S. S. JAIN SUBODH P.G. (AUTONOMOUS) COLLEGE, JAIPUR

FACULTY OF SCIENCE

PROGRAMME NAME : TWO YEARS POSTGRADUATE PROGRAMME IN SCIENCE

SUBJECT/DISCIPLINE : PHYSICS

SYLLABUS AS PER NEW EDUCATION POLICY - 2020
&
CHOICE BASED CREDIT SYSTEM (CBCS)

MEDIUM OF INSTRUCTION : ENGLISH

W.E.F. ACADEMIC SESSION 2023-24

Programme Name : P.G. - Two Years M.Sc. (Physics)

Name of College	**S.S. Jain Subodh P.G. (Autonomous) College, Jaipur**
Name of Faculty	**Science**
Name of Programme	**PG - M.Sc.**
Name of Discipline	**Major Discipline - Physics**

PROGRAMME PREREQUISITES

Physics and Mathematics courses at the UG level or B.Sc. (Physics)

PROGRAMME OUTCOMES (POs)

1. Proficiency in Scientific Principles : Students will demonstrate a strong understanding of advanced scientific principles in physics and mathematics. They will be able to apply these principles to analyse and solve complex problems.
2. Analytical and Critical Thinking : Students will develop analytical and critical thinking skills through the study of physics. They will be able to evaluate and interpret data, formulate hypotheses, and draw logical conclusions based on evidence.
3. Quantitative and Computational Skills : Students will acquire proficiency in quantitative and computational methods. They will be able to perform calculations, manipulate mathematical expressions, and use computational tools to solve scientific problems.
4. Experimental and Laboratory Skills : Students will gain hands-on experience in conducting experiments, using laboratory equipment, and analysing experimental data. They will understand the importance of accurate measurement, data interpretation, and documentation.
5. Problem Solving and Modelling : Students will develop problem-solving skills and the ability to create mathematical models to represent real-world phenomena. They will apply mathematical and scientific concepts to formulate and solve problems in physics and related fields.
6. Interdisciplinary Understanding : Students will develop an interdisciplinary perspective by integrating concepts from physics, chemistry, and mathematics through additional elective papers, such as, nanotechnology. They will understand the connections and interdependencies among these disciplines and their applications in other scientific and technological areas.
7. Effective Communication : Students will develop effective oral and written communication skills. They will be able to communicate scientific ideas, theories, and experimental results clearly and concisely to both technical and non-technical audiences.
8. Ethical and Professional Responsibility : Students will understand and adhere to ethical and professional standards in scientific research and practice. They will demonstrate integrity, responsible conduct, and respect for intellectual property.
9. Lifelong Learning : Students will recognize the importance of lifelong learning and professional development. They will be motivated to pursue further studies, engage in research, and keep up with advancements in physics.
10. Teamwork and Collaboration : Students will develop teamwork and collaboration skills through group projects, laboratory work, and research activities. They will be able to work effectively in diverse teams and contribute to collective goals.

Scheme of Examination :

1 Credit = 25 Marks For Examination/Evaluation

Continuous assessment, in which sessional work and the terminal examination, will contribute to the final grade. Each course in Semester Grade Point Average (SGPA) has two components - Continuous internal assessment (CIA - 30% weightage) and End of Semester Examination (EoSE - 70% weightage).

1. Sessional work will consist of class tests, mid-semester examination(s) (CIA), homework assignments, etc., as determined by the faculty in charge of the courses of study.
2. Each paper of the End of Semester Examination (EoSE) shall carry 70% of the total marks of the course/subject. The EoSE will be of 3 hours duration. Each question will carry equal marks and will have two pars in the following manner :
    - Part A of the paper shall have multiple questions of equal marks. This first question shall be based on knowledge, understanding and applications of the topics/texts covered in the syllabus.
    - Part B of the paper shall consist of 4 questions with an internal choice of each. The four questions will be set with one from each of the units with internal choice. Third to fourth questions shall be based on applications of the topics/texts covered in the syllabus (60% weightage) and shall involve solving problems (40% weightage), if applicable.
3. 75% Attendance is mandatory for appearing in EoSE.
4. To appear in the EoSE examination of a course/subject student must appear in the mid-semester examination (CIA) and obtain at least a "C" grade in the course/subject.
5. Credit points in a Course/Subject will be assigned only if, the student obtains at least a C grade in midterm and EoSE examination of a Course/Subject.
6. Students also have the option of completing a course of his/her choice with minimum assigned credits through MOOC/Swayam platform in the third & fourth semesters, respectively. On successful completion of the course with minimum credits, the acquired credits will be added into the final grade sheet of the student.

Contact Hours –

15 Weeks per Semester

L – Lecture	(1 Credit = 1 Hour/Week)
T – Tutorial	(1 Credit = 1 Hour/Week)
S – Seminar	(1 Credit = 2 Hours/Week)
P – Practical/Practicum	(1 Credit = 2 Hours/Week)
F – Field Practice/Projects	(1 Credit = 2 Hours/Week)
SA – Studio Activities	(1 Credit = 2 Hours/Week)

I – Internship (1 Credit = 2 Hours/Week)
C – Community Engagement and Service (1 Credit = 2 Hours/Week)

Exit and Entrance Policy

1. Students who opt to exit after completion of the first six months and have secured 24 credits will be awarded a **PG Certificate** if, in addition, they complete one internship of 4 credits during the summer vacation of the first year (Total 28 credits). These students are allowed to re-enter the degree programme within two years and complete the degree programme within the stipulated maximum period of six years.
2. Students who opt to exit after completion of the first year and have secured 56 credits will be awarded the **PG diploma** if, in addition, they complete one internship of 4 credits during the summer vacation of the second year (Total 60 credits). These students are allowed to re-enter within a period of two years and complete the degree programme within the maximum period of six years.
3. Students who wish to undergo a 2-year PG programme will be awarded PG Degree in Physics after successful completion of two years, securing 112 credits and satisfying the minimum credit requirement.

Letter Grades and Grade Points

Letter Grade	Grade Point	Marks Range (%)
O (outstanding)	10	91 - 100
A+ (Excellent)	9	81 - 90
A (Very good)	8	71 - 80
B+ (Good)	7	61 - 70
B (Above average)	6	51 - 60
C (Average)	5	40 - 50
P (Pass)	4	
F (Fail)	0	
Ab (Absent)	0	

When students take audit courses, they may be given a pass (P) or fail (F) grade without any credits.

S. S. Jain Subodh P.G. (Autonomous) College, Jaipur

Master of Science (M.Sc.) - Physics

Examination Scheme For Each Paper - Choice Based Credit System (CBCS) New Education Policy (NEP) - 2020

Part A 7 QUESTIONS (Very Short Answer Type Questions) 7 x 2 MARKS EACH = 14 Marks

Part B 4 QUESTIONS (1 Question from Each Unit with Internal Choice)

14 x 4 MARKS EACH = 56 Marks

Max. Marks of End Semester Exam (Duration of Exam of 3 Hours) = 70 Marks

Continuous Internal Assessment (CIA) = 30 Marks

Maximum Marks (Each Theory Paper) = 100 Marks

(Internal Marks 30 + External Marks 70)

Max. Practical Marks With Dissertation/Seminar = 200 Marks

Total of Theory Papers : 4 x 100 Marks Each = 400 Marks per semester

(Min. Pass Marks in Theory Papers = 40% of 400 Marks = 160 Marks;

Min. of 21 marks required in each of the theory papers separately in end-semester exam)

Total of Practical Exam Marks (CIA + EoSE + Seminar/PRJ/STP/D) per semester = 200 Marks

(Min. Pass Marks 40% = 80 Marks)

Grand Total of Marks of All Courses Per Semester = 600 Marks

Semester - I

Paper (I) - Classical Mechanics

(DSC MPHY 101, Credits Theory 04, Lectures 60)

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions of 14 marks and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. (7 x 2 = 14 Marks)

Part B of the paper will consist of four questions, one question from each unit with internal choice. Each question will carry 14 marks. (4 x 14 = 56 Marks)

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
I	DSC MPHY 101	Classical Mechanics	8	4
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	**Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.**		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the course is to provide students with a comprehensive understanding of advanced classical mechanics. The course aims to develop their knowledge and skills in analysing and solving problems related to these topics, using appropriate mathematical formalism and physical concepts.			

Unit - I : Holonomic & Non-Holonomic Constraints

D'Alembert's principle & Lagrange's equation, Velocity dependent potentials, Simple applications of Lagrangian formulation, Hamilton principle, Calculus of variations, Derivation of Lagrange's equation from Hamilton's principle, Extension of Hamilton's principle for nonconservative & non-holonomic systems, Method of Lagrange's multipliers, Conservation theorems & Symmetry properties, Noether's theorem, Conservation of energy, linear momentum & angular momentum as a consequence of homogeneity of time & space, Isotropy of space. **(15 Lectures)**

Unit - II : Generalized Momentum, Legendre Transformation & Hamilton's Eqns. of Motion

Simple applications of Hamiltonian formulation, Cyclic coordinates, Hamiltonian formulation of relativistic mechanics, Derivation of Hamilton's canonical equation from Hamilton's variational principle, The Principle of least action. **(15 Lectures)**

Unit - III : Canonical Transformation, Integral Invariant of Poincare

Lagrange's & Poisson brackets as canonical invariants, Equation of motion in Poisson bracket formulation, Infinitesimal contact transformation & Generators of symmetry, Liouvilee's theorem, Hamilton-Jacobi equation & its applications. **(15 Lectures)**

Unit - IV : Action Angle Variable & Adiabatic Invariance of Action Variable

The Keppler problem in action angle variables, Theory of small oscillation in Lagrangian formulation, Normal coordinates and its applications, Orthogonal transformation, Euler's theorem, Eigenvalues of the inertia tensor, Euler equations, Force free motion of a rigid body.

(15 Lectures)

Reference Books/Text Books

1. Classical Mechanics by Goldstein , Pearson Education.
2. Classical Mechanics by Landau and Lifshitz , Reed Educational and Professional Publishing Ltd.
3. Classical Mechanics by A. Raychoudhary , Oxford University Press, USA.
4. Classical Mechanics by J. M. Finn, Laxmi Publications.
5. Classical Mechanics by T. Kibble & F. H. Berkshire, Imperial College Press.

Suggested E-Resources :

1. MIT OpenCourseWare: Classical Mechanics - This resource provides lecture notes, problem sets, and solutions for a complete course on classical mechanics : https://ocw.mit.edu/courses/physics/8-01sc-classical-mechanics-fall-2016/
2. HyperPhysics - This online resource provides concise explanations and interactive simulations for various topics in mechanics : http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
3. NPTEL/Swayam : https://onlinecourses.nptel.ac.in/noc22_ph28/preview
4. IIT Madras Lectures : https://www.youtube.com/playlist?list=PLtUBquogGkRukyAAWOmq2LmQx8Yf9H_3E

Course Learning Outcomes :

By the end of the course, students should be able to:

1. Understand the concept of Holonomic & non-holonomic constraints.
2. Understanding of theory of Lagrangian formulation, its applications, and Lagrange's multipliers.
3. Understanding of theory of Hamilton's principle and its extensions.
4. Basic theoretical formulation of conservation theorems, conservation of energy, Noether's theorem.
5. Understanding of linear & angular momentum in reference to homogeneity of time & space, isotropy of space.
6. Deep understanding of theories of cyclic coordinates, Hamiltonian formulation of relativistic mechanics.
7. Derivation of Hamilton's canonical equation from Hamilton's variational principle.
8. Theory of principle of least action and applications.
9. Theoretical formulation of Lagrange's and Poisson brackets as canonical invariants.
10. Development of equation of motion in Poisson bracket formulation.
11. Understanding of infinitesimal contact transformation and generators of symmetry & Liouvilee's theorem.
12. Explanation of Hamilton-Jacobi equation and applications.
13. Fundamental knowledge of theory of action angle variable, adiabatic invariance of action variable.
14. Formulation of Keppler problem in action angle variables.
15. Theoretical knowledge of small oscillation in Lagrangian reference.
16. Theory of orthogonal transformation, Euler's theorem.
17. Eigenvalues of inertia tensor, Euler equations.

M.Sc. (Physics)

Semester - I

Paper (II) - Quantum Mechanics

(DSC MPHY 102, Credits Theory 04, Lectures 60)

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions of 14 marks and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. (7 x 2 = 14 Marks)

Part B of the paper will consist of four questions, one question from each unit with internal choice. Each question will carry 14 marks. (4 x 14 = 56 Marks)

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
I	DSC MPHY 102	Quantum Mechanics	8	4
Level of Course	Type of The Course	Delivery Type of The Course		
Introductory	Core	Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the course is to provide students with a comprehensive understanding of quantum mechanics at a step higher than the UG level. The course aims to develop their knowledge and skills in analysing and solving problems related to these topics, using appropriate mathematical formalism and physical concepts. The course targets development of advanced fundamentals in students for higher level problems of quantum mechanics and to prepare their advanced level fundamentals to enable to study them advanced quantum mechanics in upcoming semesters.			

Unit - I : States, Amplitude and Operators

States of a quantum mechanical system, Representation of quantum mechanical states, Properties of quantum mechanical amplitude, Operators & change of a state, A complete set of basis states, Products of linear operators, Language of quantum mechanics, Postulates, Essential definitions & commutation relations.

Observables & description of quantum system : Process of measurement, Expectation values, Time dependence of quantum mechanical amplitude, Observable with no classical analogue, Spin dependence of quantum mechanical amplitude on position, The wave function, Superposition of amplitudes, Identical particles. **(15 Lectures)**

Unit - II : Hamiltonian Matrix & Time Evolution of Quantum Mechanical States

Hermiticity of the Hamiltonian matrix, Time-independent perturbation of an arbitrary system, Simple matrix examples of time-independent perturbation, Energy eigenstates of a two-state system, Diagonalizing of energy matrix, Time-independent perturbation of two state system, The perturbative solution : Weak field & Strong field cases, General description of two state system, Pauli matrices, Ammonia molecule as an example of two state system. **(15 Lectures)**

Unit - III : Transition Between Stationary States

Transitions in a two-state system, Time-dependent perturbations - The Golden Rule, Phase space, Emission & absorption of radiation, Induced dipole transition & Spontaneous emission of radiation energy width of a quasi-stationary state.

The co-ordinate Representation : Compatible observables, Quantum conditions & uncertainty relation, Coordinate representation of operators, position, momentum & angular momentum, Time-dependence of expectation values, Ehrenfest's Theorem, The time evolution of wave function, Schrödinger's equation, Energy quantization, Periodic potential as an example.

(15 Lectures)

Unit - IV : Symmetries & Angular Momentum

Compatible observables & constants of motion, Symmetry transformation & conservation laws, Invariance under space & time translations, space rotation, Conservation of momentum, energy & angular momentum.

Angular momentum operators & their Eigenvalues, Matrix representations of the angular momentum operators & their eigenstates, Coordinate representations of the orbital angular momentum operators & their eigen state (spherical harmonics), Composition of angular momenta, Clebsch-Gordon coefficients tensor operators & Wigner-Eckart theorem, Commutation relations, of J_x, J_y,J_z with reduced tensor operator, Matrix elements of vector operators, Time reversal invariance & vanishing of static electric dipole moment of stationary state. **(15 Lectures)**

Reference Books/Text Books

1. Quantum Mechanics - A Modern Approach by Ashok Das and A.C. Melissinos, Gordon and Breach Science Publishers.
2. Quantum Mechanics by P.A.M. Dirac, Oxford University Press.
3. Quantum Mechanics by E. Merzbacher, Second Edition, John Wiley & Sons.
4. Quantum Mechanics - Relativistic Theory by L.P. Landau and E.M. Lifshitz, Pergamon Press.
5. Quantum Mechanics - Theory and Applications by A. Ghatak and S. Lokanathan, Third Edition, Mac. Millan, India Ltd.

Suggested E-Resources :

1. MIT OpenCourseWare : Introductory Quantum Mechanics - This resource offers lecture notes, assignments, and exams for a complete course on introductory quantum mechanics : https://ocw.mit.edu/search/?q=introductory%20quantum%20mechanics%20
2. HyperPhysics - This online resource provides concise explanations and interactive simulations for various topics in introductory quantum mechanics : http://hyperphysics.phy-astr.gsu.edu/hbase/quacon.html#quacon
3. IIT Madras Lectures : https://www.youtube.com/watch?v=vJR94oyY-as
4. Cosmo Learning : https://cosmolearning.org/courses/quantum-mechanics-lessons-from-drphysicsa/
5. Documentaries on Quantum Mechanics : https://cosmolearning.org/physics/documentaries?topic=18&sort=za

Course Learning Outcomes :

By the end of the course, students should be able to :

1. Understand the concept of Holonomic & non-holonomic constraints.

2. Understanding of theory of Lagrangian formulation, its applications, and Lagrange's multipliers.
3. Understanding of theory of Hamilton's principle and its extensions.
4. Basic theoretical formulation of conservation theorems, conservation of energy, Noether's theorem.
5. Understanding of linear & angular momentum in reference to homogeneity of time & space, isotropy of space.
6. Deep understanding of theories of cyclic coordinates, Hamiltonian formulation of relativistic mechanics.
7. Derivation of Hamilton's canonical equation from Hamilton's variational principle.
8. Theory of principle of least action and applications.
9. Theoretical formulation of Lagrange's and Poisson brackets as canonical invariants.
10. Development of equation of motion in Poisson bracket formulation.
11. Understanding of infinitesimal contact transformation and generators of symmetry & Liouvilee's theorem.
12. Explanation of Hamilton-Jacobi equation and applications.
13. Fundamental knowledge of theory of action angle variable, adiabatic invariance of action variable.
14. Formulation of Keppler problem in action angle variables.
15. Theoretical knowledge of small oscillation in Lagrangian reference.
16. Theory of orthogonal transformation, Euler's theorem.
17. Eigenvalues of inertia tensor, Euler equations.

M.Sc. (Physics)

Semester - I

Paper (III) - Classical Electrodynamics (I)

(DSC MPHY 103, Credits Theory 04, Lectures 60)

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. (2 x 7 = 14 Marks)

Part B of the paper will consist of four questions, one question from each unit with internal choice. Each question will carry 14 marks. (4 x 14 = 56 Marks)

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
I	DSC MPHY 103	Classical Electrodynamics (I)	8	4
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	**Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.**		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the first course in classical electrodynamics is to provide students with a comprehensive understanding of classical electrodynamics at a step higher than the UG level. The course aims to develop their knowledge and skills in analysing and solving problems related to these topics, using appropriate mathematical formalism and physical concepts. The course targets development of advanced fundamentals in students for higher level problems of classical electrodynamics, and to prepare their advanced level fundamentals to enable them solving advanced problems in classical electrodynamics in upcoming semesters.			

Unit - I : Electrostatics

Electric field, Gauss Law, Differential form of Gaussian law, Another equation of electrostatics & scalar potential, Surface distribution of charges, dipoles & discontinuities in the electric field and potential, Poisson & Laplace equations, Green's theorem, Uniqueness of the solution with the Dirichlet or Neumann boundary Conditions, Formal solutions of electrostatics, Boundary value problem with Green's function, Electrostatic potential energy and energy density, capacitance.

Boundary Value Problems in Electrostatics : Methods of images, Point charge in the presence of a grounded conducting sphere, Point charge in the presence of a charged insulated conducting sphere, Point charge near a conducting sphere at a fixed potential, Conducting sphere in a uniform electric field by method of images, Green function for the sphere, General solution for the potential, Conducting sphere with hemispheres at different potentials, Orthogonal functions & expansion. **(15 Lectures)**

Unit - II : Multipoles, Electrostatics of Macroscopic Media, Dielectrics

Multipoles, Electrostatics of Macroscopic Media : Multipole expansion, Multipole expansion of the energy of a charge distribution in an external field, Elementary treatment of electrostatics with permeable media.

Dielectrics : Boundary value problems with dielectrics, Molar polarizability & electric susceptibility, Models for molecular polarizability, Electrostatic energy in dielectric media.

(15 Lectures)

Unit - III : Magnetostatics

Introduction & definition, Biot & Savart Law, The differential equations of magnetostatics & Ampere's law, Vector potential & Magnetic induction for a current loop, Magnetic fields of a localized current distribution, Magnetic moment, Force, torque & energy of a localized current distribution in an external induction, Macroscopic equations, Boundary conditions on B and H, Methods of solving Boundary value problems in magnetostatics, Uniformly magnetized sphere, Magnetized sphere in an external field, Permanent magnets, Magnetic shielding, Spherical shell of permeable material in an uniform field. **(15 Lectures)**

Unit - IV : Time Varying Fields, Maxwell's Equations, Conservation Laws

Energy in a magnetic field, Vector & Scalar potentials, Gauge transformations, Lorentz gauge, Coulomb's gauge, Green function for the wave equation, Derivation of the equations of macroscopic electromagnetism, Poynting's theorem & conservation of energy and momentum for a system of charged particles & EM fields, Conservation laws for macroscopic media, Electromagnetic field tensor, Transformation of four potentials & four currents, Tensor dissipation of Maxwell's equations. **(15 Lectures)**

Reference Books/Text Books

1. Classical Electrodynamics by J.D. Jackson, Wiley Student Ed.
2. Classical Electrodynamics & Magnetism by Panofsky & Phillip, Dover Publications.
3. Introduction to Electrodynamics by Griffith, Cambridge University Press.
4. Classical Theory of Electrodynamics by Landau &Lifshitz, Elsevier.
5. Electrodynamics of Continuous Media by Landau &Lifshitz, Elsevier.

Suggested E-Resources :

1. MIT OpenCourseWare: Electricity and Magnetism - This resource offers lecture notes, assignments, and exams for a complete course on electricity and magnetism: https://ocw.mit.edu/courses/physics/8-02sc-physics-ii-electricity-and-magnetism-spring-2011/
2. HyperPhysics - This online resource provides concise explanations and interactive simulations for various topics in electromagnetism : http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
3. NPTEL/Swayam Platform : https://onlinecourses.nptel.ac.in/noc21_ph05/preview
4. Physics Stack Exchange : https://physics.stackexchange.com/questions/9449/video-lectures-on-graduate-level-classical-electrodynamics
5. Cosmo Learning : https://cosmolearning.org/courses/special-relativity-and-electrodynamics-578/video-lectures/
6. IIT Madras Lectures : https://www.youtube.com/playlist?list=PLtUBquogGkRv5CME_m2oudBqW3_ffv33

Course Learning Outcomes :

By the end of the course, students should be able to :

1. Understand the concept of advanced electrostatics in the framework of Poisson & Laplace equations, Green's theorem, Dirichlet or Neumann boundary conditions.
2. Understand the concept of boundary value problems in electrostatics.
3. Grasping the concept of electrostatics to develop capability to solve problems.
4. Understand the concept of multipoles, electrostatics of macroscopic media & dielectrics.
5. Understand the concept of boundary value problems in dielectrics.
6. Understand the concept of advanced magnetostatics in detail.
7. Understand the concept of boundary value problems in magnetostatics.
8. Understand the concept of time varying fields, Maxwell's equations, conservation laws of macroscopic media.

M.Sc. (Physics)

Semester - I

Paper (IV) - Mathematical Methods In Physics

(DSC MPHY 104, Credits Theory 04, Lectures 60)

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. **(2 x 7 = 14 Marks)**

Part B of the paper will consist of four questions, one question from each unit with internal choice. Each question will carry 14 marks. **(4 x 14 = 56 Marks)**

Semester	**Code of The Course**	**Title of the Course/Paper**	**NHEQF Level**	**Credits**
I	DSC MPHY 104	**Mathematical Methods In Physics**	8	4
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	**Core**	**Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.**		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the first course in mathematical methods in physics is to provide students with a comprehensive understanding of mathematical methods at the beginning stage of PG level. This is certainly steps higher than the mathematical physics studied at the UG level. The course aims to develop their knowledge and skills in analysing and solving problems related to these topics, using appropriate mathematical formalism and physical concepts. The course targets development of advanced fundamentals in students to enable them to cope-up with higher level complexities in mathematical theories in physics. It will prepare students with advanced level fundamentals to enable them understanding complex physical theories that possess the essential components of mathematics, and also to solve complex numericals in all branches of physics.			

Unit - I : Coordinates Transformation in *N*-Dimensional Space

Contravariant & covariant tensor, Jacobian, Relative tensor, Pseudo tensors (Example : charge density, angular momentum), Algebra of tensors, Metric tensor, Associated tensors, Riemann space (Example: Euclidean space and 4D Minkowski space), Christoffel symbols, Transformation of Christoffel symbols, Covariant differentiation, Ricci's theorem, Divergence, Curl & Laplacian tensor form, Stress & strain tensors, Hook's law in tensor form, Lorentz covariance of Maxwell equation, Klein Gordon & Dirac Equation, Test of covariance of Schrödinger equation.

(15 Lectures)

Unit - II : Group of Transformation : (Example : Symmetry Transformation Of Square)

Generators of a finite group, Normal subgroup, Direct product of groups, Isomorphism & Homomorphism, Representation theorem of finite groups, Invariants subspace & Reducible representations, Irreducible representation, Crystallographic point groups, Irreducible representation of C4V, Translation group & Reciprocal lattice. **(15 Lectures)**

Unit - III : Fourier Transforms

Development of Fourier integral from Fourier Series, Fourier & inverse Fourier transform, Simple Applications : Finite wave train, Wave train with Gaussian amplitude, Fourier transform of derivatives, Solution of wave equation as an application, Convolution theorem, Intensity in terms of spectral density for quasi monochromic EM waves, Momentum representation, Application of Fourier transform to diffraction theory : Diffraction pattern of one and two slits. **(15 Lectures)**

Unit - IV : Laplace Transforms & Applications

Laplace transformation of derivatives & integrals, Derivatives & integral of Laplace transformation, Convolution theorem, Impulsive function, Application of Laplace transform in solving linear differential equations with constant coefficient & with variable coefficient and linear partial differential equation. **(15 Lectures)**

Reference Books/Text Books

1. Mathematical Methods for Physicists by George Arfken, Academic Press.
2. Applied Mathematics for Engineers and Physicists by L. A. Pipe, McGraw Hill.
3. Mathematical Methods by Potter and Goldberg, Prentice Hall of India.
4. Elements of Group Theory for Physicists by A.W. Joshi, Wiley Eastern Ltd.
5. Vector Analysis (Schaum Series), McGraw Hill.

Suggested E-Resources :

1. Britannica : Mathematical Physics - This resource offers lecture notes, assignments, and exams for a complete course on mathematical physics : https://www.britannica.com/science/fractal
2. Study.com- This online resource provides concise explanations and interactive simulations for various topics in mathematical physics : https://study.com/academy/lesson/mathematical-physics-overview-application-concepts.html
3. NPTEL/Swayam Platform : https://onlinecourses.nptel.ac.in/noc22_ph36/preview
4. Online Lectures : https://www.youtube.com/playlist?list=PLDlWMHnDwyljd4tfGXbAft6fYCo0NksQw
5. Cosmo Learning : https://cosmolearning.org/courses/numerical-methods-and-programing/video-lectures/
6. Cosmo Learning : https://cosmolearning.org/topics/computational-physics/
7. IIT Madras Lectures : https://www.youtube.com/playlist?list=PLtUBquogGkRuZH23UO-8AWR4dzcu-La8_

Course Learning Outcomes :

By the end of the course, students should be able to :

1. Understand the concept of coordinate transformation in *N*-dimensional space.
2. Understand the concept of group transformation.
3. Understand the concept of Fourier transforms with special reference to applications in physical theories.
4. Understand the concept of Laplace transforms.
5. Understand the concept of associated properties of Laplace transformation.
6. Understand the concept of Laplace transformation with special reference to applications in physical theories.

M.Sc. (Physics)

Semester - I

Physics Practical Lab I(A) - Electronics/Advanced Optics/General Laboratory

(DSCP MPHY 111, Credits Practical 06, Practical Hours 180)

Note: Out of following experiments, 6 experiments must be done by the students in each semester.

(9 hrs. per week)

External Exam Duration : 4 hrs. **Max. Marks : 60**

Internal Exam Duration : 2 hrs. **Max. Marks : 40**

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
I	DSCP MPHY 111	Physics Practical Lab I(A) (Electronics/Advanced Optics/General Lab)	8	6
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	Practical Hours, One Hundred & Eighty hours of postgraduate level experiments including diagnostic and formative assessments.		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the first course in practical physics is to provide students with a comprehensive understanding of practical physics. The course aims to develop their knowledge and skills in developing experimental skills at the postgraduate level and to endow them with a zeal for experimental physics. This will help nurture their interests in experimental domain to enable them to take-up research in physics as well in addition to preparing their experimental attitude for future careers in physics, such as, teaching at the school & UG, PG level.			

DSCP MPHY 111 : Physics Practical Lab I(A)

The inclusion of new experiments should be intimated and approved by the Convenor, Board of Studies before the start of the academic session. It is binding to have an experimental set-up of at least ten experiments listed below. In case the number of experiments performed by the student is less than eight, his marks shall be scaled down in the final examination on a pro-rata basis. Laboratory examination paper will be set by the external examiner out of eight or more experiments available at the center.

List of Experiments : Semester - I

1. To study transistor bias stability for determination of Q-point, leakage current and stability factor.

2. To study the non-inverting, inverting, unity buffer, adder & subtractor properties of an operational amplifier.
3. To study the integration and differentiation applications of an operational amplifier using CRO.
4. To design a single stage amplifier of a given voltage gain and lower cut of frequencies.
5. To design a RC coupled two stage amplifier of a given gain and the cutoff frequencies.
6. To determine Planck's constant using solar cell.
7. To determine Planck's constant and work function by a photocell.
8. To study regulated power supply using (a) Zener diode only, (b) Zener diode with a series transistor, (c) Zener diode with a shunt transistor.
9. To determine angle of minimum deviation and verify Fresnel's formula.
10. To study the percentage regulation and variation of ripple factor with load for a full wave rectifier.
11. To study analog to digital and digital to analog conversion.
12. To study a driven mechanical oscillator.
13. To verify Hartmann's formula using constant deviation spectrograph.
14. To find e/m of electron using Zeeman effect.
15. To design and study of pass filters in half-wave and full-wave rectifiers.
16. To align Michelson's Interferometer using He-Ne laser to observe concentric circular fringes.
17. To determine the wavelength of He-Ne laser using circular fringes with the help of Michelson's Interferometer.
18. To determine the wavelength of Na lamp and difference between the wavelengths of two sodium D-lines with the help of Michelson's Interferometer.
19. To study fringes of equal inclination and equal thickness using Na lamp in Michelson's Interferometer.
20. To align and determine the wavelength of He-Ne laser using Fabry-Perot Interferometer.
21. To determine the velocity of ultrasonic waves using ultrasonic interferometer.
22. To study elliptically polarized light using Babinet compensator.
23. To verify the Cauchy's dispersion relation of a given prism.
24. To study the DC gate control characteristics and anode current characteristics of SCR.
25. To determine wavelength of the laser monochromatic radiation by diffraction grating.
26. To determine numerical aperture, beam divergence and bending losses of in optical fiber.
27. To determine wavelength of the laser monochromatic radiation by slit method.
28. To study the characteristics of a UJT and use it to design a relaxation oscillator and measure its frequency.
29. To design a multivibrator of given frequency and study its wave shape.
30. To study the current-voltage characteristics of an FET.
31. To study the frequency-response of Hartley oscillator.
32. To determine Lo. Co. and RF of a given coil and to study the variations of RF with frequency.
33. Any other experiment compatible with the postgraduate level physics theory.

Course Learning Outcomes :

Through these experiments, students will develop practical skills in experimental techniques, data collection, analysis, and interpretation. They will also enhance their understanding of fundamental concepts and principles in advanced electronics & optics. The lab experiences will foster critical thinking, problem-solving abilities, and the application of theoretical knowledge to real-world scenarios.

M.Sc. (Physics)

Semester - I

Physics Practical Lab I(B) - Seminar (I)/Lab Project Work

(DSEP MPHY 131, Credits Practical 06, Practical Hours 180)

Note: Out of Seminar or presentation or Lab Project Work, student needs to select a practical work.

(9 hrs. per week)

External Exam Duration : 1 hrs. **Max. Marks : 60**

Internal Exam Duration : 1 hrs. **Max. Marks : 40**

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
I	DSEP MPHY 131	Physics Practical Lab I(B) (Electronics/Advanced Optics/General Lab)	8	6
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	Practical Hours, One Hundred & Eighty hours of postgraduate level experiments including diagnostic and formative assessments.		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the first course in practical physics is to provide students with a comprehensive understanding of practical physics. The course aims to develop their knowledge and skills in developing experimental skills at the postgraduate level and to endow them with a zeal for experimental physics. This will help nurture their interests in experimental domain to enable them to take-up research in physics as well in addition to preparing their experimental attitude for future careers in physics, such as, teaching at the school & UG, PG level.			

DSCP MPHY 131 : Physics Practical Lab I(B)

The inclusion of new experiments should be intimated and approved by the Convenor, Board of Studies before the start of the academic session. It is binding to have an experimental set-up of at least ten experiments listed below. In case the number of experiments performed by the student is less than eight, his marks shall be scaled down in the final examination on a pro-rata basis. Laboratory examination paper will be set by the external examiner out of eight or more experiments available at the center.

M.Sc. (Physics)

Semester - II

Paper (V) - Electronics

(DSC MPHY 201, Credits Theory 04, Lectures 60)

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. (2 x 7 = 14 Marks)

Part B of the paper will consist of four questions, one question from each unit with internal choice. Each question will carry 14 marks. (4 x 14 = 56 Marks)

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
II	DSC MPHY 201	Electronics	8	4
Level of Course	Type of The Course	Delivery Type of The Course		
Introductory	Core	Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/University.			
Objectives of The Course :	The objective of the course in electronics in physics is to provide students with a comprehensive understanding of electronics at the initial postgraduate level. The course aims to develop their knowledge and skills in analysing and solving problems related to these topics, using appropriate mathematical formalism and physical concepts. The course targets development of advanced fundamentals in students to enable them to cope-up with higher level complexities in electronics theories in physics. It will prepare students with advanced level fundamentals in electronics to enable them understanding complex circuit theories and learn their applications in solving circuits.			

Unit - I : Operational Amplifiers

Differential amplifier - circuit configurations - dual input, balanced output differential amplifier, DC analysis, inverting and non-inverting inputs, CMRR-constant current bias level translator, Block diagram of typical OP-Amp analysis, Open-loop configuration, Inverting & Non-Inverting amplifiers, Op-Amp with negative feedback, Voltage series feedback, Effect of feedback on closed loop gain, Input resistance, Bandwidth & Output offset voltage, Voltage follower, Practical Op-Amp, Input offset voltage-input bias current-input offset current, Total output offset voltage, CMRR frequency response, DC & AC amplifier, Integrator & Differentiator. **(15 Lectures)**

Unit - II : Oscillators & Wave Shaping Circuits

Oscillator principle, Frequency stability response, The phase shift oscillator, Wein bridge oscillator, LC tunable oscillators, Multivibrators - Monostable, astable (free running) & bistable, Comparators, Square wave & Triangle wave generation, Clamping & Clipping circuits.

(15 Lectures)

Unit - III : Digital Electronics

Combinational logic : Standard representations for logic functions, Karnaugh map representation of logical functions, Simplification of logical functions using K-Map, Minimization of logical functions specified in Minterms/Maxterms or truth table, Don't care conditions, Adder (half & full), Subtractor (half & full), Comparator, Multiplexers and their uses, Demultiplexer/Decoders and their uses, BCD arithmetic, Parity generators/ Checkers, Code converters, Priority encoders, Decoder /Drivers for display devices, Seven segment display device, ROM, Programmable logic array, Basic concepts about fabrication & characteristics of integrated circuits. **(15 Lectures)**

Unit - IV : Sequential Logic

Flip-Flops : One-bit memory, RS, JK, JK master slave, T & D type flip flops, Shift resisters - Synchronous & Asynchronous counters, Cascade counters, Binary counter, Decade counter, A/D & D/A conversion- Basic principles, circuitry & simple applications, Voltage regulators - Fixed regulators, Adjustable voltage regulators, Switching regulators, Basic idea of IC 555 & its applications as Multivibrator & Square Wave Generator, Opto-electronic Devices : Photo diode, Phototransistor, Light Emitting Diode (LED) & applications. **(15 Lectures)**

Reference Books/Text Books

1. "Electronic Devices and Circuit Theory" by Robert Boylested and Louis Nashdsky, PHI, New Delhi - 110001, 1991.
2. "OP-AMP and Linear Integrated Circuits" by Ramakanth, A. Gayakwad, PHI, Second Edition 1991.
3. "Digital Principle and Applications" by A.P. Malvino and Donald P. Leach, TataMcGraw Hill Company, New Delhi, 1993.

Suggested E-Resources :

1. MIT OpenCourseWare : Electronics - This resource offers lecture notes, assignments, and exams for a complete course on electronics : https://ocw.mit.edu/search/?q=electronics
2. HyperPhysics - This online resource provides concise explanations and interactive simulations for various topics in electronics : http://hyperphysics.phy-astr.gsu.edu/hbase/Electronic/etroncon.html#c1
3. NPTEL/Swayam Platform : https://nptel.ac.in/courses/122106025
4. NPTEL/Swayam Platform : https://onlinecourses.nptel.ac.in/noc22_ee55/preview
5. Cosmo Learning : https://cosmolearning.org/courses/circuits-and-electronics-457/video-lectures/

Course Learning Outcomes :

By the end of the course, students should be able to :

1. Understand the concept of operational amplifiers.
2. Understand the concept of characteristics of operational amplifiers.
3. Understand the concept of applications of operational amplifiers.
4. Understand the concept of oscillators & wave-shaping circuits.
5. Understand the concept of characteristics of digital electronics of combinatorial circuits.
6. Understand the concept of sequential logic.
7. Understand the concept of optoelectronic devices & sequential logic.

M.Sc. (Physics)

Semester - II

Paper (VI) - Atomic & Molecular Physics

(DSC MPHY 202, Credits Theory 04, Lectures 60)

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. (2 x 7 = 14 Marks)

Part B of the paper will consist of four questions, one question from each unit with internal choice. Each question will carry 14 marks. (4 x 14 = 56 Marks)

Semester	Code of The Course	Title of the Course/Paper	NHEQF Level	Credits
II	DSC MPHY 202	Atomic & Molecular Physics	8	4
Level of Course	**Type of the Course**	**Delivery Type of The Course**		
Introductory	Core	Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/University.			
Objectives of The Course :	The objective of the course in atomic & molecular physics is to provide students with a comprehensive understanding of atomic & molecular physics. The course aims to develop their knowledge and skills in analysing and solving problems related to these topics, using appropriate mathematical formalism and physical concepts. The course targets development of basic and advanced fundamentals in students to enable them to cope-up with higher level complexities in atomic and molecular theories in physics. It will prepare students with advanced level fundamentals in atomic & molecular physics to enable them understanding complex theories of atoms and molecules inculcating quantum mechanics as well.			

Unit - I : Gross Structure of Energy Spectrum of Hydrogen Atom

Interaction with external fields : Non-degenerate first order perturbation method, Relativistic correction to energy levels of an atom, Atom in a weak uniform external electric field - first & second order Stark effect, Calculation of polarizability of the ground state of hydrogen atom & of an isotropic harmonic oscillator, Degenerate stationary state perturbation theory, Linear Stark effect for hydrogen atom levels, Inclusion of spin-orbit interaction & weak magnetic field, Zeeman effect, Effect of strong magnetic field, Magnetic dipole interaction, Hyperfine structure & Lamb shift (only qualitative description). **(15 Lectures)**

Unit - II : Systems With Identical Particles

Indistinguishability & Exchange symmetry, Many particle wave functions & Pauli's exclusion principle, Spectroscopic terms for atoms, Helium atom, Variational method and its use in calculation of ground state energy, Hydrogen molecule, Heitler London method for hydrogen molecule, WKB method for 1D-problem, Application to bound states (Bohr Sommerfeld quantization) and the barrier penetration. **(15 Lectures)**

Unit - III : Spectroscopy (Qualitative)

General features of the spectra of one and two electron systems - singlet, doublet and triplet characters of emission spectra, General features of alkali spectra, Rotation & Vibration band spectrum of a molecule, P,Q & R branches, Raman spectra for rotational & vibrational transitions, Comparison with infrared spectra - Application to learning about molecular symmetry, General features of electronic spectra, Frank-Condon's principle. **(15 Lectures)**

Unit - IV : Laser Cooling & Trapping of Atoms

Scattering force, Slowing an atomic beam, Chirp cooling, Optical molasses technique, Doppler cooling limit, Magneto-optical trap, Introduction to dipole force, Theory of dipole force, Optical lattice, Sisyphus cooling technique – description and its limit, Atomic fountain, Magnetic trap (only qualitative description) for confining low temperature atoms produced by laser cooling, Bose-Einstein condensation in trapped atomic vapors, Scattering length, Bose-Einstein condensate, Coherence of a Bose- Einstein Condensate, Atomic Laser. **(15 Lectures)**

Reference Books/Text Books

1. Atomic Spectra by White, McGraw Hill (CBS).
2. Molecular Spectra by Herzberg, Read Books.
3. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles by Eisberg & Resnik, Wiley & Sons.
4. Atomic & Molecular Spectra by Rajkumar, LASER, KNRN Publishers.

Suggested E-Resources :

1. NPTEL : Atomic & Molecular Physics - This resource offers lecture notes, assignments, and exams for a complete course on atomic & molecular physics : https://onlinecourses.nptel.ac.in/noc23_ph16/preview
2. Study.com- This online resource provides concise explanations and interactive simulations for various topics in atomic & molecular physics : https://study.com/search/text/academy.html?q=Atomic+%26+Molecular+Physics+&pageType=lesson#/topresults/Atomic%20%26%20Molecular%20Physics
3. Cosmo Learning : https://cosmolearning.org/physics/courses?topic=19

Course Learning Outcomes :

By the end of the course, students should be able to:

1. Understanding of energy spectrum of hydrogen atom.
2. Understanding of effects of atoms in an electric field and a magnetic field.
3. Understanding of Stark effect & Zeeman effect.
4. Understanding of systems with identical particles.
5. Understanding of Hydrogen molecule, Heitler London method for hydrogen molecule.
6. Understanding of WKB method for 1D-problem, application to bound states (Bohr Sommerfeld quantization) and the barrier penetration.
7. Understanding of qualitative features of spectroscopy
8. Understanding of rotational & vibrational spectra in Raman spectroscopy & physics involved.
9. Understanding of Laser Cooling And Trapping of Atoms.
10. Understanding of magneto-optical trap.
11. Understand the concept of magnetic trap for atoms cooled by laser cooling technique.
12. Understand the concept of Bose-Einstein condensation in trapped atomic vapors & the concept of atomic lasers.

M.Sc. (Physics)

Semester - II

Paper (VII) - Classical Electrodynamics (II)

(DSC MPHY 203, Credits Theory 04, Lectures 60)

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. (2 x 7 = 14 Marks)

Part B of the paper will consist of four questions, one question from each unit with internal choice. Each question will carry 14 marks. (4 x 14 = 56 Marks)

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
II	DSC MPHY 203	Classical Electrodynamics (II)	8	4
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/University.			
Objectives of The Course :	The objective of the second course in classical electrodynamics is to provide students with a comprehensive understanding of advanced classical electrodynamics. The course aims to develop their knowledge and skills in analysing and solving problems related to these topics, using appropriate mathematical formalism and physical concepts. The course targets development of advanced fundamentals in students for higher level problems of classical electrodynamics, and to prepare their advanced level fundamentals to enable them solving advanced problems in classical electrodynamics.			

Unit - I : Plane Electromagnetic Waves & Wave Equation

Plane wave in a nonconducting medium, Frequency dispersion characteristics of dielectrics, Conductors & plasma, Waves in a conducting dissipative medium, Superposition of waves in one dimension, Group velocity, Casualty connection between D & E, Kramer's-Kroning relation.

(15 Lectures)

Unit - II : Magnetohydrodynamics & Plasma Physics

Introduction & definitions, MHD equations, Magnetic diffusion, Viscosity & Pressure, Pinch effect, Instabilities in pinched plasma column, Magnetohydrodynamics waves, Plasma oscillations, Short wave length limit of plasma oscillations & Debye shielding distance.

(15 Lectures)

Unit - III : Covariant Form of Electrodynamic Equations

Mathematical properties of the space- time special relativity, Invariance of electric charge covariance of electrodynamics, Transformation of electromagnetic field, Radiation by moving charges : Lienard-Wiechert Potential for a point charge, Total power radiated by an accelerated charge : Larmour's formula & its relativistic generalization, Angular distribution of radiation emitted by an accelerated charge, Radiation emitted by a charge in arbitrary extremely relativistic motion, Distribution in frequency & angle of energy radiated by accelerated charges, Thomson scattering & radiation, Scattering by quasi-free charges, Coherent & incoherent scattering, Cherenkov radiation. **(15 Lectures)**

Unit - IV : Radiation Damping, Self-Fields of A Particle, Scattering & Absorption of Radiation by A Bound System

Introductory considerations, Radiative reaction force from conservation of energy, Abraham-Lorentz evaluation of the self-force, Difficulties with Abraham-Lorentz model, Integro-differential equation of motion including radiation damping, Line breadth & level shift of an oscillator, Scattering & absorption of radiation by an oscillator, Energy transfer to a harmonically bound charge. **(15 Lectures)**

Reference Books/Text Books

1. Classical Electrodynamics by J.D. Jackson, Wiley Student Ed.
2. Classical Electrodynamics & Magnetism by Panofsky & Phillip, Dover Publications.
3. Introduction to Electrodynamics by Griffith, Cambridge University Press.
4. Classical Theory of Electrodynamics by Landau &Lifshitz, Elsevier.
5. Electrodynamics of Continuous Media by Landau &Lifshitz, Elsevier.

Suggested E-Resources :

1. MIT OpenCourseWare: Electricity and Magnetism - This resource offers lecture notes, assignments, and exams for a complete course on electricity and magnetism: https://ocw.mit.edu/courses/physics/8-02sc-physics-ii-electricity-and-magnetism-spring-2011/
2. HyperPhysics - This online resource provides concise explanations and interactive simulations for various topics in electromagnetism : http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
3. NPTEL/Swayam Platform : https://onlinecourses.nptel.ac.in/noc21_ph05/preview
4. Electrodynamics Lectures : https://www.youtube.com/playlist?list=PLtUBquogGkRv5CME__m2oudBqW3_ffv33

Course Learning Outcomes :

By the end of the course, students should be able to :

1. Understand the concept of plane electromagnetic wave & development of wave equations.
2. Understand the concept of magnetohydrodynamics & plasma physics.
3. Understand the concept of covariant form of electrodynamic equations.
4. Understand the concept of Thomson scattering, radiation & Cherenkov radiation.
5. Understand the concept of Radiation Damping, Self-Fields of A Particle, Scattering & Absorption of Radiation by a bound system.
6. Understanding of these advanced concepts with the ability to solve correlated problems.

M.Sc. (Physics)

Semester - II

Paper (VIII) - Numerical Methods

(DSC MPHY 204, Credits Theory 04, Lectures 60)

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. **(2 x 7 = 14 Marks)**

Part B of the paper will consist of four questions, one question from each unit with internal choice. Each question will carry 14 marks. **(4 x 14 = 56 Marks)**

Semester	Code of The Course	Title of the Course/Paper	NHEQF Level	Credits
II	DSC MPHY 204	Numerical Methods	8	4
Level of Course	**Type of the Course**	**Delivery Type of the Course**		
Introductory	**Core**	**Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.**		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/University.			
Objectives of The Course :	The objective of the course in numerical methods in physics is to provide students with a comprehensive understanding of numerical methods. The course aims to develop their knowledge and skills in analysing and solving problems related to these topics, using appropriate mathematical formalism and physical concepts. The course targets development of advanced fundamentals in students to enable them to cope-up with higher level complexities in mathematical theories in physics. It will prepare students with advanced level fundamentals to enable them understanding complex physical theories that possess the essential components of numerical methods, and also to solve complex numericals in all branches of physics.			

Unit - I : Errors in Numerical Analysis

Source of Errors, Round-off error, Computer arithmetic, Error analysis, Condition & stability, Approximation, Functional & Error analysis, Method of undetermined coefficients, Use of interpolation formula, Iterated interpolation, Inverse interpolation, Hermite interpolation & Spline interpolation, Solution of Linear equations : Direct and Iterative methods, Calculation of eigen values and eigen vectors for symmetric matrices.

(15 Lectures)

Unit - II : Solution of Nonlinear Equation

Bisection method, Newton's method, Modified Newton's method, Method of Iteration, Newton's method & method of iteration for a system of causation Newtons' method for the case of complex roots, Integration of a function, Trapezoidal & Simpson's rules, Gaussian quadrature formula, Singular integrals, Double integration. **(15 Lectures)**

Unit - III : Integration of Ordinary Differential Equation

Predictor-corrector methods, Runga-Kutta method, Simultaneous & Higher order equations. Numerical Integration & Differentiation of Data, Least-Squares Approximations, Fast Fourier Transform (FFT). **(15 Lectures)**

Unit - IV

Elementary probability theory, Random variables, Binomial, Poisson & Normal distributions. **(15 Lectures)**

Reference Books/Text Books

1. A First Course in Numerical Analysis by A. Relston and P. Rabinowitz, McGraw Hill (1985).
2. Introductory Methods of Numerical Analysis by S. S. Sastry, Prentice-Hall of India (1979).
3. Numerical Methods by P. Kandasamy& et al., S. Chand & Company.
4. Numerical Methods in Engineering & Science With Programs in C, C++ & Matlab by B. S. Grewal, Khanna Publishers.
5. A Text Book of Numerical Analysis by Dr. C. P. Awasthi, Prakashn Kendra Lucknow.
6. Numerical Analysis by Faires J., Cengage Learning, Inc.

Suggested E-Resources :

1. NPTEL/Swayam Platform : https://onlinecourses.nptel.ac.in/noc23_ma44/preview
2. NPTEL/Swayam Platform : https://onlinecourses.swayam2.ac.in/cec22_ma13/preview
3. Online Lectures : https://www.youtube.com/playlist?list=PLDlWMHnDwyljd4tfGXbAft6fYCo0NksQw
4. Cosmo Learning : https://cosmolearning.org/courses/numerical-methods-and-programing/video-lectures/
5. Cosmo Learning : https://cosmolearning.org/topics/computational-physics/
6. IIT Madras Lectures : https://www.youtube.com/playlist?list=PLtUBquogGkRuZH23UO-8AWR4dzcu-La8_

Course Learning Outcomes :

By the end of the course, students should be able to :

1. Understand the concept of errors in numerical analysis.
2. Understand the concept of nonlinear equations and solution methodology in special reference to Newton's method.
3. Understand the concept of integration of ordinary differential equation.
4. Understand the concept of Runga-Kutta method.
5. Understand the concept of probability theory, Poisson & normal distribution.
6. Understand the concepts of numerical analysis in physical theories.

M.Sc. (Physics)

Semester - II

Physics Practical Lab II(A) - Electronics/Advanced Optics/Gen. Laboratory

(DSCP MPHY 211, Credits Practical 06, Practical Hours 180)

Note: Out of following experiments, 6 experiments must be done by the students in each semester.

(9 hrs. per week)

External Exam Duration : 4 hrs. **Max. Marks : 60**

Internal Exam Duration : 2 hrs. **Max. Marks : 40**

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
II	DSCP MPHY 211	Physics Practical Lab II(A) (Electronics/Advanced Optics/General Lab)	8	6
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	Practical Hours, One Hundred & Eighty hours of postgraduate level experiments including diagnostic and formative assessments.		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the second course in practical physics is to provide students with a comprehensive fundamental understanding of practical physics. The course aims to develop their knowledge and skills in developing experimental skills at the postgraduate level and to endow them with a zeal for experimental physics. This will help nurture their interests in experimental domain to enable them to take-up research in physics as well in addition to preparing their experimental attitude for future careers in physics, such as, teaching at the school & UG, PG level.			

DSCP MPHY 211 : Physics Practical Lab II(A)

The inclusion of new experiments should be intimated and approved by the Convenor, Board of Studies before the start of the academic session. It is binding to have an experimental set-up of at least ten experiments listed below. In case the number of experiments performed by the student is less than eight, his marks shall be scaled down in the final examination on a pro-rata basis. Laboratory examination paper will be set by the external examiner out of eight or more experiments available at the center.

List of Experiments : Semester - II

1. To study transistor bias stability for determination of Q-point, leakage current and stability factor.

2. To study the non-inverting, inverting, unity buffer, adder & subtractor properties of an operational amplifier.
3. To study the integration and differentiation applications of an operational amplifier using CRO.
4. To design a single stage amplifier of a given voltage gain and lower cut of frequencies.
5. To design a RC coupled two stage amplifier of a given gain and the cutoff frequencies.
6. To determine Planck's constant using solar cell.
7. To determine Planck's constant and work function by a photocell.
8. To study regulated power supply using (a) Zener diode only, (b) Zener diode with a series transistor, (c) Zener diode with a shunt transistor.
9. To determine angle of minimum deviation and verify Fresnel's formula.
10. To study the percentage regulation and variation of ripple factor with load for a full wave rectifier.
11. To study analog to digital and digital to analog conversion.
12. To study a driven mechanical oscillator.
13. To verify Hartmann's formula using constant deviation spectrograph.
14. To find e/m of electron using Zeeman effect.
15. To design and study of pass filters in half-wave and full-wave rectifiers.
16. To align Michelson's Interferometer using He-Ne laser to observe concentric circular fringes.
17. To determine the wavelength of He-Ne laser using circular fringes with the help of Michelson's Interferometer.
18. To determine the wavelength of Na lamp and difference between the wavelengths of two sodium D-lines with the help of Michelson's Interferometer.
19. To study fringes of equal inclination and equal thickness using Na lamp in Michelson's Interferometer.
20. To align and determine the wavelength of He-Ne laser using Fabry-Perot Interferometer.
21. To determine the velocity of ultrasonic waves using ultrasonic interferometer.
22. To study elliptically polarized light using Babinet compensator.
23. To verify the Cauchy's dispersion relation of a given prism.
24. To study the DC gate control characteristics and anode current characteristics of SCR.
25. To determine wavelength of the laser monochromatic radiation by diffraction grating.
26. To determine numerical aperture, beam divergence and bending losses of in optical fiber.
27. To determine wavelength of the laser monochromatic radiation by slit method.
28. To study the characteristics of a UJT and use it to design a relaxation oscillator and measure its frequency.
29. To design a multivibrator of given frequency and study its wave shape.
30. To study the current-voltage characteristics of an FET.
31. To study the frequency-response of Hartley oscillator.
32. To determine Lo. Co. and RF of a given coil and to study the variations of RF with frequency.
33. Any other experiment compatible with the postgraduate level physics theory.

Course Learning Outcomes:

Through these experiments, students will develop practical skills in experimental techniques, data collection, analysis, and interpretation. They will also enhance their understanding of fundamental concepts and principles in advanced electronics & optics. The lab experiences will foster critical thinking, problem-solving abilities, and the application of theoretical knowledge to real-world scenarios.

M.Sc. (Physics)

Semester - II

Physics Practical Lab II(B) – Seminar (II)/Lab Project Work

(DSEP MPHY 231, Credits Practical 06, Practical Hours 180)

Note: Out of Seminar or presentation or Lab Project Work, student needs to select a practical work.

(9 hrs. per week)

External Exam Duration : 1 hrs. **Max. Marks : 60**

Internal Exam Duration : 1 hrs. **Max. Marks : 40**

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
I	DSEP MPHY 231	Physics Practical Lab II(B) (Electronics/Advanced Optics/General Lab)	8	6
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	Practical Hours, One Hundred & Eighty hours of postgraduate level experiments including diagnostic and formative assessments.		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the first course in practical physics is to provide students with a comprehensive understanding of practical physics. The course aims to develop their knowledge and skills in developing experimental skills at the postgraduate level and to endow them with a zeal for experimental physics. This will help nurture their interests in experimental domain to enable them to take-up research in physics as well in addition to preparing their experimental attitude for future careers in physics, such as, teaching at the school & UG, PG level.			

DSCP MPHY 231 : Physics Practical Lab II(B)

The inclusion of new experiments should be intimated and approved by the Convenor, Board of Studies before the start of the academic session. It is binding to have an experimental set-up of at least ten experiments listed below. In case the number of experiments performed by the student is less than eight, his marks shall be scaled down in the final examination on a pro-rata basis. Laboratory examination paper will be set by the external examiner out of eight or more experiments available at the center.

M.Sc. (Physics)

Semester - III

Paper (IX) - Advanced Quantum Mechanics

(DSC MPHY 301, Credits Theory 04, Lectures 60)

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. (2 x 7 = 14 Marks)

Part B of the paper will consist of four questions, one question from each unit with internal choice. Each question will carry 14 marks. (4 x 14 = 56 Marks)

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
III	DSC MPHY 301	Advanced Quantum Mechanics	9	4
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the course is to provide students with a comprehensive knowledge of advanced level of quantum mechanics in the beginning of the final year. The course aims to develop their knowledge and skills in analysing and solving problems related to these topics, using appropriate mathematical formalism and physical concepts. The course targets development of advanced fundamentals in students for higher level problems of advanced quantum mechanics and to prepare their advanced level fundamentals to enable to study them advanced quantum mechanics and solving related problems.			

Unit - I : Scattering (Non-Relativistic)

Differential & Total scattering cross section, Transformation from CM frame to Lab frame, Solution of scattering problem by the method of partial wave analysis, Expansion of a plane wave into a spherical wave & scattering amplitude, The optical theorem.

Applications - Scattering from a delta potential, Square well potential & Hard sphere scattering of identical particles, Energy dependence & Resonance scattering, Breit-Wigner formula, Quasi stationary states, The Lippman-Schwinger equation & the Green's functions approach for scattering problem, Born-approximation & its validity for scattering problem, Coulomb scattering problem under first Born approximation in elastic scattering. **(15 Lectures)**

Unit - II : Relativistic Formulation & Dirac Equation

Attempt for relativistic formulation of quantum theory, The Klein-Gordon equation, Probability density & probability current density, Solution free particle, K.G. equation in momentum representation, Interpretation of negative probability density & negative energy solutions, Dirac equation for a free particle, Properties of Dirac matrices & algebra of gamma matrices, Nonrelativistic correspondence of the Pauli equation (inclusive of electromagnetic interaction). Solution of free particle Dirac equation, Orthogonality & Completeness relations for Dirac spinors, Interpretation of negative energy solution & hole theory. **(15 Lectures)**

Unit - III : Symmetries of Dirac Equation

Lorentz covariance of Dirac equation, Proof of covariance & Derivation of Lorentz boost & rotation matrices for Dirac spinors, Projection operators involving four momentum and spin, parity (P), charge conjugation (C), time reversal (T), and CPT operators for Dirac spinors, Bilinear covariants, and their transformations, Behaviour under Lorentz transformation, P,C,T and CPT, Expectation values of coordinate & velocity involving only positive energy solutions and the associated problems, Inclusion of negative energy solution, Zitterbewegung, Klein paradox. **(15 Lectures)**

Unit - IV : The Quantum Theory of Radiation

Classical radiation field, Transversality condition, Fourier decomposition & radiation oscillators, Quantization of radiation oscillator, creation, annihilation & number operators, Photon states, Photon as a quantum mechanical excitation of the radiation field, fluctuations & Uncertainty relation, Validity of classical description, Matrix element for emission & absorption, Spontaneous emission in the dipole approximation, Rayleigh scattering, Thomson scattering & the Raman effect, Radiation damping & Resonance fluorescence. **(15 Lectures)**

Reference Books/Text Books

1. Quantum mechanics - A Modern Approach by Ashok Das and A.C. Melissinos, Garden and Breach Science Publishers.
2. Quantum Mechanics by Eugen Merzbacher, 2nd Edition John Wiley & Sons.
3. Relativistic Quantum Mechanics by Bjorken and Drell, McGraw Hill.
4. Advanced Quantum Mechanics by J.J. Sakurai, Wiley & Sons.
5. Advanced Quantum Mechanics by A. K. Singh, Centrum Press.
6. The Principles of Quantum Mechanics by P. A. M. Dirac, www.snowballpublishing.com, ISBN-13:978-1607965602.
7. Advanced Quantum Mechanics A Practical Guide 2018 Edition by Yuli V. Nazarov& J. Danon, Cambridge Publishers.

Suggested E-Resources :

1. MIT OpenCourseWare : Introductory Quantum Mechanics - This resource offers lecture notes, assignments, and exams for a complete course on introductory quantum mechanics : https://ocw.mit.edu/search/?q=introductory%20quantum%20mechanics%20
2. HyperPhysics : This online resource provides concise explanations and interactive simulations for various topics in introductory quantum mechanics : http://hyperphysics.phy-astr.gsu.edu/hbase/quacon.html#quacon
3. Cosmolearning : https://cosmolearning.org/courses/advanced-quantum-mechanics-with-leonard-susskind/
4. NPTEL/Swayam Platform : https://onlinecourses.nptel.ac.in/noc22_ph40/preview
5. Prof. Susskind's Online Lectures : https://theoreticalminimum.com/courses/advanced-quantum-mechanics/2013/fall

Course Learning Outcomes :

By the end of the course, students should be able to:

1. Deep understanding of scattering in the non-relativistic domain.
2. Explanation of change of plane wave into a spherical wave, optical theorem.
3. Understanding of applications of scattering and associated physics.
4. Understanding of scattering from a delta potential, square well potential and the hard sphere scattering of identical particles, energy dependence and resonance scattering. Breit-Wigner formula, quasi stationary states.
5. Understanding of Breit-Wigner formula, quasi stationary states, The Lippman-Schwinger equation & the Green's functions approach for scattering problem, Born-approximation and its validity for scattering problem, Coulomb scattering problem under first Born approximation in elastic scattering.
6. Understand the concept of relativistic formulation of quantum theory.
7. Understand the concept of The Klein-Gordon equation & solution free particle K.G. equation in momentum representation, interpretation of negative probability density and negative energy solutions.
8. Understand the concept of Dirac equation for a free particle & properties of Dirac matrices.
9. Understand the concept of nonrelativistic correspondence of the Pauli equation.
10. Understand the concept of Dirac spinors.
11. Understand the concept of symmetries of Dirac equation.
12. Understand the concept of Klein paradox.
13. Understand the concept of quantum theory of radiation.
14. Understand the concept of Rayleigh scattering, Thomson scattering and the Raman effect, radiation damping and resonance fluorescence.

M.Sc. (Physics)

Semester - III

Paper (X) - Statistical & Solid State Physics

(DSC MPHY 302, Credits Theory 04, Lecture 60)

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. **(2 x 7 = 14 Marks)**

Part B of the paper will consist of four questions, one question from each unit with internal choice. Each question will carry 14 marks. **(4 x 14 = 56 Marks)**

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
III	DSC MPHY 302	Statistical & Solid State Physics	9	4
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the course is to provide students with a comprehensive understanding of statistical physics inclusive of canonical & grand canonical ensembles, and advanced statistical physics in form of partition functions & statistics in the realm of quantum mechanics. The objective of the course is to provide students with a comprehensive understanding of solid state physics. The course aims to develop their knowledge and skills in analysing and solving problems related to theory of metals & band theory. The objective of the course in Statistical Physics & Solid State Physics is to provide students with a comprehensive understanding of statistical physics & solid state physics. Statistical physics is focused on statistical approaches as applied to thermodynamics concepts & theories. Solid state physics provides details of metal theories and band theories to be applied to conductors & semiconductors. The course aims to develop their knowledge and skills in analysing and solving problems related to these topics, using appropriate mathematical formalism and physical concepts. The course targets development of advanced fundamentals in students to enable them to cope-up with higher level complexities in mathematical theories in physics. It will prepare students with advanced level fundamentals.			

Unit - I : Basics of Statistical Physics

Basic principles, Canonical & Grand Canonical ensembles : Concept of statistical distribution, Phase space, Density of states Liouville's theorem, Systems & Ensemble, Entropy in statistical mechanics, Connection between thermodynamic & Statistical quantities, Micro-canonical ensemble, Equation of state, Specific heat & Entropy of a perfect gas, Using microcanonical ensemble, Canonical ensemble. Thermodynamic functions for canonical ensemble, Calculation of means values, Energy fluctuation in a gas, Grand canonical ensemble. Thermodynamic functions for the grand canonical ensemble, Density fluctuations. **(15 Lectures)**

Unit - II : Advanced Statistical Physics

Partition functions & Statistics : Partition functions & properties, Partition function for an ideal gas & Calculation of thermodynamic quantities, Gibbs paradox, Validity of classical approximation, Determination of translational, rotational & vibration contributions to the partition function of an ideal diatomic gas, Specific heat of a diatomic gas, Ortho- & Para-hydrogen, Identical particles & Symmetry requirement, Difficulties with Maxwell-Boltzmann statistics, Quantum distribution functions, Bose-Einstein & Fermi-Dirac statistics, and Planck's formula, Bose-Einstein condensation, Liquid He_4 as a Bosonic system, Quantization of harmonic oscillator, Creation & Annihilation of phonon operators, Quantization of fermion operators. **(15 Lectures)**

Unit - III : Theory of Metals

Theory of Metals : Fermi-Dirac distribution function, Density of states, Temperature-dependence of Fermi energy, Specific heat, Fermi-Dirac statistics for calculation of thermal conductivity & electrical conduction band, Drude theory of light, Absorption in metals. **(15 Lectures)**

Unit - IV : Band Theory

Bloch's theorem, Kronig-Penny model, Effective mass of electrons, Winger-Sietz approximation, NFE model, Tight binding method & Calculation of density for a band in simple cubic lattice, Pseudo-potential method. **(15 Lectures)**

Reference Books/Text Books

1. Statistical Mechanics by Huang, Wiley & Sons.
2. Fundamentals of Statistical and Thermal Physics by Reif, Sarat Book Distributors.
3. Elementary Statistical Physics by Kittel, Dover Publications.
4. Introduction To Solid State Physics by Kittel, Wiley India Edition.
5. Solid State Physics by Levy, Elsevier.

Suggested E-Resources :

1. MIT OpenCourseWare : Statistical Physics - This resource provides lecture notes, problem sets, and solutions for a complete course on statistical physics : https://ocw.mit.edu/search/?q=statistical%20physics
2. HyperPhysics : This online resource provides concise explanations and interactive simulations for various topics in statistical physics : http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/disfcn.html
3. MIT OpenCourseWare : Solid State Physics - This resource offers lecture notes, assignments & exams for a complete course on solid state physics : https://ocw.mit.edu/courses/8-231-physics-of-solids-i-fall-2006/
4. HyperPhysics : This online resource provides concise explanations and interactive simulations for various topics in solid state physics : http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
5. NPTEL/Swayam : https://archive.nptel.ac.in/courses/115/106/115106111/
6. Cosmolearning : https://cosmolearning.org/courses/thermal-statistical-physics/video-lectures/
7. NPTEL/Swayam : https://onlinecourses.nptel.ac.in/noc21_ph21/preview
8. International Centre For Theoretical Physics (ICTP) : https://mediacore.ictp.it/media/solid-state-physics-lecture-1-of-20

Course Learning Outcomes :

By the end of the course, students should be able to:

1. Explanation of thermodynamics in the framework of statistical approach.
2. Formulation of classical statistics to form phase space, micro- and macro-spaces, thermodynamic probability, monoatomic ideal gas & heat capacity of solids. Understand classical statistics and its validity. Study phase space, microstates, macrostates, thermodynamic probability, and entropy.
3. Formulation of quantum statistics & explanations.
4. Postulates of quantum statistics, wavefunction, exchange degeneracy, Bose-Einstein & Fermi-Dirac statistics, Planck distribution function.
5. Learn about quantum statistics, including Bose-Einstein and Fermi-Dirac distribution laws, calculation of the thermodynamic functions of weakly and strongly degenerate gases.
6. Understand the concept of theory of metallic solids in Fermi-Dirac distribution function approach.
7. Understanding of band theory of solids, Bloch's theorem & Kronig-Penny model.
8. Understand the concept of Winger-Seqtz approximation, NFE model, tight-binding method.

M.Sc. (Physics)

Semester - III

Paper (XI) - Nuclear Physics (I)

(DSC MPHY 303, Credits Theory 04, Lectures 60)

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. (2 x 7 = 14 Marks)

Part B of the paper will consist of four questions, one question from each unit with internal choice. Each question will carry 14 marks. (4 x 14 = 56 Marks)

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
III	DSC MPHY 303	Nuclear Physics (I)	9	4
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	**Core**	**Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.**		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the course in nuclear physics is to provide students with a comprehensive understanding of nuclear forces, scattering theories in nuclear physics, interaction of radiation & charged particles with matter and detectors, counters & accelerators. The course aims to develop their knowledge and skills in analysing and solving problems related to these topics, using appropriate physical concepts. The course targets development of advanced fundamentals in students to enable them to cope-up with higher level complexities in nuclear physics. It will prepare students with advanced level fundamentals to enable them understanding complex nuclear physics fundamentals.			

Unit - I : Two Nucleon System & Nuclear Forces

General nature of the force between nucleons, Saturation of nuclear forces, Charge-independence & spin-dependence, General forms of two nucleon interaction, Central, noncentral & velocity dependent potential, Analysis of the ground state (3S1) of deuteron using a square well potential, Range-depth relationship, Excited states of deuteron, Discussion of the ground state of deuteron under noncentral force, Calculation of electric quadrupole & magnetic dipole moments, D-state admixture. **(15 Lectures)**

Unit - II : Nucleon-Nucleon Scattering & Potentials

Partial wave analysis of neutron- proton scattering at low energy assuming central potential with square well shape, Concept of scattering length, Coherent scattering of neutrons by protons in (ortho and para), Hydrogen molecule : Conclusions of these analyses regarding scattering lengths, Range and depth of the potential, The effective range theory (in neutron-proton scattering) & shape-independence of nuclear potential, A qualitative discussion of proton-proton scattering at low energy, General features of two-body scattering at high energy effect of exchange forces, Phenomenological Hamada-Johnston a hard-core potential, Reid hard core & Soft-core potentials; Main features of the One Boson Exchange Potentials (OBEP) : No derivation. **(15 Lectures)**

Unit - III : Interaction of Radiation & Charged Particle with Matter (Not Derivation)

Law of absorption & attenuation coefficient, Photoelectric effect, Compton scattering, Pair production, Klein-Nishina cross sections for polarized & unpolarized radiation, Angular distribution of scattered photon & electrons, Energy loss of charged particles due to ionization, Bremsstrahlung, Energy target & projectile dependence of all three processes, Range-energy curves, Straggling. **(15 Lectures)**

Unit - IV : Experimental Techniques

Gas filled counters, Scintillation counter, Cherenkov counters, Solid state detectors, Surface barrier detectors, Electronic circuits used with typical nuclear detectors, Multiwire proportion chambers, Nuclear emulsions, Techniques of measurement & analysis of tracks, Proton synchrotron, Linear accelerators, Acceleration of heavy ions. **(15 Lectures)**

Reference Books/Text Books

1. Theoretical Nuclear Physics by J.M. Blatt and V.E. Weisskopf, Springer, USA.
2. Introductory Nuclear Theory by L.R.B. Elton, ELBS Publications, London.
3. Nuclear Physics by B. K. Agarwal, Lokbharti Publication Allahabad, 1989.
4. Nuclear Physics by R. R. Roy and B. P. Nigam, Willey -Easter, 1979.
5. Structure of the Nucleus by M. A. Preston & R. K. Bhaduri, Addition-Wesley, 1975.
6. Introductory Experimental Nuclear Physics by R.M. Singru, Wiley Eastern Pvt. Ltd.
7. Techniques on Nuclear Structure (Vol. I) by England, Macmillan.

Suggested E-Resources :

1. MIT OpenCourseWare : Nuclear Physics - This resource offers lecture notes, assignments, and exams for a complete course on nuclear physics : https://ocw.mit.edu/courses/8-701-introduction-to-nuclear-and-particle-physics-fall-2020/
2. HyperPhysics : This online resource provides concise explanations and interactive simulations for various topics in nuclear physics : http://hyperphysics.phy-astr.gsu.edu/hbase/Nuclear/nucstructcon.html
3. NPTEL/Swayam Platform : https://onlinecourses.nptel.ac.in/noc20_ph19/preview
4. MOOC List : https://www.mooc-list.com/tags/nuclear-physics

Course Learning Outcomes :

By the end of the course, students should be able to:

1. Understand the concept of two-nucleon system, deuteron system for explanation of nuclear properties.
2. Understand the concept of nuclear forces and properties.
3. Understand the concept of nucleon-nucleon scattering theory & potentials.
4. Explanation of the concept of interaction of radiation and charged particle with matter.
5. Explanation of different types of experimental techniques in nuclear physics of detectors, counters, synchrotrons & accelerators.

M.Sc. (Physics)

Semester - III

Elective Paper [XII(A)] - Microwave Electronics (I)

[DSE MPHY 304(A), Credits Theory 04, Lectures 60]

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions of 14 marks and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. (2 x 7 = 14 Marks)

Part B of the paper will consist of four questions, one question from each unit with internal choice. Each question will carry 14 marks. (4 x 14 = 56 Marks)

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
III	DSE MPHY 304(A)	Microwave Electronics (I)	9	4
Level of Course	Type of The Course	Delivery Type of The Course		
Introductory	Elective	Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.		
Prerequisites	PG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the course in Microwave Electronics (I) is to provide students with a comprehensive understanding of microwave electronics at the initially at the introductory level. The course targets development of advanced fundamentals in students to enable them to cope-up with higher level complexities in microwave electronics theories in physics. It will prepare students with advanced level fundamentals in microwave electronics to enable them understanding complex microwave theories and learn their applications.			

Unit - I : Introduction To Microwaves & Waveguides

Introduction to microwaves & frequency spectrum, Application of microwaves. Waveguides :

(a) Rectangular waveguides : Wave equation & solutions, TE & TM modes, Dominant mode & choice of waveguide, Dimension methods of excitation of waveguide.

(b) Circular wave guide-wave equation & its solutions, TE, TM & TEM modes.

(c) Attenuation - Cause of attenuation in wave guides, wall current & derivation of attenuation constant, Q of the wave guide. **(15 Lectures)**

Unit - II : Resonators & Ferrites

Resonators : Resonant modes of rectangular & cylindrical cavity resonators, Q of the cavity resonators, Excitation techniques, YIG tuned solid state resonators, Introduction to microstrip & dielectric resonators, Frequency meter.

Ferrites : Microwave propagation in ferrites, Faraday rotation, Devices employing Faraday rotation (Isolator, Gyrator, Circulator), Introduction to single crystal ferromagnetic resonators.

(15 Lectures)

Unit - III : Microwave Measurement

(a) Microwave Detectors : Power, Frequency, Attenuation, Impedance using Smith chart, VSWR, Reflectometer, Directivity, Coupling using direction coupler.

(b) Complex permittivity of material & its measurement : Definition of complex of Solids, liquids & powders using shift of minima method. **(15 Lectures)**

Unit - IV : Microwave Tubes, Klystrons, Magnetrons & Gyrotrons

Microwave Tubes : TWT (Travelling Wave Tube) : O & M type travelling wave tubes, Beam focusing.

Klystrons : Velocity modulation, Two cavity Klystron, Reflex Klystron, Efficiency of Klystrons.

Magnetrons : Types & description, Theoretical relations between electric & magnetic field of oscillations, Modes of oscillation & Operating characteristics.

Gyrotrons : Constructions of different Gyrotrons & Field-particle interaction in gyrotron.

(15 Lectures)

Reference Books/Text Books

1. Theory and Application of Microwaves by A.B. Brownwell & R.E. Beam, McGraw Hill.
2. Introduction to Microwave Theory by Atwater, McGraw Hill.
3. Principles of Microwave Circuit by G.C. Montgomery, McGraw Hill.
4. Microwave Circuits & Passive Devices by M.L. Sisodia and G.S. Raghuvanshi, New Age International.
5. Foundations of Microwave Engineering by RE. Collin, McGraw Hill.
6. Microwave by M.L. Sisodia and Vijay Laxmi Gupta, New Age International. Foundations of Microwave Engineering by R. E. Collins, McGraw Hills.
7. Electromagnetic Waves & Radiating Systems by E.C. Jordan & K. G. Buhmin.

Suggested E-Resources :

1. MIT OpenCourseWare : Microwave Electronics - This resource offers lecture notes, assignments, and exams for a complete course on microwave electronics : https://ocw.mit.edu/courses/6-013-electromagnetics-and-applications-spring-2009/pages/lecture-notes/
2. HyperPhysics : This online resource provides concise explanations and interactive simulations for various topics in microwave electronics : http://hyperphysics.phy-astr.gsu.edu/hbase/Nuclear/nucstructcon.html
3. NPTEL/Swayam Platform : https://onlinecourses.nptel.ac.in/noc20_ee91/preview
4. IIT Guwahati : https://freevideolectures.com/course/4125/nptel-microwave-engineering

Course Learning Outcomes :

By the end of the course, students should be able to:

1. Understand the concept of microwaves & waveguides.
2. Understand the concept of different types of waveguides, TE & TM modes & attenuation.
3. Understand the concept of resonators & ferrites.
4. Understand the concept of ferrites in microwave technology.
5. Understand the concept of microwave measurement in form of various microwave detectors & measurement of complex permittivity of a material.
6. Understand the concept of microwave tubes, Klystrons, magnetrons & gyrotrons.

M.Sc. (Physics)

Semester – III

Physics Practical Lab III(A) - Advanced Physics Laboratory

(DSCP MPHY 311, Credits Practical 06, Practical Hours 180)

Note: Out of following experiments, 6 experiments must be done by the students in each semester.

(9 hrs. per week)

External Exam Duration : 4 hrs. **Max. Marks : 60**
Internal Exam Duration : 2 hrs. **Max. Marks : 50**

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
III	DSCP MPHY 311	Physics Practical Lab III(A) (Advanced Physics Laboratory)	9	6
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	Practical Hours, One Hundred & Eighty hours of postgraduate level experiments including diagnostic and formative assessments.		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the third course in practical physics is to provide students with a comprehensive fundamental understanding of practical physics. The course aims to develop their knowledge and skills in developing experimental skills at the postgraduate level and to endow them with a zeal for experimental physics. This will help nurture their interests in experimental domain to enable them to take-up research in physics as well in addition to preparing their experimental attitude for future careers in physics.			

DSCP MPHY 311 : Physics Practical Lab III(A)

The inclusion of new experiments should be intimated and approved by the Convenor, Board of Studies before the start of the academic session. It is binding to have an experimental set-up of at least ten experiments listed below. In case the number of experiments performed by the student is less than eight, his marks shall be scaled down in the final examination on a pro-rata basis. Laboratory examination paper will be set by the external examiner out of eight or more experiments available at the center.

List of Experiments : Semester - III

1. To determine half-life of a radio-isotope using GM counter.

2. To study absorption of particles and determine range using at least two sources using GM counter.
3. To study characteristics of a GM counter and to study statistical nature of radioactive decay.
4. To study spectrum of particles using Gamma ray spectrometer.
5. To calibrate a scintillation spectrometer and determine energy of g-rays from an unknown source.
6. To study temperature variation of resistivity for a semiconductor and to obtain band gap using four probe method.
7. To study hall effect and to determine hall coefficient using a semiconductor.
8. To study the dynamics of a lattice using electrical analog.
9. To study ESR and determine g-factor for a given spectrum.
10. To determine ultrasonic velocity and to obtain compressibility for a given liquid.
11. To study the characteristics of a given Klystron and calculate the mode number, E.T.S. and transit time.
12. To study the radiation pattern of a given Pyramidal horn by plotting it on a Polar-graph paper. To find the half power beam width and calculate its gain.
13. To find the dielectric constant of a given solid (Teflon) for three different lengths by using slotted section.
14. To find the dielectric constant of a given liquid (organic) using slotted section of X-band.
15. To verify Bragg's diffraction law using microwaves for macro-crystals.
16. (a) To study variation of energy resolution for a Nai (Tp) detector.

    (b) To determine attenuation coefficient (u) for rays from a given sources.
17. To study Compton scattering of gamma rays and verify the energy shift formula.
18. To study the variation of rigidity of a given specimen as a function of the temperature.
19. To study the simulated L.C.R. Transmission line (audio frequency) and to find out the value for a Zo experimentally from the graph.
20. Any other experiment compatible with the postgraduate level physics theory.

Course Learning Outcomes :

Through these experiments, students will develop practical skills in experimental techniques, data collection, analysis, and interpretation. They will also enhance their understanding of fundamental concepts and principles in advanced solid state physics & microwave electronics. The lab experiences will foster critical thinking, problem-solving abilities, and the application of theoretical knowledge to real-world scenarios.

M.Sc. (Physics)

Semester – III

Physics Practical Lab III(B) - Advanced Physics Laboratory

(DSEP MPHY 331, Credits Practical 06, Practical Hours 180)

Note: Out of Project Work, Summer Training Programme and Dissertation, one must be chosen by the student.

(9 hrs. per week)

External Exam Duration : 1 hrs. — **Max. Marks : 60**

Internal Exam Duration : 1 hrs. — **Max. Marks : 40**

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
III	DSEP MPHY 331	Physics Practical Lab III(B) (Advanced Physics Laboratory)	9	6
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	Practical Hours, One Hundred & Eighty hours of postgraduate level experiments including diagnostic and formative assessments.		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the third course in practical physics is to provide students with a comprehensive fundamental understanding of practical physics. The course aims to develop their knowledge and skills in developing experimental skills at the postgraduate level and to endow them with a zeal for experimental physics. This will help nurture their interests in experimental domain to enable them to take-up research in physics as well in addition to preparing their experimental attitude for future careers in physics.			

DSCP MPHY 331 : Physics Practical Lab III(B)

The inclusion of new experiments should be intimated and approved by the Convenor, Board of Studies before the start of the academic session. It is binding to have an experimental set-up of at least ten experiments listed below. In case the number of experiments performed by the student is less than eight, his marks shall be scaled down in the final examination on a pro-rata basis. Laboratory examination paper will be set by the external examiner out of eight or more experiments available at the center.

M.Sc. (Physics)

Semester - IV

Paper (XIII) - Introductory Quantum Field Theory

(DSC MPHY 401, Credits Theory 04, Lectures 60)

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions of 14 marks and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. (2 x 7 = 14 Marks)

Part B of the paper will consist of four questions, one question from each unit with internal choice. Each question will carry 14 marks. (4 x 14 = 56 Marks)

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
IV	DSC MPHY 401	Introductory Quantum Field Theory	9	4
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.		
Prerequisites	PG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the course on Introductory Quantum Field Theory (QFT) is to provide students with a comprehensive knowledge of quantum field theory at the introductory level. The course aims to develop their knowledge and skills in analysing and solving problems related to these topics, using appropriate mathematical formalism and physical concepts. The course targets development of advanced fundamentals in students of quantum field theory (QFT) and to prepare their advanced level fundamentals to enable to study them advanced quantum mechanics. It will prepare students with advanced level fundamentals to enable them understanding complex physical theories that possess the essential components of quantum field theory, and also to solve complex problems in quantum field theory.			

Unit - I : Introduction To Quantum Field Theory (QFT)

Scalar & Vector fields, Classical Lagrangian field theory, Euler Lagrange's equation, Lagrangian density for electromagnetic field, Occupation number, Representation for simple harmonic oscillator, Linear array of coupled oscillators, Second quantization of identical bosons, Second quantization of real Klein-Gordon field & complex Klein-Gordon field, The Meson propagator.

(15 Lectures)

Unit - II : Fermions In Quantum Field Theory
Occupation number, Representation for fermions, Second quantization of Dirac field, The fermion propagator, EM interaction & Gauge invariance, Covariant quantization of free electromagnetic field, The photon propagator. **(15 Lectures)**

Unit - III : S-Matrix Formalism, Wick's Theorem & Feynman Representations & Rules
S-matrix, S-matrix expansion, Wick's theorem, Diagrammatic representation in configuration space, Momentum representation, Feynman diagrams of basic processes, Feynman rules of QED. **(15 Lectures)**

Unit - IV : Applications of S-matrix formalism
Coulomb scattering, Bhabha scattering, Moller scattering & Compton scattering. **(15 Lectures)**

Reference Books/Text Books

1. Quantum Field Theory by F. Mandal& G. Shaw, Wiley & Sons.
2. Relativistic Quantum Mechanics by J. D. Bjorken & S. Drell, McGraw Hill Book Co.
3. Advanced Quantum Mechanics by J. J. Sakurai, Pearson Education.
4. Element of Advanced Quantum Theory by J. M. Ziman, Cambridge University Press.
5. A First Book of Quantum Field Theory by A. Lahiri, Narosa Publishers.
6. Introduction To Quantum Field Theory by Kiselev, Taylor & Francis.
7. An Introduction To Quantum Field Theory by M. E. Peskin & D. V. Schroeder, Westview Press.

Suggested E-Resources :

1. MIT OpenCourseWare : Introductory Quantum Field Theory - This resource offers lecture notes, assignments, and exams for a complete course on introductory quantum field theory : https://ocw.mit.edu/courses/8-323-relativistic-quantum-field-theory-i-spring-2008/
2. Physics Stack Exchange : https://physics.stackexchange.com/questions/10021/online-qft-video-lectures
3. Cosmo Learning : https://cosmolearning.org/physics/courses?topic=503
4. NPTEL/Swayam Platform : https://onlinecourses.nptel.ac.in/noc21_ph28/preview
5. University of Cambridge Lectures : http://www.damtp.cam.ac.uk/user/tong/qftvids.html

Course Learning Outcomes :
By the end of the course, students should be able to:

1. Understand the concept of quantum field theory at an introductory level.
2. Understand the concept of fermions in quantum field theory.
3. Understand the concept of S-matrix formalism, Wick's theorem & Feynman representations & rules.
4. Understand the applications of S-matrix formalism.

M.Sc. (Physics)

Semester - IV

Paper (XIV) - Solid State Physics

(DSC MPHY 402, Credits Theory 04, Lectures 60)

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions of 14 marks and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. (2 x 7 = 14 Marks)

Part B of the paper will consist of four questions, one question from each unit with internal choice. Each question will carry 14 marks. (4 x 14 = 56 Marks)

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
IV	DSC MPHY 402	Solid State Physics	9	4
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.		
Prerequisites	PG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the course in solid state physics in the final semester is to provide students with a comprehensive understanding of solid state physics pertaining to lattice dynamics & optical properties of solids, semiconductors, advanced magnetism theories & concepts, and superconductivity. The course aims to develop their knowledge and skills in analysing and solving problems related to these topics, using appropriate mathematical formalism and physical concepts. The course targets development of advanced fundamentals in students to enable them to cope-up with higher level complexities in materials physics. It will prepare students with advanced level fundamentals to enable them understanding complex materials physics theories, and also to solve complex problems in advanced solid state physics.			

Unit - I : Lattice Dynamics & Optical Properties Of Solids

Interatomic forces, Lattice dynamics, Simple metals, Ionic & covalent crystals, Optical phonons & Dielectric constants, Inelastic neutron scattering, Mossbauer effect, Debye-Waller factor, Anharmonicity, Thermal expansion & thermal conductivity, Interaction of electrons & phonons with photons, Direct & indirect transitions, Absorption in insulators, Polaritons, One-phonon absorption, Optical properties of metals, Skin effect & anomalous skin effect. **(15 Lectures)**

Unit - II : Semiconductors

Law of mass action, Calculation of impurity conductivity, Ellipsoidal energy surfaces in Si & Ge, Hall effect, Recombination mechanism, Optical transitions & Shockley-Read theory, Excitons, Photoconductivity, Photoluminescence, Points line, Planar & bulk defects, Colour centers, F-centre & Aggregate centers in alkali halides. **(15 Lectures)**

Unit - III : Magnetism

Larmor diamagnetism, Paramagnetism, Curie, Langevin & Quantum theories, Susceptibility of rare-earth & transition metals, Ferromagnetism : Domian theory, Weiss molecular field theory & exchange, Spin waves : Dispersion relation & Experimental determination by inelastic neutrons scattering, Heat capacity, Nuclear magnetic resonance (NMR) : Conditions of resonance, Bloch equations, NMR-experiment & characteristics of an absorption line. **(15 Lectures)**

Unit - IV : Superconductivity

(a) Experimental Results : Meissner effect, Heat capacity, Microwave & infrared properties, Isotope effect, Flux quantization, Ultrasonic attenuation, Density of states, Nuclear spin relaxation, Giaever, AC & DC Josephson tunneling.

(b) Cooper pairs and derivation of BCS Hamiltonian, results of BCS Theory (no derivation). **(15 Lectures)**

Reference Books/Text Books

1. Introduction to Solid State Physics by Kittel, Wiley & Sons.
2. Solid State Physics by Levy, Elsevier Publications.
3. Solid State Physics by Patterson, Springer.
4. Solid State & Semiconductor Physics by McKelvey, Krieger Publication Co.

Suggested E-Resources :

1. MIT OpenCourseWare : Solid State Physics - This resource offers lecture notes, assignments & exams for a complete course on solid state physics : https://ocw.mit.edu/courses/8-231-physics-of-solids-i-fall-2006/
2. HyperPhysics : This online resource provides concise explanations and interactive simulations for various topics in solid state physics : http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
3. NPTEL/Swayam : https://onlinecourses.nptel.ac.in/noc21_ph21/preview
4. International Centre For Theoretical Physics (ICTP) : https://mediacore.ictp.it/media/solid-state-physics-lecture-1-of-20

Course Learning Outcomes :

By the end of the course, students should be able to:

1. Understand the concept of lattice dynamics & anharmonicity.
2. Understand the concept of inelastic neutron scattering, Mossbauer effect, Debye-Waller factor.
3. Understand the concept of optical properties of solids.
4. Understand the concept of semiconductors in detail.
5. Understand the concept of Shockley-Read theory & F-centers.
6. Understand the concept of magnetic theories in detail.
7. Understand the concept of spin-waves and experimental determination by inelastic neutron scattering.
8. Understand the concept of nuclear magnetic resonance (NMR) spectroscopy.
9. Understand the concept of superconductors in detail.
10. Understand the concept of AC & DC Josephson tunnelling.
11. Understand the concept of Cooper pairs.
12. Understand the concept of BCS theory.

M.Sc. (Physics)

Semester - IV

Paper (XV) - Nuclear Physics (II)

(DSC MPHY 403, Credits Theory 04, Lectures 60)

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions of 14 marks and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. (2 x 7 = 14 Marks)

Part B of the paper will consist of four questions, one question from each unit with internal choice. Each question will carry 14 marks. (4 x 14 = 56 Marks)

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
IV	DSC MPHY 403	Nuclear Physics (II)	9	4
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.		
Prerequisites	PG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the course in Nuclear Physics (II) is to provide students with a comprehensive understanding of nuclear shell model, collective nuclear model, nuclear gamma & beta decay, and nuclear reactions. The course aims to develop their knowledge and skills in analysing and solving problems related to these topics, using appropriate physical concepts. The course targets development of advanced fundamentals in students to enable them to cope-up with higher level complexities in nuclear physics theories to describe nucleus structures, compositions & interactions. It will prepare students with advanced level fundamentals to enable them understand complex nuclear physics fundamentals involving nuclear reactions and gamma & beta decay.			

Unit - I : Nuclear Shell Model

Single particle & collective motions in nuclei : Assumptions and justification of the shell model, Average shell potential, Spin-orbit coupling, Single particle wave functions & level sequence, Magic numbers, Shell model predictions for ground state parity, Angular momentum, Magnetic dipole & Electric quadrupole moments, and their comparison with experimental data, Configuration mixing, Single particle transition probability according to the shell model, Selection rules, Approximate estimates for transition probability, Weisskopf units, Nuclear isomerism.

(15 Lectures)

Unit - II : Collective Nuclear Model

Collective variable to describe cooperative modes of nuclear motion, Parameterization of nuclear surface, A brief description of collective model Hamiltonian (in quadratic approximation), Vibrational modes of a spherical nucleus, Collective modes of a deformed even-even nucleus & moments of inertia, Collective spectra & electromagnetic transition in even nuclei & comparison with experimental data, Nilsson model for single particle states in deformed nuclei. **(15 Lectures)**

Unit - III : Nuclear Gamma & Beta Decay

Electric & magnetic multipole moments, Gamma decay probabilities in nuclear system (no derivations), Reduced transition probability, Selection rules, Internal conversion & zero-zero transition, General characteristics of weak interaction, Nuclear beta decay & lepton capture, Electron energy spectrum & Fermi-Kurie plot, Fermi theory of beta decay (Parity conserved selection rules, Fermi & Gamow-Teller) for allowed transitions, *ft*-values, General interaction Hamiltonian for beta decay with parity conserving & non-conserving terms, Forbidden transitions, Experimental verification of parity violation, The V-A interaction & experimental verification.

(15 Lectures)

Unit - IV : Nuclear Reactions

Theories of nuclear reactions, Partial wave analysis of reaction cross-section, Compound nucleus formation & breakup, Resonance scattering & reaction-Breit-Wigner dispersion formula for s-waves ($l = 0$), Continuum cross-section, Statistical theory of nuclear reactions, Evaporation probability & cross section for specific reactions, Optical model, Stripping & pick-up reactions and their simple theoretical description (Butler theory) using Plane-Wave Born Approximation (PWBA), Shortcomings of PWBA nuclear structure studies with deuteron stripping (d,p) reactions.

(15 Lectures)

Reference Books/Text Books

1. Structure of Nucleus by M.A. Preston and R.K. Bhaduri, Addison Wesley, 1975.
2. Nuclear Physics by R.R. Roy and B.P. Nigam, Wiley-Eastern. 1979.
3. Introductory Nuclear Theory by L.R.B. Elton, ELeBS Pub. London, 1959.
4. Nuclear Physics by B. K. Agrawal, Lokbharati Publt., Allahabad 1989.
5. Nuclear Structure by M. K. Pal, Affiliated East-West Press, 1982.
6. Theoretical Nuclear Physics by J.B. Blatt and V.F. Weisskopf.
7. Introduction to Nuclear Physics by H. Enge., Addison - Wesley, 1970.
8. Concept of Nuclear Physics by B.L. Cohen, Tata McGraw Hill, 1988.
9. Element of Nuclear Physics by W.E. Burchema, ELBS, Longman, 1988.
10. The Atomic Nucleus by R.D. Evans ,McGraw Hill, 1955.
11. Nuclei and Particles by E. Segre, Benjamin, 1977.

Suggested E-Resources :

1. MIT OpenCourseWare : Nuclear Physics - This resource offers lecture notes, assignments, and exams for a complete course on nuclear physics : https://ocw.mit.edu/courses/8-701-introduction-to-nuclear-and-particle-physics-fall-2020/
2. NPTEL/Swayam Platform : https://onlinecourses.nptel.ac.in/noc20_ph19/preview
3. MOOC List : https://www.mooc-list.com/tags/nuclear-physics

Course Learning Outcomes :

By the end of the course, students should be able to:

1. Understand the concept of nuclear shell model in detail.
2. Understand the concept of collective nuclear model in detail.
3. Understand the concept of nuclear gamma & beta decay in detail.
4. Understand the concept of nuclear reactions in detail.

M.Sc. (Physics)

Semester - IV

Elective Paper [XVI(A)] - Microwave Electronics (II)

[DSE MPHY 404(A), Credits Theory 04, Lectures 60]

Duration of EoSE : 3 hrs. **Max. Marks : 70**

Note: There will be two parts in end semester theory paper.

Part A of the paper shall contain eight short answer type questions of 14 marks and the candidate is required to attempt any seven questions. Each question will carry two marks for correct answer. (2 x 7 = 14 Marks)

Part B of the paper will consist of four questions, one question from each unit with internal choice.

Each question will carry 14 marks. (4 x 14 = 56 Marks)

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
IV	DSE MPHY 404(A)	Microwave Electronics (II)	9	4
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	Lecture, Sixty Lectures including diagnostic and formative assessments during lecture hours.		
Prerequisites	PG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the elective course in Microwave Electronics (II) is to provide students with a comprehensive understanding of microwave electronics at an advanced stage in the final semester. The course targets development of advanced fundamentals of avalanche transit time device, transferred electron device & passive devices, parametric amplifier, microwave antennas & microwave communication in students to enable them to cope-up with higher level complexities in microwave electronics. It will prepare students with advanced level fundamentals in microwave electronics to enable them understanding complex microwave theories and learn their applications.			

Unit - I : Avalanche Transit Time Device, Transferred Electron Device & Passive Devices

(a) Avalanche Transit Time Device : Read diode, Negative resistance of an avalanching *p-n* junction diode, IMPATT & TRAPATT oscillator.

(b) Transferred Electron Device : Gunn effect, Two valley model, High field domains, Different modes for microwave generation.

(c) Passive Devices : Termination (Short circuit & matched terminations), Precision attenuator, Precision shifter phase changers, E-H Plane Tees, Hybrid junctions & Directional coupler.

(15 Lectures)

Unit - II : Parametric Amplifier

Varactor, Equation of capacitance in linearly graded & abrupt *pn* junction, Manely Rowe relations, Parametric upconverter & Negative resistance parametric amplifier, Use of circulator, Noise in parametric amplifiers. **(15 Lectures)**

Unit - III : Microwave Antennas

Introduction to antenna parameters, Magnetic currents, Electric & magnetic current sheet, Field of Huygen's source, Radiation from a slot antenna, Open end of a waveguide & Electromagnetic horns, YAGI UDA antenna with radiation pattern, Radiation fields of microstrip waveguide, Microstrip waveguide, Microstrip antenna calculations, Microstrip design formulas. **(15 Lectures)**

Unit - IV : Microwave Communication

(a) LOS microwave systems, Derivation of LOS communication range, OTH microwave systems, Derivation of field strength of tropospheric waves, Transmission interference & signal damping, Duct propagation.

(b) Satellite Communication: Satellite frequencies allocation, Synchronous satellites, Satellite orbits, Satellite location with respect to earth and look angle, Earth coverage & slant range, Eclipse effect, Link Calculation, Noise consideration, Factors affecting satellite communication & their consequences. **(15 Lectures)**

Reference Books/Text Books

1. Antenna Theory & Design by RS Elliott, LPHI Ltd.
2. Microwave Electronics by RE Soohoo, Addisen Wesley Public Company.
3. Microwave Active Devices, Vacuums and Solid State by M.L. Sisodia, New Age International Publishers.
4. Solid State Physical Electronics by A. Van der Ziel, Prentice Hall of India.
5. Handbook of Microwave Measurement Vol. - II by M. Sucher& J. Fox, Polytechnic Press.
6. Microwave Devices & Circuits by S. Y. Liao, Prentice Hall of India.
7. Microwave Principles by H. J. Reich, CBS Publishers.
8. Simple Microwave Technique For Measuring The Dielectric Parameters of Solids & Their Powder by J. M. Gandhi, J.S. Yadav, J. of Pure & Applied Physics, Vol. 30, pp-427431, 199.
9. Microstrip Antennas by Bahl & Bhartiya, Artech House, Massachusetts.
10. Antenna Theory Analysis & Design by C.A. Balanis Harper & Row. Pub. & Inc. New York.
11. Solid State Electronic Devices by Streetman, PHI.

Suggested E-Resources :

1. MIT OpenCourseWare : Microwave Electronics - This resource offers lecture notes, assignments, and exams for a complete course on microwave electronics : https://ocw.mit.edu/courses/6-013-electromagnetics-and-applications-spring-2009/pages/lecture-notes/
2. HyperPhysics : This online resource provides concise explanations and interactive simulations for various topics in microwave electronics : http://hyperphysics.phy-astr.gsu.edu/hbase/Nuclear/nucstructcon.html
3. NPTEL/Swayam Platform : https://onlinecourses.nptel.ac.in/noc20_ee91/preview
4. IIT Guwahati : https://freevideolectures.com/course/4125/nptel-microwave-engineering

Course Learning Outcomes :

By the end of the course, students should be able to:

1. Understand the concept of avalanche transit time device, & passive devices.
2. Understand the concept of transferred electron device.
3. Understand the concept of passive devices.
4. Understand the concept of parametric amplifier.
5. Understand the concept of microwave antennas and microwave communication.

M.Sc. (Physics)

Semester - IV

Physics Practical Lab IV(A) - Advanced Physics Laboratory

(DSCP MPHY 411, Credits Practical 06, Practical Hours 180)

Note: Out of following experiments, 6 experiments must be done by the students in each semester.

(9 hrs. per week)

External Exam Duration : 4 hrs. **Max. Marks : 60**

Internal Exam Duration : 2 hrs. **Max. Marks : 40**

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
IV	DSCP MPHY 411	Physics Practical Lab IV(A) (Advanced Physics Laboratory Work)	9	6
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	Practical Hours, One Hundred & Eighty hours of postgraduate level experiments including diagnostic and formative assessments.		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the fourth course in practical physics is to provide students with a comprehensive fundamental understanding of practical physics. The course aims to develop their knowledge and skills in developing experimental skills at the postgraduate level and to endow them with a zeal for experimental physics. This will help nurture their interests in experimental domain to enable them to take-up research in physics as well in addition to preparing their experimental attitude for future careers in physics.			

DSCP MPHY 411 : Physics Practical Lab IV(A)

The inclusion of new experiments should be intimated and approved by the Convenor, Board of Studies before the start of the academic session. It is binding to have an experimental set-up of at least ten experiments listed below. In case the number of experiments performed by the student is. less than eight, his marks shall be scaled down in the final examination on a pro-rata basis. Laboratory examination paper will be set by the external examiner out of eight or more experiments available at the center.

List of Experiments : Semester - IV

1. To determine half-life of a radio-isotope using GM counter.
2. To study absorption of particles and determine range using at least two sources using GM counter.
3. To study characteristics of a GM counter and to study statistical nature of radioactive decay.
4. To study spectrum of particles using Gamma ray spectrometer.
5. To calibrate a scintillation spectrometer and determine energy of g-rays from an unknown source.
6. To study temperature variation of resistivity for a semiconductor and to obtain band gap using four probe method.
7. To study hall effect and to determine hall coefficient using a semiconductor.
8. To study the dynamics of a lattice using electrical analog.
9. To study ESR and determine *g*-factor for a given spectrum.
10. To determine ultrasonic velocity and to obtain compressibility for a given liquid.
11. To study the characteristics of a given Klystron and calculate the mode number, E.T.S. and transit time.
12. To study the radiation pattern of a given Pyramidal horn by plotting it on a Polar-graph paper. To find the half power beam width and calculate its gain.
13. To find the dielectric constant of a given solid (Teflon) for three different lengths by using slotted section.
14. To find the dielectric constant of a given liquid (organic) using slotted section of X-band.
15. To verify Bragg's diffraction law using microwaves for macro-crystals.
16. (a) To study variation of energy resolution for a Nai (Tp) detector.

    (b) To determine attenuation coefficient (u) for rays from a given sources.
17. To study Compton scattering of gamma rays and verify the energy shift formula.
18. To study the variation of rigidity of a given specimen as a function of the temperature.
19. To study the simulated L.C.R. Transmission line (audio frequency) and to find out the value for a Zo experimentally from the graph.
20. Any other experiment compatible with the postgraduate level physics theory.

Course Learning Outcomes:

Through these experiments, students will develop practical skills in experimental techniques, data collection, analysis, and interpretation. They will also enhance their understanding of fundamental concepts and principles in solid state physics & microwave electronics. The lab experiences will foster critical thinking, problem-solving abilities, and the application of theoretical knowledge to real-world scenarios.

M.Sc. (Physics)

Semester - IV

Physics Practical Lab IV(B) - Advanced Physics Laboratory

(DSEP MPHY 431, Credits Practical 06, Practical Hours 180)

Note: Out of following experiments, 6 experiments must be done by the students in each semester.

(9 hrs. per week)

External Exam Duration : 4 hrs. **Max. Marks : 60**

Internal Exam Duration : 2 hrs. **Max. Marks : 40**

Semester	Code of The Course	Title of The Course/Paper	NHEQF Level	Credits
IV	DSEP MPHY 411	Physics Practical Lab IV(B) (Advanced Physics Laboratory Work)	9	6
Level of Course	**Type of The Course**	**Delivery Type of The Course**		
Introductory	Core	Practical Hours, One Hundred & Eighty hours of postgraduate level experiments including diagnostic and formative assessments.		
Prerequisites	UG level qualification with Physics as a core subject from a UGC recognized college/Univ.			
Objectives of The Course :	The objective of the fourth course in practical physics is to provide students with a comprehensive fundamental understanding of practical physics. The course aims to develop their knowledge and skills in developing experimental skills at the postgraduate level and to endow them with a zeal for experimental physics. This will help nurture their interests in experimental domain to enable them to take-up research in physics as well in addition to preparing their experimental attitude for future careers in physics.			

DSEP MPHY 431 : Physics Practical Lab IV(B)

The inclusion of new experiments should be intimated and approved by the Convenor, Board of Studies before the start of the academic session. It is binding to have an experimental set-up of at least ten experiments listed below. In case the number of experiments performed by the student is less than eight, his marks shall be scaled down in the final examination on a pro-rata basis. Laboratory examination paper will be set by the external examiner out of eight or more experiments available at the center.