Revised Syllabus for Two Years Master's (M.Sc.) Programme in Physics (Materials Science) (2023-2024)

DEPARTMENT OF PHYSICS

INSTITUTE OF CHEMICAL TECHNOLOGY

(University Under Section-3 of UGC Act, 1956)

Elite Status and Center for Excellence

Government of Maharashtra

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A. Preamble:

Physics is both important and influential because advances in its understanding have often translated into newer technologies, which are of interdisciplinary consequences. Any newer area of research is characterized by a statement of different enforcing conditions; success lies in how correctly the basic physical phenomena are interpreted in these conditions.

In tune with the aforesaid, to make research and development meaningful and effective, a post-graduate (PG) program in Physics with specialization in Materials science was started in 2014. This program is designed to educate students-

- In basic physics – Physics at atomic and molecular level.
- In various statistical, computational and numerical methods.
- In fundamentals of Materials science-from microscopic understanding to applications
- In physical and analytical characterization methods used in Materials research.
- In research areas, by introducing electives and assigning result oriented research projects. The research areas will include various aspects of materials science in line with the expertise of faculties in the department.

This course is developed to equip students with a basic understanding of relevant Physics and various analytical tools. Students, hence, can effectively contribute to multiple industries and/or emerging branches of research. This entire approach resonates with the national initiative taken by MHRD, MNRE and Govt. of India to have healthy educational and research culture.

B. Regulations Related to the M. Sc. Physics (Materials Science) Course

- **Intake**

20 candidates shall be admitted every year. The distribution of seats shall be as per the Institute's norms.

- **Admission**

The candidate who have taken the post-H.S.C. 3-year degree course of Bachelor of Science with 6 units of Physics at the third year of the course and any two of chemistry, mathematics or statistics as the two other subjects at the first and second years of University of Mumbai or of any other recognized University; and passed the qualifying examination with at least 60% of the marks in aggregate or equivalent grade average. (55% for the backward class candidates only from Maharashtra State are eligible to apply).

The candidates who have cleared the qualifying examination in one sitting will be preferred. The admissions will be done strictly on the basis of merit, based on the marks obtained in the qualifying examination.

- **Course structure:**
  a. The course is a credit-based 4-semester (2-year) course.
  b. The course has an exit option after one year with a "Diploma" as per the guidelines of NEP 2020.
  c. There will be two semesters in a year:
     i. Semester – I and Semester – III (July to December)
     ii. Semester – II and Semester – IV (December to May)

iii. Each semester will consist of 15-16 weeks of instruction, including seminars/projects/assignments.

d. The On Job Training (OJT) will be at the end of the second semester (during summer vacations) for 8 – 10 weeks and carries 4 credits.

e. At the end of each semester, the candidates will be assessed as per the institute's norms.

f. Semesters will be governed by the institute's academic calendar.

g. The requirement of attendance of the students shall be as per the norms of the institute.

h. All the institute's relevant academic regulations shall be applicable to the course.

i. Students will be assessed as per the institute's norms.

j. In case of any difficulty regarding any assessment component of the course, the Departmental Committee shall take an appropriate decision, which will be considered final.

k. **Evaluation Process:**

Evaluation for the courses will be according to the revised document of R.9 credit system and mode of evaluation; the link is provided below, or you can visit the website (ictmumbai.edu.in) for the details.

Link:
https://www.ictmumbai.edu.in/uploaded_files/R_9(Revised)_Credit_system.pdf
A general evaluation process for theory and lab courses is given below

Theory Courses

Continuous Assessment Test (CAT): Continuous assessment will vary from course to course; the instructor will decide the evaluation mode. Two to three CATs (Continuous Assessment Tests) will be conducted throughout the course, usually before and after the midsemester examination. These CATs will carry a total weightage of 20%. Depending on the instructor, assignments, case studies, group discussions, and seminars could also form part of the continuous assessment.
Mid-semester exam: Total 30 Marks (theory paper)
End-semester exam: Total 50 Marks (theory paper)

Practical Courses (PYP 2XXX)

Continuous assessment: 50 Marks
Performing given experiments as per the instructions, submission of lab journal on time, viva voce, group/personal discussions, and quizzes can be part of continuous assessment. The course instructor will discuss the composition of marks for these at the beginning of the course.
End Semester: 50 Marks (Lab experiment performance followed by viva-voce examination)

l. **Electives:**

i. Elective course will be offered during the each of the semester programme and the list of electives will be made available to the students before commencement of the semester.
ii. Open electives will also be offered which may be of two types: (a) students may be allowed to take it from well-established MOOC courses with prior approval from the department (b) it may also be proposed by a faculty with detailed syllabus and get prior approval from the department.

m. **Research Project:**
   i. At the end of the Second semester, the Head of Department in consultation with the Departmental Committee will assign topics for the Research Projects (4 credits) to the students and assign the supervisors.
   ii. The students will do the Research Projects (6 credits) in semester IV on the topics assigned under the supervision of the assigned faculty member.
   iii. The students shall submit the project report before the prescribed date which will be a date before the last date of the semester IV. The report shall be submitted with soft binding.
   iv. The project report will be examined by the supervisor along with one other internal/external referee to be appointed by the Departmental committee. The referees shall give marks to the report as per the norms.
   v. The students will make presentation on the work in front of the Project Evaluation Committee (PEC) appointed by the Departmental Committee, in open defence form. The PEC will give marks to the presentation.

The comments received from the referees as well as given by the PEC need to be incorporated in the final project report in consultation with the supervisor.

Department of Physics

A semester-wise pattern of the M.Sc. (Physics) course
(As per NEP guidelines)

SEMESTER I

SUBJECT CODE	SUBJECT	Credits	Hrs/Week			Marks distribution			
			L	T	P	CA	MS	ES	Total
PYT 2111	Classical Mechanics & Mathematical Physics	4	3	1	-	20	30	50	100
PYT 2112	Quantum Mechanics I	4	3	1	-	20	30	50	100
PYT 2113	Solid State Physics	4	3	1	-	20	30	50	100
PYT 211X	Elective-I	4	3	1	-	20	30	50	100
PYP 2115	General Physics Laboratory	2	-	-	4	50	-	50	100
HUT 21XX	Research Methodology	4	3	1	-	20	30	50	100
	Total	22	15	05	04				600

SEMESTER II

SUBJECT CODE	SUBJECT	Credits	Hrs/Week			Marks distribution			
			L	T	P	CA	MS	ES	Total
PYT 2211	Materials Science & Synthesis	4	3	1	-	20	30	50	100
PYT 2212	Materials Characterisation Techniques	4	3	1	-	20	30	50	100
PYT 2213	Quantum Mechanics II	2	1	1	-	20	30	50	100
PYT 221X	Elective-II	4	3	1	-	20	30	50	100
PYP 2215	Chemical Physics Laboratory	2	-	-	4	50	-	50	100
PYP 2216	Internship (On Job Training)	4	-	-	8	100	-	-	100
	Total	20	10	04	12				600

SEMESTER III

SUBJECT CODE	SUBJECT	Credits	Hrs/Week			Marks distribution			
			L	T	P	CA	MS	ES	Total
PYT 2311	Colour Physics	2	1	1	-	20	30	50	100
PYT 2312	Classical Electrodynamics	4	3	1	-	20	30	50	100
PYT 2313	Introduction to Nanoscience	4	3	1	-	20	30	50	100
PYT 231X	Elective-III	4	3	1	-	20	30	50	100
PYP 2315	Electronics Laboratory	2	-	-	4	50	-	50	100
PYP 2316	Research Project-I	4	-	-	8	100	-	-	100
	Total	20	10	4	12				600

SEMESTER IV

SUBJECT CODE	SUBJECT	Credits	Hrs/Week			Marks distribution			
			L	T	P	CA	MS	ES	Total
PYT 2411	Numerical Techniques using Python	4	3	1	-	20	30	50	100
PYT 2412	Molecular Quantum Mechanics	2	1	1	-	20	30	50	100
PYT 2413	Statistical Mechanics	4	3	1	-	20	30	50	100
PYT 241X	Elective-IV	4	3	1	-	20	30	50	100
PYP 2415	Research Project-II	6	-		12	200	-	-	200
	Total	20	10	4	12				600

Program Outcomes (POs) for M.Sc. Physics (Material Science)

PO1	Fundamentals of Physics: A strong grasp of the fundamentals of physics required in solving complex physics problems.
PO2	Experimental Skill set: Expertise in techniques of advanced experimental measurement, and analysis of results to determine physical quantities.
PO3	Foundation of Materials Science: Sound understanding of the physics of materials. Skill to select, design, synthesize, characterize, and thoroughly investigate materials from a fundamental and applied point of view.
PO4	Modern tool usage: Select, modify, and apply appropriate existing techniques, resources, and modern IT tools for the solution of relevant problems.
PO5	Problem analysis: Identify, formulate, review research literature, and analyze complex real-life problems using mathematics, statistics, and computational methods.
PO6	Sustainability: Awareness of the importance of sustainability and environmental impact in the context of using materials for technological applications.
PO7	Research based Teaching Learning: Possess the necessary skills to compete at the national and international level for entrance exams and placements in academia and industry.
PO8	Societal Applications: Apply the knowledge gained to devise solutions that address societally relevant problems.
PO9	Ethics: Strict adherence and commitment to follow ethical principles and norms of the practice of physical and material sciences in all verticals of industry and society.
PO10	Individual and teamwork: Ability to work effectively as an individual and as a member or leader in diverse teams, and in multidisciplinary settings.
PO11	Communication: Communicate effectively on complex industrial/natural problems, understand the functional requirements, identify the gaps, and be able to provide solutions. Possess skills in effective dissemination of information to a diverse audience.
PO12	Life-long learning: Recognize the need for and have the ability to engage in independent and life-long learning.

Program Specific Outcomes (PSOs) for M.Sc. Physics (Material Science)

PSO1	Exposure and ability to use advanced formalism in Physical Sciences to analyze the problems in Materials science from fundamental view point.
PSO2	Students will be equipped with necessary knowledge and expertise to quantum mechanically analyze a variety of problem in materials science
PSO3	Competence in handling the necessary numerical techniques required in Materials science.
PSO4	Students will have a good grasp over advanced mathematical techniques used for analysis of physical problems.
PSO5	Develop a sound understanding of materials properties from the Physico-chemical perspective and their dependance on various parameters.
PSO6	Ability to select, design, synthesize, process, characterize, and thoroughly investigate materials from a functional viewpoint.

SEMESTER-I

	Course Code: PYT 2111	**Course Title: Classical Mechanics and Mathematical Physics**	**Credits = 04**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 60**	**3**	**1**	**-**

List of prerequisite Courses		
Adequate number of Physics courses at undergraduate level		
List of Courses where this course will be a prerequisite		
PYT2213-Quantum Mechanics-II, PYT2312-Classical Electrodynamics, PYT2414-Molecular Quantum Mechanics		
Description of relevance of this course in the M.Sc. Physics Program		
This course gives the foundation for most of the advanced topics in Physics. The concepts of Lagrangian, Hamiltonian and other formalisms covered in this course are important to understand introduction course on quantum mechanics. Mathematical methods covered here are essential in covering topics in electrodynamics, thermodynamics/statistical physics.		
Course Outcomes (students will be able to…..)		
CO1	Understand the Lagrangian formulation of Classical Mechanics as an alternative approach to the Newtonian approach and its advantages in solving advanced Classical Mechanics problems.	K3
CO2	Use the Hamilton's equation to analyze systems and to calculate the Poisson brackets and set up the Poisson equation of motion.	K4
CO3	Apply the above formulations to study small oscillations of mechanical systems and to calculate the vibrational frequencies of simple molecules.	K5
CO4	Use Laplace transforms and the Frobenius method to solve differential equations.	K3
CO5	Calculate contour integrals using algebra of functions of complex variable.	K4
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	**Lagrangian Formulation of classical mechanics:** Degrees of freedom, constraints and types of constraints. D' Alembert's principle and the Lagrange's equations of motion. Velocity dependent potentials and dissipation function. Hamilton's principle, derivation of Lagrange's equations from Hamilton's principle. Some techniques of the calculus of variation, conservation theorems and symmetry properties.	10
2	**The Hamilton equations of motion:** Legendre transformations and the Hamilton equations of motion, cyclic coordinates and constants of motion. The physical significance of the Hamiltonian. Canonical transformations, the equations of canonical transformation, examples, Poisson brackets and the Poisson equation of motion.	10
3	**Small oscillations:** Formulation of the problem, the eigenvalue equation and the principal axes transformation, normal coordinates, free vibrations of a triatomic molecule and its eigenfrequencies.	10
4	**Complex Analysis:** Functions of a complex variable, analytic functions and the Cauchy -Riemann conditions. Contour integrals, Cauchy-Goursat theorem, Cauchy integral formula and its applications. Taylor and Laurent series. Residues and poles, the residue theorem and applications.	12
5	**Integral Transforms:** Laplace Transform, definition and properties. The inverse Laplace transform, Applications.	06

6	**Differential Equations:** First and second order differential equations, the Frobenius method of series solutions. The Bessel, Legendre, Laguerre and Hermite equations and their solutions. Green's function and its applications.	12
List of Textbooks/Reference books		
	References Classical Mechanics: 1. Classical Mechanics: H. Goldstein, Poole and Safko 3rd edition, Pearson 2. Classical Mechanics: N. C. Rana and P.S. Joag Tata McGraw Hill publication 3. Mechanics: Landau and Lifshitz, Butterworth, Heinmann 4. Mechanics: K.R. Symon 5. Introduction to Classical Mechanics: R. G. Takwale and P. S. Puranik **References Mathematical Physics:** 1. M. L. Boas, Mathematical Methods in the Physical Sciences, Wiley India 2. G. Arfken: Mathematical Methods for Physicists, Academic Press 3. A.K. Ghatak, I. C. Goyal and S. J Chua, Mathematical Physics, Macmillan 4. J. Mathews and R.L. Walker, Mathematical methods of Physics. 5. R. V. Churchill and J.W. Brown, Complex Variables and Applications, V. McGraw Hill.	

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	2	2	3	3	3	3	3	3	2	2
CO2	2	2	2	3	2	3	3	3	3	3	2	2
CO3	2	2	2	3	2	3	3	3	3	3	2	2
CO4	2	2	2	2	3	3	3	3	3	3	2	2
CO5	2	2	2	2	2	3	3	3	3	3	2	2

K1-remember; K2-comprehension; K3-application; K4-analysis; K5-synthesis; K6-evaluation

Mapping of course outcome (CO) to the program specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	2	2	2	3	3
CO2	2	2	2	3	2	3
CO3	2	2	2	3	2	3
CO4	2	2	2	3	3	3
CO5	2	2	2	2	2	3

Course Code: PYT 2112	**Course Title: Quantum Mechanics I**	**Credits = 04**			
		L	**T**	**P**	
Semester: I	**Total contact hours: 60**	**3**	**1**	**-**	

List of prerequisite Courses
Adequate number of physics courses at undergraduate level
List of Courses where this course will be a prerequisite
PYT2211-Quantum Mechanics II, PYT2412-Molecular Quantum Mechanics

Description of relevance of this course in the M.Sc. Physics Program		
Students will be equipped with necessary knowledge and expertise to quantum mechanically analyze the variety of problem in physical and Chemical sciences.		
Course Outcomes (students will be able to…..)		
CO1	Understand the basic postulates of quantum Mechanics.	K2
CO2	Use quantum mechanical operators and formulate the Schrodinger equation.	K3
CO3	Use the Schrodinger equation to obtain eigenvalues and eigenfunctions for a variety of time independent potentials.	K3
CO4	Understand the concept of commutator of operators and the underlying symmetries the Hamiltonian and the eigenfunctions/eigenvalues.	K3
CO5	Solve eigenvalue problems using the advanced formalism of Quantum Mechanics (i.e the Dirac formalism)	K4
CO6	Calculate expectation values of observables for a hydrogen atom, by solving the Schrodinger equation in three dimensions using polar coordinates.	K4
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	**Review of concepts:** Wave Particle duality and the de Broglie hypothesis, Heisenberg's uncertainty principle; probability waves and Born interpretation. Definition of the probability current density J and the continuity equation satisfied by J.	06
2	**Theory:** Postulates of QM: Observables and operators, measurement, the state function and expectation values. The time-dependent Schrodinger equation conversion to the steady state equation for time independent potentials. Time development of the state, eigenvalues and eigenfunctions. Properties of well-behaved wave functions. The most general solution to the Schrodinger equation. Expansion of an arbitrary state in an orthonormal eigenbasis. Calculation of the expansion coefficients. Expectation values in mixed states. Definition of commutator and the corresponding commutation relations among various operators. Ehrnfest theorems. Symmetries of the Hamiltonian and associated conserved quantities. Parity operator. Wave packets, definition and relation to the Heisenberg uncertainty principle. Parseval's theorem.	20
3	**Schrodinger equation solutions: One-dimensional Problems**: Particle in a box, finite potential well, finite barrier, step potential and harmonic oscillator in terms of creation and annihilation operators. General properties of the Hermite polynomials.	13
4	**Formalism:** Dirac notation, Hilbert space, Hermitian operators and their properties, matrix mechanics, basis and representations, unitary and similarity transformations, Schrodinger, Heisenberg and Dirac pictures of quantum mechanics. The Heisenberg equation of motion.	10
5	**Quantum theory of the hydrogen atom**	

	Schrodinger equation for hydrogen atom, separation of variables, angular equations: spherical harmonics, radial equation: eigenvalues and eigenfunctions, degeneracy. Probability distribution in various states.	11
List of Textbooks/Reference books		
	1) Introductory Quantum Mechanics – R. Liboff 2) Quantum Mechanics – A. Ghatak and S. Lokanathan 3) Introduction to Quantum Mechanics – D. J. Griffiths 4) Principles of Quantum Mechanics – R. Shankar 5) E. Merzbacher, Quantum Mechanics, 3rd ed., 1998. 6) G. Baym, Lectures on Quantum Mechanics, 1969.	

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	2	1	3	1	3	1	2	2	2	3
CO2	3	1	2	1	3	1	3	1	2	2	2	3
CO3	3	1	2	1	3	1	3	1	2	2	2	3
CO4	3	1	2	1	3	1	3	1	2	2	2	3
CO5	3	1	2	1	3	1	3	1	2	2	2	3
CO6	3	1	2	1	3	1	3	1	2	2	2	3

0= No correlation; 1=Weak correlation; 2=moderate correlation; 3=strong correlation

Mapping of course outcome (CO) to the program specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	1	2	1	1
CO2	3	3	1	2	1	1
CO3	3	3	1	2	1	1
CO4	3	3	1	2	1	1
CO5	3	3	1	2	1	1
CO6	3	3	1	2	1	1

	Course Code: PYT 2113	**Course Title: Solid State Physics**	**Credits = 04**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 60**	**3**	**1**	**-**

List of prerequisite Courses

Adequate number of Physics courses at the undergraduate level

List of Courses where this course will be a prerequisite

PYT2214-Introduction to ceramics, PYT2312-Introduction to Nanoscience, Materials Science

Description of the relevance of this course in the M.Sc. Physics Program

It forms the foundation for understanding the physics of materials from a fundamental viewpoint, thereby helping to attain program-specific outcomes.

Course Outcomes (students will be able to…..)

CO1	Understand the detailed structure of solids and identify symmetry, periodicity in lattices.	K2
CO2	Understand and Interpret results of diffraction experiments for crystal structure determination.	K3
CO3	Understand lattice vibration and their role in determining thermal and optical properties of solids.	K2
CO4	Correlate structural symmetry with dielectric properties by understanding the microscopic origins of polarization.	K4
CO5	Understanding origins of magnetic ordering and classify materials based on their magnetic and/or superconducting properties.	K4
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	**Crystal structure & Crystal Defects:** Crystalline Periodicity, Crystal symmetry; position, planes and directions in crystals. Interplanar spacing Point defects, equilibrium concentration of point defects, colour centres, Screw and edge dislocations, stacking faults, grain boundaries; Role of crystal defects in crystal growth.	10
2	**Diffraction in crystals: X-rays, electron and neutron:** Elastic scattering of waves by a point scatterer, atom and a lattice. Interference of waves & Laue conditions. Reciprocal lattice and X ray diffraction. Ewald construction. Atomic scattering factor and structure factor. Experimental techniques for diffraction.	10
3	**Fermi surface, lattice vibrations and thermal physics** Fermi surfaces in free electron and nearly free electron approximation, Zone schemes. Lattice vibrations: normal modes in mono and diatomic chain of atoms. Dispersion relations and normal mode frequencies. Quantisation of lattice vibrations, scattering of phonons – normal and Umklapp process, lattice thermal resistivity. Lattice optical properties in Infra Red region.	10
4	**Dielectric and Optical Properties:** The local field. Sources of polarizability. Dielectric properties, Clausius-Mossoti relation, Ferroelectrics and piezoelectrics. Electronic polarizability, Ionic polarizability.	10
5	**Magnetism:** Magnetic susceptibility and classification of magnetic materials. Diamagnetism, paramagnetism- free ion, Hund's Rules. Crystal Field splitting, Cooling by Adiabatic demagnetisation of a paramagnetic salt. Magnetic ordering: Spontaneous magnetisation and ferromagnetism, Ferri and Antiferromagnetism. Magnetic domains and hysteresis loop.	10
6	**Superconductivity:** Classical superconductors; Meissner effect, critical field, Type I & II superconductors. Tunnelling and Josephson effect. Theory of superconductivity (Qualitative only)	10

	High Temperature Superconductors (HTSC) Classification and structure, Preparation, Comparison with the properties of classical superconductors. Application of superconductors.	
List of Textbooks/Reference books		
	1) Introduction to Solid State Physics – C. Kittel 2) Elementary Solid State Physics – M. A. Omar 3) Solid State Physics – A. J. Dekker 4) Solid State Physics- N. Ashcroft and D. Mermin	

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	1	2	1	2	1	2	1	2	3
CO2	3	3	3	1	2	1	2	1	2	1	2	3
CO3	3	1	3	1	2	1	2	1	2	1	2	3
CO4	3	1	3	1	2	1	2	1	2	1	2	3
CO5	3	1	3	1	2	1	2	1	2	1	2	3

0= No correlation; 1=Weak correlation; 2=moderate correlation; 3=strong correlation

Mapping of course outcome (CO) to the program specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	1	1	3	2
CO2	3	2	1	1	3	2
CO3	3	2	1	1	3	2
CO4	3	2	1	1	3	2
CO5	3	2	1	1	3	2

	Course Code: PYT 211X	**Course Title: Elective-I**	**Credits = 04**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 60**	**3**	**1**	**-**
	See the course content from the electives subject section.				
Confirm the availability of the course from the given list of electives with the Department office.					
	Course Contents (Topics and subtopics)		**Reqd. hours**		
List of Textbooks/Reference books					

<table>
<tr><td rowspan="3"></td><td rowspan="2">Course Code: PYP 2115</td><td rowspan="2">Course Title: General Physics Laboratory</td><td colspan="3">Credits = 02</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>Semester: I</td><td>Total contact hours: 60</td><td>-</td><td>-</td><td>04</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">List of prerequisite Courses</td></tr>
<tr><td colspan="6">Adequate number of Physics courses at undergraduate level</td></tr>
<tr><td colspan="6">List of Courses where this course will be a prerequisite</td></tr>
<tr><td colspan="6">PYP2215-Chemical Physics laboratory, PYP2315-Electronics laboratory</td></tr>
<tr><td colspan="6">Description of relevance of this course in the M.Sc. Physics Program</td></tr>
<tr><td colspan="6">This laboratory give exposure to various established phenomenon in physical sciences, improve skills in experimental techniques needed in various disciplines.</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">Course Outcomes (students will be able to…..)</td></tr>
<tr><td>CO1</td><td colspan="2">Independently set up, handle and use basic setups to obtain properties and parameters of materials.</td><td colspan="3">K3</td></tr>
<tr><td>CO2</td><td colspan="2">design measurement protocols keeping in mind the dependent variables, independent variables, and constants involved.</td><td colspan="3">K4</td></tr>
<tr><td>CO3</td><td colspan="2">correlate and use directly measured quantities to obtain the relevant parameters through appropriate formulae, calculations, and/or graphical plotting, thereby</td><td colspan="3">K5</td></tr>
</table>

	enabling them to understand the measurement principle involved in the experimental setups.	
CO4	preliminarily treat the obtained data-sets statistically in order to obtain errors in the experiments.	K4
	Course Contents (Topics and subtopics) (any ten experiments will be allotted)	**Reqd. hours**
1	Determination of Carrier Concentration: Hall Effect	06
2	Resistivity and Band-gap of a Semiconductor: Four-probe method	06
3	Compressibility of Liquids: Ultrasonic Interferometer	06
4	Photoelectric effect	06
5	Determination of g-factor: Electron Spin Resonance	06
6	Magnetic Susceptibility of a Paramagnetic material: Quincke's method	06
7	Analysis of the Sodium Spectrum	06
8	Determination of wavelength of light: Michelson's Interferometer	06
9	Zeeman effect	06
10	Carrier Lifetime in Diodes: Pulse-reverse method	06
11	Lees disc method for determining thermal conductivity of bad thermal conductors	06

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	2	1	3	1	3	1	2	2	2	3
CO2	3	1	2	1	3	1	3	1	2	2	2	3
CO3	3	1	2	1	3	1	3	1	2	2	2	3
CO4	3	1	2	1	3	1	3	1	2	2	2	3

0= No correlation; 1=Weak correlation; 2=moderate correlation; 3=strong correlation

Mapping of course outcome (CO) to the program specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	1	2	1	1
CO2	3	3	1	2	1	1
CO3	3	3	1	2	1	1
CO4	3	3	1	2	1	1

	Course Code: HUT 21XX	**Course Title: Research Methodology**	**Credits = 04**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 60**	**3**	**1**	**-**

Note: **MSc Physics students will be required to take the Research Methodology course offered by the Department of Chemistry**

Course Outcomes (students will be able to…..)		
1		
5		
	Course Contents (Topics and subtopics)	**Reqd. hours**
1		
2		
3		
List of Textbooks/Reference books		

SEMSTER-II

	Course Code: PYT 2211	**Course Title: Materials Science and Materials Synthesis**	**Credits = 04**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 60**	**3**	**1**	**-**

List of prerequisite Courses

PYT2112 (Solid State Physics); Basic and advanced undergraduate courses in physics, 12th standard chemistry courses

List of Courses where this course will be a prerequisite

PYT2214 (Introduction to Ceramics); PYT2313 (Introduction to Nanoscience); PYT2314 (Polymer Physics); Advanced courses in materials processing, Analytical techniques and Advanced materials characterization lab courses

Description of the relevance of this course in the M.Sc. Physics Program

This course forms the foundation for the more advanced and material-specific courses to be offered in the higher semesters of this program. This course offers a deep understanding of the properties, structure, and behaviour of materials on atomic and molecular scales, crucial for progress in multiple fields. Students gain insights into emerging materials, technologies and material synthesis techniques. This equips them to tailor materials to desired specifications, addressing real-world challenges and fostering innovation. Spanning physics, chemistry, engineering, and biology, the course fosters interdisciplinary thinking, preparing students for research, innovation, and diverse career paths within materials-related industries.

<table>
<tr><th colspan="3">Course Outcomes (students will be able to…..)</th></tr>
<tr><td>CO1</td><td>Identify and classify different types of materials based on their composition, structure, and properties.</td><td>K4</td></tr>
<tr><td>CO2</td><td>Understand the underlying principle governing the material properties and select proper materials for their application.</td><td>K3</td></tr>
<tr><td>CO3</td><td>Analyse the structure-property relationships and microstructural correlations in smart materials.</td><td>K4</td></tr>
<tr><td>CO4</td><td>Apply principles of materials selection and design to choose appropriate smart materials for specific applications.</td><td>K6</td></tr>
<tr><td>CO5</td><td>Understand various methods and techniques of materials synthesis in the form of bulk- powder synthesis, thin film deposition, and nanostructure growth.</td><td>K5</td></tr>
<tr><td>CO6</td><td>Analyse the impact of preparative parameters on the properties of synthesized materials. Envisage the optimal processing to tune the materials properties as per end requirement.</td><td>K6</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td></td><td>Course Contents (Topics and subtopics)</td><td>Reqd. hours</td></tr>
<tr><td>1</td><td>Classification and properties of materials:
Classification of materials: metals, intermetallic, metallic alloys, ceramics, polymers, composites, silicates, carbon-based materials. Bonding-structure-property correlations to classify materials. Significant properties of materials: mechanical (defects and their implications to mechanical behaviour), physical (electrical, optical, etc.), chemical, thermal, etc.</td><td>13</td></tr>
<tr><td>2</td><td>Overview of smart materials and structures:
Classification of smart materials, Components of a smart system, Applications of smart material, Piezoelectricity, Piezo-resistivity, Electro-strictive materials, Electro-rheological fluids, Chromic materials, Conductive polymer, Shape memory alloys, Shape memory ceramics, and polymers, Principles of magnetostriction, Magneto rheological fluids, Materials for energy applications: energy harvesting, conversion, and energy storage.</td><td>21</td></tr>
<tr><td>3</td><td>Synthesis and processing of Materials:
Basics of powder processing and heat treatments: production, compaction, annealing, sintering, calcination, vitrification reactions, phenomenon of particle coalescence, concept of quenching, glass formation.
Chemical synthesis: principles of chemical synthesis, synthesis of nanoparticles, thin films, and composites, precipitation, sol-gel, hydrothermal method, solvothermal, synthesis from the melt, combustion technique.
Vapor based and sputtering techniques: Basic concepts of chemical vapor deposition (case study- growth of carbon nanotubes CNT), Physical vapor deposition (PVD), Sputtering, Pulse laser deposition (PLD), and Molecular beam epitaxy (MBE)</td><td>26</td></tr>
<tr><th colspan="3">List of Textbooks/Reference books</th></tr>
<tr><td></td><td>1. Materials Science and Engineering: An Introduction by William Callister & David Rethwisch. Wiley
2. Smart Structures and Materials by Brian Culshaw Artech House, 2000
3. Thin film Technology and Application by K. L. Chopra & L. K. Malhotra.</td><td></td></tr>
</table>

4. The Material Science of thin films by Milton Ohring.
5. Handbook of thin film Technology by Frey, Hartmut, Khan and Hamid R
6. Solidification Processing by M.C. Flemmings, McGraw-Hill College, 1974
7. Fundamentals of Solidification by W. Kurz and D.J. Fisher, CRC Press, 1998.
8. Ultrasonic methods and application by Jack Blitz Van Nostrand Reinhold Company, 2011.

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3	2	2	3	2	2	2	2	2	3
CO2	3	2	3	2	2	3	3	2	2	2	2	3
CO3	3	2	3	2	3	2	3	2	3	3	3	3
CO4	3	3	3	2	3	3	3	3	3	3	3	3
CO5	3	3	3	2	3	3	3	3	2	3	3	3
CO6	3	3	3	2	3	3	3	3	3	3	3	3

K1-knowledge;K2-comprehension; K3-application; K4-analysis; K5-synthesis; K6-evaluation

Mapping of course outcome (CO) to the program-specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	2	2	3	3
CO2	3	3	2	2	3	3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3
CO5	3	3	2	2	3	3
CO6	3	3	3	3	3	3

Course Code: PYT 2212	**Course Title: Materials Characterisation Techniques**	**Credits = 04**		
		L	**T**	**P**
Semester: II	**Total contact hours: 60**	**3**	**1**	**-**

List of prerequisite Courses

PYT 2113 (Solid State Physics); PYP 2115 (General Physics Laboratory)

List of Courses where this course will be a prerequisite

PYT 2313 (Introduction to Nanoscience); PYT2314 (Polymer Physics)

Description of the relevance of this course in the M.Sc. Physics Program

This course helps understand different classes of materials from the atomic level to the bulk composition level. During the program, this course will help distinguish materials characterizations and various techniques to investigate these different categories of materials.

Course Outcomes (students will be able to…..)

CO1	Identify techniques suitable for quantitative or qualitative analysis of a given material.	K3
CO2	Understand the working principle behind various materials characterization techniques.	K3
CO3	Analyse the sample's Structure/ micro-structure/ composition/ electronic structure using the appropriate characterization technique.	K4

CO4	Measure and analyse the mechanical and thermal properties of the material and correlate them to its structural properties.	K4
CO5	Estimate the percentage content of various components in solids, liquids, and gases using chromatographic and spectrometric techniques.	K5
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	**Molecular Absorption and Emission Spectroscopy:** Review of molecular spectra, electronic, vibrational, and rotational energy levels, theory of molecular absorption, Beer-Lambert's law. UV-visible spectroscopy and electronic energy levels, molecular structure using IR/FTIR and Raman spectroscopy, and photoluminescence.	15
2	**Structural, Micro-structural, and Composition Analysis of Solids:** X-ray diffraction (XRD), electron and neutron diffraction, scanning electron microscopy (SEM), transmission electron microscopy (TEM), scanning tunneling microscopy (STM), atomic force microscopy (AFM), Auger electron spectroscopy (AES) and X-ray photoelectron spectroscopy (XPS).	15
3	**Chromatography** Introduction to chromatographic methods, gas chromatography, liquid chromatography, behaviour of solutes, column efficiency and resolution, band broadening, gas chromatographs, stationary phases and column selection, GC detectors, high performance liquid chromatography, HPLC instrumentation, sample introduction, separation columns, detectors.	10
4	**Thermal Characterisation:** Differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), differential thermal analysis (DTA). Mechanical Characterisation Dynamic mechanical analysis (DMA), universal testing machine (UTM).	10
5	**Other Techniques** Mass Spectroscopy (MS, GC/MS), Light scattering / particle size analysis, Atomic Absorption Spectroscopy (AAS), Two probe and four probe conductivity measurement techniques.	10
	List of Textbooks/Reference books	
	1) Fundamentals of Molecular Spectroscopy – C. Banwell and E. McCash 2) Instrumental Methods of Analysis – H. H. Willard, I. I. Merritt and J. A. Dean 3) Dye Lasers – F. P. Schafer 4) Infrared Spectra of Complex Molecules – L. J. Bellamy 5) Fundamentals of Surface and Thin Film Analysis – L. C. Feldman and J. W. Mayer 6) X-ray Structure Determination – G. H. Stout and I. H. Jensen 7) Physical Methods – R. S. Drago 8) Advances in Electrochemical Science and Engineering – I. I. Gerischer and C. W. Tobnia	

Mapping of course outcome (CO) to the program outcome (PO)												
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	3	2	3	2	1	2	1	2	2	2	3
CO2	1	3	2	3	2	1	2	1	2	2	2	3
CO3	1	3	2	3	2	1	2	1	2	2	2	3
CO4	1	3	2	3	2	1	2	1	2	2	2	3
CO5	1	3	2	3	2	1	2	1	2	2	2	3

K1-knowledge; K2-comprehension; K3-application; K4-analysis; K5-synthesis; K6-evaluation

Mapping of course outcome (CO) to the program-specific outcome (PSO)						
	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	1	3	1	3	3
CO2	3	1	3	1	3	3
CO3	3	1	3	1	3	3
CO4	3	1	3	2	3	3
CO5	3	1	3	2	3	3

	Course Code: PYT 2213	**Course Title: Quantum Mechanics-II**	**Credits = 02**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 30**	**01**	**01**	**-**
List of prerequisite Courses					
Adequate number of Physics courses at an undergraduate level					
List of Courses where this course will be a prerequisite					
PYT2412-Molecular Quantum Mechanics					
Description of the relevance of this course in the M.Sc. Physics Program					
Students will be equipped with the necessary knowledge and expertise to quantum mechanically analyze the variety of problems in physical and chemical sciences.					
Course Outcomes (students will be able to…..)					
CO1	Formulate the angular momentum operators and their resulting commutation relations.		K4		
CO2	Express angular momentum of spin half systems using the Pauli spinors and Pauli spin matrices.		K3		
CO3	Calculate the Clebsch-Gordon coefficients for addition of different spins.		K4		
CO4	Compute the effect of perturbing Hamiltonians under various cases on the eigenvalues and the eigenfunctions.		K4		
CO5	Compute the cross sections for various scattering events.		K3		

	Course Contents (Topics and subtopics)	Reqd. hours
1	**Angular momentum** Angular momentum operators and ladder operators. Eigen values and eigen functions of L^2 and L_Z, commutator relations. Matrix representation of angular momentum. Addition of angular momenta and Clebsch-Gordan coefficients. Pauli spin matrices and spinors. Identical particles: symmetric/antisymmetric wavefunctions.	10
2	**Approximation methods** Time-independent perturbation theory, non-degenerate and degenerate cases, applications. Ritz variational method, applications. Time-dependent perturbation theory, fermi's golden rule, applications	12
3	**Scattering theory** A brief introduction to scattering theory, differential and total cross sections, and method of partial waves. Simple examples, the Born approximation.	08
	List of Textbooks/Reference books	
	1) Introductory Quantum Mechanics – R. Liboff 2) Quantum Mechanics – A. Ghatak and S. Lokanathan 3) Introduction to Quantum Mechanics – D. J. Griffiths 4) Principles of Quantum Mechanics – R. Shankar 5) E. Merzbacher, Quantum Mechanics, 3rd ed., 1998. 6) G. Baym, Lectures on Quantum Mechanics, 1969	

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	2	1	2	1	3	1	2	1	2	3
CO2	3	1	2	1	2	1	3	1	2	1	2	3
CO3	3	1	2	1	2	1	3	1	2	1	2	3
CO4	3	1	2	1	2	1	3	1	2	1	2	3
CO5	3	1	2	1	2	1	3	1	2	1	2	3

0= No correlation; 1=Weak correlation; 2=moderate correlation; 3=strong correlation

Mapping of course outcome (CO) to the program specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	1	2	2	1
CO2	3	3	1	2	2	1
CO3	3	3	1	2	2	1
CO4	3	3	1	2	2	1
CO5	3	3	1	2	2	1

<table>
<tr><td rowspan="3"></td><td rowspan="2">Course Code: PYT 221X</td><td rowspan="2">Course Title: Elective-II</td><td colspan="3">Credits = 04</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>Semester: II</td><td>Total contact hours: 60</td><td>3</td><td>1</td><td>-</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6"></td></tr>
<tr><td></td><td colspan="2">See the course content from the electives subject section.</td><td colspan="3"></td></tr>
<tr><td colspan="6">Confirm the availability of the course from the given list of electives with the Department office.</td></tr>
<tr><td></td><td colspan="2">Course Contents (Topics and subtopics)</td><td colspan="3">Reqd. hours</td></tr>
<tr><td colspan="6">List of Textbooks/Reference books</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="3"></td></tr>
</table>

	Course Code: PYP 2215	**Course Title: Chemical Physics Laboratory**	**Credits = 02**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 60**	**-**	**-**	**04**

List of prerequisite Courses

Basic and advanced undergraduate courses in physics, 12^{th} standard chemistry courses

List of Courses where this course will be a prerequisite

Advanced characterization lab courses and Advanced courses on materials properties

Description of the relevance of this course in the M.Sc. Physics Program

This course will train the students for the use of advanced, research-grade experimental facilities used in the characterization of materials properties, inculcate an ability to correlate experimental results with materials characteristics and properties and teach data analysis techniques to obtain relevant quantities using raw experimental data.

Course Outcomes (students will be able to…..)

CO1	Independently set up, handle, and use advanced, research-grade experimental setups used in the analytical characterization of various types of materials.	K3
CO2	Choose appropriate analytical techniques to investigate different aspects of any material of interest through an understanding of the purpose and working principle of the instruments.	K4
CO3	Understand how various advanced characterization instruments are fully controlled and operated using computers.	K3
CO4	Use basic data analysis techniques to obtain relevant quantities using raw experimental data.	K5
CO5	Understand the infrastructural requirements and the safety protocols required to house advanced characterization facilities in a research lab/industry.	K6

	Course Contents (Topics and subtopics)	**Reqd. hours**
1	Beer-Lambert's law I: Verification	6

2	Beer-Lambert's law II: Two-component analysis	6
3	Colour Physics I: Colour specification	6
4	Colour Physics II: Colour Difference	6
5	Thermal Properties of Polymers: Differential Scanning Calorimetry	6
6	Mechanical Properties of Polymers: Universal Testing Machine	6
7	Functional group analysis: Fourier Transform Infrared (FTIR) Spectrometer	6
8	Nuclear Magnetic Resonance (NMR) Spectrometer	6
9	Solar cells: I-V (Current-Voltage) characteristics	6
10	Structural Properties of Materials: Polycrystalline X-ray Diffraction Lab	6

Mapping of course outcome (CO) to the program outcome (PO)												
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	2	2	3	3	3	3	2	3	3
CO2	3	3	3	2	2	2	3	3	3	2	3	3
CO3	3	3	3	3	3	2	3	2	3	2	3	3
CO4	3	3	3	3	3	2	2	2	3	2	3	3
CO5	3	3	3	2	2	3	2	3	3	3	3	3

K1-knowledge; K2-comprehension; K3-application; K4-analysis; K5-synthesis; K6-evaluation

Mapping of course outcome (CO) to the program specific outcome (PSO)						
	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	2	2	2	2	3
CO2	3	3	2	2	3	3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3
CO5	2	2	2	2	2	3

	Course Code: PYP 2216	**Course Title: On Job Training (Internship)**	**Credits = 04**		
			L	**T**	**P**
	Semester: II	**Total contact hours: 60**	**0**	**0**	**08**
List of prerequisite Courses					
HUT21XX (Research Methodology (offered by dept. of Chemistry))					
List of Courses where this course will be a prerequisite					
PYP2316 (Research project-I); PYP2415 (Research project-II)					
Description of the relevance of this course in the M.Sc. Physics Program					
In this, students will join various research institutes/industries and undergo training/research on related problems in experimental/computational physics and materials science, which will help them in their future course of study.					

	Students will have to consult the allotted guide for the topic of research.	
Grading at the end of the OJT will be done as per the R.9 document upon submission of **internship report and presentation**.		

SEMESTER-III

<table>
<tr><td rowspan="3"></td><td rowspan="2">Course Code: PYT 2311</td><td rowspan="2">Course Title: Colour Physics</td><td colspan="3">Credits = 02</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>Semester: III</td><td>Total contact hours: 30</td><td>1</td><td>1</td><td>-</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">List of prerequisite Courses</td></tr>
<tr><td colspan="6">Basic 12th standard courses of Physics and Mathematics</td></tr>
<tr><td colspan="6">List of Courses where this course will be a prerequisite</td></tr>
<tr><td colspan="6">Advanced courses in colour science and industrial colour technology, courses related to colourants and their applications in polymer and textile technology.</td></tr>
<tr><td colspan="6">Description of the relevance of this course in the M.Sc. Physics Program</td></tr>
<tr><td colspan="6">This interdisciplinary course will familiarize the students with the importance of understanding the science of colour, its relation to materials and the need to specify and communicate colour accurately in a way that it can be unambiguously understood and reproduced. The course shall enable the students to communicate colour in the way it is done in the industrial setting and equip them with the know-how related to aspects of measurement and technology of colour that is needed in various materials industries. This course is therefore of high relevance especially to the textiles, paints and dyestuffs/colourant industries from the standpoint of standardization and control in production.</td></tr>
<tr><td colspan="6">Course Outcomes (students will be able to…..)</td></tr>
<tr><td>CO1</td><td colspan="2">Understand the concept of colour appearance and the physical interactions between a source, object, and observer that lead to colour.</td><td colspan="3">K2</td></tr>
<tr><td>CO2</td><td colspan="2">Understand the luminous output of a source and daylight illumination.</td><td colspan="3">K2</td></tr>
<tr><td>CO3</td><td colspan="2">Understand about colour coding process in human observers.</td><td colspan="3">K3</td></tr>
<tr><td>CO4</td><td colspan="2">Specify a colour stimulus by understanding various colour specification systems and colour spaces.</td><td colspan="3">K6</td></tr>
<tr><td>CO5</td><td colspan="2">Predict recipe formulations for matching target colours.</td><td colspan="3">K5</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td></td><td colspan="2">Course Contents (Topics and subtopics)</td><td colspan="3">Reqd. hours</td></tr>
</table>

1	**Understanding concept of colour** Concept of colour appearance, illumination, sources/ illuminants, lamp efficacy and colour rendering properties of source, interaction of electromagnetic radiation with matter, specular and diffused reflectance, concept of gloss / matt, absorption, Beer-Lambert's Law, Kubelka-Munk theory, Colour perception by human observer, various colour theories, metamerism and colour constancy, standard observer.	14
2	**Colour specification and communication** Additive and subtractive mixing, real and basic primaries, quantification of colour, various CIE colour spaces & colour specifications, Munsell colour order system, colour measuring instruments: tintometer and spectrophotometers, single constant theory, colourant simulation and recipe match prediction.	16
	List of Textbooks/Reference books	
	1) Colour Physics for Industry – R.Mcdonald 2) Color: A Multidisciplinary Approach – H. Zollinger 3) The Colour Science of Dyes and Pigments – K. Mclaren 4) Color in Business, Science and Industry – D.B.Judd 5) The Elements of Colour – J. Itten 6) Industrial Colour Physics- G. A. Klein 7) Measuring Colour- R.W.G. Hunt and M. R. Pointer	

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	2	2	2	2	3	2	2	3	3
CO2	3	2	2	2	2	2	2	3	2	2	3	3
CO3	3	2	2	2	3	2	2	3	2	2	3	3
CO4	3	3	2	3	3	2	3	3	2	2	3	3
CO5	3	3	2	3	3	3	3	3	2	2	3	3

K1-knowledge; K2-comprehension; K3-application; K4-analysis; K5-synthesis; K6-evaluation

Mapping of course outcome (CO) to the program specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	2	2	3	2
CO2	3	2	2	2	3	3
CO3	3	2	2	2	2	2
CO4	3	3	3	3	2	3
CO5	3	3	3	3	3	3

<table>
<tr><td rowspan="3"></td><td rowspan="2">Course Code: PYT 2312</td><td rowspan="2">Course Title: Classical Electrodynamics</td><td colspan="3">Credits = 04</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>Semester: III</td><td>Total contact hours: 60</td><td>3</td><td>1</td><td>-</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">List of prerequisite Courses</td></tr>
<tr><td colspan="6">PYT2111-Classical Mechanics and Mathematical Physics</td></tr>
<tr><td colspan="6">List of Courses where this course will be a prerequisite</td></tr>
<tr><td colspan="6">Advanced graduate-level courses</td></tr>
<tr><td colspan="6">Description of the relevance of this course in the M.Sc. Physics Program</td></tr>
<tr><td colspan="6">Exposure and ability to use the advance formalism to analyse problems in various physical systems from a fundamental point of view. It enables students to understand the effect of electric and magnetic fields on the properties of matter.</td></tr>
<tr><td colspan="6">Course Outcomes (students will be able to…..)</td></tr>
<tr><td>CO1</td><td colspan="2">Apply advanced techniques in vector calculus and algebra.</td><td colspan="3">K4</td></tr>
<tr><td>CO2</td><td colspan="2">Formulate all the laws of Electrodynamics in operator notation, calculate the Maxwell stress tensor for various systems, and understand various conserved quantities of the electromagnetic field.</td><td colspan="3">K3</td></tr>
<tr><td>CO3</td><td colspan="2">Use Maxwell’s equations to understand wave propagation in vacuum and in media and thereby calculate reflectance and transmission at conducting surfaces.</td><td colspan="3">K3</td></tr>
<tr><td>CO4</td><td colspan="2">Calculate the frequency dependence of various physical quantities in a particular media.</td><td colspan="3">K4</td></tr>
<tr><td>CO5</td><td colspan="2">Calculate the radiation from point charges in motion and for various extended charge configurations, using a potential formulation of electrodynamics and gauge transformations.</td><td colspan="3">K4</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td></td><td colspan="2">Course Contents (Topics and subtopics)</td><td colspan="3">Reqd. hours</td></tr>
<tr><td>1</td><td colspan="2">Vector algebra and calculus:
Review of differential operators and related identities. Introduction to Cartesian Tensors and their transformation properties, the Levi- Civita symbol.</td><td colspan="3">06</td></tr>
<tr><td>2</td><td colspan="2">Review of classical Electrodynamics:</td><td colspan="3">10</td></tr>
</table>

	Maxwell's equations, conservation laws of charge, energy. Energy and momentum in Electrodynamics: Newton's third law in electrodynamics, Poynting theorem, Maxwell's stress tensor, conservation of linear and angular momentum.	
3	**Electromagnetic Waves in Nonconducting Media:** Monochromatic waves in free space, energy and momentum of electromagnetic waves, Polarization. Propagation through linear media, Reflection and transmission at normal incidence (review) and at oblique incidence. Electromagnetic Waves in Conductors: The modified wave equation, Monochromatic plane waves in conducting media. Reflection and transmission at a conducting surface, the frequency dependence of $\epsilon, \mu, \sigma, \alpha$. Dispersion in nonconductors. Wave guides, TE, TM and TEM modes. TE waves in a rectangular wave guide.	22
4	**Electromagnetic Radiation:** Potential Formulation of Electrodynamics, scalar and vector potentials, Gauge transformations, the Coulomb gauge and the Lorentz gauge.The Lorentz law in potential form. Retarded potentials, Lienard- Wiechert potentials and the fields due to a point charge in motion. Multipole expansion for a charge distribution in free space. Radiation by multipole moments: Radiation from electric dipole and magnetic dipole moment.	16
	List of Textbooks/Reference books	
	1. W. Greiner, Classical Electrodynamics, Springer – Verlag ,2000 (WG). 2. M.A. Heald and J. B. Marion, Classical Electromagnetic radiation Saunders (HM). 3. J. D Jackson, Classical Electrodynamics, 4th edition, John Wiley and sons. 4. D. J. Griffith, Introduction to Electrodynamics, 2nd edition, Prentice Hall (India). 5. J. R. Reitz, E. J. Milford and R.W. Christy, Foundation of Electromagnetic Theory, 4th edition Addison- Wesley. 6. W. K. H. Panofsky and M. Phillips, Classical Electricity and Magnetism 2nd edition, Addison – Wesley 7. Engineering electromagnetics, Nathan Ida, Springer.	

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	2	1	2	1	3	2	2	1	2	3
CO2	3	1	2	1	2	1	3	2	2	1	2	3
CO3	3	1	2	1	2	1	3	2	2	1	2	3
CO4	3	1	2	1	2	1	3	2	2	1	2	3
CO5	3	1	2	1	2	1	3	2	2	1	2	3

0= No correlation; 1=Weak correlation; 2=moderate correlation; 3=strong correlation

Mapping of course outcome (CO) to the program specific outcome (PSO)						
	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	1	1	2	2	1
CO2	3	1	1	2	2	1
CO3	3	1	1	2	2	1
CO4	3	1	1	2	2	1
CO5	3	1	1	2	2	1

	Course Code: PYT 2313	**Course Title: Introduction to Nanoscience**	**Credits = 04**		
			L	**T**	**P**
	Semester: III	**Total contact hours: 60**	**3**	**1**	**-**

List of prerequisite Courses
First years of undergraduate courses in Physics, Chemistry, and Mathematics
List of Courses where this course will be a prerequisite
1. PYP2415: Research Project; 2. PhD programs in Material Science, Physics 3. Graduate-level courses on energy storage devices, sustainability, green chemistry etc.
Description of the relevance of this course in the M.Sc. Physics Program
This course gives the flavor of materials at the nano-size regime. It will discuss the property variation with size and dimensionality to understand the reasons behind this, keeping in mind the material science principles it follows. This course also includes a discussion on the unique and novel materials discovered in the last century. The characterization techniques required to understand the size, morphology, structure, bonding, and functionalization groups will be discussed, along with their commercial applications.

Course Outcomes (students will be able to…..)		
CO1	Understand the importance of nanoscience and property variation with size.	K1
CO2	Know the different methods of synthesis based on requirements.	K3
CO3	Understand the Working Principle and utilization of characterization techniques.	K3
CO4	Know the properties of Special Nanomaterials and the reason behind them	K3
CO5	Understand the Applicability of Nanomaterials for commercial usage	K4

	Course Contents (Topics and subtopics)	**Reqd. hours**
1	**Introduction:** Metal Nanoclusters, magic Numbers, modeling of nanoparticles, bulk to nano transitions, effect of size reduction on the physical and chemical properties of materials, properties of nanomaterials.	08

2	**Synthesis Techniques:** High energy mechanical milling, melt mixing, Evaporation-condensation method, ionized cluster beam deposition, sputter deposition, ALD, PVD, Chemical Vapor Deposition, pulse laser methods, Chemical Reduction Method, microemulsion, sol-gel method,	10
3	**Characterization techniques:** Structural and chemical characterization: XRD, UV-visible, near-infrared, SEM, TEM, photoluminescence, XPS, EXAFS, ESR, NMR.	12
4	**Special Nanomaterials:** One-, two- and three-dimensional Nanomaterials, Band structure, property variation, Carbon nanostructures: fullerenes, carbon nanotubes. Bulk nanostructured materials, solid disordered nanostructures, nanostructured multilayers, metal nanoclusters, composite glasses, porous silicon.	15
5	**Application of Nanomaterials:** Nanofabrication, Lithography, Nanoelectronics, quantum dots and quantum well devices, plasmon waveguides (optical devices), Energy sector, automobiles, space, defense, sports, and cosmetics. Commercial Status of Nanomaterials	15
List of Textbooks/Reference books		
	1) Introduction to Nanotechnology – C. P. Poole, Jr. and F.J. Owens 2) Nanotechnology: Principles and Practices – S. K. Kulkarni 3) Nanostructures and Nanomaterials – G. Cao 4) Nanomaterials – A. S. Edelstein, R. C. Cammaratra 5) Nanostructures: Theory and Modeling – C. J. Delerue and M. Lannoo 6) Carbon nanotubes – S. Fiorito	

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	3	3	2	2	3	2	3	2	2	2	2
CO2	2	3	2	3	2	2	3	2	2	2	2	2
CO3	3	2	2	3	2	2	3	2	2	2	2	2
CO4	3	2	3	2	2	2	2	2	2	2	2	2
CO5	2	2	2	2	2	3	3	3	3	2	2	2

K1-knowledge; K2-comprehension; K3-application; K4-analysis; K5-synthesis; K6-evaluation

Mapping of course outcome (CO) to the program specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	2	3	3	3

CO2	2	2	3	2	3	3
CO3	3	3	3	2	2	3
CO4	2	3	2	2	3	3
CO5	2	2	2	2	3	3

<table>
<tr><td rowspan="3"></td><td rowspan="2">Course Code: PYT 231X</td><td rowspan="2">Course Title: Elective-III</td><td colspan="3">Credits = 04</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>Semester: III</td><td>Total contact hours: 60</td><td>3</td><td>1</td><td>-</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6"></td></tr>
<tr><td></td><td colspan="2">See the course content from the electives subject section.</td><td colspan="3"></td></tr>
<tr><td colspan="6">Confirm the availability of the course from the given list of electives with the Department office.</td></tr>
<tr><td></td><td colspan="2">Course Contents (Topics and subtopics)</td><td colspan="3">Reqd. hours</td></tr>
<tr><td colspan="6">List of Textbooks/Reference books</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="3"></td></tr>
</table>

	Course Code: PYP 2315	Course Title: Electronics Laboratory	Credits = 02		
			L	**T**	**P**
	Semester: III	**Total contact hours: 60**	-	-	04

	List of prerequisite Courses	
	PYT2114 (Electronics)	
	List of Courses where this course will be a prerequisite	
	NA	
	Description of relevance of this course in the M.Sc. Physics Program	
	This course enables students to understand measurement automation and data acquisition in instruments used in materials science research. The course contents also prepare students for various competitive exams and enables them for employment in hardware industry.	
	Course Outcomes (students will be able to…..)	
CO1	Understand basics of electrical circuits/components/power supply and microprocessor.	K3
CO2	Use 8051 microprocessor for basic arithmetic and logical operations.	K4
CO3	Utilize oscilloscope to test the electrical signal/functions/circuits and verify/debug the same.	K4
CO4	Understand and develop transducers to convert physical input into appropriate electrical signal.	K3
CO5	Interfacing microprocessor with input and output devices, viz. 8051 to LCD, 8051 with keyboard etc.	K5

	Course Contents (Topics and subtopics)	**Reqd. hours**
1	Constant Current Source	06
2	Constant Voltage Source	06
3	Waveform generation using Op-Amp	06
4	Active Filters using Op-Amp	06
5	Linear Sweep Generator using 555 timer	06
6	8-bit DAC	06
7	Adder / Subtractor	06
8	Presettable Counters	06
9	Shift Register	06
10	Multiplexer / Demultiplexer	06
11	8051 Microcontroller Programming	06
12	Port Programming using 8051 Microcontroller	06

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	1	3	1	1	3	2	2	2	1	3
CO2	2	2	1	3	1	1	3	2	2	2	1	3
CO3	2	2	1	3	1	1	3	2	2	2	1	3
CO4	2	2	1	3	1	1	3	2	2	2	1	3
CO5	2	2	1	3	1	1	3	2	2	2	1	3

0= No correlation; 1=Weak correlation; 2=moderate correlation; 3=strong correlation

Mapping of course outcome (CO) to the program specific outcome (PSO)						
	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	1	1	2	2	2	2
CO2	1	1	2	2	2	2
CO3	1	1	2	2	2	2
CO4	1	1	2	2	2	2
CO5	1	1	2	2	2	2

	Course Code: PYP 2316	**Course Title: Research Project-I**	**Credits = 04**		
			L	**T**	**P**
	Semester: III	**Total contact hours: 60**	**0**	**0**	**08**

List of prerequisite Courses

HUT21XX (Research Methodology (offered by dept. of Chemistry))

List of Courses where this course will be a prerequisite

PYP2415 (Research project-II)

Description of the relevance of this course in the M.Sc. Physics Program

In this, students will execute the research project allotted by the guide/department in line with the vision-mission of the physics department. The students will get hands-on experience in various aspects of experimental physics/materials science, which will help them pursue research as a career.

Student will have to consult allotted guide for the topic of research.

Grading at the end of the semester will be done as per the R.9 document upon submission of **research report** (this will lead to a research thesis at the end of semester IV, research project-II PYP2415) and **viva-voce**.

SEMESTER IV

<table>
<tr><td rowspan="3"></td><td rowspan="2">Course Code: PYT 2411</td><td rowspan="2">Course Title: Numerical Techniques using Python</td><td colspan="3">Credits = 04</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>Semester: IV</td><td>Total contact hours: 60</td><td>3</td><td>1</td><td>-</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">List of prerequisite Courses</td></tr>
<tr><td colspan="6">PYT2111-Classical Mechanics and Mathematical Physics</td></tr>
<tr><td colspan="6">List of Courses where this course will be a prerequisite</td></tr>
<tr><td colspan="6">This course will be useful in advanced computational techniques courses.</td></tr>
<tr><td colspan="6">Description of the relevance of this course in the M.Sc. Physics Program</td></tr>
<tr><td colspan="6">This course will enable students to select, modify, and apply existing software and computational methods towards solving/simulating various physical problems.</td></tr>
<tr><td colspan="6">Course Outcomes (students will be able to…..)</td></tr>
<tr><td>CO1</td><td colspan="2">Learn basic and advanced Python programming.</td><td colspan="3">K2</td></tr>
<tr><td>CO2</td><td colspan="2">Understand how numerical methods are implemented and used for computing.</td><td colspan="3">K2</td></tr>
<tr><td>CO3</td><td colspan="2">Understand how to improve numerical methods for better accuracy.</td><td colspan="3">K4</td></tr>
<tr><td>CO4</td><td colspan="2">Apply the above methods to problems in Physics and related fields.</td><td colspan="3">K5</td></tr>
<tr><td>CO5</td><td colspan="2">Use various Python libraries to perform numerical computing</td><td colspan="3">K5</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td></td><td colspan="2">Course Contents (Topics and subtopics)</td><td colspan="3">Reqd. hours</td></tr>
<tr><td>1</td><td colspan="2">Introduction to Linux and Python Programming
Basic Linux commands, editing files in Linux
What is programming, programming strategies, algorithms and flow charts, integer and floating point operations.

Basics of python programming (variables, conditional statements, for loops, lists, dictionaries), plotting with MatplotLib all using an integrated development environment</td><td colspan="3">10</td></tr>
<tr><td>2</td><td colspan="2">Advanced Python Programming
Introduction to NumPy and linear algebra
Introduction to SciPy and solution of ordinary differential equations (initial value problems), curve fitting, interpolation, linear and logistic regression
Introduction to the Jupyter notebook for general analysis (including analytical manipulations using Sympy)
Introduction to ChatGPT and automated code generation from text prompts.</td><td colspan="3">16</td></tr>
<tr><td>3</td><td colspan="2">Numerical Methods
Algebraic and transcendental equations: Iterative, bisection and Newton–Raphson methods, least-square curve fitting, straight line and polynomial fits, Newton and Lagrange interpolation formulae.</td><td colspan="3">20</td></tr>
</table>

	Simultaneous linear equations: Gauss elimination method, Gauss-Jordan matrix inversion method. Numerical integration: Trapezoidal rule, Simpson and Gaussian quadrature methods Ordinary differential equation: Euler and Runge–Kutta methods.	
4	**Stochastic Methods** Random number generators, Monte Carlo Integration, hit and miss, important sampling, Markov chain, Metropolis method, Brownian motion as random walk problems, phase transition in 2d Ising model.	14
	List of Textbooks/Reference books	
	1) Numerical methods for scientific and Engineering Computation, Jain M. K., Iyengar S. R. K, Jain R. K., New Age International, 1992. 2) Understanding Molecular Simulation, Daan Frenkel and B. Smit, Academic Press, 1996. 3) Computational Physics – S. E. Koonin and D. C. Meredith 4) Computational methods in physics and engineering – S. S. M. Wong 5) A primer to scientific programming in Python- Hans Petter Langtangen 6) Introduction to Computation and Programming using Python-John V. Guttag	

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	1	3	3	1	3	2	2	1	2	3
CO2	2	2	1	3	3	1	3	2	2	1	2	3
CO3	2	2	1	3	3	1	3	2	2	1	2	3
CO4	2	2	1	3	3	1	3	2	2	1	2	3
CO5	2	2	1	3	3	1	3	2	2	1	2	3

0= No correlation; 1=Weak correlation; 2=moderate correlation; 3=strong correlation

Mapping of course outcome (CO) to the program specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	1	3	3	3	2
CO2	2	1	3	3	3	2
CO3	2	1	3	3	3	2
CO4	2	1	3	3	3	2
CO5	2	1	3	3	3	2

	Course Code: PYT 2412	Course Title: Molecular Quantum Mechanics	Credits = 02		
			L	T	P
	Semester: IV	Total contact hours: 30	1	1	-

List of prerequisite Courses

PYT2103 (Quantum Mechanics-I); PYT2201 (Quantum Mechanics-II)

List of Courses where this course will be a prerequisite

Advanced graduate courses in molecular modeling

Description of the relevance of this course in the M.Sc. Physics Program

Students will be equipped with the necessary knowledge and expertise to quantum mechanically analyze the variety of problems in physical and chemical sciences.

Course Outcomes (students will be able to…..)

CO1	Formulate the Hamiltonian for various molecular systems by understanding the Born-Oppenheimer approximation.	K3
CO2	Calculate the eigenvalues and the eigenfunctions of molecules using the LCAO and VB approaches and the concept of molecular orbitals.	K3
CO3	Understand the concept of Hybridization in polyatomic molecules quantitatively using the LCAO technique and using Huckel's theory to understand simple conjugated systems.	K3
CO4	Create the group multiplication table for discrete groups and to calculate the group characters and formulate the group character table.	K4

	Course Contents (Topics and subtopics)	Reqd. hours
1	**Quantum Chemistry** Molecular Schrodinger equation, the Born-Oppenheimer approximation, molecular orbital and valence bond theory of molecule formation. The H^+ and H_2 systems eigenvalues and eigenfunctions in the BO approximation. Excited states of the H_2 molecule. Spin singlet and triplet states in molecules and their separation, transitions between singlet and triplet states.	15
2	Hybridisation of orbitals and molecular structure. Simple Huckel theory of linear conjugated systems. Examples of simple Huckel calculations.	05
3	**Group Theory in Molecular Quantum Mechanics** Introduction to group theory, definitions and postulates. Examples of discreate groups and group multiplication tables. Molecular symmetries and point groups, representations of groups, irreducible representations and the great orthogonality theorem. Character tables for point groups.	10

List of Textbooks/Reference books

1) Chemical Applications of Group Theory – F. A. Cotton
2) Introductory Quantum Mechanics – A. K. Chandra
3) Molecular Quantum Mechanics – Atkins and Friedman
4) Quantum Chemistry – I. Levine
5) Introduction to Group Theory – A. W. Joshi

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	3	1	2	1	2	2	2	1	2	3
CO2	3	1	3	1	2	1	2	2	2	1	2	3
CO3	3	1	3	1	2	1	2	2	2	1	2	3
CO4	3	1	3	1	2	1	2	2	2	1	2	3

0= No correlation; 1=Weak correlation; 2=moderate correlation; 3=strong correlation

Mapping of course outcome (CO) to the program-specific outcome (PSO)						
	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	2	2	2	2
CO2	3	3	2	2	2	2
CO3	3	3	2	2	2	2
CO4	3	3	2	2	2	2

	Course Code: PYT 2413	**Course Title: Statistical Mechanics**	**Credits = 04**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: 60**	**3**	**1**	**-**

List of prerequisite Courses		
PYT2111-Classical Mechanics and Mathematical Physics, PYT2112-Quantum mechnics-I; PYT2213-Quantum mechanics-II		
List of Courses where this course will be a prerequisite		
Advanced graduate-level courses in statistical mechanics, molecular modeling, and materials science		
Description of the relevance of this course in the M.Sc. Physics Program		
Exposure and ability to use advance formalism to analyze problems in various physical systems from fundamental point of view. It enables students to understand the behavior and calculate physical quantities for a system of large number of particles.		
Course Outcomes (students will be able to…..)		
CO1	Understand the need for a statistical approach to analyse system containing large number of particles, and capability to use necessary statistical techniques.	K3
CO2	Understand the concept of equilibrium and fluctuations from equilibrium for system with large number of particles.	K3
CO3	Analyse classical statistical systems using concepts of ensemble and using the partition function to compute thermodynamic quantities.	K4
CO4	Ability to analyse quantum statistical systems using techniques of ensemble.	K3
CO5	Ability to analyse non-ideal gases, gain familiarity with Ising (1D-2D) model and its solutions using Monte-Carlo technique.	K4
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	**Review of statistical thermodynamics** Thermodynamics and kinetic theory, introduction to probability, binomial, Poisson and Gaussian distributions, specification of the state of a system, concept of statistical ensemble, phase space, Liouville's theorem, equilibrium and fluctuations.	10
2	**Ensemble theory** Microcanonical ensemble, statistical concept of temperature, canonical ensemble, partition function, calculation of thermodynamic variables from the partition function, ideal monoatomic gas in a canonical ensemble, Gibbs' paradox, equipartition theorem, Maxwell-Boltzmann velocity distribution, grand canonical ensemble, chemical potential and fugacity, grand partition function, applications.	20
3	**Quantum statistical mechanics** Quantum distribution functions, partition function for ideal quantum gases, thermodynamic quantities and equations of state for ideal Fermi and Bose gases.	15
4	**Interacting Systems** Equation of State for non-ideal gas (Van der Waals), hard core interaction, Ising model for ferromagnetism, solution to one dimensional Ising model (using transfer matrix), Monte Carlo Simulations (2D Ising and 2D system of hard rods)	15
List of Textbooks/Reference books		
	1) Statistical Mechanics: An Introduction – S. Lokanathan and R. S. Gambhir	

	2) Statistical Mechnics – R. K. Pathria 3) Fundamentals of Statistical and Thermal Physics – F. Reif 4) Introduction to Statistical Physics, K. Huang	

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	3	1	3	1	2	1	2	3
CO2	3	1	1	1	3	1	3	1	2	1	2	3
CO3	3	1	1	1	3	1	3	1	2	1	2	3
CO4	3	1	1	1	3	1	3	1	2	1	2	3
CO5	3	1	1	1	3	1	3	1	2	1	2	3

0= No correlation; 1=Weak correlation; 2=moderate correlation; 3=strong correlation

Mapping of course outcome (CO) to the program-specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	1	2	2	1
CO2	3	3	1	2	2	1
CO3	3	3	1	2	2	1
CO4	3	3	1	2	2	1
CO5	3	3	1	2	2	1

	Course Code: PYT 241X	**Course Title: Elective-IV**	**Credits = 04**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: 60**	**3**	**1**	**-**

List of prerequisite Courses

List of Courses where this course will be a prerequisite

Description of the relevance of this course in the M.Sc. Physics Program		
	See the course content from the electives subject section.	
Confirm the availability of the course from the given list of electives with the Department office.		
	Course Contents (Topics and subtopics)	**Reqd. hours**
List of Textbooks/Reference books		

	Course Code: PYP 2415	**Course Title: Research Project-II**	**Credits = 06**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: 90**	**0**	**0**	**12**
List of prerequisite Courses					
PYP2316 (Research Project-I); HUT21XX (Research Methodology (offered by dept. of Chemistry))					
List of Courses where this course will be a prerequisite					
NA					
Description of the relevance of this course in the M.Sc. Physics Program					

In this, students will execute the research project allotted by the guide/department in line with the vision-mission of the physics department. The students will get hands-on experience in various aspects of experimental physics/materials science, which will help them pursue research as a career.
Student will have to consult allotted guide for the topic of research.
Grading at the end of the semester will be done as per the R.9 document upon submission of the research thesis and viva voce.

Open electives offered for MSc. Physics (Materials Science) Program

Sr. No.	Subject Code	Semester in which course is offered	Subject title	Credits			Marks		
				L	T	P	CA	M	ES
1	PYT 2114	First	Electronics	3	1	-	20	30	50
2	PYT 2214	Second	Introduction to Ceramics	3	1	-	20	30	50

3	PYT 2314	Third	Polymer Physics	3	1	-	20	30	50
4	PYT 2414	Fourth	Introduction to Phase transformation	3	1	-	20	30	50
5	PYT 2416	Fourth	Advanced Polymer Physics and Polymer composites	3	1	-	20	30	50
6	PYT 2417	Fourth	Solar Energy and Non-Conventional Energy Sources	3	1	-	20	30	50

L- Lecture, T-Tutorial, P-Practicals; CA-Continuous assessment, M- Mid semister, E- End Semester Examination

	Course Code: PYT 2114	**Course Title: Electronics**	**Credits = 04**		
			L	**T**	**P**
	Semester: I	**Total contact hours: 60**	**3**	**1**	**-**
List of prerequisite Courses					
N.A.					
List of Courses where this course will be a prerequisite					
PYP2315-Electronics laboratory					
Description of the relevance of this course in the M.Sc. Physics Program					

This course enables students to understand measurement automation and data acquisition in instruments used in materials science research. The course contents also prepare students for various competitive exams and enable them for employment in the hardware industry.		
Course Outcomes (students will be able to…..)		
CO1	Understand basics of electrical circuits/components/power supply and microprocessor.	K2
CO2	Use 8051 microprocessor for basic arithmetic and logical operations.	K4
CO3	Utilize oscilloscope to test the electrical signal/functions/circuits and verify/debug the same.	K4
CO4	Understand and develop transducers to convert physical input into appropriate electrical signal.	K5
CO5	Interfacing microprocessor with input and output devices, viz. 8051 to LCD, 8051 with keyboard etc.	K6
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	**Power Supplies** Monolithic IC regulators (3-terminal regulators): ac to dc conversion, load line, basic types of IC regulators, the LM78XX series, fixed regulator, the LM79XX series, regulated dual supplies, adjustable regulators, ripple rejection Switching regulators: the pass transistor, switching the pass transistor on and off, topologies, buck regulator, boost regulator, buck-boost regulator, monolithic buck regulators, monolithic boost regulators, monolithic buck-boost regulator, wireless power supplies.	04
2	**Oscilloscope** Introduction to oscilloscope, loading effect (T), waveform analysis, DSO	04
3	**Transducers** Strain gauge, capacitive transducer, load cell, piezo-electrical transducer, photoelectric transducer, photo-voltaic cell, semiconductor photodiode, phototransistor, thermocouple, semiconductor diode temperature sensor, IC-type sensor, pyrometer, total radiation pyrometer, infrared pyrometer, optical pyrometer, ultrasonic temperature transducer, pH sensor.	08
4	**Digital circuits** concept of Pull-Up, Pull-Down, Source, Sink, voltage levels of logic gates (TTL, CMOS), Combinational Logic, FPGA, Karnaugh simplifications, POS, SOP, sequential logic	08
5	**Digital Arithmetic** Unsigned binary numbers: limits, overflow, sign-magnitude numbers: range of sign-magnitude numbers, 2’s complement representation: 1’s complement, 2’s complement, positive and negative numbers, converting to and from 2’s complement representation, 2’s complement arithmetic: addition, subtraction, overflow	04
	Introduction to Microcontrollers	

6	Introduction, Microcontrollers and Microprocessors, Harvard and Von Neumann Architectures, Registers in MCS-51, 8051 Pin Description, 8051 Connections, Memory Organization. Programming: MCS-51 using C (Keil µVision) Instructions and Simple programs - I/O Ports, Introduction to R Pi, Aurdino 8051 microcontroller: timer/counters, serial communication, interrupts [9+3T] Programming 8051 timers, counter programming, basics of serial communication, 8051 connection to RS232, 8051 serial port programming in assembly, 8051 interrupts, programming timer interrupts, programming external hardware interrupts	08
7	**Interfacing with 8051** LCD and keyboard interfacing: LCD interfacing, keyboard interfacing, ADC, DAC and sensor interfacing: interfacing ADC to 8051(only interfacingADC0804 and ADC0808 to 8051), DAC 1408, sensor interfacing and signal conditioning Motor control: relay, opto-isolators, dc and stepper motors, relays and opto-isolators, stepper motor interfacing, dc motor interfacing and PWM	12
List of Textbooks/Reference books		
	1. Digital Principles and Applications – D. P. Leach, A. P. Malvino and G. Saha 2. 8051 Micro-controller – K. J. Ayala 3. The 8051 Microcontroller and Embedded Systems – M. A. Mazidi, J. G. Mazidi and R. D. Mckinlay 4. Digital Fundamentals – Floyd Thomas L	

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	1	3	1	1	3	2	2	2	1	3
CO2	2	2	1	3	1	1	3	2	2	2	1	3
CO3	2	2	1	3	1	1	3	2	2	2	1	3
CO4	2	2	1	3	1	1	3	2	2	2	1	3
CO5	2	2	1	3	1	1	3	2	2	2	1	3

0= No correlation; 1=Weak correlation; 2=moderate correlation; 3=strong correlation

Mapping of course outcome (CO) to the program-specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	1	1	2	2	2	2
CO2	1	1	2	2	2	2
CO3	1	1	2	2	2	2
CO4	1	1	2	2	2	2
CO5	1	1	2	2	2	2

<table>
<tr><td rowspan="3"></td><td rowspan="2">Course Code: PYT 2214</td><td rowspan="2">Course Title: Introduction to Ceramics</td><td colspan="3">Credits = 04</td></tr>
<tr><td>L</td><td>T</td><td>P</td></tr>
<tr><td>Semester: II</td><td>Total contact hours: 60</td><td>3</td><td>1</td><td>-</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">List of prerequisite Courses</td></tr>
<tr><td colspan="6">PYT2113 (Solid State Physics); PYT2112 (Quantum Mechanics-I)</td></tr>
<tr><td colspan="6">List of Courses where this course will be a prerequisite</td></tr>
<tr><td colspan="6">PYT2314(Polymer Physics)</td></tr>
<tr><td colspan="6">Description of the relevance of this course in the M.Sc. Physics Program</td></tr>
<tr><td colspan="6">This course relates the fundamental understanding of solid-state physics/chemistry with ceramic structures and its effect on various physio-chemical properties of ceramic materials. The concepts of electrical, mechanical, and thermal properties studied in various MSc courses from a fundamental viewpoint will be explored from a material-specific view in this course.</td></tr>
</table>

Course Outcomes (students will be able to…..)		
CO1	Understanding the various structures of the ceramics, synthesis mechanisms, and structure-property co-relationships	K2
CO2	Identify various possible defect reactions and write them using Kröger-Vink notations for various ceramics systems and atmospheric conditions.	K3
CO3	Apply statistical models to understand and estimate the mechanical behavior of the ceramics.	K4
CO4	Understand the electrical behavior of various ceramics families and classify them based on potential applications.	K3
CO5	Demonstrate preparation of samples for measurement of electrical properties.	K4
CO6	Analyze the electrical data using various mathematical equations and circuit fitting models.	K4
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	**Introduction:** Bonding and crystal structure, point defects, Kröger-Vink notations, effects of partial pressure of oxygen and temperature on defect concentration, effect of microstructure on the properties of ceramics	14
2	**Synthesis** Synthesis of ceramic powders and nanoparticles, sintering and grain growth mechanisms, solid state sintering, Liquid phase sintering, Hot pressing and hot isostatic pressing	10
3	**Mechanical properties** Theoretical fracture strength, Griffith's theory of brittle fracture, fracture toughness, factors affecting mechanical properties of ceramic materials, toughening mechanisms, Transformation toughening, R-curve behaviour and designing with ceramics, Weibull modulus, creep and fatigue in ceramic materials.	12
4	**Electrical and Thermal properties** Electronic ceramics, Dielectric properties of ceramics, polarization Mechanisms, Capacitors and insulators, piezoelectric, ferro and anti-ferroelectric ceramics. Thermal expansion, thermal conductivity, thermal stress, and thermal shock resistance, spontaneous microcracking, thermal tempering	16
5	**Introduction to glassy materials** Glass formation, Glass structure, Ceramic composites, glass ceramics, measurement of ceramic properties	08
List of Textbooks/Reference books		
	1) Fundamentals of ceramics – M. W. Barsoum 2) Ceramic science and technology – W. D. Kingery, H. K. Bowen and D. R. Ulman 3) Ceramic fabrication processes – F. F. Y. Wang 4) Better ceramics through chemistry – C. J. Brinker, D. E. Clark and D. R. Ullrich	

Mapping of course outcome (CO) to the program outcome (PO)												
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3	1	2	1	1	1	3	2	2	2
CO2	2	3	3	1	3	1	2	1	3	2	2	2
CO3	2	3	3	3	2	1	3	2	3	2	2	2
CO4	3	3	3	3	3	1	2	2	3	2	2	2
CO5	2	3	3	3	3	1	3	3	3	2	2	2
CO6	3	3	3	3	3	1	3	3	3	2	2	2

0= No correlation; 1=Weak correlation; 2=moderate correlation; 3=strong correlation

Mapping of course outcomes (CO) to the program-specific outcome (PSO)						
	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	1	1	1	1	1	2
CO2	1	1	1	1	1	2
CO3	3	1	3	3	3	3
CO4	2	1	3	2	3	3
CO5	3	1	3	2	3	3
CO6	3	1	3	2	3	3

	Course Code: PYT 2314	**Course Title: Polymer Physics**	**Credits = 04**		
			L	**T**	**P**
	Semester: III	**Total contact hours: 60**	**3**	**1**	**-**

List of prerequisite Courses

PYT2113 (Solid State Physics); PYT2112 (Quantum Mechanics-I)

List of Courses where this course will be a prerequisite

PYT2416 (Advanced Polymer Physics and Polymer Composites)

Description of the relevance of this course in the M.Sc. Physics Program

This course forms the core of the specialization offered in the MSc Physics program. With this course, students will explore the world of polymers and apply the basic knowledge gained in their physics courses to understand polymer synthesis via the kinetics of reactions, mechanical properties, and various other physical properties.

Course Outcomes (students will be able to…..)

CO1	Classify the polymers based on structure, synthesis mechanism, and applications.	K2

CO2	Understand the concept of Molecular weight and polydispersity and calculate the same for any given polymer.	K2
CO3	Examine the polymers that can be synthesized by step and/or chain polymerization techniques and assess the feasibility/rate and other factors for the chosen method.	K3
CO4	Understand the concept of glass transition temperature (T_g), and design the polymer/composite suitable for particular applications based on the T_g (or changing the T_g).	K3
CO5	Students should distinguish between the applicability of viscoelastic models for polymers and create/modify various model elements to satisfy the given viscoelastic behaviour.	K4
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	**Introduction:** General introduction to macromolecules, classification of polymers, structure of crystalline and amorphous polymers, lamellar, fibrillar, globular and spherulitic structures, domain structure of amorphous polymers, Molecular weight of Polymers, polydispersity, and their determination. Effect of chain entanglement, Chain conformation in polymers.	10
2	**Synthesis of polymers:** Classification of polymerization reactions. Step Polymerization: polycondensation, polyaddition polymerization. Radical polymerization, ionic polymerization, coordination polymerization, co-polymerization: Step, Chain, Block copolymerization. Kinetics of various polymerization processes.	14
3	**Thermal behaviour:** Glass transition temperature, melting temperature, heat distortion temperature, factors affecting Tg and its relationship with various properties, Thermal transitions, melting of crystalline polymers, thermal degradation, thermal expansion in polymers, thermogravimetry, differential scanning calorimetry. Effect of structure on thermal properties of polymers.	12
4	**Mechanical behaviour:** Fundamental concepts of rheology, elastic deformation in polymers, theory of linear viscoelasticity, concept of relaxation, stress-strain behaviour, its dependence on internal and external factors, fatigue and lifetime of polymers, viscoelastic mechanical models. Polymer structure and mechanical properties.	16
5	**Electrical behaviour:** Diffusion of fluids through polymeric surfaces, barrier properties. Dielectric properties: dielectric measurements and its use, dielectric relaxation, dielectric breakdown. Conduction in polymers: conducting, composites, ionic conduction, inherently conducting polymers; polymer electronics: LED, solar cells transistors etc. Gel electrolytes for batteries.	08
	List of Textbooks/Reference books	
	1. Textbook of Polymer Science – F. W. Billmeyer 2. Introduction to polymers- Robert J. Young and Peter A. Lovell 3. Polymer Science: V. R. Gowariker, N. V. Viswaanathan 4. Polymer Physics – U. W. Gedde 5. Macromolecular Physics: Part II and Part III – B. Wunderlich	

	6. Principles of Polymer Morphology – D. C. Bassett

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	3	2	2	2	2	2	2	2	2	3
CO2	2	2	3	2	3	2	2	2	2	2	2	3
CO3	2	2	2	2	3	2	2	2	2	2	2	3
CO4	2	2	2	3	3	2	2	2	2	2	2	3
CO5	2	2	2	3	3	2	2	2	2	2	2	3

0= No correlation; 1=Weak correlation; 2=moderate correlation; 3=strong correlation

Mapping of course outcome (CO) to the program-specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	1	1	2	2	2	2
CO2	1	1	3	2	3	3
CO3	1	1	2	2	3	2
CO4	1	1	2	2	2	3
CO5	1	1	3	2	3	2

	Course Code: PYT 2414	**Course Title: Introduction to Phase Transformations**	**Credits = 04**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: 60**	**3**	**1**	**-**

List of prerequisite Courses

PYT2211-Materials science and synthesis, PYT2113-Solid State Physics

List of Courses where this course will be a prerequisite

Advances courses in materials science and metallurgy

Description of the relevance of this course in the M.Sc. Physics Program

This course enables students to understand the thermodynamics behind the formation of materials and phase transformations and correlate this with materials applications.

Course Outcomes (students will be able to…..)

CO1	Understand the fundamental thermodynamics and the process of diffusion in solids and kinetics.	K2
CO2	Estimate the eutectic temperature, phase formation/identification from binary/ternary phase diagrams.	K3

CO3	Analyse the Fe-C phase diagrams for various possible phases with temperature and Carbon content.	K3
CO4	Apply precipitation hardening/dispersion strengthening/transformation strengthening mechanisms for toughening metals/ceramics.	K4
CO5	Explore various techniques to strengthen metals and ceramics.	K4
	Course Contents (Topics and subtopics)	**Reqd. hours**
1	Interatomic bonding, structure of materials, crystal defects and deformation. Diffusion. Interface-structure and energies, migration of interfaces and diffusion-controlled growth.	14
2	Laws of thermodynamics, Gibbs equation, Free energy-composition diagrams, Formation and analysis of binary and ternary phase diagrams. Solidification, solid to solid nucleation theory, thermodynamics and kinetics of phase transformations, precipitation, diffusive and displacive transformations, order-disorder transformations.	20
3	**Applications** Non-equilibrium phase diagrams-Phase transformations in steels, crystallography of martensitic transformation, shape-memory alloys, glass transformation, bulk material glass, advanced ceramics- transformation strengthening and phase stability, electric and magnetic materials. High pressure phase transformation.	26
	List of Textbooks/Reference books	
	1) Phase transformations in Metals and Alloys – D A Porter and Easterling 2) Materials Science and Engineering -William D. Callister, Jr. 3) Theory of structural transformations in solids – A. G. Khachaturyan 4) Phase diagrams: Materials science and technology, vol. 6 – A. M. Alper	

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	1	3	1	1	2	3	3	2	1	2	3
CO2	2	1	3	1	1	2	3	3	2	1	2	3
CO3	2	1	3	1	1	2	3	3	2	1	2	3
CO4	2	1	3	1	1	2	3	3	2	1	2	3
CO5	2	1	3	1	1	2	3	3	2	1	2	3

0= No correlation; 1=Weak correlation; 2=moderate correlation; 3=strong correlation

Mapping of course outcome (CO) to the program-specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	1	1	1	3	3

CO2	3	1	1	1	3	3
CO3	3	1	1	1	3	3
CO4	3	1	1	1	3	3
CO5	3	1	1	1	3	3

	Course Code: PYT 2416	**Course Title: Advanced Polymer Physics and Polymer Composites**	**Credits = 04**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: 60**	**3**	**1**	**-**

List of prerequisite Courses

PYT2314 (Polymer Physics)

List of Courses where this course will be a prerequisite

Higher-level graduate courses

Description of the relevance of this course in the M.Sc. Physics Program

This course complements the other elective courses offered in earlier semesters in the MSc Physics program. With this course, students will understand the nuances of polymer mixing, rheology and nanocomposites.

Course Outcomes (students will be able to…..)

CO1	Understand the importance of composite materials from a mechanical strength point of view.	K2
CO2	Calculate the weight fractions of reinforcement and matrix and estimate its performance.	K4
CO3	Apply the concepts of rheology to various manufacturing processes.	K4
CO4	Learn to blend and mix various polymers for desired results.	K3

	Course Contents (Topics and subtopics)	Reqd. hours
1	Importance of polymer blends/composites, concept of polymer miscibility, interchange forces in polymer blends, phase equilibria and transitions, phase separation, behaviour of polymer mixtures: upper and lower critical solution temperatures, polymer-polymer compatibility, role of additives	15
2	Dispersion of nanomaterials (layered silicates, carbon nanotubes) in host materials, preparation of nanocomposites: intercalation, exfoliation, common solvent, polymer melt intercalation methods, in-situ polymerisation method, crystallization of nanocomposites, various properties of nanocomposites	15
3	**Polymer rheology [8+4T]** Concept of stress and strain tensors, constitutional equations of rheology, shear and extensional viscosities, dependence of viscosity on temperature, pressure and molecular weight, flow curve, flow of Newtonian and non-Newtonian liquids, rheology of extrusion and calendaring	15
4	**Polymer mixing [6+3T]** Theory of mixing, macro- and micro-mixing, distributive and dispersive mixing, polymerpolymer mixing, melt mixing, solution blending, mixing by reaction	15
	List of Textbooks/Reference books	
	1) Structure and properties of oriented polymers – I. M. Ward 2) Polymer-clay nanocomposites – T. J. Pinnavaia and G. W. Beall 3) Principles of polymer morphology – D. C. Bassett 4) Polymer alloys and blends – L.A. Utracki 5) Thermal characterization of polymeric materials – E. A. Turi 6) Polymer Characterisation: Physical Techniques – D. Cambell and J. R. White 7) Introduction to Polymer Spectroscopy – W. Klopffer	

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	2	2	2	2	1	2	1	2	1	2	3
CO2	1	3	2	2	3	1	3	1	2	1	2	3
CO3	1	2	2	2	3	1	3	1	2	1	2	3
CO4	1	2	2	3	2	1	3	1	2	1	2	3

0= No correlation; 1=Weak correlation; 2=moderate correlation; 3=strong correlation

Mapping of course outcome (CO) to the program-specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	1	1	1	3	3
CO2	2	1	1	3	3	3

CO3	2	1	1	1	3	3
CO4	2	1	1	1	3	3

3, Strong Contribution; 2, Moderate Contribution; 1, Low Contribution; 0− No Contribution
K, knowledge level from the cognitive domain

	Course Code: PYT 2417	**Course Title: Solar Energy and Non-Conventional Energy Sources**	**Credits = 04**		
			L	**T**	**P**
	Semester: IV	**Total contact hours: 60**	**3**	**1**	**-**
List of prerequisite Courses					
PYT2211 (Materials science and synthesis); PYT2313 (Introduction to Nanoscience)					
List of Courses where this course will be a prerequisite					
Higher-level graduate courses.					
Description of the relevance of this course in the M.Sc. Physics Program					
This course will introduce students to energy storage and conversion materials. Students will learn the underlying mechanism behind these storage techniques.					
Course Outcomes (students will be able to…..)					
CO1	Understand the importance of various renewable energy sources.		K2		
CO2	Calculate the energy requirement and output of a renewable energy device/source.		K4		
CO3	Use the knowledge of solar photovoltaics for efficient energy generation.		K3		
CO4	Apply proper utilization of energy sources and extract better efficiency from the energy sources.		K4		
	Course Contents (Topics and subtopics)		**Reqd. hours**		
	Conventional energy resources				

1	Conventional energy sources, energy conservation and efficiency in production transfer and utilization (potential and limitations), climate changes and environmental pollution, measurement of pollution, pollution management	15
2	**Renewable energy resources** Renewable energy sources, advantages of renewable energy utilisation Solar energy: solar radiation, availability, measurement and estimation, solar thermal conversion device and storage application	15
3	**Solar photovoltaics:** fundamentals of photo voltaic energy, conversion physics and material properties, basics to photovoltaic conversions, different types of solar cells	15
4	Tidal energy, wind energy, bioenergy as renewable energy sources	15
5	Harnessing energy for utilisation, product design, and development of newer ways, their management	15
List of Textbooks/Reference books		
	1) Fundamentals of Solar Cells – A. L. Fahrenbruch and R. H. Bube 2) Solar Cell Device Physics – S. Fonash 3) Solar energy: principles of thermal collection and storage – S. P. Sukhatame 4) Solar engineering of thermal process – J. A. Duffie and W. A. Beckman 5) Renewable energy resources – T. Twidell and A. D. Weir 6) Principles of Solar energy – D. Y. Goswami, F. Kreith and J.F Kreider	

Mapping of course outcome (CO) to the program outcome (PO)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	1	2	2	2	2	2	2	3	2	2	3
CO2	1	1	2	2	2	2	2	2	3	2	2	3
CO3	1	1	2	2	2	2	2	2	3	2	2	3
CO4	1	1	2	2	2	2	2	2	3	2	2	3

0= No correlation; 1=Weak correlation; 2=moderate correlation; 3=strong correlation

Mapping of course outcome (CO) to the program-specific outcome (PSO)

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	1	1	1	3	3
CO2	2	1	1	1	3	3
CO3	2	1	1	1	3	3
CO4	2	1	1	1	3	3

3, Strong Contribution; 2, Moderate Contribution; 1, Low Contribution; 0− No Contribution
K, knowledge level from the cognitive domain