Proceedings of Board of Studies Meeting
(Held on May 04, 2026)

Course Structure & Syllabus for the programs Master of Science in Physics (Specialization in Materials Science & Nanotechnology)

(As per the Ordinances for Master of Science as per Academic Council, w.e.f. 2026-27)

Offered By

DEPARTMENT OF PHYSICS
HARCOURT BUTLER TECHNICAL UNIVERSITY, KANPUR-208002, UP
May, 2026

Department of Physics

CURRICULA & SYLLABI

M.Sc. Physics (Specialization in Materials Science & Nanotechnology)
Vision: To cultivate advanced knowledge and research excellence in Physics, with a focus on materials science and nanotechnology, enabling students to contribute to cutting-edge technologies and sustainable development.

Mission:

- ❖ Deliver advanced education in materials science, nanotechnology, and applied physics.
- ❖ Foster research aptitude and innovation through experimental and computational approaches.
- ❖ Enable students to engage with cutting-edge developments in nanoscience and advanced materials.
- ❖ Build collaboration skills for multidisciplinary research and industrial applications.
- ❖ Cultivate socially responsible scientists contributing to sustainable technological advancement.

Programme Outcome (POs)

PO1: Fundamental Knowledge
Apply advanced concepts of physics, particularly in materials science and nanotechnology, to understand and analyze physical systems.
PO2: Problem Analysis
Identify, formulate, and solve complex problems using analytical, mathematical, and computational tools.
PO3: Research Skills
Design and conduct experiments, analyze data, and interpret results to draw meaningful scientific conclusions.
PO4: Modern Tool Usage
Utilize modern scientific instruments, computational techniques, and simulation tools relevant to materials science and nanotechnology.
PO5: Innovation and Development
Develop innovative solutions and contribute to emerging technologies in advanced materials, energy systems, and nanodevices.
PO6: Interdisciplinary Approach
Integrate knowledge from physics, engineering, and related disciplines to address real-world challenges.
PO7: Ethics and Professional Responsibility
Apply ethical principles and professional responsibility in scientific research and technological applications.
PO8: Communication Skills
Communicate scientific ideas effectively through reports, presentations, and publications.
PO9: Lifelong Learning
Engage in continuous learning and adapt to evolving scientific and technological advancements.
PO10: Environment and Sustainability
Understand the environmental and societal impact of materials and nanotechnology, promoting sustainable development.

Programme Educational Objectives (PEO)

PEO1: Advanced Knowledge and Expertise
Demonstrate strong conceptual understanding of physics with specialization in materials science and nanotechnology, enabling them to pursue higher studies and research.
PEO2: Research and Innovation
Engage in scientific research, innovation, and development in academia, research laboratories, and advanced technology sectors.
PEO3: Professional Career Development
Build successful careers in teaching, research, industry, or interdisciplinary fields such as energy, nanotechnology, and semiconductor technologies.
PEO4: Problem Solving and Technical Skills
Apply analytical, computational, and experimental skills to solve complex scientific and engineering problems.
PEO5: Ethics and Societal Contribution
Exhibit ethical responsibility, effective communication, and contribute to sustainable and socially relevant technological advancements.

Programme Specific Outcome (PSOs)

PSO1: Materials Characterization and Analysis
Apply principles of condensed matter physics to analyze the structural, electronic, optical, and magnetic properties of materials using experimental and computational techniques.
PSO2: Nanoscience and Device Understanding
Understand and model nanoscale phenomena and evaluate the working principles of nanomaterials and devices such as semiconductors, thin films, and spintronic systems.
PSO3: Experimental and Computational Skills
Utilize modern characterization tools and simulation methods for materials research and analysis.
PSO4: Research and Technological Applications
Develop the ability to engage in research and innovation in emerging areas such as energy materials, nanotechnology, and advanced functional materials.

Syllabus and Credit structure: Credit Structure for M. Sc. Physics (Specialization in Materials Science & Nanotechnology) (For newly admitted students from Session 2026-2027)

Category	I	II	III	IV	Total
Programmes Core Courses (PCC)	16	16	8	4	44
Programmes Elective Courses (PEC)	-	-	4	4	08
Engineering Sciences Courses (ESC)	4	4	4	4	16
Internship /Seminar Courses (ISC)			2	-	02
Project			2	8	10
Total	20	20	20	20	80

Curriculum for M.Sc. in Physics
(For newly admitted students from Session 2024-2025)

Semester-I

S. N.	Course Type	Subject Code	Course Title	L	T	P	Credits
1.	PCC	NPH-501	Mathematical Physics	3	1	0	4
2,	PCC	NPH-503	Classical Mechanics	3	1	0	4
3.	PCC	NPH-505	Quantum Mechanics	3	1	0	4
4.	PCC	NPH-507	Electronics	3	0	2	4
5.	ESC	NPH-509	Materials Science and Technology	3	1	0	4
			Total Credit	15	4	2	20

Semester-II

S. N.	Course Type	Subject Code	Course Title	L	T	P	Credits
1.	PCC	NPH-500	Electromagnetic Theory	3	1	0	4
2.	PCC	NPH-502	Thermodynamics and Statistical Mechanics	3	1	0	4
3.	PCC	NPH-504	Solid State Physics	3	0	2	4
4.	PCC	NPH-506	Nuclear and Particle Physics	3	1	0	4
5.	ESC	NPH-508	Physics of Semiconducting Devices & Technology	3	0	2	4
			Total Credit	15	3	4	20

Semester-III

S. N.	Course Type	Subject Code	Course Title	L	T	P	Credits
1.	PCC	NPH-601	Atomic, Molecular Physics and Lasers	3	0	2	4
2.	PCC	NPH-603	Nano Science and Technology	3	1	0	4
3.	ESC	NPH-605	Spintronics: Fundamentals and Applications	3	1	0	4
4.	ISC	NPH-607	Seminar	0	0	4	2
5.	PEC	NPH-609*	Elective-I	3	0	2	4
6.	PCC	NPH-611	Minor Project	0	0	4	2
			Total Credit	12	2	12	20

* One course from Program Electives-I

Semester-IV

S. N.	Course Type	Subject Code	Course Title	L	T	P	Credits
1.	PCC	NPH-600	Advanced Characterization Techniques in Materials Science	3	1	0	4
2.	ESC	NPH-602	Science and Technology of Thin Films	3	1	0	4
3.	PEC	NPH-604*	Elective-II	3	1	0	4
4.	PCC	NPH-606	Capstone Project	0	0	16	8
			Total Credit	9	3	16	20

**One course from Program Electives-II

Programme Electives Courses-I (PEC-I)

S. N.	Course Type	Subject Code	Course Title	L	T	P	Credits
1.	NPH-609	Computational Physics		3	0	2	4
2.	NPH-613	Advanced Condensed Matter Physics		3	1	0	4

Programme Electives Courses-II (PEC-II)

S. N.	Course Type	Subject Code	Course Title	L	T	P	Credits
1.	NPH-604	Advanced Quantum Mechanics		3	1	0	4
2.	NPH-612	Science and Technology of Solar Energy, Hydrogen and other Renewable Energies		3	1	0	4

Table 1: Evaluation Scheme for Various Courses

S.N.	Course Title	Credits	Sessional Marks				ESM	Total Marks
			MSE	TAQ	Lab	Total		
1	Theory Courses	4(3-1-0)	30	20	-	50	50	100
2	Theory cum Lab Courses	4(3-0-2)	15	20	15	50	50	100
3	Project / Lab	2(0-0-4)	-	50	-	50	50	100
4	Internship/Seminar (ISC)	2(0-0-4)	-	50	-	50	50	100
5	Capstone Project/Lab	8(0-0-16)	-	50	-	50	50	100

MSE: Mid Semester Exam
TAQ: Tutorials/Assignments/Quizzes/Attendance ESM: End Semester Exam

Distribution of Marks for Dissertation [Minor Project (NPH-611)/Capstone Project (NPH-606)] and Internship/Seminar [NPH-607]

The dissertation is divided in semester III and semester IV as Dissertation Part-I [Minor Project (NPH-611) and Internship/Seminar (NPH-607)] and Dissertation Part-II [Capstone Project (NPH-606)] respectively. The dissertation may be related to a theoretical, modeling, simulation and analysis, experimental investigation, a proto-type design, product design and development, a new correlation and analysis of data, fabrication and setup of new equipment/experiment etc. preferably useful for the society/industry. A dissertation grade is awarded in both the semesters on the basis of the prescribed evaluation process.

In semester III [Minor Project (NPH-611)] and Internship/Seminar [NPH-607]

S. N.	Assessment Basis		Duration	Marks
1	Continuous Evaluation	Mid Term Presentation Literature Survey/Progress Review	-	30
2		Preliminary Dissertation/Seminar Report, Effort and Regularity (awarded by supervisor)	-	20
3	End Semester Presentation (Methodology adopted/Work Plan/Progress)		-	50

The portion of dissertation work/Seminar work carried out in semester III [Minor Project (NPH-611)/ Internship/Seminar (NPH-607)] shall be examined at the end of semester III. The dissertation/Seminar work will be evaluated by a committee consisting of Head of Department, Dissertation Supervisor(s) and two senior faculty members of department. Any student securing less than 40 marks ('F' grade) shall have to repeat the Dissertation part-I/Seminar in the next semester.

In semester IV [Capstone Project (NPH-606)]

The major examination of Dissertation will be held only after the student has secured Pass Grades in all the program core/program electives requirements satisfactorily.

S. N.	Assessment Basis		Duration	Marks
1	Continuous Evaluation	Mid Term Presentation (Intermediate Results/Innovation in Work)	-	10
2		Pre-Submission Presentation (Results Obtained/Dissertation Outcome)	-	20
3		Final Dissertation Report/Attendance (awarded by supervisor)	-	20
4	End Semester Examination	Publication of Research Paper(s)*	-	10 (Max)
5		Supervisor on the basis of Dissertation Work		10
6		External Examiner on the basis of Dissertation Evaluation		10
7		Board of Examiners based on merit of dissertation and viva-voce performance.		20

Any student securing less than 40 marks ('F' grade) shall have to repeat the Dissertation Part-II in the next semester.

*Publication of Research Paper(s) jointly with supervisor in Refereed Journal/Conferences. These marks are to be awarded by the Board of Examiners.

(i) upto 10 marks for the paper(s) Published/Accepted for publication in Referred Journal.
(ii) upto 8 marks for the paper(s) to be considered for possible publication in Referred Journal i.e. on production of acceptance with revision.
(iii) upto 5 marks for the paper(s) communicated for possible publication in a Referred Journal/Presented or accepted/communicated for possible presentation in a Conference of repute.

Note: *In case a student is allowed to work in an Institute/industry other than HBTU Kanpur, a certification from the co-guide of that Institute/ industry for the progress of work (satisfactory/unsatisfactory) is required.*
Plagiarism checking is mandatory and will be carried out by the Examination cell for ensuring originality of submitted content of dissertation. After pre-submission presentation, a soft copy of dissertation in word format must be forwarded by supervisor and Head of Department to Examination Cell. The dissertation has to be checked by anti-plagiarism software before loose binding and sending it for evaluation. If any text strings/figures are found to be copied or dubious without proper acknowledgement of the source or the percentage of plagiarism exceeds the approved limit as prescribed by the University from time to time, the dissertation has to be thoroughly revised and resubmitted after presentation in the department.

The Examiners must be of no lower than the rank of Associate Professor of the concerned discipline. The examiners should be a faculty of IITs/NITs/ reputed engineering colleges or Universities/ industrial professionals from concerned discipline/scientists from central, state and regional labs.

Those who change the dissertation sub-area will be allowed to submit the thesis not before six months from the date of change of area. However, such change is not permissible in semester IV. The students are encouraged to take the dissertation problem worth patenting.

SYLLABUS

NPH-501: Mathematical Physics

Course Category	Paper Code	Subject Name	L	T	P	Credits
PCC	NPH-501	Mathematical Physics	3	1	0	4

Course Assessment:
Continuous/Sessional assessment through
Two Mid Semester Exam (1 Hrs each): 15+15=30 Marks,
TAQ (Tutorials/Assignments/Quizzes): 20 Marks
End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs):
1. Gain a strong understanding of the mathematical tools used in physics, including vector calculus, linear algebra, and eigenvalue analysis.
2. Learning problem-solving tools related to differential equations and special functions.
3. To learn the basics of complex analysis and various series.
4. To gain knowledge about the tensors.
5. To acquire proficiency in integral transform.

UNIT I

Vector Calculus, Linear Algebra and Matrices: vector calculus, Green's theorem, Stoke's theorem, Linear algebra, matrices: operations, determinants, eigenvalues and eigenvectors, diagonalization, linear systems, Cayley-Hamilton theorem and its applications.

UNIT II

Differential Equations and Special Functions: Linear ordinary differential equations, separable equations, integrating factor methods, linear equations, exact equations, homogeneous and non-homogeneous equations, solution methods (undetermined coefficients, variation of parameters), Bessel functions, Hermite functions, Legendre polynomials, Laguerre polynomials, properties and applications of these functions.

Unit III

Complex Analysis: Elements of complex analysis, analytic functions; Taylor & Laurent series; poles, residues, and evaluation of integrals. elementary probability theory, random variables, binomial, Poisson, and normal distributions, central limit theorem.

UNIT IV

Tensor Analysis: Tensor Algebra, linear combinations, direct product, contraction, tensor densities, the transformation of an affine connection, covariant differentiation, gradient, curl, and divergence.

UNIT V

Integral Transform: Laplace transform, development of Fourier integral, Fourier sine/cosine transforms-inversion theorem, convolution theorem, momentum representation, transfer functions, Neumann Series, separable Kernels, Hilbert-Schmidt theory.

Books & References:

1. G. B. Arfken, Mathematical Methods for Physicist (Academic Press), 7th edition, 2011, Elsevier
2. A. W. Joshi, Elements of Group Theory for Physicist (New Age)
3. Mary L. Boas, Mathematical Methods in the Physical Sciences, 4th edition, 2019, Wiley
4. Heather Whitney, and Joshua Whitney, Handbook of Mathematical Methods, and Problem- Solving Tools for Introductory Physics, 2009, IOP Publishing Ltd.
5. Richard Courant and David Hilbert, Methods for Mathematical Physics, 2nd edition, 2000, Wiley-VCH.

NPH-503 Classical Mechanics

Course Category	Paper Code	Subject Name	L	T	P	Credits
PCC	NPH-503	Classical Mechanics	3	1	0	4

Course Assessment:
Continuous/Sessional assessment through
Two Mid Semester Exam (1Hrs each):15+15=30Marks,
TAQ (Tutorials/Assignments/Quizzes): 20 Marks
and End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs):

1. To study the dynamics, stability, and conservation laws of systems.
2. To study the rigid body dynamics.
3. To analyze a classical system under Lagrangian formalisms.
4. To study and apply variational principle in classical systems.
5. To study Hamilton and Lagrange's based problems

Unit-I

Mechanics of a Single Particle and of System of Particles: Newton's laws of motion, motion of a charged particle in an electromagnetic filed, motion of a system with variable mass, Dynamical systems, stability of circular orbits, Equivalent one-body problem, Motion in a central force field, equation of orbit, Kepler'slaw of planetary motion,

Unit-II

Rigid Body Dynamics: Euler's theorem, angular momentum and kinetic energy, calculus of variation –Euler-Lagrange Equation, Variational principle: configuration space, techniques of the calculation of variation, applications of variational principle.

Unit-III

Lagrangian Formalism: Constraint, classification of constraints, virtual displacement and principle of virtual work, generalized coordinates, Generalized momenta, D'Alembert's principle, Lagrange's equations, symmetries and conservation laws, cyclic coordinates. Lagrange's Equations.

Unit-IV

Variational Principle: Hamilton's principle, Lagrange's Equations from Hamilton's principle, problem based on Lagrange's Equations, Principle of least action.

Unit-V

Hamilton mechanics and Canonical Transformation: Hamilton's equations and problems based on it, Canonical transformation, Generating function, Poisson brackets and their properties, invariance of Poission bracket under canonical transformations.

Reference Books:

1. Mechanics: Course of Theoretical Physics, Volume1, Sixth Edition, Elsevier Butter worth-Heinemann, 2017
2. Classical Mechanics and Relativity, Herald J.W. Muller-Kirsten, (World Scientific,2008)
3. Classical Mechanics, H. Goldstein, (3rd Edition, Addison-Wesley, 2001)
4. Classical Mechanics of Particles and Rigid bodies, K.C. Gupta, (John Wiley,1988)
5. Advanced Classical and Quantum Dynamics, W. Dittrich, W. M. Reuter, (Springer, 1992)
6. Classical Mechanics, T.W. Kibble, Frank H. Berkshire, (Imperial College Press,2004)
7. Mathematical Methods of Classical Mechanics, V.I. Arnold, (Springer, 1989)
8. Classical Mechanics, Rana & Joag, (Tata McGraw Hill, 2001)

NPH 505 Quantum Mechanics

Course Category	Paper Code	Subject Name	L	T	P	Credits
PCC	NPH-505	Quantum Mechanics	3	1	0	4

Course Assessment:
Continuous/Sessional assessment through
Two Mid Semester Exam (1 Hrs each): 15+15=30 Marks,
TAQ (Tutorials/Assignments/Quizzes): 20 Marks
End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs):
1. The students will develop the foundation for understanding Quantum mechanics.
2. The student will understand the concepts of quantum mechanics and solving operator equations for different quantum problems.
3. Apply the Schrödinger Equation to analyze the one-dimensional motion.
4. The students will understand wave mechanical formulation of quantum particles and various rules arising out of it.
5. Understand the concept of adding angular momenta and apply the general formalism of angular momentum algebra.

Unit-I
Mathematical Preliminaries: Mathematical preliminaries and the foundational concept of Hilbert space, dimension and basis of a vector space, linearly independent and dependent vectors, wave functions and the essential framework of Dirac's bra and ket notations, fundamental properties of kets, bras, and bra-kets operators, linear operators, Hermitian adjoint, Hermitian and skew-Hermitian operators, projection operators, properties of projection operators, Matrix representation of kets, bras, and operators

Unit-II
Applications of the Schrödinger Equation: Properties of One-Dimensional motion, discrete spectrum, bound States, continuous spectrum, unbound states, symmetric potentials, nondegenerate and degenerate states, Schrodinger equation and the free particle solution, wave packets concepts

Unit-III
Theory of Orbital Angular Momentum: Angular momentum, orbital angular momentum, orbital, spin and total angular momentum operators, commutation relations, general formalism of angular momentum, eigenstates and eigenvalue equations of the angular momentum operator

Unit-IV
Theory of Spin Angular Momentum: Electron spin hypothesis, spin angular momentum, relation between spin angular momentum and total angular momentum operators, commutation relations, general theory of spin, Pauli's spin matrices and eigenvalue equations, general formalism, eigenstates and eigenvalues equations of the spin momentum operator.

Unit-V
Addition of Angular Momentum: Addition of angular momenta, general formalism in angular momentum algebra, eigenvalues of J_2 and J_z, Clebsch-Gordon coefficients

NPTEL courses and resources:
- **Quantum Mechanics II:** https://nptel.ac.in/courses/115104096
- **Foundations of Quantum Mechanics:** https://nptel.ac.in/courses/115101107

Books & References:
1: Quantum Mechanics: Concepts & Applications, Nouredine Zettili (John Wiley & Sons), 2nd Edition (2017)
2: Modern Quantum Mechanics by J. J. Sakurai (Pearson Education India), 3rd Edition (2014)
3: Quantum Mechanics, Vol. (I) by Albert Messiah (North Holland Publishing Company, Amsterdam, 1961)
4: Concepts in Quantum Mechanics by V. S. Mathur and Surendra Singh (CRC Press), 2nd Edition (2013)
5: Quantum Mechanics by L.I. Schiff (Mc-Graw Hill Inc.)

6: Quantum Mechanics by B. K. Agarwal and Hari Prakash (Prentice-Hall of India Pvt Ltd, New Delhi, 2005)
7. Quantum Mechanics by Ajoy K Ghatak (McMillan Co. of India), 2005

NPH-507 Electronics

Course Category	Paper Code	Subject Name	L	T	P	Credits
PCC	NPH-507	Electronics	3	0	2	4

Course Assessment:
Continuous/ Sessional assessment through
One Mid Semester Exam (1Hrs each):15 Marks, TAQ (Tutorials/Assignments/Quizzes): 20 Marks
Lab Exam: 15 Marks
And End Semester Examination (2.5 Hours): 50 Marks
Course Outcomes (COs):

1. Understand various types of semiconducting materials, p-n junctions, and various breakdown mechanisms.
2. Learn the concepts of BJT and FET structure, their working mechanism, and various characteristics.
3. Develop understanding about Operational amplifiers in various configuration mode, their use for practical applications.
4. Understand and learn about basic concepts number systems, combinational and sequential circuits for digital circuit's applications.
5. Develop basic understanding of advance electronic devices based on semiconductor materials

Unit-I
Semiconductor Physics
Intrinsic and extrinsic semiconductors, charge densities in p- and n-type semiconductors, conduction by charge drift and diffusion, the p-n junction, energy level diagrams of the p-n junction under forward and reverse bias conditions, derivation of diode equation, Zener and avalanche breakdowns,

Unit-II
Transistor: BJT: basic working principle, current components in BJT: common emitter, common base operation and common collector operation, different modes of operation, input & output characteristics,
The basic working principle of bipolar junction transistor (BJT), configurations and characteristics, Transistor hybrid model, h parameters, analysis of a Transistor amplifier circuit using h parameters.

Unit-III
Operational Amplifier Circuits
Basic Characteristics and parameters of Operational Amplifier (Op-Amp), ideal characteristics, Op-Amp as inverting amplifier, effect of finite open loop gain, generalized basic equation of Op-Amp with impedances, integrator and differentiator, inverting and non-inverting summer, voltage follower. Op-Amp parameters, offset voltage and current, slew rate, full wave BW, CMRR. Op-Amp as voltage regulator.

Unit-IV
Digital Circuits
Number systems, Logic simplification using K-maps, SOP and POS design of logic circuits, demultiplexer, decoder, encoder, latches, flip-flops-SR, J-K, D, T, and master slave–characteristics table and equation-clock timing diagrams, shift register, serial and parallel configuration, shift register counters, ring counter, Johnson counter, asynchronous ripple or serial counter-asynchronous up/ down counter.

Unit-V

Semiconductor Devices

Light emitting diodes (LED), tunnel diode, gunn diode, semiconductor laser, photodiodes, solar cell, IMPATT devices, liquid crystal displays (LCD).

NPTEL courses and resources:

- **Basic Electronics:** https://nptel.ac.in/courses/122106025
- **Analog Electronics:** https://nptel.ac.in/courses/108102112
- **Digital Electronics:** https://nptel.ac.in/courses/108105132

Books & References:

1. Solid State Electronic Devices, B. G. Streetman and S. Banerjee, PrenticeHall,2000
2. Milman J. and Halkias C.C., Electronic Devices and Circuits, Tata McGraw-Hill,1993
3. Semiconductor Physics and Devices by D. A. Neamen, (3rd Ed.,Tata McGraw-Hill),2002.
4. Electronic Principles by A.P. Malvino (Tata McGraw, New Delhi),7th edition, 2009.
5. Electronic Devices and Circuits Theory: Boylested and Nashelsky, (Pearson Education)10th ed. 2009.

List of Experiments

1. Identification of basic electronic component and measurement of frequency of Cathode Ray Oscilloscope (CRO).
2. To understand the working principle and practical applications of an Op-Amp.
3. To measure and analyze current-voltage (I-V) characteristics of p-n junction and Zener diode.
4. Analysis of I-V characteristics of LEDs and determination of Planck's constant.
5. Input and output characteristics of Bipolar Junction Transistor (BJT) in CE/CC/CB configuration.
6. Study the Flip-Flop circuit using basic elementary gates.

NPH-509 Materials Science and Technology

Course Category	Paper Code	Subject Name	L	T	P	Credits
ESC	NPH-509	Materials Science and Technology	3	1	0	4

Course Assessment: Continuous/Sessional assessment through
Two Mid Semester Exams (1 Hrs each): 15+15=30 Marks
TAQ (Tutorials/Assignments/Quizzes): 20 Marks
Lab Exam: 15 Marks
End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs): The students will be able to

1. Understand the fundamental principles of materials science: (e.g., crystal structures, bonding, electronic structure, phase transformations, electrical and optical behavior, etc.)
2. Evaluate different synthesis and processing techniques for various materials.
3. Analyze and anticipate future trends in materials science and engineering.
4. Explore emerging applications of materials in diverse fields: (e.g., energy, electronics, healthcare, aerospace, etc.)
5. Develop critical thinking and problem-solving skills in the context of materials engineering and become familiar with the latest advancements and research trends in materials science and technology.

Unit-I:
Foundations of Materials Science: Introduction to Materials Science, Electronic Structure and Properties, Thermal Behavior: Phase Diagrams and Transformations, Electrical and Optical Properties of Materials

Unit-II:
Materials Processing and Characterization: Synthesis and Processing Methods, Functional Materials and Applications: Electronic Materials and Applications, Ionic Materials and Devices, Energy Materials and Technologies, Advanced Composite Materials and Structures

Unit-III:
Functional Materials and Applications: Liquid crystal, Ionic Materials and Devices: Batteries, fuel cells, and other electrochemical devices, Energy Materials and Technologies: Advanced Composite Materials and Structures: Composites design, properties, and applications.

Unit-IV:
Emerging Trends and Future Directions: Sustainable Materials and Green Technologies, Ethical and Societal Implications of Materials Technologies, Future Directions in Materials Science and Engineering

Unit-V:
Fundamentals of Different Materials for Technological Applications: Fundamentals of Energy Materials, Introduction to Energy Storage and technologies: Electrolytes, Cathode materials, Anode materials, Binders and Separators, batteries, supercapacitors

NPTEL Courses

- **Advanced Materials Science:** https://onlinecourses.nptel.ac.in/noc19_mm13/preview
- **Materials Science and Engineering-II:** https://onlinecourses.nptel.ac.in/noc22_mm05/preview

Books & References:

1. B.S. Murthy, "Advances in Materials Science and Engineering", Elsevier, 2014.
2. J.H. Simmons and W.D. Callister Jr., "Materials Science for Engineers an Interactive Learning Approach", 3rd Edition, Wiley, 2013.
3. Luque, A., & Hegedus, S. (2011). Handbook of photovoltaic science and engineering. John Wiley & Sons.
4. Vielstich, W., Lamparter, A., & Gasteiger, H. (2013). Handbook of fuel cells: Fundamentals, technology and applications. John Wiley & Sons.
5. Sze, S. M. (2022). Physics of semiconductor devices
6. Goodenough, J. B. (2012). Why batteries matter: The science and economics of the energy revolution. Yale University Press.
7. Dresselhaus, M. S., & Mavronicolas, V. P. (2010). Materials science of semiconductors: Volume 1. Springer.
8. W.D. Callister Jr., "Materials Science and Engineering: An Introduction", 9th Edition, Wiley, 2013

NPH-500 Electromagnetic Theory

Course Category	Paper Code	Subject Name	L	T	P	Credits
PCC	NPH-500	Electromagnetic Theory	3	1	0	4
Course Assessment: Continuous/ Sessional assessment through Two Mid Semester Exam(1Hrseach):15+15=30 Marks TAQ (Tutorials/Assignments/Quizzes): 20 Marks						

End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs):

1. Grasp the fundamentals of electric Fields and their practical applications.
2. Explore the core principles of magnetic fields and their real –world uses.
3. The students will understand various physics of electromagnetic waves.
4. Understand the Maxwell's equation and solve its problem.
5. The students will be able to demonstrate problem-solving abilities and analyze scenarios involving electromagnetic phenomena.

UNIT- **I**

Electrostatics:

The Electric field, principle of superposition, Coulomb's law, Gauss's law, and applications of Gauss's law, Solution of electrostatic problems in Cartesian, spherical, and cylindrical coordinates.

UNIT-II

Magnetostatics:

Biot- Savert's law, differential equation for static magnetic field, Faraday's law of induction, Ampere's law, modification of Ampere's law, magnetic energy of steady state current.

UNIT-III

Maxwell's Equation:

Displacement current, differential and integral form of all electromagnetic equation and its physical significance, Maxwell's equation, vector and scalar potential, gauge symmetry, Coulomb's and Lorentz gauges, electromagnetic energy and momentum, conservation law in homogeneous wave equation.

UNIT-IV

Electromagnetic Waves

Maxwell's wave equations in free space and physical significance, plane wave in vacuum non-conducting medium, conducting medium, and polarization of electromagnetic wave, Poynting theorem, skin depth.

Unit-V:

Applications of Electrodynamics

Wave guide, propagation in rectangular wave guide, TE and TM modes, relativistic electrodynamics, Electromagnetic tensor, covariant formulation of Maxwell's equations

NPTEL courses and resources:

- **Electromagnetic Theorycourse:**https://onlinecourses.nptel.ac.in/noc23_ee97/preview
- **Introduction to ElectromagneticTheory:**https://onlinecourses.nptel.ac.in/noc21_ee83/preview

Books & References:

1. David J. Griffith-Introduction to Electrodynamics, Fourth Edition, Prentice Hall, 2013
2. L. D. Landau & E. M. Lifshitz- Electrodynamics of Continuous Media, Pergamon Press1960
3. J. D. Jackson, Classical Electrodynamics, Wiley
4. Andrew Zangwill, Modern Electrodynamics, Cambridge University Press, 2013, United Kingdom,
5. Parcell, Edward M., Electricity and Magnetism, 2ndEdition, McGraw-Hill Company,1985
6. S. P. Puri, Classical Electrodynamics, (Narosa Publishing House)2011.
7. A. Z. Capriand, P. V. Panat, Introduction to Electrodynamics, (Narosa Publishing House)2010
8. Saroj K. Dash & Smruti R. Khuntia-Fundamentals of Electromagnetic Theory, PHI
9. Edward C. Jordan, Electromagnetic Waves and Radiating System, Prentice Hall Electrical Engineering Series.

NPH-502 Thermodynamics and Statistical Mechanics

Course Category	Paper Code	Subject Name	L	T	P	Credits
PCC	NPH-502	Thermodynamics and Statistical-Mechanics	3	1	0	4

Course Assessment: Continuous/Sessional assessment through
Two Mid Semester Exam(1Hrseach):15+15=30Marks,
TAQ (Tutorials/Assignments/Quizzes): 20 Marks
End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs):

1. To acquire knowledge about the behaviors of gases
2. To gain knowledge about the fundamentals of thermodynamic systems
3. To understand the applicability of various empirical relations of thermodynamics
4. Understanding the basics of statistical physics
5. To learn the applications of classical and quantum statistics

UNITI
First Law of Thermodynamics
Thermodynamics equilibrium, thermodynamic processes, configuration work and dissipative work, internal energy, heat of transformation, heat capacity, Enthalpy, the first law of thermodynamics, work done in different processes, The difference between specific heats (Mayer's relation),

UNITII
Thermodynamic Systems: Heat Engines: Rankine cycle, Otto cycle, Diesel cycle. thermal efficiency, second law of thermodynamics, Carnot cycle, Carnot's theorem, refrigerator, different statements of the second law, reversible and irreversible processes, entropy, entropy change in reversible and irreversible processes

UNIT III Thermodynamic potentials
The Helmholtz function and Gibbs function, thermodynamics potentials Maxwell’s relations and TdS equations, the Clausius- Clapeyron latent heat equation, The third law of thermodynamics, chemical potentials

UNITIV
Micro and Macro States: Phase space, macrostates and microstates, postulates of statistical mechanics, Liouville’s Theorem in classical statistical mechanics, micro-canonical, canonical and grand-canonical ensembles and their comparative study and partition functions; fluctuation of energy, Free energy and its connection with thermodynamic quantities, Entropy of mixing of gases (Ising partition function), Gibbs paradox and its resolution.

UNITV
Phase Transitions: Degenerate Fermi gas, Ideal Bose and Fermi gases, Maxwell-Boltzmann, Bose –Einstein Equation and Fermi-Dirac statistics, and Bose-Einstein condensation, blackbody radiation and Planck's distribution law, first-and second-order phase transitions. phase equilibria, critical point. The Ising model, Exact solution of Ising model in one-dimension, mean field solution in higher dimensions.

Books & References:

1. Frederick Reif, Fundamentals of Statistical and Thermal Physics, Wavel and PrInc,2008.
2. F.W. Sears and G.L. Salinger Thermodynamics Kinetic Theory and Statistical Thermodynamics, Narosa Publishing House, 1998
3. Kerson Huang, Statistical Mechanics, Wiley,2ndEd., 1987.
4. R K Pathria, Paul D. Beale, Statistical Mechanics, Academic Press,3rd Ed.,2011.
5. Statistical Mechanics, Richard P. Feynman, West view Press, USA, 2008

NPH-504 Solid State Physics

Course Category	Paper Code	Subject Name	L	T	P	Credits
PCC	NPH-504	Solid State Physics	3	0	2	4

Course Assessment:
Continuous/Sessional assessment through
One Mid Semester Exam (1 Hrs each): 15 Marks,
TAQ (Tutorials/Assignments/Quizzes): 20 Marks
Lab Exam: 15 Marks
and End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs):
1. Understand fundamental knowledge about crystal structures and defects in solids.
2. Learn concepts of X-ray diffraction and various bonding mechanism in crystals
3. Develop understanding about the behavior of electrons in solids and fundamental equations.
4. Learn various magnetic properties of solids, their origin, and fundamental concepts.
5. Learn various properties and applications of superconducting materials.

Unit-1 9
Crystalline and Amorphous Solids: Crystal structures, Bravais lattices, basis vectors, unit cell, various symmetry operations, Point groups and space groups, Miller indices, Directions and planes in crystals, Inter-planar spacing, Simple Crystal (SC), BCC, FCC, HCP crystal structures. Various kinds of crystal imperfections, point defect, Schottky and Frenkel defect, Dislocations, edge and screw dislocation, grain boundary.

Unit-II 9
X-ray Diffraction and Various Bonds: Bragg's law, Laue pattern, X-ray diffractometer, determination of lattice parameter using XRD, absorption of X-rays, absorption edge. Primary and secondary bonds, ionic bond, covalent bond, metallic bond, hydrogen bond, Vander-waals bond, forces between atoms, cohesive energy.

Unit-III
Band Theory: Free electron model, Bloch theorem, Electrons in a periodic potential, Kronig-Penny model, Band theory of solids, effective mass, concept of hole, direct and indirect band gap semiconductors, Fermi-Distribution function, Electrical and thermal conductivity of metals and semiconductors, Hall effect.

Unit-IV
Magnetic Properties of Materials: Magnetic Properties of Materials, Diamagnetism, Langevin equation, Quantum theory of Para magnetism, Curie law, paramagnetic in rare earth and iron group ions, Elementary idea of crystal field effects, Ferromagnetism, Curie-Weiss law, Anti-ferromagnetism, Neel Temperature.

Unit –V
Superconductivity: Superconductors, Type– I and Type – II superconductors, Meissner effect, BCS Theory, Coherence and phase of Cooper pairs, London's equations, penetration depth, Thermodynamic properties of superconductors: Entropy and specific heat, Application of superconductors: Josephson effect: dc and ac effects, superconducting quantum interference device (SQUID).

NPTEL courses and resources:
• Solid State Physics course: https://nptel.ac.in/courses/115105099
• Physics of Solids course: https://nptel.ac.in/courses/115105099

Reference /Text Books:
1. Introduction to Solid State Physics, C. Kittel (Wiley, New York 2019)
2. Principles of the Theory of Solids, J. Ziman (Cambridge University Press, 1972)
3. Solid State Physics, H. Ibach and H. Luth (3rd edition Springer Berlin, 2002)
4. Solid State Theory, Walter A. Harrison (Tata McGraw-Hill, New Delhi 1970)

List of Experiments

1. To determine the type of charge carrier and carrier concentration of a given semi-conductor Materials using Hall effect.
2. To measure the resistivity of a Ge/Si semiconductor using four probe method with varying Temperature and calculate the band gap.
3. Study of B-H curve and hysteresis loss in Ferromagnets.
4. Analysis of Magnetic Susceptibility

References:

1. Introduction to Solid State Physics by C.Kittel (Wiley Eastern, New Delhi)
2. Solid State Physics by N.W. Ashcroft and N.D. Mermin, Brooks/Cole
3. Elementary Solid-State Physics: Principle and Application by Omar Ali (Addison Wesley, London)
4. Quantum Theory of Solid by C. Kittel (John Wiley and Sons, London)

NPH-506 Nuclear and Particle Physics

Course Category	Paper Code	Subject Name	L	T	P	Credits
PCC	NPH-506	Nuclear and Particle Physics	3	1	0	4

Course Assessment:
Continuous/Sessional assessment through
Two Mid Semester Exam (1 Hrs each): 15+15=30 Marks,
TAQ (Tutorials/Assignments/Quizzes): 20 Marks
End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs):
1. To analyze nuclear structure, its energy and conservation laws.
2. Analysis of various kinds of nuclear models.
3. To study and analyze nuclear radiations.
4. Analysis of elementary particles and their characteristics.
5. To study nuclear detectors and applications of nuclear reactions.

UNIT I

Basic Nuclear Properties: Constituents of nucleus, nuclear size, mass, charge, density, spin and parity, Nature of the nuclear force, Binding energy, mass defect, packing fraction, fusion and fission, nuclear angular momentum, nuclear magnetic dipole moment, electric quadrupole moment.

UNIT II

Nuclear Models: Single-particle model, Liquid drop model, semi- empirical mass formula, Mass of most stable isobars, Achievements and Failures of Liquid Drop Model. form of nucleon-nucleon potential, Deuteron problem. shell model; Magic numbers, the spin-orbit coupling, evidences of shell structure, achievements and failures of Shell model., rotational spectra.

Unit III

Nuclear Radiations: Laws of disintegration, radioactive series, law of successive disintegration, alpha emission, alpha spectrum, Gamow theory of alpha decay, beta decay; conditions for spontaneous emission, electron capture, neutrino antineutrino and their detection. Gamma decay; internal conversion, internal Pair conversion, interaction of gamma ray with matter, selection rules of alpha, beta, and gamma decay, nuclear reactions, types of nuclear reactions, compound nuclei and direct reactions.

UNIT IV

Elementary Particles: Classification of fundamental forces, types of interactions, elementary particles and their classification mass spectra and decays of elementary particles, Leptons, Hadrons, Mesons, Baryons quantum numbers (charge, spin, parity, isospin, strangeness, etc.). Gell Mann-Nishijima formula. Quark model, baryons and mesons. C, P, and T invariance. application of symmetry arguments to particle reactions, parity non conservation in weak interaction.

UNIT V

Nuclear detectors and Applications: Gas detectors: GM counter, proportional counter, scintillation detectors, semiconductor detectors, Particle accelerators, applications of nuclear physics in medicine, agriculture, and industry.

Books & References:

1. Concepts of Nuclear Physics by B.L. Cohen (Tata McGraw Hill)
2. Nuclear Physics by I. Kaplan (Addison-Wesley)
3. Introduction to Elementary Particles by D. Griffiths (Academic Press, 2nd ed. 2008)
4. Nuclear and Particle Physics: An Introduction by B. R. Martin (Wiley, 2006)
5. Physics of Nuclei and Particles by Pierre Marmier and Eric Sheldon (Elsevier)
6. Nuclei and Particles by Emilio G. Segre (2nd ed. Basic Books)
7. Introduction to Nuclear and Particle Physics by A. Das and T. Ferbel (World Scientific)

NPH-508 Physics of Semiconducting Devices & Technology

Course Category	Paper Code	Subject Name	L	T	P	Credits
ESC	NPH-508	Physics of Semiconducting Devices & Technology	3	0	2	4

Course Assessment:
Continuous/ Sessional assessment through
One Mid Semester Exam(1Hrseach):15Marks, TAQ (Tutorials/Assignments/Quizzes): 20 Marks
Lab Exam: 15 Marks
End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs): Students will be able to

1. Learn fundamental knowledge about metal-semiconductor junctions.
2. Develop basic concepts of Homojunction and Hetero junction's devices.
3. Learn fundamental concepts of FET, and their characteristics.
4. Develop fundamental understanding of MOSFET and their characteristics.
5. Understand fundamentals of various devices of technological importance.

Unit-I

Metal-Semiconductor junction: Band diagram, depletion region and junction capacitance, junction breakdown, Ohmic and rectifying contacts, Schottky Diodes, Schottky diode under bias, Fermi level pinning & surface states, image force lowering.

Unit-II

Homojunction and Heterojunction: p-n junction, band diagram and potential profiles in p-n junctions, depletion capacitance, p-n junctions under various biasing conditions, diode characteristics, diffusion capacitance, degenerate p-n junctions: tunnel diode, I-V characteristics, heterojunctions, types of heterojunctions, concept of 2DEG, modulation doping.

Unit-III

Field-Effect Transistors (FET): Structure, Working, Construction and characteristics of JFET, transfer characteristic, Measurement of gm and rd, JFET fixed bias, self-bias and voltage divider configurations, JFET source follower (common-drain) configuration, JFET common-gate configuration

Unit-IV

MOSFET: Structure and operating principle, construction& principle of operation of p-& n-channel enhancement& depletion mode, pinch-off and saturation. MOSFET: derivation of I-V, gradual channel approximation, sub-threshold current & S slope; device scaling and Moore's law.

Unit-V

Device of Technological importance: Light Emitting Diodes (LEDs), solar cell, photodiode, phototransistor, single electron transistors (SET), High electron mobility transistor (HEMT), bipolar Transistor (HBT), resonant tunneling diode (RTD)

Experiments:

1. To study the output and transfer characteristics of MOSFET and to determine the threshold voltage
2. To study the output and transfer characteristics of FET and to determine the threshold voltage
3. To explore I-V characteristics of a tunnel diode and to determine the negative coefficient of resistance
4. Measurement of Planck's constant using LED.

To stud

NPTEL courses and resources:

1. **Physics of Semiconductor or Devices course:**
   https://onlinecourses.nptel.ac.in/noc23_ee82/preview

Books & References:

2. Solid State Physics by A-J. Dekkar (McMillan and Co., London)
3. Introduction to Solid State Physics by C. Kittel (Wiley Eastern, New Delhi)
4. Semiconductor Physics and Devices by D. A. Neamen,(3rdEd.,Tata Mc-Graw-Hill),2002.
5. Fundamental of Semiconductor Fabrication by SM Sze
6. The Science and Engineering of Microelectronic Fabrication by Stephen A Campbell
7. Semiconductor Material and Device Characterization, 3rd Edition, D. K. Schroder, Wiley-IEEE Press (2006).

NPH-601 Atomic, Molecular Physics and Lasers

Course Category	Paper Code	Subject Name	L	T	P	Credits
PCC	NPH-601	Atomic, Molecular Physics and Lasers	3	0	2	4

Course Assessment:
Continuous/Sessional assessment
through
One Mid Semester Exam. (1Hrs. each):15 Marks,
TAQ (Tutorials/Assignments/Quizzes): 20 Marks
Lab Exam: 15 Marks
End Semester Examination (2.5Hours): 50 Marks

Course Outcomes (COs):
1. Understand the basics of spectroscopy.
2. Able to analyze the spectral components of Helium and alkali atoms.
3. Learn about the spin-orbit interaction
4. Understand molecular spectral components.
5. Familiar with lasers and their applications.

Unit-I
Basics of Spectroscopy: Introduction to Quantum theory, spin orbit interaction energy, spectroscopic, description of atomic electronic states-term symbols, fine structure of hydrogen lines, solution of radials equations for hydrogen atom, Rydberg Schruster law, Runge's law,

Unit-II:
Spectroscopy of Helium and Alkali Atoms: Special distribution and exaction values of the electron in different quantum states, electron spin, Spectrum of helium; symmetry of the wave function, energy levels of the Helium atom, alkali atom. relativistic corrections for energy levels of Hydrogen atom, hyperfine structure; Zeeman Effect of Hyperfine structure levels.

Unit-III
Spin-Orbit Interaction Spectroscopy: Fine structure, anomalous and normal Zeeman Effect, Paschen-back effect and Stark effect, electron spin resonance, Nuclear magnetic resonance, LS & JJ couplings. Zeeman, Paschen-Bach & Stark effects. Electron spin resonance. Nuclear magnetic resonance.

Unit-IV
Molecular Spectral Analysis: Microwave spectroscopy-rotational spectra, diatomic and polyatomic molecules**,** rotational vibrational spectra of diatomic molecules, Raman spectroscopy-pure rotational Raman spectra**,** rigid rotator.

Unit-V
Lasers: Physical principles, spontaneous and stimulated emission, Einstein A& B coefficients, optical pumping, generation of population inversion, rate equation. optical resonators, different types of Lasers

List of Experiments
1. To study Zeeman effect using Na lamp.
2. Determination of wavelength of spectral lines of mercury using plane transmission grating.
3. Determination of wavelength of hydrogen spectral lines and calculation of Rydberg constant.
4. Determination of wavelength of sodium light using Newton's rings method.

Books & References:

1: Physics of Atoms and Molecules by B.H. Bransden and C.J. Joachain, Pearson
2: Quantum Chemistry by I.N. Levine, Prentice Hall
3: Quantum Mechanics by L.D. Landau and E.M. Lifshitz, Pergamon Press
4: Molecular Quantum Mechanics by P.W. Atkins and R.S. Friedman, Oxford University Press
5: Atomic & Molecular Spectra: Laser by Rajkumar, Kedar Nath and Ram Nath, Meerut.
6: Introduction to Spectroscopy by Donald L. Pavia, Gary M. Lampman, George S. Kriz, James R. Vyvyan, Cengage Learning Pvt. Limited.
7: Molecular Structure and Spectroscopy by G. Aruldhas, PHI, Learning Pvt. Limited.
8: Atomic, Laser and Spectroscopy by S.N. Thakur and D.K. Rai, Prentice Hall of India, New Delhi, India

NPH-603 Nano Science and Technology

Course Category	Paper Code	Subject Name	L	T	P	Credits
PCC	NPH-603	Nano Science and Technology	3	1	0	4

Course Assessment:
Continuous/Sessional assessment through
Two Mid Semester Exam (1 Hrs each): 15+15=30 Marks,
TAQ (Tutorials/Assignments/Quizzes): 20 Marks
End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs): Students will be able to
1. Understand the fundamental concepts and principles of nanoscience and technology
2. Gain comprehensive knowledge of various nanofabrication and characterization techniques: Explore different methods for creating and analyzing nanomaterials.
3. Identify and analyze the potential applications of nanotechnology in physics-related discipline.
4. Stay informed about the latest advancements and ethical considerations in nanoscience and technology
5. To develop critical thinking and problem-solving skills in the context of nanoscience and nanotechnology.

UNIT I

Introduction to Nanoscience and Technology: History and evolution of nanoscience and technology, Basic principles of quantum mechanics and their relevance to nanoscale phenomena, classification of nanomaterials: zero-dimensional, one-dimensional, two-dimensional, and three-dimensional.

UNIT II

Synthesis of Nanomaterials: Top- down approaches: ball milling, lithography, bottom- up approaches: sol-gel methods, chemical vapour deposition (cvd), hydrothermal synthesis, self- assembly techniques.

Unit III

Properties of Nanomaterials: Structural properties, optical properties, electrical properties, magnetic properties, mechanical properties, size-dependent properties.

UNIT IV

Applications of Nanomaterials in Physics: Nanoelectronics and nanoscale devices: transistors, sensors, and flexible electronics, Nanostructured materials for energy applications: batteries, supercapacitors, fuel cells and solar cells, Nanomedicine, and drug delivery: targeted drug delivery.

UNIT V

Future Trends, Ethics, and Research Discussions: Emerging areas and future trends in nanoscience and technology, ethical considerations and potential risks associated with nanotechnology, discussion and presentations on recent research advancements in specific areas of interest.

NPTEL courses and resources:

- **Nano Science and Technology:** https://nptel.ac.in/courses/113106093

Books & References:

8. Nanotechnology: Principles and Applications by Richard Bandyopadhyay (Springer, 2013)
9. Introduction to Nanoscience and Nanotechnology by Gabor F. Somorjai (Wiley, 2010)
10. Physics of Nanomaterials by Hari Singh Nalwa (Academic Press, 2004)
11. Characterization of Nanoparticles: Physicochemical Techniques by Ivan Kralchevsky et al. (Elsevier, 2017)
12. Nanoworld: Science and Technology in the Nanoscale by Michael S. Dresselhaus et al. (Springer, 2014)
13. The Fundamentals of Nanoscience and Nanotechnology" by C.P. Poole Jr. and Frank J. Owens
14. Introduction to Nanoscience by James F. Jones 8. "Nanoscale Science and Technology" by Robert K. Sharma and Michael R. Köhler

NPH-605 Spintronics: Fundamentals and Applications

Course Category	Paper Code	Subject Name	L	T	P	Credits
ESC	NPH-605	Spintronics: Fundamentals and Applications	3	1	0	4

Course Assessment:
Continuous/Sessional assessment through
Two Mid Semester Exam (1 Hrs each): 15+15=30 Marks,
Assignments and Quizzes: 20 Marks
End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs): After completion of course, students will be able to

1. Explain quantum mechanical principles of electron spin and magnetic ordering
2. Analyze spin transport and relaxation mechanisms in materials.
3. Interpret spin-dependent transport phenomena such as GMR and AMR.
4. Understand the fabrication of tunnel magnetoresistance devices
5. Evaluate the working principles of spintronic devices like MRAM and spin transistors

Unit-I 8

Fundamentals of Electron Spin and Magnetism: Electron spin, magnetic moment, and quantum description, Types of magnetism: diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, altermagnetism, exchange interaction, superparamagnetic, spin polarization and measurement

Unit-II 8

Spin Transport and Spin Dynamics: Introduction- overview of the development of Spintronics and its future scope, spin current and spin accumulation, Spin diffusion and drift, Spin relaxation mechanisms (Elliott–Yafet, D'yakonov–Perel), Bloch equations for spin dynamics, spin injection and detection techniques, Spin Hall Effect, inverse spin Hall effect

Unit-III 9

Spin-Dependent Transport Phenomena: Magnetic multilayers, interlayer exchange coupling and exchange bias, spin-dependent transport – anisotropic magnetoresistance, giant magneto resistance (GMR) effect - Phenomenological theory, microscopic theory for current in plane (CIP) and current perpendicular to plane (CPP) GMR, Effects of spin-dependent scattering.

Unit-IV 9

Spin-Dependent Tunneling Phenomena: Spin-dependent tunneling, tunnel magnetoresistance (TMR), effects of Fermi surface, effect of interfacial states, diffusive tunneling, elastic and inelastic tunneling, localized states, bias voltage dependence of TMR, magnetic tunnel Junctions (MTJ), tunnel Junctions with half metals

Unit-V 8

Spintronic Devices and Applications: Magnetic Random Access Memory (MRAM), spin-transfer torque (STT) and spin orbit torque (SOT) devices, spin transistors (Datta & Das model), domain wall motion and racetrack memory, sensors and industrial applications

Reference Books:

1. S. Blundell, Magnetism in Condensed Matter, 1st edition, Oxford University Press, 2001.
2. R. C. O' Handley, Modern Magnetic Materials, John Wiley & Sons, Inc., 2000.
3. T. Shinjo (Ed.) Nanomagnetism and Spintronics, 1st edition, Elsevier, 2009.
4. E. Y. Tsymbal and I Zutic, Handbook of Spin Transport and Magnetism, CRC Press, 2012.

NPH-600 Advanced Characterization Techniques in Materials Science

Course Category	Paper Code	Subject Name	L	T	P	Credits
PCC	NPH-600	Advanced Characterization Techniques in Materials Science	3	1	0	4

Course Assessment:
Continuous/Sessional assessment through
Two Mid Semester Exam (1Hrs. each):15 +15 = 30 Marks
TAQ (Tutorials/Assignments/Quizzes): 20 Marks
End Semester Examination (2.5Hours): 50 Marks

1. Analyze the structure of materials using X-ray diffraction, microscopy techniques, and surface analysis methods.
2. The foundation for understanding different types of Characterization techniques and their applications.
3. The student will be able to understand different characterization techniques for devices and their applications.
4. The foundation for understanding of experimental methods for characterizing and their applications.
5. The student will be able to analyze the properties of materials using computational and theoretical methods and also understand the measurements of the physical properties of thin films.

Unit-I
Determination of crystal structure: X-ray diffraction (XRD), Microscopy techniques: Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM).

Unit-II
Structural Characterization and Surface analysis: Energy dispersive X-ray microanalysis (EDS), X-ray photoelectron spectroscopy (XPS), Atomic Force Microscopy (AFM)

Unit-III
Optical Characterization Tools: Basics of FTIR, Photoluminescence and Raman Spectroscopy, UV-visible, optical properties, and determination of band gap

Unit-IV
Electrical Characterization: Electrochemical Impedance spectroscopy (EIS), Cyclic Voltammetry (CV), Galvanostatic charge-discharge (GCD).

Unit-V
Magnetic and Thermal Characterization: Ferromagnetic resonance (FMR), thermal characterization of ionic materials: differential scanning calorimetry (DSC), Thermo-gravimetric analysis (TGA), Transient plane source Techniques (TPS).

NPTEL courses and resources:

- **Advanced Materials Characterization by IIT Kanpur:** https://nptel.ac.in/courses/113104004

Reference Books:

1. K. Tyagi, Mainak Roy, S. K. Kulshreshtha and S. Banerjee, Advanced Techniques for Materials Characterization, Trans Tech Publications Ltd., Switzerland, 2009
2. Ch Sateesh Kumar, M. Muralidhar Singh, Ram Krishna, Advanced Materials Characterization Basic Principles, Novel Applications, and Future Directions, CRC Press, 2024
3. Ramiro Pérez Campos, Materials Characterization, Springer, 2016

NPH-602 Science and Technology of Thin Films

Course Category	Paper Code	Subject Name	L	T	P	Credits
ESC	NPH-602	Science and Technology of Thin Films	3	1	0	4

Course Assessment:
Continuous/Sessional assessment through
Two Mid Semester Exam (1 Hrs each): 15+15=30 Marks,
TAQ (Tutorials/Assignments/Quizzes): 20 Marks
and End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs):
1. Understanding of the fundamentals of thin films materials.
2. To understand the principle of various fabrication methods of thin films.
3. Analyze methods for thickness measurements of thin films.
4. To learn about the magnetic thin films and spintronics devices.
5. Learning of applications of thin films.

UNIT I
Basics of Thin Films: Definition and importance of thin films, thin films materials: metals, semiconductors, insulators, Various types of growth mechanisms of thin films, structure and properties of thin films.

UNIT II
Vacuum Technology and Substrate Preparation: basics of vacuum science, vacuum pumps: rotatory, diffusion, turbo molecular, pressure measurement techniques. substrate materials, cleaning and preparation of substrates.

Unit III
Thin Film Deposition Techniques: fabrication methods of thin films, physical vapor deposition (PVD) methods - thermal evaporation, sputtering, and pulsed laser deposition; chemical vapor deposition (CVD)methods, sol-gel technique, electrochemical deposition.

UNIT IV
Thickness Measurement: Measurement of thickness of thin films, different methods and instruments for thickness measurements, quartz crystal monitor, optical, mechanical, electrical, and structural properties of thin films.

UNIT V
Applications of Thin Films: Optical coatings, thin film solar cells, semiconductors devices, sensors, magnetic thin films, protective and decorative coatings.

NPTEL courses and resources:

- **Thin Film Technology**: https://nptel.ac.in/courses/113104075

Books & References:

1. K. L. Chopra and S. R. Das, Thin Film Solar Cells, Springer, 1983
2. L. I. Maissel and Glang, Handbook of Thin Film Technology, McGraw Hill Higher Education, 1970.
3. J. C. Anderson, The Use of Thin Films in Physical Investigation, Academic Press Inc., 1966.
4. J. J. Coutts, Active and Passive Thin Film Devices, Academic Press Inc., 1978.
5. R.W. Berry, P.M. Hall, and M.T. Harris, “Thin Film Technology”, Van Nostrand, 1968.

Pools of Programme Electives Courses: There are two pools of programme elective courses PEC-I and PEC-II
First Pool of Programme Electives Courses-I (PEC-I) NPH-609 Computational Physics

Course Category	Paper Code	Subject Name	L	T	P	Credits
PEC	NPH-609	Computational Physics	3	0	2	4

Course Assessment:
Continuous/Sessional assessment through
One Mid Semester Exam (1 Hrs): 15 Marks,
TAQ (Tutorials/Assignments/Quizzes): 20 Marks
Lab Exam: 15 Marks
End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs):
1. Understand the basic concepts of periodic solids, band structure and electron behavior inside the solids.
2. Learn the fundamental concepts and theorem of Density Functional theory (DFT).
3. Develop understanding about exchange-correlation (XC) functionals, their types and uses.
4. Learn fundamentals of basis set and Pseudopotential methods in DFT analysis.
5. Basic concepts to calculate and analyze the electronic structure of materials.

Unit-I:
Band Structures: Basic concepts of periodic solids and band structure of metal, insulator and semiconductor, the reciprocal lattice and Brillouin zone, Bloch theorem, Basic equations for interacting electrons and nuclei, Coulomb interaction in condensed matter, one dimensional Schrodinger equation for a particle.

Unit-II:
Many-body Problem: Approximation methods for many electron systems, Born-Oppenheimer approximation, Foundations of Density Functional Theory (DFT): Thomas-Fermi-Dirac approximations: example of a functional, Hohenberg-Kohn (HK) theorem, The self- consistent Kohn-Sham equations.

Unit: III:
Computational and Theoretical Methods: Basic introduction to Density Functional Theory (DFT), various Computational tools for DFT analysis, , Exchange-Correlation (XC) Functional, local density approximation (LDA), Generalized-gradient approximation (GGAs), LDA and GGA expressions for the potential, strengths of DFT, DFT- hybrid functionals.

Unit-IV:
Basis set: Linear combination of atomic orbitals (LCAO) and Plane waves methods, Basics - The independent particle Schrodinger equation in a plane wave basis, Pseudopotential method - Projector augmented waves (PAWs) and Norm conserving method.

Unit-V
Electronic Structure Calculations: Simple crystals structures, bands, - Definition of Supercells: Geometry optimization, total energy, force, and stress - illustrative examples - square lattice and any 2D materials planes - Examples of bands: semiconductors and metal, electronic structure of nanomaterials
Experiments:

1. To understand materials data visualization and analysis in Quantum atomistic tool Kit (ATK).
2. To analyse the lattice structure of materials and perform geometry optimization.
3. Calculation of Electronic band structure and Density of state (DOS) of materials.
4. Analysis of Substutational doping in materials.
5. Analysis of the adsorption process and calculation of binding Energy.

NPTEL Courses and Resources:
1. Introduction to computational Physics: nptel.ac.in/courses/115106118

2. Introduction to Computational Chemistry nptel.ac.in/courses/104101002

Reference Books:

1. Density Functional Theory of atoms and Molecules by Robert G. Parr and Weitao Yang
2. Lily Chen, "Computational Materials Science: Theory and Applications", Willford press, 2018. Martin E. Glicksman, James E. Mark, Steven P. Marsh,"
3. Computational Methods in Materials Science", Materials Research Society,1992.

NPH -613 Advanced Condensed Matter Physics

Course Category	Paper Code	Subject Name	L	T	P	Credits
PEC	NPH -613	Advanced Condensed Matter Physics	3	1	0	4

Course Assessment: Continuous/Sessional assessment through
Two Mid Semester Exam (1 Hrs each): 15+15=30 Marks,
TAQ (Tutorials/Assignments/Quizzes): 20 Marks
End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs):
1. Understand the electrical transport properties of solids.
2. Learn about various optical properties and optical transitions in solids.
3. Understands fundamentals and working mechanism of various optical detectors.
4. Develop understanding about various advance concepts of magnetism.
5. Learn about fundamental and advance topics in superconductivity.

Unit-I:
Transport Properties of Solids: Resistivity of metals and semiconductors, Fermi surface, Landau levels, De Hass van Alphen effect, Quantum Hall effect- Integral quantum Hall effect and Magnetoresistance.

Unit-II:
Optical properties: Optical constants and their physical significance, Reflectivity in metals, plasmonic properties of metals, determination of band gap in semiconductors: direct and indirect band gap, defect mediated optical transitions, excitons and photoluminescence.

Unit-III
Optical detectors: Photodetectors, type of photo detectors, basic characteristics of photo detectors, photo transistors and photo conductor, definition of various photodetectors parameters: Responstivity, Quantum efficiency, Photo gain, Detectivity, etc.

Unit: IV:
Magnetism: Quantum theory of diamagnetism, Landau diamagnetism, Paramagnetism, Pauli Paramagnetism, Ferromagnetism, Cuire-weiss Law, temperature dependence of magnetization, Heisenberg's exchange interaction, Ferromagnetic domains, Magnetic domains–exchange energy, magnetostatic energy, wall energy, magnetostrictive energy.

Unit-V:
Superconductivity: Meissner effect. London's equations, Thermodynamics of the superconducting phase transition: Free energy, entropy and specific heat jump. Ginzburg-Landau theory of superconductivity: Type-I and Type II superconductors, The Cooper problem, BCS ground state and energy gap, Cooper pairs, coherence, vortex states, Josephson effect: dc and ac effects.

Books & References:
1. Solid state physics, N.N. Ashcroft and N.D. Mermin
2. Solid State Physics – A.J. Dekker.
3. Magnetism and Magnetic Materials, B. D. Cullity
4. Optical Properties of Solids, Frederick Wooten, Ac Press (New York) 1972

Second Pool of Programme Electives Courses-II (PEC-II)

NPH-604 Advanced Quantum Mechanics

Course Category	Paper Code	Subject Name	L	T	P	Credits
PEC	NPH-604	Advanced Quantum Mechanics	3	1	0	4

Course Assessment:
Continuous/ Sessional assessment through
Two Mid Semester Exam (1Hrseach):15+15=30 Marks,
TAQ (Tutorials/Assignments/Quizzes): 20 Marks
End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs):
1. The students will learn the advanced concepts of quantum mechanics and its application to understand molecular structure.
2. Formulate the Dirac equation and explain its mathematical framework.
3. Apply the Dirac equation to a free particle and discuss the significance of helicity.
4. Understand the perturbation theory and its properties.
5. Study the WKB approximation and semi classical theory

Unit-I
Formulation of Relativistic Quantum Theory: Relativistic notations, need of relativistic quantum mechanics, difference from quantum mechanics, the Klein-Gordon equation, physical interpretation, probability current density & inadequacy of Klein-Gordon equation, negative energy states.

Unit-II
Dirac Equation: Dirac relativistic equation & Mathematical formulation, α and β matrices and related algebra, Properties of four matrices α and β, Matrix representation of $\alpha^{'s}$ and β, True continuity equation and Interpretation.

Unit-III
Covariance of Dirac Equation: covariant form of Dirac equation, Dirac gamma (γ)matrices, representation and properties, trace identities, fifth gamma matrix γ^5, solution of Dirac equation for free particle (plane wave solution), Dirac spinor, helicity operator, explicit form

Unit-IV
Perturbation theory: Introduction of perturbation theory, first order and second order perturbation theory. time dependent and time independent perturbation theory. degenerate level.

Unit-V
Approximation: Derivation of WKB approximation**,** tunneling, validity of the WKB approximation, semi classical theory

NPTEL courses and resources:
Advance Quantum Mechanics: https://nptel.ac.in/courses/115106066 (Focuses on Schrodinger equation, operators, angular momentum, and more)

Books & References:

1: Advanced Quantum Mechanics by J. J. Sakurai (Pearson Education India)
2: Relativistic Quantum Mechanics by James D.B jorken and Sidney D .Drell(McGraw-Hill Book Company; New York, 1964).
3: An Introduction to Relativistic Quantum Field Theory by S. S. Schweber (Harper & Row, NewYork, 1961).
4: Quantum Field Theory by F.Mandl & G.Shaw (John Wiley and Sons Ltd,1984)
5: A First Book of Quantum Field Theory by A. Lahiri & P.B . Pal (Narosa Publishing House,New Delhi, 2000)

NPH-612 Science and Technology of Solar Energy, Hydrogen and other Renewable Energies

Course Category	Paper Code	Subject Name	L	T	P	Credits
PEC	NPH-612	Science and Technology of Solar Energy, Hydrogen and other Renewable Energies	3	1	0	4

Course Assessment: Continuous/Sessional assessment through
Two Mid Semester Exam (1 Hrs each): 15+15=30 Marks,
TAQ (Tutorials/Assignments/Quizzes): 20 Marks
End Semester Examination (2.5 Hours): 50 Marks

Course Outcomes (COs):
1. To study the fundamentals of energy conversion.
2. To study about solar energy conversion.
3. To study advanced solar cells.
4. To study about hydrogen energy production and storage.
5. To study material properties for the storage of hydrogen.

Unit-I

Fundamental and Material Aspects: Fundamentals of photovoltaic Energy Conversion Physics and Material Properties, Basics of Photovoltaic Energy Conversion: Optical properties of Solids. Direct and indirect transition semiconductors, interrelationship between absorption coefficients and band gap recombination of carriers.

Unit-II

Solar Energy: Different Types of Solar Cells: Types of Solar Cells, p-n junction solar cell, Transport Equation, Current Density, Open circuit voltage and short circuit current, Brief description of single crystal silicon and organic and Polymer Solar Cells,

Unit-III

Advanced Solar Cells: Elementary Ideas of Advanced Solar Cells e.g. Tandem Solar cells, Solid Liquid Junction Solar Cells, Nature of Semiconductor, Principles of Photo-electrochemical Solar Cells.

Unit-IV

Hydrogen Energy: Fundamentals, Production and Storage: Relevance in relation to depletion of fossil fuels and environmental considerations. Solar Hydrogen through Photo electrolysis

Unit-V

Hydrogen Storage: Physics of material characteristics for production of Hydrogen storage, Brief discussion of various storage processes, special features of solid hydrogen storage materials, Structural and electronic characteristics of storage materials. New Storage Modes.

NPTEL courses and resources:

- **Science and Technology of Solar Energy, Hydrogen and other Renewable Energies by Professor V. N. Shukla:** https://nptel.ac.in/courses/103103206 (Focuses on solar, wind, biomass, geothermal, and hydrogen energy)
- **By Professor Arunachalam Kumar:** https://archive.nptel.ac.in/courses/115/103/115103123/ (Specifically covers solar energy technologies and applications)

Books & References:

- Solar Cell Device Physics, Stephen J. Fonash, Current Edition: 4th Edition (2020), Publisher: Wiley-IEEE Press
- Fundamentals of Solar Cells, Alvin L. Fahrenbruch and Richard H. Bube, 3rd Edition (2016), Springer
- Photoelectrochemical Solar Cells, S. Chandra, 1st Edition (1984), Publisher: Elsevier
- Hydrogen as an Energy Carrier Technologies Systems Economy, Christine Winter and Merle Nitz (Eds.): 2nd Edition (2019), Publisher: Wiley-VCH
- Hydrogen as a Future Energy Carrier, Andreas Züttel, Andreas Borgschulte, and Louis Schlapbach, 1st Edition (2012), Publisher: Wiley-VCH