NSC/NSS Camps duly supported by certificate; (d) Participation in Educational Excursions, which form a part of teaching in any subject, conducted on working days duly certified by the concern Course Teacher/Head of Department /Dean; and (e) to cover all unforeseen reasons like illness, hospitalization, personal engagements elsewhere or other personal reasons which compel a student to absent herself/himself from attending the classes. Hence, it shall be mandatory/compulsory to every student to have attendance in 75% classes held in particular course. No waiver, for whatsoever reason, shall be given. Accordingly, no application requesting waiver below 75% attendance shall be entertained by the Department. The attendance of a newly admitted candidate shall be counted from the date of her/his admission/registration or date of beginning of classes, whichever is later. In the case of promoted candidates, attendance shall be counted from the date on which respective class begins. However, if a new student is admitted late after the commencement of the classes, s/he must get herself/himself registered in the desired courses following the due procedure within 6 working days after the admission failing which her/his attendance shall be counted after 6 working days from the date of admission.

Removal of Student Name from the Program: The name of a student falling under any one of the following categories shall automatically stand removed from the rolls of the University: (a) A student who has failed to fulfill the minimum grade point requirements prescribed for the Program during the maximum duration of the Program, (b) A student who has already exhausted the maximum duration allowed for completion of the Program and has not fulfilled the requirements for the award of the degree, (c) A student who is found to be involved in misconduct, forgery, indiscipline or any other objectionable conduct, upon recommendation of the Disciplinary Committee or any other procedure deemed fit by the University & (d) A student who has failed to attend the classes as stipulated under the clause of attendance requirements in this booklet.

Student Advisor/Mentor: The Department shall appoint an Advisor/Mentor for student(s) from amongst the members of the faculty concerned. All faculty members of the department shall function as Student Advisors/Mentors and shall have more or less equal number of students. The Student Advisor/Mentor shall advise the student in choosing courses and render all possible support and guidance to him/her.

Remedial and Additional Class: Remedial and additional classes/Lab. will be conducted as and when necessary.

Repeating Course(s): A student having attendance shortage in any course may repeat the course by taking re-admission in that course in subsequent odd/even semester(s), whenever the course is being offered, within the maximum permissible duration of the Program. If the student has fulfilled the attendance requirement but did not obtain the necessary grade to pass the paper, s/he will have to take all the examinations (Internal and End-Semester) afresh. In such case the course content shall be based on the syllabi of the course in force at the time of repeat of the course. The student needs to complete the formalities as per SSU/CoE rules and regulations before repeating the course(s).

Power to Relax and Amendments: All the above guidelines are subject to the amendments, as and when required, as per the decisions pertaining to rules, regulations and norms of the University Statutory Bodies and other Regulatory Bodies etc. from time to time.

Notwithstanding anything stated in the guidelines, for any unforeseen issues arising, and not covered by the guidelines, or in the event of differences of interpretation, the Vice-Chancellor may take a decision, after obtaining the opinion/advice, if required, Deans/HoDs/Registrar. The decision of the Vice-Chancellor shall be final.

Total Credits: 100 Credits:

Electives: Either Reading Course *or* Project in IVth semester.

Distribution of Credits: A student must successfully earn 100 credits to receive M.Sc. Degree in Physics distributed as:

Semester	Credits
I	26
II	26
III	26
IV	22
Total	**100**

Credit System: Theory: 01 hour lecture per week – 01 credit.

Physics Lab.: 02 hours – 01 credit

Qualifying Marks: Pass Mark: 50 points for each paper.

Distribution of Points: Theory (T) = 100 points; Practical (P) = 100 points.

1. Theory of each paper: 100 points

Distribution of points (Theory):

1.A: *Continuous Assessment Test (CAT)/ Internal Exams*: 40 points.

1.B: *End-Term/Final exam*: 60 points.

Examination Question Pattern: CAT at the discretion of course instructor.

Following pattern will be followed on end-term physics exams.

(i) Objective/Multiple choice questions (Any number of options may be correct. Points will be awarded if all the correct answers are marked).
(ii) Explanation/Reasoning/Analytical thinking.
(iii) Problems.

(iv) Discussion/Note.
(v) Derivation

2. Physics Lab.: 100 points

2.A: *Continuous Assessment Test (CAT)/Internal Exams*: Two CATs will be conducted during regular lab. hours. Each CAT will carry 30 points. Total Points = 2 x 30 = 60 points.

[Distribution of points of CAT Practical: (i) Exam: 20 points; (ii) Viva: 05 points, (iii) Overall record up to that CAT (Performance, write-up and on time submission): 05 points.]

2.B: *Seminar:* Each student will give a seminar on the first experiment performed by him/her. Points: 10 points.

2.C: *Final practical examination*: 30 points.

[Distribution of points of Final Exam: (i) Exam: 20 points, (ii) Viva: 05 points, (iii) Overall record (Performance, write-up and on time submission throughout the semester): 05 points.]

Examination(s) will not be conducted for Extra Curricular Activities (ECA), Reading Course, and Project. Points will be awarded on the basis of performance.

SYLLABUS

M.Sc. in Physics - Semester Wise Course Structure (Total 100 Credits)

Paper Code	Course Title	Credits		
	Semester I	L	T	P
MPH 101	Mathematical Physics - I	4	0	0
MPH 102	Classical Mechanics	4	0	0
MPH 103	Electrostatics & Magnetostatics	4	0	0
MPH 104	Quantum Mechanics - I	4	0	0
MPH 105	Electronics - I	4	0	0
MPH 106	Physics Lab.- I	0	0	6
	Total Credits of Semester I	**26**		
	Semester II	L	T	P
MPH 201	Mathematical Physics - II	4	0	0
MPH 202	Quantum Mechanics - II	4	0	0
MPH 203	Solid State Physics - I	4	0	0
MPH 204	Waves & Optics	4	0	0
MPH 205	Electronics - II	4	0	0
MPH 206	Physics Lab.- II	0	0	6
	Total Credits of Semester II	**26**		
	Semester III	L	T	P
MPH 301	Mathematical Physics - III	4	0	0
MPH 302	Solid State Physics - II	4	0	0
MPH 303	Thermal Physics & Statistical Mechanics	4	0	0
MPH 304	Advanced Optics	4	0	0
MPH 305	Atomic & Molecular Physics	4	0	0
MPH 306	Physics Lab.- III	0	0	6
	Total Credits of Semester III	**26**		
	Semester IV	L	T	P
MPH 401	Mathematical Physics - IV	4	0	0
MPH 402	Classical Electrodynamics, Relativity, & Plasma Physics	4	0	0
MPH 403	Nuclear & Particle Physics	4	0	0
MPH 404	Physics Lab.- IV	0	0	6
MPH 405 *or*	Reading Course *or*	4		
MPH 406	Project	4		
	Total Credits of Semester IV	**22**		
	TOTAL CREDITS	**100**		

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Semester – I

Mathematical Physics – I

Course Objectives: Provide mathematical knolwedge required for physics

1. Fourier and Laplace transforms.
2. Special class of functions – Legendre, Bessel, Hermite, Laguerre, Chebyshev, Mathieu, and Green functions.
3. Applications of Fourier & Laplace transformations and special functions in other branches of science & technology.

Learning Outcomes: After completion of the course, learners will be able to

1. Apply the concept of Fourier transform in electronics, quantum mechanics, and other branches of science.
2. Transform various functions from one domain to another domain.
3. Apply the concepts of special functions for complicated differential equations.
4. Solve Schrodinger equation in quantum mechanics using this special class of functions and understand various quantum numbers.
5. Concepts in other mathematical/computational physics

Fourier and Laplace Transforms

Fourier Transform: Introduction, sine, cosine, and complex transforms; properties & representations of Dirac delta functions and Fourier transform, transform of derivatives, Parseval's theorem, convolution theorem, momentum representation, transfer functions, application to partial differential equations, discrete Fourier transform, introduction to fast Fourier transform.

Laplace Transform: Introduction, properties & examples of Laplace transform, convolution theorem & its applications, solving differential equations using Laplace transform technique.

Special Functions

Legendre Functions: Definition, generating function, recurrence relations, orthogonality, associated Legendre functions, spherical harmonics, orbital angular momentum operators, addition theorem for spherical harmonics, Legendre functions of second kind, vector spherical harmonics.

Bessel Functions: Definition, Bessel functions of the first kind, orthogonality, Neumann functions, Hankel functions, modified Bessel functions, asymptotic expansions, spherical Bessel functions.

Other Special Functions: Hermite functions, Laguerre functions, Chebyshev functions, hypergeometric functions, Mathieu functions, and Green functions.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Mathematical Methods for Physicists – G. Arfken & H. Weber.
2. Mathematical Methods in the Physical Sciences – M. Boas.
3. Higher Engineering Mathematics – B.S. Grewal.
4. Mathematics for Physicists & Engineers – Pipes.
5. The Use of Integral Transforms – I.N. Sneddon.
6. A Text Book of Mathematical Physics – S. Chandra.
7. Mathematical Physics – H.K. Dass & R. Verma.
8. Mathematical Physics – P.K. Chattopadhyay.
9. Engineering Mathematics Through Applications – K. Singh.

Classical Mechanics

Course Objectives:

1. Provide knowledge of system of particles, rotational motion, and gravitation.
2. Acquaint students with the basic concept of
   i. Variational principle.
   ii. Euler's equation of motion of rigid bodies.
   iii. Central force.
   iv. Lagrangian and Hamiltonian formulations.
   v. Canonical Transformations.
   vi. Hamilton-Jacobi Theory
   vii. Action-Angle Variables.
   viii. Small Oscillation.
3. Orient students with the simple applications of normal modes & normal frequencies, and Canonical transformation.
4. Make students understand the basic concepts of Poisson brackets and their properties.

Learning Outcomes: After completion of the course, learners will be able to

1. Apply the concept of conservation of linear momentum, energy and angular momentum in various classical systems.
2. Derive the Euler's equations of motion for a rigid body.
3. Describe basic concepts of normal modes.
4. Construct Lagrangian and Hamiltonian of physical systems (classical and quantum mechanical).
5. Describe basic concepts of canonical transformation, Poisson brackets and properties of Poisson brackets.
6. Transform the coordinates and variables in generalized coordinate system.
7. Apply the concept of small oscillation to physical systems.
8. Answer questions and solve problems related to

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i. System of particles, rotational motion, gravitation.
ii. Central forces including Keplar problems.
iii. Normal modes and normal frequencies.
iv. Hamiltonian & Lagrangian formulations.

Problems and Applications for a System of Particles, Rotational Motion, & Gravitation: Calculation of centroids of various bodies, motion of a point mass tied to the string wound on a cylinder, solid cylinder rolling down without slipping on an inclined plane, Euler's equation of motion, Euler angles, motion of a spinning top, statics in a uniform gravitational field, determination of gravitational field/potential of various systems, motion in a resisting medium, variable mass - rocket motion, Gyroscopic motion.

Variational Principles and Lagrange's Equations: Hamilton's principle, some techniques of the calculus of variations, derivation of Lagrange's equations from Hamilton's principle, extension of Hamilton's principle to nonholonomic systems, advantages of variational principle formulation, conservation theorems & symmetry properties, energy functions & the conservation of energy.

Central Force Problem: Reduction to the equivalent one-body problem, equations of motion & first integrals, equivalent one-dimensional problem & classification of orbits, virial theorem, differential equation for the orbit & integrable power-law potentials, conditions for closed orbits (Bertrand's theorem), Kepler problem, motion in time in Kepler problem, Laplace-Runge-Lenz vector, scattering in central force field, transformation of scattering problem to lab. co-ordinates, three-body problem.

Hamilton Equations of Motion: Legendre transformations & the Hamilton equations of motion, cyclic coordinates & conservation theorem, Routh's procedure, Hamiltonian formulation of relativistic mechanics, derivation of Hamilton's equations from variational principle, principle of least action.

Canonical Transformations: Equations of canonical transformation, examples of canonical transformations, harmonic oscillator, symplectic approach to canonical transformations, Poisson brackets & other canonical invariants, equations of motion, infinitesimal canonical transformations, conservation theorems in the Poisson bracket relations, symmetry groups of mechanical systems, Liouville's theorem.

Hamilton-Jacobi Theory and Action-Angle Variables: The Hamilton-Jacobi equation for Hamilton's principle function, harmonic oscillator problem as an example of the Hamilton-Jacobi method, Hamilton-Jacobi equation for Hamilton's characteristic function, separation of variables in the Hamilton-Jacobi equation, ignorable coordinates & Kepler problem, action-angle variables in systems of one-degree of freedom, action-angle variables for completely separable systems, Kepler problem in action-angle variables.

Small Oscillation: Stable & unstable equilibrium, dynamic equilibrium, metastable equilibrium, study of small oscillations using generalized coordinates, normal modes, non-degenerate and degenerate cases.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Classical Mechanics – H. Goldstein, C. Poole, & J. Safko.
2. Classical Mechanics – N.C. Rana & P.S. Joag.
3. Theory and Problems of Theoretical Mechanics – M.R. Spiegel (Schaum series).
4. Introduction to Classical Mechanics – R.G. Takwale & P. Puranik.
5. Classical Mechanics of Particles and Rigid Bodies – K.C. Gupta.
6. A student's Guide to Lagrangian and Hamiltonian – P. Hamill.
7. Classical Mechanics – R.D. Gregory.

Electrostatics and Magnetostatics

Course Objectives:

1. Acquaint students with the basic concept of electrostatics, magnetostatics, boundary value problems & special techniques, electromagnetic induction.
2. Provide in-depth knowledge of electromagnetic waves, potentials, fields, and radiation and their various applications in transmission and communication process.
3. Create thinking ability of applying the concept of electrostatics and magnetostatics in various media.

Learning Outcomes: After completion of the course, learners will

1. Have in-depth understanding of relevant topics.
2. Be able to
    - i. Answer conceptual questions of electrostatics & magnetostatics.
    - ii. Apply concept in understanding properties (electrical, thermal and optical) of various media.
    - iii. Design electrical circuits.
    - iv. Understand
        - a) Articles related to electric and magnetic fields.
        - b) Nature of wave propagation in any medium.
    - v. Solve
        - a) Conceptual problems related to electrostatics & magentistics.
        - b) Boundary value problems in electrostatics & magentostatics.
        - c) Laplace's equation in one-, two-, & three-dimensional coordinate systems.

Electrostatics: Electric flux, integral and differential form of Gauss's law and its applications, scaler potential, Poisson and Laplace's equations, line, surface, and volume charge density, electric potential and equipotential surface, curl of **E**, relation between field and potential, energy due to system of point charges, boundary conditions, electric field and potential due to continuous/discrete charge distribution, conductors and their basic properties, induced charges, Green's theorem, uniqueness theorem, work & energy in electrostatics.

Special Techniques: Laplace's equation in one, two, and three dimensional rectangular coordinates, boundary value problems in spherical and cylindrical coordinates; method of images and applications, method of inversion, Green's function for a sphere, conducting spheres with hemispheres at different potentials, orthogonal functions and expansion; separation of variables in Cartesian and spherical coordinates; basic concept of multipole expansion, field and potential of monopole, dipole, quadrupole, and octupole, detailed study of electric dipole (field and potential of a dipole, force and torque on a dipole, potential energy of a dipole, dipole-dipole interactions/potential energy between two dipoles).

Electric Fields in Matter: Dielectric, alignment of polarized molecules, induced dipoles, field due to polarized object, field inside a dielectric, capacitor with and without dielectric, Gauss's law in dielectrics, dielectric constant, polarizability, permittivity, and susceptibility, dielectric breakdown, Clausius-Mossotti relation, boundary value problems with dielectrics, electrostatic energy in dielectric media.

Magnetostatics: Biot-Savart law and its application, integral and differential form of Ampere's law, calculation of **B** for various cases, force between two parallel conductors, magnetic field of a solenoid and toroid, magnetic vector potential, multipole expansion of vector potential; magnetic dipole (**m**), potential energy of **m**, dipole-dipole interaction; Lorentz force, charged particle in an electric field & magnetic field, cyclotron and cycloid motion, Hall effect; Faraday's law of electromagnetic induction, magnetic flux, motional emf, self and mutual inductance, self-inductance of solenoid, energy in magnetic field, transformer.

Magnetic Fields in Matter: Review of diamagnetism, paramagnetic, ferromagnetism, magnetic domain, susceptibility, permeability, magnetization (**M**), & magnetic intensity (**H**); magnetized sphere, magnetized sphere in an external field, magnetic shielding; Ampere's law in magnetic materials, Bohr magnetron, relation between **B**, **M**, & **H**, magnetic hysteresis & **B-H** curve; boundary conditions on **B** and **H**.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Classical Electrodynamics – J.D. Jackson.
2. Introduction to Electrodynamics – D. Griffith.
3. Electricity & Magnetism – E.M. Purcell & D.J. Morin.
4. Electromagnetic Field Theory – Bo Thidé.
5. Classical Electricity & Magnetism – W.K.H Panofsky & M. Philips.
6. Electromagnetics – J. Edminister (Schaum series).

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Quantum Mechanics – I

Course Objectives: Acquaint students with the

1. Foundation of quantum mechanics – failure of classical mechanics, blackbody radiation, wave-particle duality, de-Broglie hypothesis, experiments with electrons, γ-ray microscope experiment, phase & group velocity, uncertainty principle.
2. Concept of operator formalism - position, momentum and energy operators, operator algebra, commutator, Hermitian operators, eigenfunctions & eigenvalues, Vector space, Hilbert space, bra & ket algebra, Dirac delta function, Kronecker delta function, Schrödinger and Heisenberg pictures.
3. Schrodinger equation and its applications (e.g., particle in one- & three-dimensional potential box, quantum mechanical tunneling, potential barrier, delta potential, potential step, transmission coefficient, Hydrogen atom, quantum numbers – n, l, m, s).
4. Concept of identical particles.

Learning Outcomes: After completion of the course, learners will

1. Know main aspects of the inadequacies of classical mechanics and understand historical development of quantum mechanics and ability to discuss and interpret experiments that reveal the dual nature of matter.
2. Understand the theory of quantum measurements, wave packets and uncertainty principle.
3. Understand the central concepts of quantum mechanics: wave functions, momentum and energy operator, the Schrodinger equation, time dependent and time independent cases, probability density and the normalization techniques.
4. Be able to
   i. Construct Schrodinger equation in Cartesian and Spherical coordinates.
   ii. Answer questions and solve problems related to
      a) Uncertainty principle, blackbody radiation, Group & phase velocity, de-Broglie wavelength and apply in x-ray diffraction technique.
      b) Solve Schrodinger equation in one and three dimension under different boundary conditions.
      c) Potential barrier, *e.g.*, tunneling through potential barrier, step potential, rectangular barrier.
      d) Quantum mechanical operators and Heisenberg uncertainty principle, Hydrogen atom.
   iii. Apply the concept of quantum mechanics in other brnaches of science (atomic, molecular, nuclear, & solid state physics physics/chemistry, statistical mechanics, nano-science, materials science)

Foundation: Blackbody radiation, Planck's quantum hypothesis, Photoelectric effect, Compton effect, Bohr's theory of atomic spectra and correspondence principle, Wilson-Sommerfeld quantization rules, de Broglie wavelength/wave-particle duality, wave packets/Gaussian wave packet, phase and group velocity, expectation value, Fourier transform and momentum-space wave function (i.e., expansion of a wave function in terms of position and momentum wave functions), experiments with electrons & photons (Young's double slit experiment), γ-ray microscope experiment, Heisenberg's uncertainty principle, causality in quantum mechanics.

Operator Formalism and Schrödinger Equation: Operator formalism, position, momentum and energy operators, operator algebra, commutator, Hermitian operators, Hermitian adjoint, various properties of Hermitian operator, operators commuting with H, simultaneous eigen functions of commuting operators, postulates of quantum mechanics, Schrodinger equation, free particle solution, superposition of wave functions, stationary states, orthogonality of eigen functions, degenerate & nondegenrate eigen values, probability current density; time dependent and time independent Schrödinger equation, applications of Schrodinger equation in one dimension-infinite square well potential, in a box (both one and three dimensional cases), finite square well, attractive delta function potential, harmonic oscillator, potential step, and potential barrier, Ehrenfest's theorem.

Bra and Ket Algebra: Vector space, Hilbert space, wave function as a vector, Dirac's notation, basis vector, expectation value, Dirac delta function and Kronecker delta function, linear operator, eigen value equation, observables, completeness condition, relationship between ket and wave function, statistical interpretation, linear harmonic oscillator, uncertainty relation, coherent states, simultaneous eigen kets of commuting operators, unitary transformation, Schrödinger and Heisenberg pictures and interaction between them, density operator.

Quantum Mechanics in Three Dimensions: Schrödinger equation in spherical coordinates, separation of variables, angular equation, radial equation, infinite spherical well, hydrogen atom, spectrum of hydrogen, angular momentum, eigen values, ladder operators, eigen functions, spin, spin ½, Pauli spin matrices, electron in magnetic field, Larmor precession, Stern-Gerlach experiment, addition of angular momenta, Clebsch-Gordon coefficients, three-dimensional harmonic oscillator, virial theorem, three dimensional virial theorem.

Identical Particles: Two-particle systems, Bosons and Fermions, exchange forces, atoms, helium, periodic table; solids-free electron gas, Fermi energy, band structure; quantum statistical mechanics – occupation number, configuration, Stirling's approximation, most probable configuration, M-B, B-E, and F-D distributions, black-body radiation.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Quantum Mechanics – R. Shankar.
2. Quantum Mechanics (Vol. I) – C. Cohen-Tannoudji, B. Die, & F. Laloë.
3. Quantum Mechanics – B.H. Bransden & C.J. Joachin.
4. Introduction to Quantum Mechanics – D.J. Griffith.
5. Quantum Mechanics – Ghatak & Loknathan.
6. Quantum Mechanics 500 Problems & Solutions – G. Aruldhas.
7. Quantum Mechanics – E. Zaarur (Schaum series).
8. Quantum Mechanics – L.I Schiff.
9. Quantum Mechanics – V. Devnathan.

10. Quantum Mechanics – G.S. Chaddha
11. Quantum Mechanics 1: Foundations – NJ.B. Green.
12. Quantum Mechanics 2: The toolkit – NJ.B. Green.
13. Concept of Modern Physics – A. Beiser, McGraw Hill.
14. Introduction to Modern Physics – H.S. Mani & G.K. Mehta.
15. Modern Physics – K. Krane.
16. Modern Physics for Engineers – J. Singh.
17. Modern Physics for Scientists & Engineers – S.T. Thornton & A. Rex.
18. Modern Physics – R.A. Serway, C.J Moses, & C.A. Moyer.
19. Modern Physics – P.A. Tipler & R.A. Llewellyn.
20. Applied Physics – A. Beiser (Schaum's Outline Series).

Electronics - I

Course Objectives:

1. Acquaint students with the basic concept of
   - i. P and N type semiconductors and application of F-D statics in relation to the various properties of semiconductor.
   - ii. Diodes and their applications such as rectifiers, filters, regulators, etc.
   - iii. Working principle of BJT and FET; negative and positive feedback.
   - iv. Applications of BJT & FET as rectIfiers, regulators, amplifiers etc.
   - v. Working principles and applications of
     - a) Operational amplifiers (OP-AMP).
     - b) Various oscillators such as phase shift, Wien Bridge oscillators, crystal oscillators, tunnel-diode oscillator, & relaxation oscillator.
     - c) Modulators - amplitude, power, & frequency modulation, analysis of AM wave, modulator, demodulator circuits.
     - d) Active, passive, low pass, high pass, and band reject filters.
     - e) Astable monostable multivibrators
2. To develop theoretical skills to understand and design electronic circuits & devices.
3. To train to handle electronic components, devices.
4. To build necessary competency to trouble-shoot electronic devices.
5. To design and perform basic and applied research involving extensive electronic circuitry.

Learning Outcomes: After completion of the course, students are expected to

1. Assimilate and possesses basic knowledge of following
   - i. N- and P- type semiconductors, mobility, drift velocity, fabrication of P-N junctions; forward and reverse biased junctions.
   - ii. Applications of F-D statics to semiconductors.
   - iii. To characterize various devices namely PN junction diodes, LEDs, Zener diode, solar cells.
   - iv. Application of PN junction for different type of rectifiers and voltage regulators.
   - v. NPN and PNP transistors and basic configurations namely common base, common emitter and common collector, and also about current and voltage gain.

vi. FET and BJT amplifiers and their working principles.
vii. Operational amplifiers and knowledge about different configurations namely inverting and non-inverting and applications of operational amplifiers
viii. Demonstrate inverting and non-inverting amplifiers using op-amps.
ix. Various types of oscillators and their working principles.
x. Amplitude modulation, frequency modulation, power modulation and their various applications in communication technology.
xi. Working principles and applications of active & passive filters, low pass, high pass, and band reject filters.

2. Answer basic and conceptual questions and solve basic problems related to diodes, transistors, amplifiers, oscillators, modulation, filters, & multivibrators.
3. Handle various sophisticated electronic devices.
4. Understand the circuit diagrams of basic and high-end electronic instruments involving various electronic components.
5. Design simple and low-cost as well as complex electronic circuits/devices by choosing appropriate components.
6. Pursue higher studies in electronics.
7. Get involved quickly in advanced laboratories.
8. Design and conduct experiments for basic and applied research involving extensive electronic circuitry.
9. Apply the concepts of electronics in communication.

Semiconductors: Introduction, intrinsic & extrinsic semiconductors, conduction & valence band, energy band/band gap, doping, p- & n- type, F-D statistics, Fermi level, Fermi energy, & Fermi velocity, electrons & holes and their mobility, concentration, dependence of concentration on temperature, Hall effect.

Diode Circuits: Nonlinear components – Current-Voltage characteristics, ideal rectifier, junction diode; rectifier circuits – half-wave, full-wave, & bridge rectifier, voltage doubler; filter circuits – capacitor, L-section, & π-section filters; diode regulators – Zener diodes & controlled rectifiers; diode circuits – clippers, clamps, AC voltmeters, detectors.

Transistors: Bipolar junction transistor (BJT), pnp & npn transistors, characteristics, different configurations (CC, CE, & CB) & comparison, characteristics of MOSFET.

Amplifiers: FET amplifiers – operating point, small-signal parameters, source follower; BJT amplifiers – bias circuit, hybrid parameters; special amplifiers – difference amplifier, complimentary symmetry, & Darlington connection; voltage amplifier – cascading, low- & high-frequency gain, decoupling, & transformer coupling; pulse amplifier – rise time & tilt; DC amplifiers – direct coupling, chopper amplifiers, and lock-in amplifier; operational amplifier (OP AMP) – circuit symbol, characteristics & some applications; voltage & power amplifiers – classification, R-C coupled transistor amplifier, power amplifiers, class A & B, comparators, Schmitt trigger; feedback – block diagram, negative feedback.

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Oscillators: Positive feedback, RC oscillators – phase shift, & Wien Bridge oscillators; resonant-circuit oscillators – LC & crystal oscillators; negative resistance oscillator – stability analysis & tunnel-diode oscillator; relaxation oscillator – saw tooth generators & multivibrators; waveform generators – diode pump, ramp, & pulses.

Modulation: Introduction, amplitude, power, & frequency modulation, analysis of AM wave, modulator, demodulator circuits.

Filters: Active & passive filters, low pass, high pass, and band reject filters.

Multivibrators: Astable and monostable multivibrators using transistor.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Basic Electronics for Scientists and Engineers – D.L. Eggleston.
2. Electronics Principle and Applications – D. Chattopadhyay & P.C. Rakshit.
3. The Art of Electronics – P. Horowitz & W. Hill.
4. Analog Electronics for Scientists – D. Barnaal.
5. Basic Electronics for Scientists – J.J. Brophy.
6. An Introduction to Modern Electronics – W.L. Faissler & J.C. Sprott.
7. Introduction to Electronics – E.D. Gates.
8. Fundamentals of Electric Circuits – C.K. Alexander & M.N.O. Sadiku.
9. Introductory Electronics for Scientists & Engineers – R.E. Simpson, Allyn, & Bacon.
10. Electronic Principles – Malvino.
11. Digital Principles and Applications – Malvino and Leech.
12. Principles of Communication Systems – Taub and Achilling.
13. Foundations of Electronics – D. Chattopadhyay, P.C. Rakshit, B. Saha, & N.N. Purkait.
14. Electronics for Scientists & Engineers – T.R. Vishwanathan, G.K. Mehta, & V. Rajaraman.
15. Principles of Electronics – V.K. Mehta.
16. Handbook of Electronics – Gupta and Kumar.
17. Digital Electronics and Logic Design – S.K. Mandal.

Physics Lab. – I

Course Objectives:

1. Verify physical laws through experiments.
2. Provide hands-on training on various PC and non-PC based instruments.
3. Make 'Learning-While-Doing' a realistic process.
4. Provide knowledge on various hardware (DAQ, interface) and software (instrument controlling software) related to experiments.

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5. Impart necessary technical skills to understand, handle, design, & trouble-shoot devices & experimental set-ups.
6. Acquaint the students with the
    i. Fundamentals of software/programing language (Mathematica/Matlab/Scilab/C).
    ii. Basic mathematics & programing.
    iii. Technique of solving mathematical problems.

Learning Outcomes: After completion of the course the learners will
1. Have
    i. Better understanding of the underlying principles of various physical phenomena.
    ii. Knowledge of various hardware and software components.
    iii. In depth knowledge of analog electronics.
2. Be able to
    i. Handle various equipments.
    ii. Analyze data using Origin software.
    iii. Able to design electronic circuits.
    iv. Understand/analyze critical electronic circuits.
    v. Trouble-shoot electronics & other devices.
    vi. Generate and manipulate various type of list.
    vii. Plot 2-D and 3-D graphs using variables/functions.
    viii. Solve using software/programing language
        a) Algebraic equations.
        b) Trigonometric problems.
        c) Problems related to differential and integral calculus.
        d) Multivariate calculus.
        e) Differential equations.
        f) Problems of linear algebra.

List of suggested experiments [NOTE: Topics not covered in lectures should be discussed at the time of demonstration during lab. hours. Students should be taught Units, Dimensional & Error Analysis (standards & units, significant figures, estimates & order of magnitudes, dimensional analysis, uncertainty, & types of errors) in first two during lab. hours. Instructor should review error analysis in the first lab.; Experiments can be added or deleted]:

1. Ultrasonic waves – velocity, standing waves, reflections, interference, and diffraction.
2. Characteristic frequencies of un-coupled pendulum, and 'in-phase' & 'in-opposite-phase' beat mode of coupled pendulum.
3. Centripetal force and moment of inertia.
4. Cavendish balance experiment to measure G.
5. Projectile motion.
6. Gyroscopic motion & Coriolis force.
7. Permeability & permittivity of air, and relation between velocity of light and permeability & permittivity of air.

8. Study of RC, LR, & LCR circuits.
9. Self & mutual induction, Faraday's law, induced emf, and Lenz's law.
10. Parallel plate capacitor – capacitance of plate capacitor, capacitance as a function of plate area and plate separation, dielectric constant of various materials.
11. To study the deflection of an electron beam by a magnetic field and an electric field.
12. Characteristics of LED & Solar cell.
13. Photoconductivity.
14. Characteristics of BJT.
15. Characteristics of FET/MOSFET.
16. Characteristics of OP-AMP.
17. Characteristics of feedback amplifier.
18. Oscillator (Hartley).
19. Zener diode, SCR, UJT.

[NOTE: Instructor should teach error analysis in the first lab.; Experiments can be added/deleted]

Recommended books for error analysis and practical physics:

1. Error Analysis – J.R. Taylor.
2. Practical Physics – Squires.
3. Experimental Physics – G. Prakash.
4. A Practical Guide to Data Analysis for Physical Science Students – L. Lyons.

Software/Programing language:

Basic Concepts: Notation and conventions, Kernel and front end, constants, 'built-in' functions, basic arithmetic operations, strings, assignment, replacement, and logical theory, tables and matrices, relations, sums and products, loops, introduction to graphics, user-defined functions, modules.

Lists: Introductions, generating lists, list manipulation, set.

Two-dimensional Graphics: Plotting functions of a single variable, additional graphics commands, special two-dimensional plots, animation.

Three-dimensional Graphics: Plotting functions of two variables, other graphic commands, special three-dimensional plots, standard shapes.

Equations: Solving algebraic equations, solving transcendental equations.

Algebra and Trigonometry: Polynomials, rational and algebraic functions, trigonometric functions.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Mathematica – E. Don (Schaum series).
2. Mathematica for Physics – R.L. Zimmerman & F.I. Olness.
3. Mathematica Exercises in Introductory Physics – R.L. Varley.
4. Physicists Guide to Mathematica – P.T. Tam.
5. An Introduction to Mathematical Physics with Mathematica – Y. Abe.
6. Mathematica Graphics Example Book for Beginners – H. Sarafian.
7. Mathematica for the Sciences – R.E. Crandall.
8. Introduction to Probability with Mathematica – K.J. Hastings.
9. Mathematica for Calculus Based Physics – M.L. DeJong.
10. Calculus & Differential Equations with Mathematica – P. Dechaumphai.
11. Multivariate Calculus & Mathematica with Applications to Geometry & Physics – K.R. Coombes, R.L. Lipsman, & J.M. Rosenberg.
12. Introduction to Partial Differential Equations for Scientists & Engineers Using Mathematica – K. Adzeivski.

Students will be taught the following during lab. sessions to provide brief overview of various experimental techniques and instruments so that they can trouble shoot devices during measurements:

Vacuum Techniques: Introduction, flow regimes (Knudsen's number, Reynold's number, turbulent, laminar, viscous, molecular), different ranges of vacuum (low, medium, high), pumps (rotary, diffusion, turbo molecular), pressure gauges (pirani, penning, ion).

Digital Instruments: Principle and working of digital meters, comparison of analog & digital instruments, characteristics of a digital meter.

Shielding and Grounding: Methods of safety grounding, energy coupling, grounding; electrostatic shielding, electromagnetic interference.

Transducers & Industrial Instrumentation: Static and dynamic characteristics of measurement systems, generalized performance of systems, zero order, first order, second order and higher order systems; electrical, thermal and mechanical systems, calibration, characteristics of transducers, transducers as electrical element and their signal conditioning, temperature transducers, capacitance change transducers, radiation sensors.

Scope of the syllabus is defined from following recommended books:

1. Vacuum Technology – A. Roath.
2. Measurement, Instrumentation and Experiment Design in Physics and Engineering – M. Sayer & A. Mansingh.

3. Experimental Methods for Engineers – J.P. Holman.
4. Introduction to Measurements and Instrumentation – A.K. Ghosh.
5. Transducers and Instrumentation – D.V.S. Murty.
6. Instrumentation Devices and Systems – C.S. Rangan, G.R. Sarma, & V.S.V. Mani.

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Semester – II

Mathematical Physics – II

Course Objectives: Impart knowledge of

1. Complex functions and variables.
2. Various series (Infinite, Taylor's, and Laurent's Series).
3. Complex differentiation.
4. Cauchy-Riemann equation & L'Hospital's rule.
5. Jordan's and Green's theorem.
6. Residue theorem.

Learning Outcomes: After completion of the course, learners will be able to

1. Solve various complex series (Infinite, Taylor's, and Laurent's Series).
2. Solve complex integration using Residue theorem.
3. Apply the concept of complex variables/functions in other branches of physics (solid state physics, materials science).

Complex Variables

Functions, Limits, and Continuity: Variables and functions, single and multiple-valued functions, inverse functions, transformations, curvilinear coordinates, the elementary functions, branch points and branch lines, Riemann surfaces, limits, theorems on limits, infinity, continuity, theorems on continuity, uniform continuity, sequences, limit of a sequence, theorems on limits of sequences, infinite series.

Complex Differentiation and Cauchy–Riemann Equations: Derivatives, analytic functions, Cauchy–Riemann equations, harmonic functions, geometric interpretation of the derivative, differentials, rules for differentiation, derivatives of elementary functions, higher order derivatives, L'Hospital's rule, singular points, orthogonal families, curves, applications to geometry and mechanics, complex differential operators, gradient, divergence, curl, Laplacian.

Complex Integration and Cauchy's Theorem: Complex line integrals, real line integrals, connection between real and complex line integrals, properties of integrals, change of variables, simply and multiply connected regions, Jordan curve theorem, convention regarding traversal of a closed path, Green's theorem in the plane, complex form of Green's theorem, Cauchy's theorem, the Cauchy–Goursat theorem, Morera's theorem, indefinite integrals, integrals of special functions, some consequences of Cauchy's theorem, Cauchy's integral formulas.

Infinite Series, Taylor's Series, and Laurent's Series: Sequences of functions, series of functions, absolute convergence, uniform convergence of sequences and series, power series, some important theorems, Taylor's theorem, some special series, Laurent's theorem, classification of singularities, entire functions, meromorphic functions, Lagrange's expansion, analytic continuation.

Residue Theorem, Evaluation of Integrals, and Series: Residues, calculation of residues, the residue theorem, evaluation of definite integrals, special theorems used in evaluating integrals, the Cauchy principal value of integrals, differentiation under the integral sign, Leibniz's rule, summation of series, Mittag–Leffler's expansion theorem, some special expansions.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

10. Mathematical Methods for Physicists – G. Arfken & H. Weber.
11. Mathematical Methods in the Physical Sciences – M. Boas.
12. Complex Variable – M.R. Spiegel (Schaum series).
13. Higher Engineering Mathematics – B.S. Grewal.
14. Mathematics for Physicists & Engineers – Pipes.
15. Complex Variables & Applications – R.V. Churchill.
16. The Use of Integral Transforms – I.N. Sneddon.
17. A Text Book of Mathematical Physics – S. Chandra.
18. Mathematical Physics – H.K. Dass & R. Verma.
19. Mathematical Physics – P.K. Chattopadhyay.

Quantum Mechanics – II

Course Objectives: Acquaint students with the concept of

1. Variational principle to understand helium atom and hydrogen ion.
2. Stark effect in quantum mechanics.
3. WKB approximation in solving Schrodinger equation.
4. Perturbation theory in understanding the Schrodinger equation under external fields and atomic emission.
5. Scattering process (differential scattering cross-section, total cross-section, partial wave method) in quantum mechanical systems.
6. Born's approximation of quantum mechanical scattering process.
7. Klein-Gordon equation, Dirac equation in relativistic quantum mechanics.

Learning Outcomes: After completion of the course, learners will be able to

1. Apply the concept of variational principle and WKB approximation in solving quantum mechanical problems.
2. Understand
   i. How a perturbation can influence the properties of quantum/atomic system.
   ii. Behavior of a quantum mechanical/atomic system under unusual circumstances (perturbed system).
3. Formulate whether the perturbation/external influence is time-independent or time-dependent.
4. Correlate the time-independent and time-dependent perturbations.
5. Understand scattering process between atoms, molecules, & nuclei.
6. Solve problems related to vibrational principle, perturbation theory, and scattering.

Variational Principle: Theory, ground state of helium, hydrogen molecule ion, Stark effect

WKB Approximation: Classical region, one-dimensional Schrödinger equation, tunneling, Bohr-Sommerfield connection formula.

Time-Independent Perturbation Theory: Non-degenerate and degenerate perturbation theory, fine structure of Hydrogen, Zeeman effect, hyperfine splitting in hydrogen.

Time-Dependent Perturbation Theory: Two-level system, emission and absorption of radiation, spontaneous emission.

Scattering: Introduction, kinematics of scattering process- differential and total cross-section, scattering amplitude, partial wave analysis, phase shifts, Born approximation, Born series, validity of Born approximation, Eikonal approximation, Green's function.

Relativistic Quantum Mechanics: Introduction, Klein-Gordon equation, Dirac equation, probability and current densities, covariance of Dirac equation, plane wave solution, electron in an electromagnetic field, hole theory and positrons.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Quantum Mechanics – R. Shankar.
2. Quantum Mechanics – B.H. Bransden & C.J. Joachin.
3. Introduction to Quantum Mechanics – D.J. Griffith.
4. Quantum Mechanics – Ghatak & Loknathan.
5. Quantum Mechanics – L.I Schiff.
6. Modern Quantum Mechanics – J.J.Sakurai.

7. Quantum Mechanics (Vol. II) – C. Cohen-Tannoudji, B. Die, & F. Laloë.
8. Quantum Mechanics – A. Das.
9. Quantum Mechanics – S. Gasiorowicz.
10. Introductory Quantum Mechanics – R.L. Liboff.
11. Quantum Mechanics 500 Problems & Solutions – G. Aruldhas.
12. Group Theory & Quantum Mechanics – Tinkham.
13. Quantum Mechanics – Y. Peleg, R. Pnini, E. Zaarur, & E. Hecht (Schaum series).
14. Quantum Mechanics 1: Foundations – N.J.B. Green.
15. Quantum Mechanics 2: The toolkit – N.J.B. Green.

Solid State Physics – I

Course Objectives:

1. Acquaint students with
    i. Various types of
        a) Crystal structures.
        b) Projections – spherical, zenithal, polar, and meridian.
    ii. Symmetry of crystals.
    iii. Symmetry elements and their notations of crystals.
    iv. Concept X-ray diffraction (Bragg law, Fourier analysis, Laue equation) and construction of Brillouin zone from the diffraction pattern.
    v. Miller indices and its applications in various crystal structures.

2. Provide an
    i. Overview of various type of various space groups and their nomenclatures of crystals.
    ii. Knowledge about reciprocal lattice and Brillouin and their relation applications in different structures (e.g., cubic, face centered, body centered etc.).

Learning Outcomes: After completion of the course, learners will be able to

1. Classify the crystals (*i.e.*, face centered, body centered, face centered).
2. Determine lattice parameters/constant (a, b, and c-axes) of simple crystals.
3. Construct various projections associated with crystal structures.
4. Apply the concept of symmetry to determine structure of a crystal and classify the crystal.
5. Transform the crystals axes.
6. Determine Miller indices of a given crystal.
7. Construct reciprocal lattice vectors and Brillouin zone of a given crystal and correlate them.
8. Analyze the X-ray diffraction pattern of crystals.

Crystal Structure: Periodic array of atoms – lattice translation vectors, basis & crystal structure, primitive lattice cell; fundamental types of lattices – 2- & 3-dimensioanl lattice types, index systems for crystal planes, simple crystal structures – sodium chloride, cesium chloride, hcp, diamond structure, cubic zinc sulphide structure etc.; non-ideal crystal structures – random stacking and polytypism.

Projection of Crystals: Perspective projections – spherical projection, types of projection, zenithal projections; gnomonic projections – polar projection, meridian projection, properties of projection; stereographic projection – polar projection, meridian projection, properties of projection, standard projection.

Crystal Lattices, Symmetry, and Transformation Theory: Periodicity in crystals – periodic repetition, choice of a unit cell, notation for directions & planes; lattice types – plane lattices, effect of symmetry, space lattices; symmetry elements – proper rotation axes, improper rotation axes, symmetry of a cube; notation of crystal faces – choice of crystal axes; transformation theory – transformation of crystallographic axes, transformation of indices of a plane, unit cell volume changes.

Group Theory Applications: Space groups – space-group symmetry, monoclinic space groups, space group nomenclature.

Describing Lattice Planes and Directions in Crystals – Miller Indices and Zone Axis Symbols: Introduction, indexing lattice directions – zone axis symbols; indexing lattice planes – Miller indices; Miller indices & zone axis symbols in cubic crystals; lattice plane spacing, Miller indices, & Laue indices; zones, zone axes & the zone law – the addition rule; indexing in the trigonal & hexagonal systems – Weber symbols & Miller-Bravis indices; transforming Miller indices and zone axis symbols.

Reciprocal Lattice: Introduction, reciprocal lattice vectors, reciprocal lattice unit cells, reciprocal lattice cells for cubic crystals, proofs of some geometrical relationships using reciprocal lattice vectors, Brillouin zones (reciprocal lattice to sc, bcc, & fcc lattices).

Wave Diffraction and Reciprocal Lattice: Diffraction of waves by crystals – Bragg law; scattered wave amplitude – Fourier analysis; Laue equation.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Crystallography for Solid State Physics – A.R. Verma & O.N. Srivastava.
2. Introduction to Solids – N.W. Azaroff & N. Mermin.
3. The Basics of Crystallography and Diffraction – C. Hmmond.
4. Introduction to Solid State Physics – C. Kittel.
5. Elements of X-ray diffraction – B.D. Cullity.
6. Solid State Physics – A. J. Dekker.
7. Solid State Physics – Ashcroft.
8. Elementary Solid State Physics: Principles and Applications – M.A. Omar.
9. Solid State Physics – S.O. Pillai.
10. The Oxford Solid State Basics – S.H. Simon.
11. Crystal Structure Determination – W. Clegg.

12. Concept of Modern Physics – A. Beiser, McGraw Hill.
13. Introduction to Modern Physics – H.S. Mani & G.K. Mehta.
14. Modern Physics – K. Krane.
15. Modern Physics for Engineers – J. Singh.
16. Modern Physics for Scientists & Engineers – S.T. Thornton & A. Rex.
17. Modern Physics – R.A. Serway, C.J Moses, & C.A. Moyer.
18. Modern Physics – P.A. Tipler & R.A. Llewellyn.
19. Applied Physics – A. Beiser (Schaum's Outline Series).
20. Chemical Bonding – M.J. Winter.

Waves & Optics

Course Objectives: To impart knowledge of

1. Oscillations – free, damped, & forced.
2. Speed of sound waves, interference of waves, Beats, Doppler Effect, & shock waves.
3. Fundamentals of laser – emission, absorption, and Einstein A & B Co-efficient.
4. Pumping (optical, electrical), population inversion, optical feedback.
5. Laser rate equation for two-, three, and four-level lasers.
6. Laser beam profile/shape.
7. Optical fibers, properties, and various transmission losses inside a fiber.

Learning Outcomes: After going through the course, students will be able to

1. Answer and solve conceptual and challenging questions and problems on waves, damped oscillation, forced oscillation, interference, diffraction, and polarization.
2. Apply the concept of matrix methods in solving problems related to lens & curved surfaces.
3. Understand
   i. Various optical phenomena, principles, workings, and applications of optical instruments.
   ii. Spontaneous and stimulated emission of radiation, optical pumping and population inversion.
   iii. Basic lasing.
   iv. Three level and four level lasers.
   v. Various types of lasers in details and their applications.
   vi. Communication through optical fiber.
   vii. Working principle of lidar and its applications.
3. Answer and solve geometrical optics, wave optics, & laser related questions and problems.
4. Handle sophisticated optical components.
5. Perform laser related experiments.
6. Pursue career in laser related atomic/fundamental and applied research and development.

Free Damped Oscillations: Introduction, damping forces, description of damped oscillation of a system having one DoF (equation of motion, solution, large, critical &small damping, energy of a weakly damped oscillator, logarithmic decrement, relaxation time and Q-factor).

Forced Oscillations and Resonance: Quantitative and qualitative description of forced oscillation of a system having one degree of freedom (DoF) (equation of motion, solution, resonance), questions/exercises/problems.

Mechanical Waves: Types of mechanical waves, mathematical description of wave (*i.e.*, classical wave equation), speed of transverse wave, energy in wave motion, wave interference, boundary conditions, and superposition, standing waves in a string, normal modes of a string.

Sound and Hearing: Sound waves, speed of sound waves, sound intensity and decibal, standing sound waves & normal modes, resonance and sound, interference of waves and Beats, Doppler Effect, shock waves, Kevin's law.

Geometric Optics: Matrix methods in geometrical optics, different parts of human eye, defects of vision and corrections, magnifier, microscopes and telescopes.

Interference: Young's experiment-coherence, intensity distribution and visibility of fringes, Fresnel's Biprism, Interference in thin films, Interference at an air wedge, Newton's rings, Michelson's interferometer.

Diffraction: Fraunhoffer and Fresnel Diffraction: Diffraction at a single slit, double slit, Diffraction by multiple slits, Diffraction grating, Resolving power- Rayleigh's criterion, Resolving power of a grating and telescope, Fresnel diffraction- half period zone, Zone plate, Diffraction at a circular aperture and at a straight edge (qualitative treatment only), Cornu's spiral.

Laser I: Emission & absorption of radiation, spontaneous emission, absorption, and stimulated emission, Einstein's A and B coefficients and relation between them, absorption of radiation, laser rate equations – three level and four level systems, properties of laser, population inversion, optical feedback, threshold condition, line shape function, population inversion & pumping threshold conditions, laser modes – axial & transverse modes, classes of laser – doped insulator, semiconductor, gas, & liquid dye lasers, applications of lasers.

Optical Fiber: Introduction, total internal reflection, planar dielectric waveguides, optical fiber waveguides – step index fibers, numerical aperture, inter-modal dispersion, single mode, graded index, & low dispersion fibers; losses in fibers – bending and intrinsic fiber losses.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Waves and Oscillation – N.K. Bajaj, Tata McGraw-Hill.
2. The Physics of Vibrations & Waves – H.J. Pain, John Wiley & Sons.
3. Geometrical & Physical Optics – R.S. Longhurst, Orient Blackswan.

4. Optics – Ghatak.
5. Fundamentals of Optics – F.A. Jenkins & H.E. White.
6. Lasers: Fundamentals & Applications – K. Thyagrajan & A.K. Ghatak.
7. Nonlinear Optics – R.W. Boyd.
8. Optical Physics – A. Lipson, S.G. Lipson, & H. Lipson.
9. Lasers & Non-linear Optics – B.B. Laud.
10. Principle of Lasers – O. Svelto.
11. Introduction to Optics – F.L. Pedrotti, L.M. Pedrotti, & L.S. Pedrotti.
12. Optoelectronic Devices – W. Hawkes.
13. Introduction to the Physics of Waves – Tim Freegards, CUP.
14. Fundamentals of Optics – Jenkins & White, McGraw Hill.
15. Schaum's Outline Optics – Eugene Hecht, McGraw Hill.
16. Laser Fundamentals – Silfvast, Cambridge University Press.

Electronics – II

Course Objectives: Objectives of Digital Electronics course are

1. To acquaint students with concepts of
   - i. Digital number systems & codes.
   - ii. Boolean functions.
   - iii. Sum of product (SOP) and product of sum (POS) representations & Karnaugh maps.
   - iv. Various gates – AND, NOR, OX, NOR, NAND.
   - v. NAND and NOR as universal gates.
   - vi. J-K, S-R, clocked, master-slave, & edge-triggered flip-flops.
   - vii. Display and memory systems.
   - viii. Introduction to A/D conversion, Digital-to-analog (DAC) & analog-to-digital (ADC) convertion.
   - ix. A/D data-acquisition system.
   - x. Multiplexers & demultiplexers.
   - xi. 4-Bit, 8-Bit, 16-Bit, & 32-Bit systems.
   - xii. Microprocessor.
   - xiii. General Purpose Interface Bus (GPIB), GPIB signals and lines, implementation of a GPIB on a PC.
   - xiv. Digital pulse modulation - Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), and Binary Phase Shift Keying (BPSK).

2. To develop theoretical knowledge and know-how to understand and design electronic circuits & devices.

Learning Outcomes: This course will enable students to

1. Have understanding of
   - i. The basics of IC and digital circuits, and difference between analog and digital circuits.
   - ii. Various logic GATES and their realization using diodes and transmitters.
   - iii. Fundamental of Bolean algebra and their role in constructing digital circuits.

iv. About combinatorial and sequential systems by building block circuits to construct multivibrators and counters.
v. Sequential systems by choosing Flip-Flop as a building bock.
vi. Memory (RAM & ROM) and memory organization.
vii. Microprocessor and assembly language programming with examples with special reference to IntelµP 8085.
viii. Modulation and demodulation of digital & analog signals and optical communication.

2. Solve problems related to Boolean algebra, logic gates, flip-flops.
3. Apply the concept of digital electronics in
   i. DAC/ADC and DAQ/PC interface.
   ii. Digital communications and data transmission.
4. Handle high-end electronic components/systems.
5. Set-up complex Physics (e.g., optics, atomic, molecular, and nuclear) experiments requiring high-end and expensive electronic components/devices.
6. Design digital circuits for research in applied physics & technology.
7. Trouble-shoot complicated experimental set-up.

Number Systems: Positional number system, binary representation, 2's complement notation, binary addition and subtraction, octal number system, hexadecimal system, binary codes – BCD and ASCII codes.

Boolean Algebra: Switching circuits, AND, OR and NOT operations, truth table, Boolean functions, postulates and theorems of Boolean algebra, duality principle, Venn diagram, canonical forms of Boolean functions, simplification of Boolean functions, sum of product (SOP) and product of sum (POS) representations, Karnaugh maps, incompletely specified functions, don't cares.

Combinational and Sequential Circuits: Logic gates, NAND and NOR as universal gates, realization of logical functions using SOP and POS techniques, XOR gate, decoders, encoders, multiplexers, de-multiplexers, code conversion using logic gates and MSI ICs, half adder, full adder, serial adder, half subtractor, full subtractor, digital comparator, TTL & CMOS.

Information Registers: Flip-flops - J-K, S-R, clocked, master-slave, & edge-triggered flip-flops, synchronizer; timer, counter, shift register.

Visual Displays: Single-element displays, seven-segment displays, decoder logic.

Memory Circuits: Read only memories, shift-register memories, Random-Access Memories.

Analog/Digital Conversion: Introduction to A/D conversion, digital-to-analog (DAC) converter, time-domain (averaging) DAC, multiplying DACs, choosing a DAC, analog-to-digital (ADC) converter, some useful A/D and D/A converters, choosing an ADC, 16-channel A/D data-acquisition system, 3½ -digit voltmeter, brief idea of multiplexers/demultiplexers.

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Microprocessor: Introduction, 4-Bit, 8-Bit, 16-Bit, & 32-Bit systems, description of 8085 microprocessor.

Digital Data Communication Standards: Serial communications: RS232, handshaking, implementation of RS232 on PC; Universal Serial Bus (USB) - USB standards, types and elements of USB transfers.

Parallel Communications: General Purpose Interface Bus (GPIB), GPIB signals and lines, handshaking and interface management, implementation of a GPIB on a PC; Basic idea of sending data through a COM port.

Digital Pulse Modulation: Need for digital transmission, pulse code modulation, digital carrier modulation techniques, sampling, quantization and encoding; concept of Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), and Binary Phase Shift Keying (BPSK); comparison with analog pulse modulation.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Basic Electronics for Scientists and Engineers – D.L. Eggleston.
2. Electronics Principle and Applications – D. Chattopadhyay & P.C. Rakshit.
3. The Art of Electronics – P. Horowitz & W. Hill.
4. Analog Electronics for Scientists – D. Barnaal.
5. Basic Electronics for Scientists – J.J. Brophy.
6. An Introduction to Modern Electronics – W.L. Faissler & J.C. Sprott.
7. Introduction to Electronics – E.D. Gates.
8. Fundamentals of Electric Circuits – C.K. Alexander & M.N.O. Sadiku.
9. Introductory Electronics for Scientists & Engineers – R.E. Simpson, Allyn, & Bacon.
10. Electronic Principles – Malvino.
11. Digital Principles and Applications – Malvino and Leech.
12. Principles of Communication Systems – Taub and Achilling.
13. Foundations of Electronics – D. Chattopadhyay, P.C. Rakshit, B. Saha, & N.N. Purkait.
14. Electronics for Scientists & Engineers – T.R. Vishwanathan, G.K. Mehta, & V. Rajaraman.
15. Principles of Electronics – V.K. Mehta.
16. Handbook of Electronics – Gupta and Kumar.
17. Digital Electronics and Logic Design – S.K. Mandal.

Physics Lab. – II

Course Objectives:

1. Train to handle various optical interferometers (Michelson, Fabry-Perot, Twyman-Green, & Mach-Zender).
2. Verify laws through experiments.
3. Provide hands-on training on various PC and non-PC based instruments, make 'Learning-While-Doing' a realistic process, & knowledge on various hardware (DAQ, interface) and software (instrument controlling software) related to experiments.
4. Develop programing skills using software/programing language.

Learning Outcomes: After completion of the course learners will be able to

1. Analyze experimental results/data using Origin software.
2. Set-up optics experiment.
3. Handle sophisticated instrument.
4. Device/construct high power laser.
5. Do research in laser.
6. Pursue laser related fundamental and applied/industrial research in atomic & molecular physics, laser-matter interaction, and health sector.
7. Write computer code and solve problems related mechanics, electricity & magnetism, & modern physics.
8. To develop technical skills to design electronic circuits & devices.
9. To train to handle electronic components, devices.
10. To build necessary competency to trouble-shoot electronic devices.
11. To design and perform basic and applied research involving extensive electronic circuitry.

List of suggested experiments [NOTE: Topics not covered in lectures should be discussed at the time of demonstration during lab. hours. Experiments can be added or deleted]:

1. Michelson Interferometer, Fabry-Perot Interferometer, Twyman-Green Interferometer, Mach-Zender Interferometer.
2. Experiment with Diode laser and He-Ne laser.
3. Polarization of Light.
4. Optical Fiber.
5. Polarimeter.
6. Thermal and electrical conductivity of solids.
7. X-ray diffraction.
8. Damping & Coupling of oscillation.
9. Wavelength & velocity of sound & light.
10. Oscillation of a string.
11. Experiments with IC.
12. To verify truth table of (i) NOT, (ii) OR, NOR gate with 3 and 4 inputs, (iii) AND, NAND gate with 3 and 4 inputs, and (v) XOR, NXOR gate with 3 and 4 inputs.

13. To study functioning of NAND gate as universal gate.
14. To study of p-n junction and band gap energy.
15. Determination of Planck's constant by LED.
16. To design the circuit of (i) Half Adder, (ii) Full Adder, (iii) Half Subtractor, and (iv) Full Subtractor.
17. To study (i) R-S Flip-flop, (ii) D Flip-flop, and (iii) J-K Flip-flop.
18. Coder, decoder, multiplexer, registers.
19. ADC & DCA.
20. Introduction of LabVIEW & digital electronics lab. with LabVIEW.
21. Experiments with NI module, microprocessors, and microcontrollers.
22. LabVIEW programming, interfacing and DAQ with stand-alone instruments such as DSO and WFG and concept of PCB.
23. Bus signals & interfacing – fundamental bus signals – data address, strobe; programd I/O – data in, programd I/O – data in, programd I/O – status registers; interrupt, direct memory access, serial communication and ASCII, GPIB, RS 232.
24. Basic programming exercises on 8085 Microprocessor.
25. Crystallography software (Suggested software – Crystallographica, Crystallography, and Crystal Office; any other software used by course instructor; website resource: www.cryst.bbk.ac.uk/BCA/index.html.)

Software/Computer programing:

Differential Calculus: Limits, derivatives, maximum and minimum values, power series.

Integral Calculus: Anti-derivatives, definite integrals, functions defined by integrals, Riemann sums.

Multivariate Calculus: Partial derivatives, maximum and minimum values, total differential, multiple integrals.

Ordinary Differential Equations: Analytical solutions, numerical solutions, Laplace and Fourier transforms.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. An Introduction to Programming with Mathematica – P. Wellin, R. Gaylord, & S. Kamin.
2. Classical Mechanics with Mathematica – A. Romano.
3. Mathematica in Theoretical Physics: Electrodynamics, Quantum Mechanics, General relativity, & Fractals – G. Baumann.
4. CRC Standard Curves & Surfaces with Mathematica.

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Semester – III

Mathematical Physics - III

Course Objectives: This course envisages providing knowledge of various mathematical domains for developing foundation for higher studies in physics and allied subjects

1. Fundamentals of tensor.
2. Types & theorem of tensors – Cartesian, covariant, contravariant, dual, psudo, Ricci's theorem/tensor, Riemann-Christoffel tensor, Bianchi identities, & Einstein tensor.
3. Relation between tensor and Kroenker delta function, tensor & Levi-Civita symbols, and tensor and coordinate transform.
4. Fundamentals of group theory.
5. Various representations of group theory.
6. Number theory and its applications.

Learning Outcomes: After completion of the course, learners will have necessary mathematical skills to

1. Answer and solve conceptual questions and problems of tensors, group theory, & number theory.
2. Apply concept of tensors and group theory in classical mechanics, quantum mechanics, and solid state physics.
3. Study advanced topics and research articles in theoretical physics.
4. Pursue research in mathematical/theoretical physics.

Tensor: Some notation, change of basis, Cartesian, covariant and contravariant tensors, algebra of tensors, quotient law, tensors δ_{ij} and ε_{ijk}, isotropic tensors, improper rotations and pseudotensors, dual tensors, integral theorems for tensors, non-Cartesian coordinates, metric tensor, general coordinate transformations and tensors, relative tensors, derivatives of basis vectors and Christoffel symbols, covariant differentiation, vector operators in tensor form, absolute derivatives along curves, geodesics, Ricci's theorem, Riemann-Christoffel tensor and its properties, Ricci tensor, Bianchi identities, Einstein tensor, applications (inertia tensor).

Group Theory: Basic definitions & simple examples, projection operators, idempotents, complete reduction of regular representation, subgroups, matrix representation of a group, reducible & irrudicable representations, unitary representation, Schur's lemmas, orthonormality & completeness relations of irreducible characters, regular representations, direct product representations, Clebsch-Gordon coefficients.

Number Theory: Division algorithm, Lame's theorem, linear Diophantine equation, fundamental theorem of arithmetic, prime counting function, statement of prime number theorem, Goldbach conjecture, binary and decimal representation of integers, linear congruences, complete set of Residues, number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Möbius inversion formula, the Greatest Integer function, Euler's phi-function.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Mathematical Methods for Physicists – G. Arfken & H. Weber.
2. Mathematical Methods in the Physical Sciences – M. Boas.
3. The use of Integral Transforms – I.N. Sneddon.
4. A Text Book of Mathematical Physics – S. Chandra.
5. Mathematical Physics – H.K. Dass & R. Verma.
6. Mathematical Physics – P.K. Chattopadhyay.
7. Fourier Analysis with Applications to Boundary Value Problems – M. Spiegel (Schaum series).
8. Elements of Group Theory for Physicists – Joshi.
9. Group Theory & Quantum Mechanics – Tinkham.
10. A Student's Guide to Vectors and Tensors – D.A. Fleisch.
11. A Student's Guide to Fourier Transforms – J.F. James.
12. Tensor Calculus – D. Kay (Schaum series).
13. Elementary Number Theory – D. M. Burton.
14. Beginning Number Theory – N. Robinns.
15. Group Theory in Physics – J. F. Cornwell (Academic, 1987).
16. Group Theory in Physics – W.-K. Tung (World Scientific, 1985).

Solid State Physics – II

Course Objectives: Imparting advanced knowledge of solid state physics for pursuing higher studies in physics & applied physics

1. Various types of crystal bonding.
2. Elastic properties of crystals.
3. Phonons and phonon wave-vector.
4. Lattice vibration and propagation of phonon waves inside solids.
5. Thermal, electron, , & optical properties of solids.
6. How properties are related to F-D statics, i.e., applications of F-D statisites/distribution function.
7. Energy band and band-gap in solids.
8. K=P model and energy band-gap.
9. Classification of solids in terms of energy band gap, i.e., metals, semiconductors, & insulators.
10. Various types of defects in crystals.
11. Different types of magnetisms and magnetic materials (diamagnetism, paramagentism, ferromagnetism, antiferromagnetism, antiferrimagnetism, ferroelectric materials, & ferromagnetic materials).

Learning Outcomes: At the end of the course, students

1. Are expected to learn and assimilate the following

i. Knowledge of lattice vibrations, phonons and in depth of knowledge of Einstein and Debye theory of specific heat of solids.
ii. Propagation of phonon waves in solids and its relation with crystal vibration and properties of solids.
iii. Applications of F-D statistics/distribution function in solids.
iv. Knowledge of different types of magnetism from diamagnetism to ferromagnetism and hysteresis loops and energy loss.
v. Secured an understanding about the dielectric and ferroelectric properties of materials.
vi. Understanding above the band theory of solids and must be able to differentiate insulators, conductors and semiconductors.

2. Will be able to
   i. Answer and solve basic questions related to phonons, energy band of solids, properties of solids.
   ii. Tackle challenging problems in solid state physics.
   iii. Study articles related to solid state physics.
   iv. Pursue higher studies in materials science and nano-science.

Crystal Binding and Elastic Constants: Crystal of inert gases, ionic crystals, covalent crystals, metals, hydrogen bonds, atomic radii, analysis of elastic strains, stiffness constant, elastic waves in cubic crystals.

Phonons I – Crystal Vibrations: Vibration of crystals with monatomic basis, two atoms per primitive basis, quantization of elastic waves, phonon momentum, inelastic scattering by phonons.

Phonons II – Thermal Properties: Phonon heat capacity, anharmonic crystal interactions, thermal conductivity.

Free Electron Fermi Gas: Energy levels in one dimension, effect of temperature on F-D distribution, free electron gas in three dimensions, heat capacity of electron gas, electrical conductivity of metals.

Energy Bands: Nearly free electron model – origin of band gap, magnitude of energy gap, Bloch functions, Kronnig-Penney (K-P) model, wave equation of electrons in a periodic potential – Bloch theorem, crystal momentum of an electron, solution of central equation, K-P model in reciprocal space, empty lattice approximation, approximate solution near a zone boundary, number of orbitals in a band – metals & insulators.

Semiconductor Crystals: Band gap, holes, effective mass, intrinsic carrier concentration, impurity conductivity, thermoelectric effects, semimetals, super lattices.

Fermi Surfaces and Metals: Reduced & periodic zone scheme, construction of Fermi surface, electron, hole, & open orbits; calculation of energy bands – tight binding method, Wigner-Seitz method, cohesive energy, pseudo potential methods; quantization of orbits in a magnetic field, De Haas-van Alphen effect, magnetic breakdown.

Defects in Solids: Introduction, brief account of various types of defects and Patterson function.

Magnetism and Magnetic Materials: Brief idea of diamagnetism, paramagentism, ferromagnetism, antiferromagnetism, antiferrimagnetism, ferroelectric materials, and ferromagnetic materials.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Introduction to Solid State Physics – C. Kittel.
2. Solid State Physics – A. J. Dekker.
3. Solid State Physics – Ashcroft.
4. Elementary Solid State Physics: Principles and Applications – M.A. Omar.
5. Band Theory and Electronic Properties of Solids – J. Singleton.
6. Optical Properties of Solids – A.M. Fox.
7. Magnetism in Condensed Matter – S.J. Blundell.
8. Solid State Physics – S.O. Pillai.
9. The Oxford Solid State Basics – S.H. Simon.
21. Elementary Dislocation Theory – J. Weertman & J.R. Weertman.
22. d-block chemistry – M.J. Winter.
23. Introduction to Molecular Symmetry – J.S. Ogden.
24. Periodicity and the s- and p- block elements – N.C. Norman.

Thermal Physics and Statistical Mechanics

Course Objectives:

1. Overview of various thermodynamic functions, relation among them, and variation with pressure, volume, &temperature.
2. Acquaint students with concept
   - i. of statistical mechanics – macrostate & microstate, phase and mu space, various type of ensembles.
   - ii. Statistical and thermodynamic definition of entropy and relation between them.
   - iii. Various statistics and distribution functions such as M-B, B-E, & F-D statistics/distributions.
   - iv. Basic of kinetic theory of gases and application of M-B distribution function.
   - v. Ideal Bose and Fermi systems.
   - vi. Various types of ensembles in statistical mechanics.
   - vii. Technique of cluster expansion.
   - viii. Critical phenomena and phase transition.
   - ix. Ising models and fluctuation.

Learning Outcomes: After completion of the course the learners will

1. Comprehend concepts of thermodynamics, laws of thermodynamics, concept of entropy and the associated theorems, thermodynamic potentials and their physical interpretations, and three distribution functions.
2. Have basic knowledge of Ising model, quantum mechanical ensembles, Bose & Fermi systems, critical phenomena, and phase transition.
3. Be able to
   i. Answer/solve questions/problems related to
      a) Thermodynamic functions (enthalpy, Gibb's free energy, Helmholtz function).
      b) M-B, B-E, and F-D statistics/distribution functions.
   ii. Apply the concept of M-B, B-E, and F-D statistics/distribution functions in other domains (*e.g.*, solid state physics, quantum mechanics, mathematical physics, and nuclear physics).
   iii. Pursue research in theoretical physics/mathematical physics/applied mathematics.
   iv. Apply the concept of entropy in social/economic problems – understanding of sociophysics.
3. Have deep understanding of kinetic theory of gas and influence of M-B statistics/distribution function in understanding various properties of a gas.
4. Have critical knowledge required for pursuing research in statistical mechanics, astrophysics.

Thermodynamics: Review of thermodynamics; enthalpy (H), Gibb's free energy (G), Helmholtz function (A), various thermodynamic relations involving H, A, & G; variation of H, G and A with P, V and T, Joule-Thomson coefficient and inversion temperature.

The Statistical Basis of Thermodynamics: Macroscopic and microscopic states, phase space, μ-space & Γ-space, phase space of a classical system, postulate of equal a priori probability, concept of ensemble – microcanonical, canonical, & grand-canonical ensembles, Ergodic hypothesis- mean value over an ensemble & mean value over time; Liouville's theorem and its consequences, contact between statistics and thermodynamics - physical significance of the number Ω (N,V,E), $S = K_B \ln \Omega$, classical ideal gas, entropy of mixing and Gibbs paradox, 'correct' enumeration of microstates.

M-B, B-E, and F-D Statistics and Distribution Functions: Introduction, differences and limit, solving problems of statistics/distribution functions, partition function.

Kinetic Theory of Gas and M-B Distribution: Basic assumptions of kinetic theory of gases, kinetic energy, DoF, mean free path, collision cross-section, Maxwell velocity distribution, momentum distribution, energy distribution, experimental verification of Maxwell distribution – Stern's experiment, free fall under gravity, Doppler broadening of spectral lines.

Canonical Ensemble: Equilibrium between a system and a heat reservoir, a system in the canonical ensemble, physical significance of various statistical quantities in the canonical ensemble, partition function, classical system, energy fluctuation in the canonical ensemble & correspondence with the microcanonical ensemble, equipartition and virial theorem, a system of harmonic oscillator, statistics of paramagnetism, thermodynamics of magnetic system: negative temperatures.

Grand Canonical Ensemble: Equilibrium between a system and a particle-energy reservoir, a system in the grand canonical ensemble, physical significance of various statistical quantities, density and energy fluctuations in the grand canonical ensemble and correspondence with other ensembles.

Formulation of Quantum Statistics: Quantum-mechanical ensemble theory – the density matrix, statistics of various ensembles – microcanonical, canonical, and grand canonical ensembles, system composed of indistinguishable particles, density matrix and partition function of a system of free particles.

Theory of Simple Gases: An ideal gas in a quantum-mechnical microcanonical ensemble, an ideal gas in other quantum-mechanical ensembles, statistics of occupation numbers, kinetic considerations, gaseous systems composed with internal motion of molecules – monatomic, diatomic, and polyatomic molecules.

Ideal Bose Systems: Thermodynamic behaviour of an ideal Bose gas and black-body radiation, field of sound waves, inertial density of sound field, elementary excitations in liquid helium II.

Ideal Fermi Systems: Thermodynamic behavior of an ideal Fermi gas, magnetic behavior of an ideal Fermi gas – Pauli paramagnetism and Landau diamagnetism, electron gas in metals – thermionic emission (Richardson effect) & photoelectric emission (Hallwachs effect), statistical equilibrium of white dwarf stars.

Statistical Mechanics of Interacting Systems – The Method of Cluster Expansion: Cluster expansion for a classical gas, virial expansion of the equation of state, evaluation of the virial coefficients, general remarks on cluster expansions, exact treatment of the second virial coefficients, cluster expansion for a quantum-mechanical system.

Statistical Mechanics of Interacting Systems – The Method of Quantized Fields: Formalism of second quantization, low-temperature behaviour of an imperfect Bose gas, low-lying states of an imperfect Bose gas, energy spectrum of a Bose liquid, states with quantized circulation, quantized vortex rings and the breakdown of superfluidity, low-lying states of an imperfect Fermi gas, energy spectrum of a Fermi liquid – Landau's phenomenological theory.

Phase Transitions: General remarks on the problem of condensation, condensation of a van der Waals gas, dynamical model of phase transitions, lattice gas and binary alloy, brief discussion of Ising model, critical exponents, thermodynamic inequalities, Landau's phenomenological theory, scaling hypothesis for thermodynamic functions, role correlation & fluctuations, critical exponents, mean field theory.

Fluctuations: Thermodynamics fluctuations, spatial co-relations in a fluid, Einstein-Smoluchowski theory of Brownian motion, Langevin theory of Brownian motion, Fokker-Planck equation, fluctuation-dissipation theorem, Onsager relation.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Introduction to Modern Physics – R.B. Singh.
2. Statistical Mechanics – R.K. Pathria.
3. Statistical Mechanics – K. Huang.
4. Thermal Physics, Kinetic Theory, and Statistical Mechanics – S.C. Garg, R.M. Bansal, & C.K. Ghosh.
5. Thermal Physics – Entropy and Free Energies – J.C. Lee.
6. Introduction to Modern Statistical Mechanics – D. Chandler.
7. Fundamentals of Statistical and Thermal Physics – F. Reif.
8. Thermodynamics, Kinetic Theory, and Statistical Mechanics – S. Salinger and G.L. Salinger.
9. Thermodynamics and Introductory Statistical Mechanics - B. Linder.
10. A Conceptual Guide to Thermodynamics – B. Poirier.
11. Concepts of Thermal Physics – S.J. Blundell & K.M. Blundell.
12. Statistical Mechanics – B.K. Agarwal & M. Eisner.
13. Basics of Statistical Mechanics – H.J.W. Müller-Kirsten.

Optics – II

Course Objectives:

1. Impart advanced knowledge of lasers
   - i. Single mode operation, frequency stabilization, & mode locking (active & passive).
   - ii. *Q*-switching, optical bandwidths & pulse broadening.
   - iii. Füchtbauer-Ladenburg relation.
   - iv. Basic concept of lidar.

1. Provide a brief account of speckle metrology.
2. Impart knowledge about non-linear optics and optical mixing.
3. Make them understand about optical communication.

Learning Outcomes: After going through the course, students will be able to

4. Answer and solve conceptual and challenging questions and problems on interference, diffraction, and polarization.
5. Understand
   - viii. Various optical phenomena, principles, workings, and applications of optical instruments.
   - ix. Spontaneous and stimulated emission of radiation, optical pumping and population inversion.
   - x. Basic lasing.
   - xi. Three level and four level lasers.
   - xii. Various types of lasers in details and their applications.
   - xiii. Communication through optical fiber.
7. Answer and solve laser related questions and problems.
8. Handle sophisticated optical components.
9. Perform laser related experiments.

10. Pursue career in laser related atomic/fundamental and applied research and development.

Lasers II: Single mode operation, frequency stabilization, mode locking (active & passive mode locking), *Q*-switching, optical bandwidths & pulse broadening, Füchtbauer-Ladenburg relation, 'optical radar' or 'lidar' (*l*ight *d*etection *a*nd *r*anging), brief account of speckle metrology.

Non-Linear Optics: Introduction, an-harmonic oscillator, harmonic generation (first, second, & third order), brief description of non-linear susceptibility and optical mixing.

Holography: Basic concepts of hologram, discussion on the uses of holograms in daily life, recording and reproduction of holograms.

Fiber Optical Waveguides: Introduction, fiber jointing – single fiber connectors & multi-fiber couplers; measurement of fiber characteristics – introduction, fiber attenuation, fiber dispersion, & refractive index profile measurements, optical time domain reflector; fiber materials and manufacture – glass and plastic fibers; fiber cables.

Modulation of Light: Kerr modulations, scanning & switching, magneto-optic devices (Faraday effect), acoustic-optic effect.

Optical Communication Systems: Modulation schemes – analog & digital modulation; free space communications, fiber optical communication system – operating wavelength, emitter design, detector design, fiber choice, system design considerations, local area networks; integrated optics – slab & stripe waveguides, devices, emitters & detectors.

Optical Fiber Sensors and Photodetectors: Single mode, multimode passive/active optical fiber sensors, light guiding fibers, thermal detectors (pyroelectric detector), photon devices (photomultipliers).

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Fundamentals of Optics – F.A. Jenkins & H.E. White.
2. Lasers: Fundamentals & Applications – K. Thyagrajan & A.K. Ghatak.
3. Nonlinear Optics – R.W. Boyd.
4. Optical Physics – A. Lipson, S.G. Lipson, & H. Lipson.
5. Lasers & Non-linear Optics – B.B. Laud.
6. Prinçiple of Lasers – O. Svelto.
7. Introduction to Optics – F.L. Pedrotti, L.M. Pedrotti, & L.S. Pedrotti.
8. Optoelectronic Devices – W. Hawkes.

Atomic and Molecular Physics

Course Objectives: Orient students with knowledge of

1. Electron spin & Pauli's exclusion principle.
2. Atomic structure and periodic table.
3. Spin – orbit coupling & total angular momentum.
4. X-ray spectra.
5. Normal and anomalous Zeeman effect, Paschen-Back effect, & Stark effect.
6. One valence and two valence electron systems.
7. Rotational spectra of diatomic molecules.
8. Vibrational spectra of diatomic molecules.
9. Electronic Spectra of Diatomic Molecules - Born - Oppenheimer approximation, molecular bonds, & Franck-Condon principle.
10. Raman, NMR, ESR, and UV-VIS-IR spectroscopy.

Learning Outcomes: After completion of the course, learner will be able to

1. Answer/solve questions/problems related rotational, vibrational, and electronic spectra of molecules.
2. Connect quantum mechanics with atomic & molecular physics.
3. Study of influence of electric and magnetic fields on atoms will help in understanding Stark effect and Zeeman Effect respectively.
4. Pursue research in basic and applied physics/mathematical physics/applied mathematics.

Atomic Spectra: Electron spin, Pauli's exclusion principle, symmetric and antisymmetric wave function, atomic structure and periodic table, spin – orbit coupling, total angular momentum, atomic spectra, characteristics X-ray spectra, line broadening mechanisms, hyperfine structure, quantum mechanical treatment of normal and anomalous Zeeman effect, Paschen-Back effect, and Stark effect, one valence and two valence electron systems.

Rotational Spectra of Diatomic Molecules: Type of molecules- diatomic linear, symmetric top, asymmetric top and spherical top molecules; rotational spectra of diatomic molecules as a rigid rotor, energy levels and spectra of non-rigid rotor, intensity of rotational lines, stark modulated microwave spectrometer (qualitative).

Vibration Spectra of Diatomic Molecules: Harmonic oscillator and the anharmonic oscillator approximation, Morse potential, vibration energy of diatomic molecule - pure vibrational transitions, vibration-rotation transitions, PQR branches, IR spectrometer (qualitative); analysis of simple diatomic molecules, intensities of vibrational lines, selection rules.

Electronic Spectra of Diatomic Molecules: Born - Oppenheimer approximation, molecular bonds, H_2^+ molecular ion, hydrogen molecule, complex molecules, hybrid orbitals, rotational energy levels, vibrational energy levels, vibrational, rotational, and electronic spectra, Franck-Condon principle; Raman, NMR, ESR, and UV-VIS-IR spectroscopy.

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Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Physics of Atoms and Molecules – B.H. Bransden and C.J. Joachain.
2. Introduction to Atomic Spectra – H.E. White.
3. Introduction to Atomic Spectra – H.G. Kuhn.
4. Quantum Physics of Atoms, Molecules, Solids, Nuclei, & Particles – R. Eisberg & R. Resnick.
5. Atom, Laser, & Spectroscopy – S.N. Thakur & D.K. Rai.
6. Foundations of Spectroscopy – S. Duckett & B. Gilbert.
7. Fundamentals of Molecular Spectroscopy – C.N. Banwell.
8. Atomic Spectra – T.P. Softley.
9. Introduction to Molecular Spectroscopy – G.M. Barrow.
10. Nuclear Magnetic Resonance – P.J. Hore.
11. Physics of the Atom – M.R. Wehr, J. A. Richard Jr. and T.W. Adair.
12. Introduction to Quantum Theory and Atomic Structure – P.A. Cox.
25. Molecular Spectroscopy – J.M. Brown.
26. Energy levels in atoms and molecules – W.G. Richards & P.R. Scott.

Physics Lab. – III

Course Objectives:

1. Technology enhanced learning and doing while learning.
2. Train to handle various advanced instruments.
3. Verify laws through experiments.
4. Provide hands-on training on various PC and non-PC based instruments, make 'Learning-While-Doing' a realistic process, & knowledge on various hardware (DAQ, interface) and software (instrument controlling software) related to experiments.
5. Develop programing skills using software/programing language.

Learning Outcomes: After completion of the course learners will have necessary technical & software skills to

1. Use Origin software extensively.
2. Set-up of a given experiment.
3. Handle sophisticated instrument.
4. Do research in laser, materials science, atomic & molecular physics.
5. Pursue laser related fundamental and applied/industrial research in atomic & molecular physics, laser-matter interaction, and health sector.
6. Write computer code and solve problems related mechanics, oscillation, electricity & magnetism.
7. Develop technical skills to design electronic circuits & devices.
8. Handle sophisticated devices.
9. Build necessary competency to trouble-shoot high-end devices.

List of suggested experiments [NOTE: Experiments can be added or deleted]:

1. Hall Effect experiment.
2. Measurement of resistivity of semiconductor by four-probe method.
3. B-H curve, hysteresis loop of an iron core, and permeability.
4. Susceptibility of a paramagnetic material.
5. Dia-, para-, and ferro-magnetism in an inhomogeneous magnetic field.
6. Curie temperature measurement of ferroelectric materials.
7. Transition temperature of a high temperature superconductor and to study the Meissner effect.
8. Zeeman effect.
9. ESR.
10. Experiment with x-rays.
11. Experiment about lattice dynamics.
12. Optical communication.
13. Faraday effect.
14. Kerr modulation.
15. Non-linear optics.

Software/Computer programing:

Newtonian Mechanics: Introduction, escape velocity, projectile in a uniform gravitational field, reflecting trajectories, falling projectile with linear and quadratic air resistance drag, rocket with varying mass.

Oscillating System: Introduction, linear oscillator, series expansion solution, potential and phase diagrams for the linear oscillator, damped linear oscillator, damped harmonic oscillator and driving force.

Electricity and Magnetism: Introduction, charged disk, uniformly charged sphere, electric dipole, superposition of point charges, point charges and grounded plane, point charges and grounded sphere, line charges and grounded plane, magnetic vector potential for a long straight wire, motion of charged particle in a uniform **B** field.

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Semester – IV

Linear Algebra and Vector Spaces

Course Objectives: Provide following advanced mathematical knowledge for pursuing higher studies in physics (*i.e.*, mathematical, theoretical, & computational) and inter-disciplinary subjects

1. Various types of matrix and matrix algebra.
2. Vector spaces and vectors.
3. Mapping of vectors.
4. Operator formulism in quantum mechanics.

5. Expansion of wave-function in vector space.
6. Determinants and various operation related to determinants.

Learning Outcomes: After completion of the course the learners will be able to

5. Answer and solve conceptual questions and problems of matrix, determinants, and linear vector space.
6. Apply concept of vector space in quantum mechanics.
7. Study advanced topics and research articles in theoretical physics.
8. Pursue research in mathematical/theoretical physics.

Vectors in R^n and C^n, Spatial Vectors: Introduction, vectors in R^n, vector addition and scalar multiplication, dot (inner) product, located vectors, hyperplanes, lines, curves in R^n, vectors in R^3 (Spatial Vectors), ijk notation, complex numbers, vectors in C^n.

Algebra of Matrices: Introduction, matrices, matrix addition and scalar multiplication, summation symbol, matrix multiplication, transpose of a matrix, square matrices, powers of matrices, polynomials in matrices, invertible (nonsingular) matrices, special types of square matrices, complex matrices, block matrices.

Systems of Linear Equations: Introduction, basic definitions, solutions, equivalent systems, elementary operations, small square systems of linear equations, systems in triangular and echelon forms, Gaussian elimination, echelon matrices, row canonical form, row equivalence, matrix formulation, matrix equation of a system of linear equations, systems of linear equations and linear combinations of vectors, homogeneous systems of linear equations, elementary matrices, LU decomposition.

Vector Spaces: Introduction, vector spaces, examples of vector spaces, linear combinations, spanning sets, subspaces, linear spans, row space of a matrix, linear dependence and independence, basis and dimension, application to matrices, rank of a matrix, sums and direct sums, coordinates.

Linear Mappings: Introduction, mappings, functions, linear mappings (linear transformations), kernel and image of a linear mapping, singular and nonsingular linear mappings, isomorphisms, operations with linear mappings, Algebra A(V) of linear operators.

Linear Mappings and Matrices: Introduction, matrix representation of a linear operator, change of basis, similarity, matrices and general linear mappings.

Inner Product Spaces & Orthogonality: Introduction, inner product spaces, examples of inner product spaces, Cauchy-Schwarz inequality, applications, orthogonality, orthogonal sets and bases, Gram–Schmidt orthogonalization process, orthogonal and positive definite matrices, complex inner product spaces, normed vector spaces.

Determinants: Introduction, determinants of orders 1 and 2, determinants of order 3, permutations, determinants of arbitrary order, properties of determinants, minors and cofactors, evaluation of determinants, classical adjoint, applications to linear equations, Cramer's rule, submatrices, minors,

24.8.19 24-08-19 Surjeet 24/8/19 24.08.19. 24/8/19 principal minors, block matrices and determinants, determinants and volume, determinant of a linear operator, multilinearity and determinants.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Linear Algebra and Its Applications – D.C. Lay.
2. Linear Algebra: Step by Step – K. Singh.
3. Linear Algebra – S. Lipschutz (Schaum series).
4. Introduction to Linear Algebra – G. Strang.
5. Vector Spaces and matrices in Physics – M.C. Jain.
6. Differential Equations and Linear Algebra – G. Strang.

Classical Electrodynamics, Relativity, and Plasma Physics

Course Objectives: To develop expertise in classical electrodynamics and relativity and their applications

1. Maxwell's equation.
2. Energy, momentum, & Poynting vector/theorem of electromagnetic waves.
3. Wave equations for electric (**E**) and magnetic (**B**) fields in air and in various media (conductor & insulator).
4. Solution electromagnetic waves in media, transmission & propagation waves in various media, and guided wave.
5. Scalar & vector potentials.
6. Gauge transformation – Coulomb and Lorentz gauge.
7. Retarded potentials.
8. Jefimenko's equations & Lienard-Wiechart potentials.
9. Fields of a moving point charge.
10. Special theory of relativity - Einstein's postulates, Lorentz Transformation and its applications (time dilation, length contraction, proper length and proper time, simultaneity, & twin paradox).
11. Relativistic dynamics.
12. Relation between relativity and electromagnetism.
13. Minkowski's four-dimensional space-time world & four-vectors.
14. Application of special theory of relativity.
15. Limitations of special theory of relativity.
16. General theory of relativity.

Learning Outcomes: After completion of the course, learners will be able to

1. Answer/solve questions/problems related to electromagnetic waves in air and different media.
2. Apply the concept of potential and field for transmission & propagation of electromagnetic waves and have conceptual knowledge of radiation from point charges and dipoles (*i.e.*, antenna etc.)
3. Answer/solve questions/problems related to relativity.

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4. Apply various mathematical formulae for transmission & propagation of electromagnetic waves and have conceptual knowledge of radiation from point charges and dipoles.
5. Self-study relevant topics of plasma physics & magneto hydrodynamics.
6. Understand research articles based on electromagnetic waves.
7. Perform mathematical simulation of propagation of electromagnetic waves in various media.

Classical Electrodynamics

Maxwell's Equations and Electromagnetic Waves: Ampere's law with Maxwell's correction, electromagnetic waves, wave equation for **E** and **B** fields, energy & momentum in electromagnetic waves, Poynting's theorem; electromagnetic waves in matter; absorption and dispersion; guided wave – wave guides, waves in rectangular wave guide, coaxial transmission line.

Potentials and Fields: Potential formulation – scalar & vector potentials, gauge transformations, Coulomb gauge & Lorentz gauge, Lorentz force law in potential form; continuous distributions – retarded potentials, Jefimenko's equations; Lienard-Wiechart potentials, fields of a moving charge.

Radiation: Electric & magnetic dipole radiation, radiation from an arbitrary source; point charges – power radiated by a point charge, radiation reaction, mechanism responsible for radiation reaction.

Relativity

Special Theory of Relativity: Lorentz Transformation: Einstein's postulates of special theory of relativity, Lorentz transformation, time dilation, length contraction, proper length and proper time, simultaneity, twin paradox.

Relativistic dynamics: Relativistic mass, momentum, force, acceleration, equivalence of mass and energy ($E = mc^2$), collision, mass defect and binding energy, transformation properties of mass, momentum, energy, force, and acceleration, invariance of space-time and energy-momentum under Lorentz transformation, relativistic Lagrangian for a free particle.

Relativity and electromagnetism: The interdependence of electric and magnetic fields, transformations for **E** and **B**, force and field near a current carrying wire, force between moving charges.

Minkowski's space: Minkowski's four-dimensional space-time world, Lorentz transformation as rotation in four-space, four-vectors.

Applications and possible limitations: Relativistic Doppler effect – aberration; reflection of light by a moving mirror, propagation of light in a moving medium – Fresnel's dragging coefficient, Thomas precession - spin-orbit interactions; relativistic classification of particles, zero rest mass (photons and neutrinos), de Broglie waves for a free particle, uncertainty relation; qualitative discussion on the possible limitations of special theory of relativity.

General Theory of Relativity: Equivalence of gravitational and inertial mass, principle of equivalence, Einstein's elevator, gravitational mass of photons, gravitational effect on clock, gravitational red shift.

Plasma Physics

Definition of plasma, Debye shielding, plasma parameter and criterion for plasma, Larmour radius, dielectric constant of plasma, plasma parameters & oscillation, plasma confinement.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Classical Electrodynamics – J.D. Jackson.
2. Introduction to Electrodynamics – D. Griffith.
3. Electromagnetic Theory – Bo Thidé.
4. Classical Electricity and Magnetism – W.K.H. Panofsky & M. Philips.
5. Special theory of Relativity – R. Resnick.
6. Special Theory of Relativity – S.P. Puri.
7. A First Course on General Relativity – B. Schutz.
8. The Fourth State of Matter: An Introduction to Plasma Physics – S. Eliezer & Y. Eliezer.
9. Plasma Physics – A. Bittencourt.
10. Introduction to Plasma Physics – F.E. Chen.

Nuclear and Particle Physics

Course Objectives: To provide knowledge about

1. Structure of nucleus/various models - Thomson model, Rutherford model, proton-electron model, proton-neutron hypothesis.
2. Properties of nucleus.
3. Meson theory of nuclear force.
4. Isotopes, isotones, isobars, isomers, magic number and mirror nuclei.
5. Various nuclear models - liquid drop model, semi empirical mass formula (Weizacker's semi-empirical formula), shell model.
6. $E = mc^2$, mass defect, binding energy and Q value.
7. Nuclear fission & fusion.
8. Nuclear reactors.
9. α-, β-, and γ- rays and their properties, Bethe-Bloch formula, annihilation of electron-positron pair, Compton effect.
10. Cosmic rays and elementary particles (gravitons, photons, leptons, hadrons etc.), quarks, antiparticle.

Learning Outcomes: After completion of the course, learners will be able to

1. Answer/solve questions/problems related to nuclear physics.
2. Apply the concept of statistical mechanics and quantum mechanics in nuclear physics.
3. Self-study relevant topics of nuclear physics.
4. Pursue research in nuclear medicine, nuclear technology/nuclear energy.

Atomic Nucleus: Structure of nucleus - Thomson model, Rutherford model, proton-electron model, proton-neutron hypothesis; properties of nucleus - mass, radius, density, nuclear angular momentum, magnetic moment, electric quadrupole moment, wave mechanical properties – BE and FD statistics, parity; atomic mass, nuclear stability, nuclear forces (Meson theory), isotopes, isotones, isobars, isomers, magic number and mirror nuclei.

Nuclear Model: Liquid drop model, semi empirical mass formula (Weizacker's semi-empirical formula), shell model.

Nuclear Reactions: $E = mc^2$, mass defect, binding energy and Q value, transmutation, nuclear energy, nuclear fission, nuclear reactors, types of nuclear reactors, Breeder reactors, nuclear fusion, nuclear fusion in stars, nuclear fusion reactors

Radioactivity and Interaction of Nuclear Radiation with Matter: α-, β-, and γ- rays and their properties; rate of energy loss, Bethe-Bloch formula, absorption of γ-rays in matter, linear and mass absorption coefficient, annihilation of electron-positron pair, Compton effect.

Detectors for Nuclear Particles: Interaction between particles and matter, ionization counter, Geiger-Muller counter, scintillation counter, solid state or semiconductor detectors, Compton suppressed germanium detectors, Cloud and Bubble chambers, Spark chambers.

Cosmic Rays and Elementary Particles: Introduction, primary and secondary cosmic rays, altitude effect, latitude effect, East-West effect, cosmic ray shower; classification of elementary particles (gravitons, photons, leptons, hadrons etc.), quarks, antiparticle.

Problems & exercises pertaining to above topics from recommended books form an integral part of the paper.

Scope of the syllabus is defined from following recommended books:

1. Nuclear & Particle Physics: An Introduction – B.R. Martin.
2. Nuclear & Particle Physics – W.E. Burcham & M. Jobes.
3. Introductory Nuclear Physics – K.S. Krane.
4. Introductory Nuclear Physics – S.S.M. Wong.
5. Nuclear Physics – V. Devnathan.
6. Concepts of Nuclear Physics – B.L. Cohen.
7. Fundamentals of Nuclear Physics – B.B. Srivastava.

8. Introduction to Nuclear Physics – H.S. Enge.
9. Nuclear Structure – M.K. Pal.
10. Atomic & Nuclear Physics – Vol. II – S.N. Ghoshal.
11. Particle Physics: A Very Short Introduction – F. Close.

Physics Lab. – IV

Course Objectives:

1. Train to handle various advanced instruments & radioactive elements.
2. Verify physics laws through experiments.
3. Computer programing using LabVIEW software for electronics.
4. Provide hands-on training on various PC and non-PC based instruments, make 'Learning-While-Doing' a realistic process, & knowledge on various hardware (DAQ, interface) and sofiware (instrument controlling software) related to experiments.
5. Develop programing skills using software/programing language.

Learning Outcomes: After completion of the course learners will acquire proficiency to

1. Analyze experimental results/data using Origin software.
2. Set-up of a given experiment.
3. Handle sophisticated instrument.
4. Pursue fundamental and applied/industrial research.
5. Get involved in nuclear power sector.
6. Write computer code and solve problems in modern physics.
7. Design & build electronic circuits & devices.
8. Handle sophisticated devices.
9. Develop code using physics and LabVIEW software.

List of suggested experiments [NOTE: Experiments can be added or deleted]:

1. NMR.
2. Experiments with Alpha, Beta, & Gamma rays and GM Counter.
3. Franck-Hertz experiment.
4. Balmer series.
5. Experiment with transducer & sensors.
6. Raman spectrometer.
7. Atomic force microscope.
8. Experiments related to lasers.
9. Experiments related to properties of materials.
10. Experiments related to electronics.
11. LabVIEW programing.

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Suggested books for electronics experiments:

1. Learning with LabVIEW – R.H. Bishop.
2. Data Acquisition Using LabVIEW – B. Ehsani.
3. LabVIEW for Everyone: Graphical Programming Made Even Easier – L.K. Wells & J. Travis.
4. PC Based Instrumentation: Concepts & Practice – N. Mathiavanan.
5. Microprocessor Architecture Programming & Applications – R.S. Gaonkar.
6. Microprocessor 8085: Architecture, Programming, & Interfacing – A. Wadhwa.

Software/Computer programing:

Linear Algebra: Vectors and matrices, matrix operations, matrix manipulation, linear systems of equations, orthogonality, eigen values and eigen vectors, diagonalization and Jordon canonical form, Gaussian elimination.

Modern Physics: Carbon dating, stable isotopes, Bohr atom, one-dimensional Schrodinger equation - particle bound in an infinite potential well, particle bound in a finite potential well, particle hitting a finite step potential, particle propagating toward a rectangular potential, one-dimensional harmonic oscillator, the hydrogen atom in spherical coordinates.

Elective

Reading Course

Course Objectives:

1. Train students to
   i. "Read to Learn and Learn to Read".
   ii. Study & understand research articles/books independently.
   iii. Read & understand topics/articles related to science, technology, and society.
   iv. Write a summary and prepare the progress report on a given topic.
   v. Compose article and final report after going through various books/articles.
   vi. Deliver a lecture using ICT on a given topic to general as well as technical people.
2. To create awareness about subjects beyond the classroom teaching.
3. To generate interest in different subjects.
4. To Develop
   i. Reading skill.
   ii. Soft-skill.
   iii. Habit of going through various materials/books/articles, do literature survey on the same topic to have a deep understanding of that topic.
   iv. A self-efficacy.

Learning Outcomes: After completion of the course, learners will be able to

1. Study any research related articles independently.
2. Connect science and technology with society.
3. Write policies related to academia.
4. Discuss scientific and social issues.
5. Present results in a lucid manner.
6. Write research articles.

Student in consultation with faculty member will choose a topic, do literature survey, regularly submit progress report, prepare final report/article, give final oral presentation, and submit the final report.

Project

Course Objectives:

1. Train students to
   i. Study & understand research articles/books independently.
   ii. Perform experiments on a given topic.
   iii. Interpret & analyze the data and result.
   iv. Write a summary and prepare the progress report.
   v. Compose article and final report.
   vi. Deliver a lecture about the research findings using ICT.
2. To create awareness about subjects beyond the classroom teaching.
3. To generate interest in different subjects.
4. To motivate in pursuing research.
5. To Develop
   v. Critical thinking and analytical ability
   vi. Reading skill.
   vii. Technical skill.
   viii. A self-efficacy.

Learning Outcomes: After completion of the course, learners will be able to

7. Study any research related articles independently.
8. Connect science and technology with society.
9. Perform advanced experiments.
10. Work on a given project.
11. Interpret and compare the results with available resources.
12. Write policies related to academia.
13. Discuss scientific and social issues.
14. Present results in a lucid manner.
15. Write research articles.
16. Pursue basic and/or applied research.

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Student in consultation with faculty member will choose a topic, do literature survey, conduct research, regularly submit progress report, prepare final report/article, give final oral presentation, and submit the final report.

~ ***END*** ~