SCHOOL OF NANOSCIENCE AND NANOTECHNOLOGY

MAHATMA GANDHI UNIVERSITY

CURRICULUM STRUCTURE AND SYLLABI

(BASED ON OUTCOME BASED EDUCATION)

For the Programme,

M. Sc. Physics (Nanoscience and Nanotechnology)

(Under the CSS Regulations 2020 of Mahatma Gandhi University

w.e.f**. 2022** Admission Onwards)

PREFACE

I am happy to present the revised curricula and syllabi of the following M. Sc. Physics (Nanoscience and Nanotechnology) Programme of the School of Nanoscience and Nanotechnology according to the OBE concept (with effect from 2022 admission onwards) for favour of approval by the Faculty and Academic Council of the University.

The Board of Studies has restructured the curriculum as per the Outcome Based Education (OBE) system. OBE is an educational approach that bases each part of the educational system with respect to the goals set for the students. OBE aims to equip the students (learners) with knowledge, competency, and orientations required for achieving their goals when they depart the institution. Further OBE empowers students to choose what they would like to study and how they would like to study it. The teaching methodologies and the evaluation system are also modified in accordance with the outcome-based approach. The Programme Specific Outcomes (PSOs) and the Course Outcomes (COs) are presented in the beginning of the syllabus. The correlation of PSOs and the COs are shown in the syllabus for each course.

The draft curricula and syllabi for the M. Sc. Physics (Nanoscience and Nanotechnology) programme was discussed rigorously in the Board of Studies of the School of Nanoscience and Nanotechnology with attention to detail. The Board of Studies has also modified the scheme, curricula and syllabi for the four M. Sc. programmes in conformity with the revised CSS Regulations 2020 by the Mahatma Gandhi University to suit the Credit and Semester System. The content of the syllabus has been modified significantly- around 20 % of the total content from the previous syllabus- by judiciously perfecting the previous courses.

The Board of Studies feels that appreciable updating could be done in keeping pace with the current developments and trends in physics and nanotechnology education.

-sd-

Prof. ……………..

(Chairman, Board of Studies of School of Nanoscience and Nanotechnology)

Members of the Board of Studies of School of Nanoscience and Nanotechnology

(vide UO No: 5435/AD A 7/2022/MGU Dated: 25.05.2022)

1. Prof. (Dr.) Sabu Thomas, Hon. Vice Chancellor & Director of School of Nanoscience and Nanotechnology.
2. Dr. Sreekala MS, Joint Director, School of Nanoscience and Nanotechnology.
3. Dr. Nandakumar Kalarikkal, School of Pure and Applied Physics.
4. Dr. Radhakrishnan EK, School of Biosciences.
5. Dr. Anitha C Kumar, School of Chemical Sciences.
6. Dr. Kuruvilla Joseph, IIST Thiruvananthapuram.
7. Dr. Sandhyarani, NIT Calicut.
8. Dr. Lissymol Jacob, SCTIMST, Thiruvananthapuram.
9. Dr. Anantharaman, CUSAT.
10. Dr. Deepthi Menon, AIMS Kochi.
11. Dr. Honey John, CUSAT.

Mahatma Gandhi University

Vision

''Mahatma Gandhi University envisions to excel in the field of higher education and cater to the scholastic and developmental needs of the individual, through continuous creation of critical knowledge base for the society's sustained and inclusive growth."

Mission

- To conduct and support undergraduate, postgraduate and research-level programmes of quality in different disciplines
- To foster teaching, research and extension activities for the creation of new knowledge for the development of society
- To help in the creation and development of manpower that would provide intellectual leadership to the community
- To provide skilled manpower to the professional, industrial and service sectors in the country so as to meet global demands
- To help promote the cultural heritage of the nation and preserve the environmental sustainability and quality of life
- To cater to the holistic development of the region through academic leadership.

School of Nanoscience and Nanotechnology

Vision

- Quality education in Physics and Chemistry with specialization in Nanoscience and Nanotechnology for the creation of a vibrant and inclusive society.

Mission

- Generation, preservation and dissemination of knowledge in the frontier areas of science.
- Equip the students to build up a scientific career and contribute towards the national development.

- national development.
- Foster collaboration with leading research institutions in knowledge production.
- Inculcate among students human values with global competence.

OBJECTIVES

School of Nanoscience & Nanotechnology, Mahatma Gandhi University launches the M. Sc. Program in Physics (Nanoscience and Nanotechnology) which has been designed to attract highly motivated science graduates. This program is intended to create highly skilled manpower in the field of Nanoscience and Nanotechnology. This program would admit 20 numbers of bright, highly motivated students with excellent academic record at the graduate level. The main objective of the program is to induce and cultivate an enhanced sense of research awareness and aptitude with perspectives on the Physics and chemistry of nanomaterials. The final semester is fully dedicated to a six-month research lab or industrial work concluded with the dissertation. This will ensure a research career-oriented post-graduate degree course uplifting the students' prospect in the ever-advancing field of Nanoscience and Nanotechnology. Upon successful completion of the two years in the program, the candidates will be awarded a Master's Degree in Physics (Nanoscience and Nanotechnology) under the Faculty of Science of Mahatma Gandhi University.

DEFINITIONS

The **Program** refers to the previous concept of degree carried out in a time-bound academic period.

The **Course** means the curricular content for teaching and learning or seminar in a specific area or theme of knowledge.

The **Core Course** means a compulsory course in a subject related to a particular program.

The **Elective Course** means an optional course which can be selected from among a group of electives provided in the program.

SEMESTER SYSTEM

The M. Sc. Program will have four semesters. There shall be a minimum of 540 hours distributed over 90 working days in each semester spread over l8 five days working weeks.

Credit (C) is the unit by which a course is measured. It is the measure of total numbers of hours of training received in a course during a semester.

Grade means a letter symbol (e. g. A, B, C. etc.) which indicates the broad level of performance of a student in an answer/course/semester/program.

Weight is a numerical measure quantifying the comparative range of an answer or the comparative importance assigned to different components like theory (internal and external examinations) Internship, Dissertation etc.

Grade Point (G) is the weightage allotted to Grade letter.

Credit Point (C) refers to the product of number of credits of a course and grade point obtained by a student for a given course.

Semester Grade Point Average (SGPA) refers to the performance of the student in a given semester. SGPA is a weighted average based on the total credit points earned by a student in all the courses in the semester divided by the total number of credits offered in a semester. SGPA will be computed as and when a student completes all the required courses of a semester with a minimum required grade as per the respective curriculum.

Cumulative Grade Point Average (CGPA) refers to the performance of the student for all semesters of the program. CGPA is a weighted average based on the SGPA earned by a student in all semesters of the program and the total number of credits required in the program.

CGPA is calculated on the basis of SGPA with the minimum required SGPAs of all semesters may not be sufficient to obtain the minimum fixed CGPA for pass in the program.

Grade Point Average (GPA) is the value obtained by dividing the sum of the weighted grade points obtained by a student in an examination of a course in a semester by the total weightage taken in that examination. The grade point average shall be rounded off to two decimal places.

Preamble

Outcome Based Education (OBE) w.e.f. the Academic Year 2022-23 SCHOOL OF NANOSCIENCE AND NANOTECHNOLOGY
Mahatma Gandhi University

Introduction

A high priority task in the context of education in India is improvement of quality of higher education for equipping young people with skills relevant for global and national standards and enhancing the opportunities for social mobility. Mahatma Gandhi University has initiated an Outcome Based Education (OBE) for enhancing employability of graduates through curriculum reforms based on a learning outcomes-based curriculum framework, upgrading academic resources and learning environment.

Learning outcomes specify what graduates completing a particular Programme of study are expected to know, understand and be able to do at the end of their programme of study. The fundamental premise underlying the learning outcomes-based approach to curriculum development is that higher education qualifications are awarded on the basis of demonstrated achievement of outcomes, expressed in terms of knowledge, understanding, skills, attitudes and values. Outcomes provide the basis for an effective interaction among the various stakeholders. It is the results-oriented thinking and is the opposite of input- based education where the emphasis is on the educational process.

Outcome Based Education (OBE) process

OBE is a comprehensive approach to organize and operate a curriculum that is focused on and defined by the successful demonstrations of learning sought from each learner. The term clearly means focusing and organising everything in an education system around "what is essential for all learners to be able to do successfully at the end of their learning experiences". OBE is an approach to education in which decisions about the curriculum and instruction are driven by the exit learning outcomes that the students should display at the end of a programme or a course. By the end of educational experience, each student should have achieved the outcomes.

Benefits of OBE

The OBE Framework is a paradigm shift from traditional education system into OBE system where there is greater focus on programme and course outcomes. It guarantees that curriculum, teaching and learning strategies and assessment tools are continuously enhanced through a continuous improvement process. All decisions including those related to curriculum, delivery of instruction and assessment are based on the best way to achieve the pre-determined outcomes. Traditionally, educators have measured learning in terms of standardized tests. In contrast, outcome-based education defines learning as what students can demonstrate that they know.

Benefits of OBE:

- More directed & coherent curriculum.
- Graduates will be more "relevant" to industry & other stakeholders (more well-rounded Graduates)
- Continuous Quality Improvement is in place.
- OBE shifts from measuring input and process to include measuring the output (outcome)

Learning Outcomes based Curriculum Framework (LOCF) for Post Graduate Programmes: IQAC MG University

One of the main objectives of OBE is to ensure continuous improvement of programmes in terms of maintaining the relevance in curriculum as well as responding to the requirements of the stakeholders. an OBE system has been proposed and to be implemented at various Departments of Mahatma Gandhi University from 2020-21acdemic year onwards, as a quality-assurance approach to improve teaching and learning outcomes and processes. This OBE plan incorporates the "outcomes assessment" process to be followed in the departments. OBE should be a key driver of the curriculum management in all the departments of the university. Therefore, as envisaged by the IQAC of Mahatma Gandhi university, an OBE based curricular framework has been proposed for the Masters programmes of School of Nanoscience and Nanotechnology w.e.f. the academic year 2020- 2021 which is presented hereafter.

In this regard, we have framed the syllabus in accordance with the programme outcomes of Mahatma Gandhi University listed below.

Programme Outcomes (PO) of Mahatma Gandhi University

PO 1: Critical Thinking and Analytical Reasoning Capability to analyse, evaluate and interpret evidence, arguments, claims, beliefs on the basis of empirical evidence; reflect relevant implications to the reality; formulate logical arguments; critically evaluate practices, policies and theories to develop knowledge and understanding; able to envisage the reflective thought to the implication on the society.

PO 2: Scientific Reasoning and Problem-Solving Ability to analyse, discuss, interpret and draw conclusions from quantitative/qualitative data and experimental evidences; and critically evaluate ideas, evidence and experiences from an unprejudiced and reasoned perspective; capacity to extrapolate from what one has learned and apply their competencies to solve problems and contextualise into research and apply one's learning to real life situations.

PO3: Multidisciplinary/Interdisciplinary/Transdisciplinary Approach Acquire interdisciplinary/multidisciplinary/transdisciplinary knowledge base as a consequence of the learning they engage with their programme of study; develop a collaborative-multidisciplinary/interdisciplinary/transdisciplinary-approach for formulate constructive arguments and rational analysis for achieving common goals and objectives.

PO 4: Communication Skills Ability to reflect and express thoughts and ideas effectively in verbal and nonverbal way; Communicate with others using appropriate channel; confidently share one's views and express herself/himself; demonstrate the ability to listen carefully, read and write analytically, and present complex information in a clear and concise manner and articulate in a specific context of communication.

PO 5: Leadership Skills Ability to work effectively and lead respectfully with diverse teams; setting direction, formulating a goal, building a team who can help achieve the goal, motivating and inspiring team members to engage with that goal, and using management skills to guide people to the right destination, in a smooth and efficient way.

PO 6: Social Consciousness and Responsibility Ability to contemplate of the impact of research findings on conventional practices, and a clear understanding of responsibility towards societal needs and reaching the targets for 12 attaining inclusive and sustainable development.

PO 7: Equity, Inclusiveness and Sustainability Appreciate equity, inclusiveness and sustainability and diversity; acquire ethical and moral reasoning and values of unity, secularism and national integration to enable to act as dignified citizens; able to understand and appreciate diversity, managing diversity and use of an inclusive approach to the extent possible.

PO 8: Moral and Ethical Reasoning Ability to embrace moral/ethical values in conducting one's life, formulate a position/argument about an ethical issue from multiple perspectives, and use ethical practices in all work. Capable of demonstrating the ability to identify ethical issues related to one's work and living as a dignified person in the society.

PO 9: Networking and Collaboration Acquire skills to be able to collaborate and network with scholars in an educational institution, professional organizations, research organizations and individuals in India and abroad.

PO 10: Lifelong Learning Ability to acquire knowledge and skills, including "learning how to learn", that are necessary for participating in learning activities throughout life, through self-paced and self-directed learning aimed at personal development, meeting economic, social and cultural objectives, and adapting to changing trades and demands of work place through knowledge/skill development/reskilling.

Eligibility for Admission

The basic requirement for admission to the M. Sc. Program will be as per ***Revised CSS (credit and semester system) Regulations with effect from 2020 admissions*** (applicable to the Postgraduate Programme of Mahatma Gandhi University). Reservations of seats are based on University/ Government Rules.

Admission Procedure

Candidates have to appear for the Common Admission Test (CAT) conducted by the MG University in April/ May of every year. The questions will be of objective multiple-choice type. Any other conditions prescribed by MG University from time to time in this regard will be applicable. Relaxation of marks and Reservation of seats under SC/ST are based on University/ Government Rules. Admission may be based on the written test alone or written test and interview or on the basis of the marks obtained in the qualifying examinations as well as the marks obtained in the written test, the interview and/or the group discussion conducted by the respective Schools as decided by the Faculty Council of Schools/Centres/Institutes from time to time. The Rank list for admission will be prepared as per university guidelines. While preparing the rank list, if there is same index marks for more than one candidate, they will be ranked on the basis of actual marks obtained in the qualifying exam (CAT). Even after this, if there is a tie; they will be ranked on the basis of date of birth that is the older person is to be ranked higher. Each semester shall comprise of a minimum of 18 instructional weeks. Every semester will be adjusted to have at least 90 working days. Continuous Internal Assessment based evaluation during the course period and End Semester Examination at the end of each semester shall be conducted.

For details regarding Course Registration, Duration of the Course, Admission to programmes, Common Academic Calendar, Course and Scheme design, Course teaching patterns, Student assessment patterns, Grading of students, course Reappearance, improvement, Readmission and Repeating, Grievance recording and redressal, Inter-school academic collaboration, etc., please refer to ***Revised CSS (credit and semester system) Regulations with effect from 2020 admissions*** of Mahatma Gandhi University

Evaluation

All work pertaining to the Examinations shall be held in the School of Nanoscience and Nanotechnology under the direct control and supervision of the Director of the Department. There shall be continuous internal assessment as well as end semester examinations for the M. Sc. programmes. Evaluation of the programme shall be done by the faculty members of the School of Nanoscience and Nanotechnology offering the courses of study. Indirect Grading is employed for the evaluation of courses. The performance of a student in each course is evaluated in terms of percentage of marks converted to grade points.

‘ADD-ON COURSES

In addition to Core, elective and practical courses the school will offer add-on courses such as; Nano catalysis, Social, ethical and legal issues of Nanoscience and Nanotechnology, Nano sensors, Advanced nanobiology, Waste management, and Water purification through Nanoscience and Nanotechnology. The course structure and syllabus will be announced before commencement of each semesters. The lectures will be delivered by reputed Professors/ Scientists from other Universities/ Institutions in India or Abroad.

Faculty

Upon successful completion of two years in the program the candidates will be awarded a Master’s Degree under the Faculty of Science.

(As per the M G University CSS regulations amended from time to time)

Scheme and Syllabi

Programme:

M. Sc. Physics (Nanoscience and Nanotechnology)

MAHATMA GANDHI UNIVERSITY

SCHOOL OF NANOSCIENCE & NANOTECHNOLOGY

PROGRAMME : M. Sc. Physics (Nanoscience and Nanotechnology)
DURATION : 2 years (2022 Admission onwards)
Credits : Core : …64…, Elective:…14…, Open course:…4…

Program Specific Outcomes (PSOs): Nanoscience and Nanotechnology being an interdisciplinary subject offers knowledge, understanding and output that is integrated and cross-disciplinary in nature. The programme specific outcome (PSO) envisaged in this post graduate programme would be;

PSO No:	PSOs
1	Train students in the field of physical sciences with specific emphasis on Nanoscience and Nanotechnology to cater to the present demands of miniaturization and energy economy.
2	Help empower students to acquire objective as well as analytical skills to carry out scientific enquiries, which help unveil the natural phenomena.
3	Foster innovative cross-disciplinary research by posing newer questions transcending traditional scientific fields and enable students to get interactive skills.
4	Facilitate the students to be able to familiarise and to work with advanced experimental and computational techniques at various scales.
5	Exposure of students to research taking place worldwide at the frontiers of physics especially at the nanometre scale.
6	Equip the students to understand the Nature at various scales spanning from quantum mechanical through continuum, which covers the subatomic to cosmological space.
7	Apply principles of theoretical and applied physics, to comprehend the scientific phenomenon in nano domain.
8	Nurture the quality of rationality and inquisitiveness, so that the students are capable of free and critical thinking to steer clear judgemental and social biases.
9	Inspire the students to be committed to deliver good to the society by judicious application of scientific skill sets they acquire doing physics at the nanoscale.

Scheme of the syllabus

Semester 1

Sl. No.	Course Code	Name of the Course	Credits	Credits Required	Total Credits
1	NSM21C31	Quantum Mechanics- I	3	18	21
2	NSM21C32	Mathematical Physics I	3		
3	NSM21C33	Classical Mechanics	3		
4	NSM21C34	Condensed Matter Physics I	3		
5	NSM21C35	Basic Electronics	3		
6	NSM21C36	Basic Electronics lab	3		
***Elective Courses (Choose any one)**					
7	NSM21E26	Introduction to Nanomaterials	3	3	
8	NSM21E27	Nanomaterials and Characterization	3		

Semester 2

Sl. No.	Course Code	Name of the Course	Credits	Credits Required	Total Credits
9	NSM21C37	Electromagnetic Theory	3	15	21
10	NSM21C38	Statistical Physics	3		
11	NSM21C39	Quantum Mechanics II	3		
12	NSM21C40	Condensed Matter Physics II	3		
13	NSM21C41	Physics Lab	3		
***Elective Courses (Choose any two)**					
14	NSM21E28	Computational Nanoscience	3	6	
15	NSM21E29	Nanoelectronics And Electrochemistry	3		
16	NSM21E30	Nanophotonics	3		
17	NSM21E31	Nanocomposites	3		

Semester 3

Sl. No.	Course Code	Name of the Course	Credits	Credits Required	Total Credits
18	NSM21C42	Numerical Methods & Programming	3	15	24
19	NSM21C43	Mathematical Physics II	3		
20	NSM21C44	Nuclear and Particle Physics	3		
21	NSM21C45	Atomic and Molecular Physics	3		
22	NSM21C46	Mini Project / Review Report	3		
***Elective Courses (Choose any two)**					
23	NSM21E32	Nanotechnology for Energy Applications	2	5	
24	NSM21E33	Computational Nanoscience and Applications	3		
25	NSM21E34	Nanomagnetic Materials	3		
26		**Open Course**	4	4	

Semester 4

Sl. No.	Course Code	Name of the Course	Credits	Credits Required	Total Credits
27	NSM21C47	Dissertation	12	16	16
28	NSM21C48	Viva-voce	4		

School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Quantum mechanics I**					
Type of Course	Core					
Course Code	NSM21C31					
Course Summary & Justification	This course provides a substantive introduction to the mathematical setting to the formulation of quantum mechanics and explains the basic concepts and elementary theory. It discusses the most important 1D and 3D quantum mechanical problems which helps to analyse the concept of quantum mechanics in potential practical applications. It also discusses Schrodinger and Heisenberg formulations of quantum mechanics.					
Semester	1		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite	Strong mathematical background in graduation level is desirable.					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Students will get an understanding of linear vector spaces that are fundamental to quantum mechanics. They will also learn concepts and properties of inner-product, basis, linear operators and Hermitian operators etc. (Module 1)	U, A	6,8

2	Students will be able to understand the postulates of quantum mechanics	U, A	2
3	Students will solve various 1-dimensional time independent problems in quantum physics. This will help them to formulate such problems and understand the general properties of solutions. (Module 3)	U, A	2,7
4	The student will learn to solve various 3-dimensional time independent problems like Hydrogen atom in Quantum Mechanics. Study of angular momentum and atomic structure will be crucial to understand other subjects like spectroscopy (Module 4).	An, E	2,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
1	**Linear Vector Spaces** de Broglie's hypothesis: matter waves and experimental confirmation, wave packets; Linear vector spaces: inner product, Hilbert space, Wave Functions; Linear operators: Hermitian operators, Projection operators, Commutator algebra, Unitary operators, Eigenvalues and Eigen vectors of a Hermitian operator; Basis: Representation in discrete bases, Matrix representation of kets, bras, and operators, Change of bases and unitary transformations, Matrix representation of the eigenvalue problem, Representation in position bases.	15	1

2	**Postulates of Quantum Mechanics** Postulates of Quantum Mechanics: State of a System, Probability Density, Superposition Principle, Observables as Operators, Position and Momentum operators, Position and Momentum representation of state vector, Connecting the position and momentum representations, Measurement in quantum mechanics, Expectation values, Commuting operators and Uncertainty relations; Time evolution of the state: Time-independent potentials and Stationary States, Time evolution operator, infinitesimal and finite Unitary Transformations; Conservation of probability; Time evolution of expectation values: Ehrenfest theorem; Poisson's brackets and commutators; Matrix and Wave mechanics.	20	2
3	**Time independent 1D problems** Discrete, continuous and mixed spectrum; symmetric potentials and parity; Infinite square well potential; Symmetric potential well; Finite square well potential: Scattering and bound state solutions; Free particle; Delta function potential; Harmonic oscillator.	10	3
4	**Time independent 3D problems** Free particle in 3-dimensions: spherically symmetric solution; Particle in a 3D box; Schrodinger equation in presence of central Potential; Orbital angular momentum: eigen values and eigen functions of L^2 and L_z; Hydrogen Atom; Scattering: Cross Section, Amplitude and Differential Cross Section, Scattering of Spin-less Particles, The Born Approximation, Validity of the Born Approximation.	15	4

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments A. Semester End examination

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5. J. J. Sakurai, Modern Quantum Mechanics, Benjamin Cummings, 1985
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7. P. M. Mathews and K. Venkatesan, A Textbook of Quantum Mechanics, Tata Mc Graw-Hill, 1977

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Implementation Date	

School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Mathematical Physics I**					
Type of Course	Core					
Course Code	NSM21C32					
Semester	First			Credit: 3		
Course Summary & Justification	This course allows the students to assimilate mathematical foundations of physics. A considerable body of background knowledge of mathematical techniques is essential for understanding and learning the theory behind every physical phenomenon. This course would equip the students with standard techniques of solving physical problems as well.					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	40	40	-	40	120
Pre-requisite	Introductory mathematical knowledge of algebra, trigonometry, calculus; basic knowledge of problem solving.					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
	Upon completion of this course, students will be able to;		
1	Categorize physical properties according to the medium of their occurrence	U, R	2, 3
2	Comprehend the linear algebra underlying many of the numerical simulation algorithms	E	1, 8

3	Customize differential equations to depict various real-world problems	A	1, 8
4	Identify the applicability of special functions and polynomials	A/An	6, 2
5	Develop skills for describing uncertainty in terms of probabilistic models and for probabilistic reasoning	E,S	9, 4
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module no.	**Module content**	**Hours**	**CO. No.**
1	**Vector and Tensor analysis:** Vectors and Tensors, Vector calculus and tensors in index notation.	10	1
2	**Linear Algebra:** Linear vector spaces, Dirac notation, Basis sets, Inner Products, Orthonormality and completeness, Gram-Schmidt orthonormalization process, Linear operators, Matrix algebra, Determinants, similarity transforms, diagonalization, orthogonal, Hermitian and unitary matrices, Spaces of square summable sequences and square integrable functions, generalized functions, Dirac delta function and its representations, Differential operators, Fourier series.	20	2
3	**Ordinary Differential Equations:** Ordinary Differential Equations, Superposition principle, Power series solutions for second-order ordinary differential equations, singular points of ODEs, Sturm-Liouville problems, Hermite, Legendre, Laugerre and Bessel functions, Recurrence relations and generating functions, Spherical harmonics, Addition theorem, Gamma, beta and error functions.	15	3, 4
4	**Probabilistic Systems Analysis** Probability theory and Random variables Probability distributions and probability densities, Standard discrete and continuous probability distributions, Moments and generating functions, Central Limit Theorem (Statement and applications).	15	5

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative
Assessment Types	**Mode of Assessment** **1. Continuous Internal Assessment (CIA)** ***Internal Test*** ***Assignment*** – Every student needs to write an assignment on a given topic based on the available published literature **2. Seminar Presentation** – A topic needs to be presented and discussed with the class **3. Semester End Examination**

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Classical Mechanics**					
Type of Course	Core					
Course Code	NSM21C33					
Semester	First			Credit: 3		
Course Summary & Justification	This course provides the student with accurate description of motion of macroscopic objects based on Newtonian, Lagrangian and Hamiltonian mechanics. This will include the mechanics arising out of the special theory of relativity. Moreover, this course will enable them to learn classical mechanics as a precursor to newer physical theories, such as quantum mechanics.					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	40	40	-	40	120
Pre-requisite	Introductory mathematical knowledge of algebra, trigonometry, vector and tensor analysis, calculus; basic knowledge of Newtonian mechanics.					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Get exposure to the Newtonian mechanics and variational formulation	U, R	4,6,7
2	Comprehend and learn more abstract Lagrangian and Hamiltonian mechanics	E	2, 6, 7

3	Identify generalized coordinates and coordinate transformations of a rigid body. Comprehend various aspects of rigid body dynamics.	An	2,6
4	Be able to solve some real-world problems using canonical transformations	A/An	2,6
5	Identify coordinates and spaces which will hold the invariance of light velocity.	U/An	5, 8, 7
6	Equip with the techniques of reconciling with speeds of objects comparable to the light velocity.	A/E	5, 8, 7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module no.	Module content	Hours	CO. No.
1	**Newtonian, Lagrangian and Hamiltonian mechanics:** Mechanics of a system of particles in vector form, Conservation of linear momentum, energy and angular momentum, Degrees of freedom, generalised coordinates and velocities, Lagrangian, action principle, external action, Euler-Lagrange equations, Constraints, Applications of the Lagrangian formalism, Generalised momenta, Hamiltonian, Hamilton's equations of motion, Legendre transform, relation to Lagrangian formalism, Phase space, Phase trajectories, Applications to systems with one and two degrees of freedom, Central force problem, Kepler problem, bound and scattering motions, Scattering in a central potential, Rutherford formula, scattering cross section.	15	1, 2
2	**Non-inertial frames of reference and pseudoforces**: Elements of rigid-body dynamics, Orthogonal transformations, Euler angles, Rigid body equations of motion, The symmetric top, Small oscillations, Normal mode analysis, Normal modes of a harmonic chain, centrifugal and Coriolis forces.	15	1
3	**Elementary ideas on general dynamical systems:** conservative versus dissipative systems, Hamiltonian systems and Liouville's theorem, Canonical	15	3,4

	transformations, Poisson brackets, Action-angle variables, Non-integrable systems and elements of chaotic motion.		
4	**Special relativity:** Internal frames, Principle and postulate of relativity, Lorentz transformations, Length contraction, time dilation and the Doppler effect, Velocity addition formula, Four- vector notation, Energy-momentum four-vector for a particle, Relativistic invariance of physical laws.	15	5, 6

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative
Assessment Types	**Mode of Assessment** **1. Continuous Internal Assessment (CIA)** ***Internal Test*** -**20 marks** ***Assignment*** – Every student needs to write an assignment on a given topic based on the available published literature – **10 marks** ***Seminar Presentation*** – A topic needs to be presented and discussed with the class- **10 marks** 2. **Semester End Examination – 60 marks**

REFERENCES

1. H. Goldstein, Classical Mechanics, 2nd Edition, Narosa Pub. House, 1989
2. I. Percival and D. Richards, Introduction to Dynamics, Cambridge University Press, 1987 [Chapters 4,5,6, 7 in particular and parts of Chapter 1-3,9, 10]
3. D. Rindler, Special Theory of Relativity, Oxford University Press, 1982
4. Stephen T. Thornton, Jerry B. Marion, Classical Dynamics of particles and system, 5th edition, Cengage; 2012
5. Douglas Gregory, Classical Mechanics; an undergraduate text, Cambridge University Press, 2006
6. Rana and Joag, Classical Mechanics, McGraw Hill Education, 2017
7. Landau and Lifshitz, Mechanics. Vol. 1 (3rd ed.). Butterworth-Heinemann, 1976.
8. Grant R. Fowles, George L. Cassiday, Analytical Mechanics, Thomson Brooks/Cole, 2005
9. John R. Taylor, Classical Mechanics, University Science Books, California, 2005

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Condensed Matter Physics I**					
Type of Course	Core					
Course Code	NSM21C34					
Course Summary & Justification	The course aims to make the learner understand the physics of solids, which forms the foundation for the study of other fields inside and outside the condensed matter physics. The course provides a clear picture about the solids and their properties used to change our society.					
Semester	1		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite	Basic understanding of graduate level quantum mechanics and solid state physics.					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Students will understand the underlying physics of solid-state materials. (Modules 1-4)	U, A	1, 6
2	Students will get an opportunity to revisit the fundamentals of solid state physics- crystal structure and space groups (Module 1)	R, U	1, 5
3	Students will learn the crystal symmetry and the macroscopic physical properties and diffraction of waves by crystals. (Module 2)	U, A	1, 5
4	The student will learn about different bindings in crystals, lattice dynamics and the thermal properties of crystals. (Module 3).	A, E	1,5, 9
5	Students will learn the details of band theory and the developments of semiconductor physics and bandgap engineering. (Module 4)	A, E	1, 5, 8
***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)**			

COURSE CONTENT

Module No:	Module Content	Hrs	CO.No.
1	**Classification of condensed matter:** crystalline, non-crystalline, nanophase solids, liquids, Crystalline solids: Bravais lattices, crystal systems, point groups, space groups and typical structures.	10	1

2	**Crystal symmetry and macroscopic physical properties:** tensors of various ranks: pyroelectricity, ferroelectricity, electrical conductivity, piezoelectricity and elasticity tensors, Propagation of elastic waves in crystals and measurement of elastic constants, Diffraction of waves by crystals: X-rays, neutrons, electrons, Bragg's law in direct and reciprocal lattice, Structure factor, Principles of diffraction techniques, Brillouin zones.	20	2
3	**Types of binding, Ionic crystals:** Born Mayer potential, Thermochemical Bom-Haber cycle, Van der Waals binding: rare gas crystals and binding energies, Covalent and metallic binding: characteristic features and examples, Lattice dynamics: monoatomic and diatomic lattices, Born-von Karman method, Phonon frequencies and density of states, Dispersion curves, inelastic neutron scattering, Reststrahlen Specific heat, Thermal expansion, Thermal conductivity, Normal and Umklapp processes.	15	3
4	Free electron theory of metals, Thermal and transport properties, Hall effect Electronic specific heat, Bloch functions, Nearly free electron approximation, Formation of energy bands, Gaps at Brillouin zone boundaries, Electron states and classification into insulators, conductors and semimetals, Effective mass and concept of holes, Fermi surface, Cyclotron resonance, Semiconductors: carrier statistics in intrinsic and extrinsic crystals, electrical conductivity, Liquid crystal: thermotropic and lyotropic, Nematics and sematics: applications, Amorphous/glassy states.	15	4

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 3. Continuous Internal Assessment (CIA) 4. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 5. Assignments B. Semester End examination

REFERENCES

1. Charles Kittel, Introduction to Solid State Physics, Wiley, 5th Edition, 1976
2. A. J. Dekker, Solid State Physics, Prentice Hall, 1957
3. N. W. Ashcroft and N. D. Mermin, Solid State Physics, Saunders College Publishing, 1976
4. J. S. Blakemore, Solid State Physics, 2nd Edition, Cambridge University Press, 1974
5. Mendel Sachs, Solid State Theory, McGraw-Hill, 1963
6. Harald Bach and Hans Luth, Solid-State Physics, Springer International Student Edition, Narosa Pub. House, 1991
7. Gerald Burns, Solid State Physics, Academic Press, 1987
8. Marder, M. P. (2010). Condensed Matter Physics. Germany: Wiley.
9. Ali Omer, Elementary solid state physics, Pearson Education (1999)
10. Simon, S. H. (2013). The Oxford Solid State Basics. United Kingdom: OUP Oxford.
11. Sander, L. M. (2009). Advanced Condensed Matter Physics. United Kingdom: Cambridge University Press.
12. Azároff, L. V. (1986). Introduction to Solids. India: Tata McGraw-Hill

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School Name	School of Nanoscience and Nanotechnology					
Programme	M. Sc. Physics (Nanoscience and Nanotechnology)					
Course Name	BASIC ELECTRONICS					
Type of Course	Core					
Course Code	NSM21C35					
Course Summary & Justification	This course aims to impart the basic knowledge of logic circuits and enable students to apply it to design a digital system. Students are expected to develop the skill to design circuits using operational amplifiers and other linear ICs for various applications. It also enables the learners capable of understanding the fundamental architecture of micro controllers. This course also enables the students to understand the basic concepts of analog and digital communication.					
Semester	1		Credit	3		
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite	Solid state devices, Semiconducting nanostructures, VLSI					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to*	Learning Domains	PSO No.
1	Explain the working of different combinational and sequential logic circuits. Students will be able to design the combinational and sequential circuits.	U,A	1, 4

2	Understand the primary applications of the operational amplifier as an adder, subtractor, differentiator, integrator, comparator, and waveform generator etc.	U	1, 4
3	Explain the working principle and instrumentation of analog and digital communications.	U	4, 7, 9
4	Explain the architecture of 8051 microcontroller, instructions, and its working.	U	4, 5
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO.No.
1	**Logic gates and Combinational systems:** Boolean postulates and laws – Logic Functions and Gates De-Morgan's Theorems, Principle of Duality, Minimization of Boolean expressions, Sum of Products (SOP), Product of Sums (POS), Karnaugh map Minimization. Combinatorial Logic Systems - Comparators, Multiplexers, Demultiplexers, Encoder, Decoder. Half and Full Adders, Subtractors, Serial and Parallel Adders, BCD Adder.	15	1
2	**Sequential systems:** Building blocks like S-R, JK and Master-Slave JK FF, Edge triggered FF, Conversion of Flipflops, Excitation table and characteristic equation. Ripple and Synchronous counters, Shift registers-SIPO, SISO, PISO, PIPO. Shift Registers with parallel Load/Shift, Ring counter and Johnson's counter. Asynchronous and Synchronous counter design, Mod N counter.	10	1

3	**8051 microcontroller**: 8051 Architecture- Register Organization- Memory and I/O addressing- Interrupts and Stack- 8051 Addressing Modes- Instruction Set- data transfer instructions, arithmetic instructions, logical instructions, Boolean instructions, control transfer instructions, Simple programs.	10	4
4	**Analog modulation and digital modulation:** Amplitude Modulation – Double and Single sideband techniques – Frequency modulation and Demodulation techniques – Bandwidth requirements – Pulse communication – Pulse width, Pulse position and Pulse amplitude modulation, Digital modulation- Pulse Code Modulation (PCM): Pulse Modulation, Sampling process, Performance comparison of various sampling techniques, Aliasing, Reconstruction, PAM, Quantization, Noise in PCM system, Modifications of PCM: Delta modulation, DPCM, ADPCM, ADM	10	3
5	**Operational amplifiers:** Operational amplifiers (Op Amps): The 741 Op Amp, Block diagram, Ideal op-amp parameters, typical parameter values for 741, Equivalent circuit, Open loop configurations, Voltage transfer curve, Frequency response curve. Op-amp with negative feedback: General concept of Voltage Series, Voltage Shunt, current series and current shunt negative feedback, Virtual ground Concept; Op-amp applications: Summer, Voltage Follower-Differential and Instrumentation Amplifiers, Voltage to current and Current to voltage converters, Integrator, Differentiator, Precision rectifiers, Comparators, Schmitt Triggers, Log and antilog amplifiers. Op-amp Oscillators and Multivibrators: Phase Shift and Wien-bridge Oscillators, Triangular and Sawtooth waveform generators, Astable and monostable multivibrators.	15	2

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.

Assessment Types	**Mode of Assessment** 1 Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments A. Semester End examination

REFERENCES

1. Mano M.M., Ciletti M.D., "Digital Design", Pearson India, 4th Edition. 2006
2. D.V. Hall, "Digital Circuits and Systems", Tata McGraw Hill, 1989
3. Roddy and Coolen, Electronic Communications, Prentice Hall 4th Ed (1995).
4. B. P. Lathi, Modern Digital and Analog Communication Systems 3rd Ed, Oxford University press (1998).
5. Gayakwad R. A., Op-Amps and Linear Integrated Circuits, Prentice Hall, 4/e, 2010 6.Roy D. C. and S. B. Jain, Linear Integrated Circuits, New Age International, 3/e, 2010
6. Raj Kamal, Microcontrollers: Architecture, Programming, Interfacing and System Design, Pearson Education.
7. A. NagoorKani, Microprocessors and Microcontrollers, Second Edition, Tata McGraw Hill
8. Thomas L. Floyd, Digital Fundamentals, Pearson Education; Eleventh edition, 2015
9. Kenneth J. Ayala, The 8051 Microcontroller, , Thomson Delmar Learning, 2005

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Basic Electronics Lab**					
Type of Course	**Practical -Core**					
Course Code	NSM21C36					
Course Summary & Justification	At the end of this course students should acquire skills in designing and testing analog and digital integrated circuits.					
Semester	1		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	0	0	25	0	25
Pre-requisite	Strong mathematical background in graduation level is desirable.					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**
1	To recognize various digital gates and ICs	A, An, S	1, 4
2	To design and implement combinational circuits using basic gates and ICs	A, An, S	1, 4
3	To design and implement sequential circuits using basic gates and ICs.	A, An, S	1, 4
4	Design and demonstrate functioning of various analog circuits	A, An, S	1, 4
***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)**			

Sl. no:	Experiments	Course outcome
	Part A **Digital Electronics**	
1a 1b	Familiarization of logic gates Realization of logic gates using universal gates	1
2a 2b	Half adder & Full Adder using basic gates and nand gates Half subtractor and Full subtractor using basic gates and nand gates	2
3a 3b	Multiplexer and demultiplexer using basic gates and nand gates Familiarization of Multiplexer ICs and demultiplexer ICs	2
4	Function implementation using multiplexer ICs	2
5a 5b	Familiarization of Decoder ICs Function implementation using Decoder ICs	2
6	Realization of flip flops using nand gates	3
7	Familiarization of Flip Flop ICs	3
8	Asynchronous and Synchronous Counters	3
	Part B **Analog Electronics**	
1	Inverting amplifier	4
2	Adder or summing amplifier	4
3	Integrator	4
4	Differentiator	4
5	Difference amplifier	4

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments A. Semester End examination

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Introduction to Nanomaterials**					
Type of Course	Elective					
Course Code	NSM21E26					
Course Summary & Justification	The emphasis of the course is to understand the physics of nanomaterials in detail and to explore its wide application. This course provides research-focused teaching and training for post-graduates wishing to develop a career in nano and functional materials. Students will gain profound understanding of the principles governing nano and functional materials' properties, behaviour and interactions as well as their characterisation.					
Semester	1		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite	Strong mathematical background in graduation level is desirable.					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**
1	Students will get an understanding of Feynman's vision on nanoscience & technology, significance of nanostructures verses bulk, quantum confinement in nanostructures, different nanostructures and visualization of these structures related.	U, A	1,5,7

	. (Module 1)		
2	Students will learn to calculate surface energies associated with different lattices, surface modifications, surface energy reduction mechanisms, derivation of Young's Laplace equation etc. Also discuss Surface energy and surface curvature, Surface energy stabilization, electrostatic stabilization, steric stabilization, electro-steric stabilization. (Module 2)	U, A	1,5,7
3	Students will learn the size and shape dependence of nanoparticles (Module 3).	An, E	1,5,7
4	Get introduced to the various theoretical and computational approaches spanning from quantum mechanical to mesoscale methods applicable to nanomaterials and structures. Introduction to programming such as flow chart, pseudocodes enable the students to attain fundamental knowledge of various algorithms. (Module 4)	A, E	1,6,7
***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)**			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
1	**Introduction:** Feynman's vision on nanoscience & technology, bulk vs nanomaterials, natural and synthetic nanomaterials, Basic principles of nanomaterials- Increase in surface area to volume ratio and quantum confinement effect - size dependent physical phenomena in semiconductor and metal nanoparticles, Classification of nanostructures, 0D, 1D and 2D nanostructures - quantum dots, quantum wells, quantum rods, quantum wires, quantum rings; bulk nanostructured, nanocomposites.	15	1

2	Surface Energy Surface energy and surface stress- Effect on the lattice parameter, Origin and estimation of surface energy, Surface Energy minimization: Sintering Ostwald ripening and agglomeration, Energy minimization by Isotropic and anisotropic surfaces, Wulff plot, Surface energy, chemical potential and surface curvature- Youngs Laplace equation, Surface energy stabilization, electrostatic stabilization – Electric double layer, Electric potential at the proximity of a solid surface - Debye-Hückel Screening strength. Interaction between nanoparticles – Van der Waals attraction potential, DLVO Theory, Steric stabilization, electro-steric stabilization.	15	2
3	Size and shape dependence of nanoparticles: Size effect on the morphology of free or supported nanoparticles, Equilibrium shape of macroscopic crystal, Wulff theorem, equilibrium shape of nanometric crystals, Wulff-Kaichew theorem, equilibrium shape of supported nanoparticles, Kinetics of phase transformations, Nucleation and growth of nuclei, critical radius, Homogeneous & Heterogeneous nucleation, Controlling nucleation, growth and aggregation in nanoparticle growth, and crystalline Phase Transitions in Nanocrystals.	15	3
4	**Computational nanoscience:** Programming fundamentals, Numerical solution of ordinary differential equations. Numerical solution of partial differential equations. Atomic Design, Atomistic Modeling, Quantum Computers, ab Initio Methods, Molecular Dynamics, average values, Mesh-free Methods, Finite Difference Time-Domain Method: Optical Responses, advantage & disadvantage, Practical implementation, Numerical examples. Finite element method: Introduction, Matrix form of the problem, Various types of finite element methods, Approximation of elliptic problems, Piecewise polynomial approach, One dimensional model problem.	15	4

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments A. Semester End examination

REFERENCES

1. Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao, Imperial college Press, (2006). (for UNIT I & II, 2nd Chapter, Unit III – Chapter 4 (3. 2), Unit IV- Chapter 7
2. Nanomaterials and Nanochemistry by C. Brechignac, P. Houdy M. Lahmani Springer-Verlag (2007). (For Unit III-Part I Chapter I)
3. Materials Science and Engineering-An Introduction, William D. Callister, (Wiley, 2007). (Chapter 10. section 1-. 2 and 10. 3) Unit II
4. Finite Element Methods for Partial Differential Equations, Lecture notes, Endre Suli, Oxford, August, 2020.
5. T. Pradeep, A textbook of Nano Science and Technology, Tata McGraw-Hill Education, 2012.
6. Introduction to the Finite Element Method, J. N. Reddy, McGraw Hill Education; 3rd edition, 2017.
7. Handbook of Theoretical and Computational Nanotechnology, M. Rieth and W. Schommers, American Scientific Publishers, 2006
8. G. Cao and Y. Wang, Nanostructures and Nanomaterials, 2 nd Ed., Imperial College Press, 2004.
9. R. Kelsall, I. Hamley and M. Geoghegan, Nanoscale Science and Technology, Wiley, 2005.

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Nanomaterials and characterization**					
Type of Course	Elective					
Course Code	NSM21E27					
Course Summary & Justification	This course provides research-focused teaching and training for post-graduates wishing to develop a career in nano and functional materials. Students will gain an in-depth understanding of the various nanofabrication techniques, synthesis strategies, and different characterization techniques.					
Semester	1		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite	Strong mathematical background in graduation level is desirable.					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**
1	Students will get an understanding of different Synthesis strategies; Bottom up and Top-down approaches. (Module 1)	U, A	1, 3, 7
2	Students will learn physical, chemical and biological characterization methods (Module 2)	U, A	1, 2, 7

3	Students will learn AFM, SEM, Deep UV and X-ray based lithography techniques (Module 3).	An, E	1, 2, 4
4	Students will learn in detail about X-ray diffractometry, Scanning probe microscopy and scanning tunneling microscopy , Optical microscopy– SEM, TEM, AFM, UV-Vis-NIR spectrometry and FTIR (Module 4)	E	1, 9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Synthesis strategies:** bottom up approaches- sol- gel technique-co-precipitation hydrolysis: sonochemical method- combustion technique- colloidal precipitation-template process Top down approach: solid state sintering- grain growth-electric arc method-ion beam induced nanostructures-grinding-ball milling-control of grain size.	15	1
2	**Physical, chemical and biological methods** Inert gas condensation -RF plasma-Ion sputtering- laser ablation- laser pyrolysis-molecular beam epitaxy -chemical vapour deposition – electrode deposition-solvothermal synthesis -metal nanocrystals by reduction-arrested precipitation -photochemical synthesis-liquid -liqid interface-cluster compounds. Biological methods: use of bacterial fungi actinomycetes for nanoparticle synthesis, magneto tactic bacteria for natural synthesis of magnetic nanoparticles- mechanism of formation – role of plants in nanoparticle synthesis.	15	2

3	**Lithographic techniques** AFM based nanolithography and nano manipulation, E beam lithography and SEM based nanolithography and nano manipulation, ion beam lithography, oxidation and matelization. Mask and its application. Deep UV lithography, X-ray based lithography.	15	3
4	**Characterization Techniques** X-ray diffractometry- fundamental of X-ray diffraction, powder diffraction method, small angle x-ray scattering and wide-angle x-ray scattering, quantitative determination of phase, strain and particle size, Scanning probe microscopy and scanning tunneling microscopy- basic principle and instrumentation and application, Optical microscopy– SEM, TEM, AFM: operation principle, instrumentation and application, UV-Vis-NIR spectrometry and FTIR – basic principle.	15	4

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 6. Continuous Internal Assessment (CIA) 7. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 8. Assignments C. Semester End examination

REFERENCES

1. Chemistry of nano materials: synthesis, properties and applications by C. N. R. Rao et, al, Wiley-VCH, 2004
2. Introduction to Nanoscience and Nanotechnology by K. K. Chattopadhyay and A. N. Banerjee, PHI Learning View All, 2009
3. Nanoparticle technology handbook by Masuo Hosokawa et. al, Elsevier Science, 2007
4. Handbook of nanoscience, engineering- Goddard et. al, CRC Press, 2012
5. Nanomaterials handbook -Yory Gogotsi, Taylor & Francis, 2006
6. Springer handbook of nanotechnology- Bharat Bhushan, 2004
7. Scanning probe microscopy: Analytical methods (nanoscience and technology)- Roland Wiesendanger, Springer, 1994
8. Advanced x-ray techniques in research and industries-A. K. Singh, New IOS Press Publication, 2005
9. X- ray diffraction procedures: for polycrystalline and amorphous materials, 2nd edition – Harold P. Klug, Leroy E Alexander, Wiley- Interscience, 1974
10. Transmission electron microscopy: A textbook for materials science (4- vol set)-David B. Williams and C. Barry carter, Springer, 2009
11. Introduction of X-ray crystallography-M. M. Woolfson, Cambridge University Press, 1970
12. Physical principles of electron microscopy: an introduction to TEM, SEM and AEM – Ray F. Egerton, Springer, 2005

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Electromagnetic Theory**					
Type of Course	Core					
Course Code	NSM21C37					
Course Summary & Justification	The course aims to develop the fundamental concepts in classical electrodynamics for students who are already familiar with the basics of electromagnetism. Maxwell's equations, the grand theory that unifies electricity, magnetism and light, will be introduced and they will be equipped with advanced mathematical methods to tackle various boundary value problems in electrodynamics.					
Semester	2		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite	Basic knowledge in classical electrodynamics.					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**
1	To understand the concepts of boundary value problems to be able to use various techniques for solving the boundary value problems	U, A	2, 6
2	Apply Maxwell’s Equations in Various situations (Module 2).	U, A	2, 8

3	The introduction of conservation laws and investigation of the propagation of electromagnetic waves in various media leads to a clear understanding and applications of Maxwell's equations (Module 3)	An, E	2, 9
4	Analyze the electromagnetic radiation phenomena (Module 4).	E	8
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
1	**Electrostatics:** Laplace and Poisson equations, Boundary value problems, Dirichlet and Neumann boundary conditions, Method of images, Concept of the Green function and its use in boundary value problems.	10	1
2	**Magnetostatics:** Ampere's law and Biot-Savart's law, Concept of a vector potential, Maxwell equations and electromagnetic waves, Maxwell equations (both differential and integral formulations), Boundary conditions on field vectors D, E, B and H, Vector and scalar potentials.	15	2
3	**Gauge transformations:** Lorentz and Coulomb gauge, Green function for the wave equation, Poynting's theorem, Conservation laws for macroscopic media, Propagation of plane waves and spherical waves in free space, dielectrics and conducting media, Reflection and refraction of electromagnetic waves, Superposition of waves, Radiation from an oscillating dipole and radiation from an accelerating charge.	20	3
4	**Electromagnetic stress tensor, Wave Guides:** Modes in rectangular and cylindrical wave guides (conducting and dielectric), Resonant cavities, Evanescent waves, Energy dissipation, Q of a cavity.	15	4

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments A. Semester End examination

REFERENCES

1. J. D. Jackson, Classical Electrodynamics, Wiley Eastern, 2nd Edition, 1975
2. David J. Griffiths, Introduction to Electrodynamics, Prentice Hall of India, 2nd Edition, 1989
3. J. R. Reitz, F. J. Milford and R. W. Christy, Foundations of Electromagnetic Theory, 3rd Edition, Narosa Pub. House, 1979
4. P. Lorrain and D. Corson, Electromagnetic Fields and Waves, CBS Publishers and Distributors, 1986
5. B. H. Chirgwin, C. Plumpton and C. W. Kilmister, Elementary Electromagnetic Theory, Vols. 1, 2 and 3" Pergamon Press, 1972
6. William Hart Hayt, John A. Buck, Engineering Electromagnetics, McGraw-Hill, 2012-

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Statistical Physics**					
Type of Course	Core					
Course Code	NSM21C38					
Course Summary & Justification	Statistical mechanics provides a theoretical bridge that takes you from the micro world to the macro world. This makes an attempt to derive the macroscopic properties of an object from the properties of its microscopic constituents and the interactions amongst them. It tries to provide a theoretical basis for the empirical thermodynamics. This course is designed at providing students with basic concepts of calculating properties of an energetically isolated system in equilibrium by imposing probability distribution over the set of microscopic states compatible with the external constraints imposed on the system. Using this probability distribution, average values of specified functions of the microscopic conditions of the gas can be calculated. Students will be able to understand what probability distribution really means, why average values for macroscopic conditions, and how do phase averages related to measured features of the macroscopic system etc. And helps the students to analyses how changing quantum mechanical basis leads to wholesale changes within statistical mechanics. Bose-Einstein statistics, Fermi Dirac statistics and Maxwell Boltzmann statistics will be discussed.					
Semester	2		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite	Basics of Thermodynamics, Quantum dynamics and Probability theory. This is based on statistical methods, probability theory and the microscopic physical laws. It can be used to explain the thermodynamic behaviour of large systems					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Gain knowledge of Thermodynamics and probability theory (Module 1)	U, A	2, 9
2	Understand the inadequacy of Quantum dynamics and Probability theory (Module 2)	U, A	2, 6
3	Identify the statistical methods and microscopic physical laws. (Module 3).	An, E	2, 6
4	Comprehend the requirement and nuances of application of quantum principles and probability to large systems	A, E	2,6
5	Apply the principles of statistical thermodynamics that can explain the thermodynamic behaviour of large systems (Module 5)	E	2, 5
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO.No.
1	Systems with a very large number of degrees of freedom: The need for statistical mechanics, Macrostates, microstates and accessible microstates, Stirling's approximation, Thermodynamical potentials, Probability distributions, Boltzmann's formula for entropy.	10	1
2	Ensemble Theory, Phase space of a classical system, Microcanonical ensemble, Canonical ensemble, partition function, free energy, calculation of thermodynamic quantities, Classical ideal gas, Maxwell-Boltzmann distribution, equipartition theorem, Paramagnetism, Langevin and Brillouin functions, Curie's law. .	10	2

3.	The entropy of mixing and Gibbs paradox - Phase space of a classical system - Liouville‟s theorem and its consequences, Equipartition theorem - Virial theorem - The density matrix, Thermodynamic behaviour of an ideal Bose gas, Thermodynamic behaviour of an ideal Fermi gas- Magnetic behaviour of an ideal Fermi Gas : (1) Pauli paramagnetism, (2) Landau diamagnetism.	20	3
4	Quantum statistics: systems of identical, indistinguishable particles, Exchange Symmetry of wavefunctions, Distribution laws, Bose Einstein Statistics, BoseEinstein condensation,——Fermi Dirac Statistics, Maxwell Boltzmann Statistics, bosons,-Pauli's exclusion principle, fermions, Grand canonical ensemble, Degeneracy, Free electron gas, Blackbody radiation, Diatomic Molecules, Einstein model of lattice vibrations, Debye's theory of the specific heat of crystals.	10	4
5	Phase diagrams, phase equilibrium and phase transitions, Phase transition of first and second kind, Yang and Lee Theory, Mean-field theory of liquid-gas transition (Van der Waals model) The Ising model, Heisenberg exchange interaction and the origin of ferromagnetism.	10	5

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments A. Semester End examination

REFERENCES

1. D. Chandler, Introduction to Modern Statistical Mechanics, Oxford University press, 1987
2. C. J. Thompson, Equilibrium Statistical Mechanics, Clarendon Press, 1988
3. R. K. Pathria, Statistical Mechanics, Elsevier, 1972
4. F. Reif, Fundamentals of Statistical and Thermal Physics, International Student Edition, McGraw-Hill, 1988
5. K. Huang, Statistical Mechanics, Wiley Eastern, 1988
6. L. D. Landau and E. M. Lifshitz, Statistical Physics (Par1I), 3rd Edition, Pergamon Press, 1989
7. F. Reif, Statistical Physics (Berkeley Physics Course, Vol. 5), McGraw Hill, 1967
8. F. Mandl, Statistical Physics, 2nd edition, ELBS & Wiley, 1988
9. E. S. R. Gopal, Statistical Mechanics and Properties of Matter MacMillan India, 1988
10. R. Kubo. Statistical Physics -Problems and Solutions, North Holland, 1965
11. Y. K. Lim, Problems and Solutions in Thermodynamics and Statistical Mechanics, World Scientific, 1990
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13. Callen, H. B., Callen, H. B., Thermodynamics and an introduction to thermostatistics. Egypt: Wiley, 1985

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Quantum mechanics II**					
Type of Course	Core					
Course Code	NSM21C39					
Course Summary & Justification	The course aims to provide an introduction to advanced level topics in quantum mechanics. These include quantum theory of angular momentum, quantum concept of identical particles and an introduction to relativistic and multi-particle quantum mechanics. This includes the formulation of quantum theorem of spin and orbital angular momentum. This course also formulates the non-relativistic scattering theory and relativistic quantum mechanics.					
Semester	2		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite						
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	Upon completion of this course, students will be able to;		

1	Get a complete understanding of total angular momenta and spin angular momenta of particles. They will be able to understand the quantum mechanical techniques to find the total angular momenta of combined system. This is very important to understand further studies of spectroscopic methods and techniques (Module I)	U, A	4, 6
2	Understand the quantum mechanical problems by approximation techniques. They will be able to study the time independent perturbation theory for understanding the quantum mechanical problems. (Module 2)	U, A	4,6
3	The student will be able to understand the quantum mechanical theories of time dependent perturbation theory. They can solve the quantum mechanical problems more accurately using this perturbation method (Module 3).	An, E	6, 9
4	Students will be able to understand the concept of identical particles. They will study the symmetric and antisymmetric wavefunctions and can understand the profound physics of bosons and fermions. Students will be able to understand the elements of relativistic quantum mechanics (Module 4).	E	6, 8, 9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO.No.**
1	**Quantum Theory of Angular Momentum** Review of Orbital angular momentum; Total angular momentum: Commutation relations, eigenvalues, Matrix representation of angular momentum; Spin angular momentum: Pauli spin matrices and their properties, Two component wave function, Pauli's equation; Addition of Angular momentum and Clebsch-Gordan coefficients.	15	1

2	**Time Independent Perturbation theory** Time-independent perturbation theory: Non degenerate perturbation theory, The Stark effect, Degenerate perturbation theory: Spin Orbit Coupling, Fine structure; Variational method; WKB method, Bound states for potential wells with no rigid walls, Tunnelling through a potential barrier.	20	2
3	**Time Dependent Perturbation theory** Schrodinger and Heisenberg Pictures of Quantum Mechanics; The interaction Picture and Time- dependent perturbation theory: Transition probability; Constant perturbation; Harmonic perturbation; Adiabatic and sudden approximations; Interaction of atoms with radiation: Transition rates for absorption and stimulated emission of radiation, Dipole approximation, Electric dipole selection rules.	10	3
4	**Relativistic and Multi Particle Quantum Mechanics** Klein-Gordon equation: Free particle solutions, Probability density; Dirac equation: Dirac matrices, Probability density, Solution of free Dirac equation and positrons; Many-particle systems: Interchange symmetry; Systems of distinguishable non-interacting particle; Systems of identical particles: Exchange degeneracy, Symmetrization postulate; Constructing symmetric and anti-symmetric wave functions, Pauli's exclusion principle	15	4

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments A. Semester End examination

REFERENCES

1. E. Merzbacher, Quantum Mechanics, 2nd Edition, Wiley International Edition, 1970
2. J. J. Sakurai Modern Quantum Mechanics, Benjamin / Cummings, 1985
3. Nouredine Zettili, Quantum Mechanics: Concepts and Applications, Wiley India, 2016
4. P. A. M. Dirac, The Principles of Quantum Mechanics, Oxford University Press, 1991
5. L. D. Landau and E. M. Lifshitz, Quantum Mechanics -Nonrelativistic Theory, 3rd Edition, Pergamon, 1981
6. P. M. Mathews and K. Venkatesan, A Textbook of Quantum Mechanics, Tata McGraw Hill, 1977
7. J. Bjorken and S. Drell, Relativistic Quantum Mechanics, McGraw-Hill, 1965
8. A. Messiah, Quantum Mechanics, Vols. 1 and 2, North Holland, 1961
9. John S. Townsend, A Modern Approach to Quantum Mechanics, University Science Books, 2000

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Condensed Matter Physics II**					
Type of Course	Core					
Course Code	NSM21C40					
Course Summary & Justification	This course aims to make the learner understand the physics of solids, mostly concerned with their properties that are of great utility, and result from the distribution of electrons in metals, semiconductors and insulators. The course discusses important advances in condensed matter physics which would facilitate better understanding of the material behaviour at the nanometer scale.					
Semester	2		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite	Strong background in basic quantum mechanics and condensed matter physics.					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**
1	Students will learn about dielectrics and ferroelectrics (Module 1)	U, A	2, 5

2	Students will learns about the magnetic properties of materials and perform mathematical derivations of different quantities. (Module 2)	U, A	2, 5
3	The student will learn about optical properties of solids and also superconductivity found in solids. This will help in understanding the different facets of solids. (Module 3).	A, E	5, 7
4	Students will learn to identify the types of point and extended defects in solids. (Module 4)	A, E	5, 7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO.No.
1	**Dielectrics and Ferroelectrics:** Internal electric field in a dielectric, Clausius-Mossotti and Lorentz-Lorenz equations, Point dipole, deformation dipole and shell models, Dielectric dispersion and loss, Ferroelectrics: types and models of ferroelectric transition.	15	1
2	**Magnetic Properties of Materials**: Diamagnetic susceptibility, Quantum theory of paramagnetism, Transition metal ions and rare earth ions in solids, Crystal field effect and orbital quenching, Ferromagnetic and antiferromagnetic ordering, Curie-Weiss theory, Heisenberg theory, Curie and Neel temperatures, Domain walls, Spin waves and magnon dispersion.	15	2
3	**Optical properties of solids:** Band to band absorption, excitons, polarons, Color centres, Luminescence, Photoconductivity. Superconductivity, experimental and theoretical aspects, new materials and models.	15	3

4	**Defects in solids:** Point defects: Thermodynamics of point defects, Frenkel and Schottky defects, Formation enthalpies, Diffusion and ionic conductivity, Superionic materials. Extended defects: dislocations, models of screw and edge dislocations, Burgers vector, Stress field around dislocations, interaction between dislocations with point defects, Work hardening,	15	4

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments A. Semester End examination

REFERENCES

1. Charles Kittel, Introduction to Solid State Physics, Wiley, 5th Edition, 1976
2. A. J. Dekker, Solid State Physics, Prentice Hall, 1957
3. N. W. Ashcroft and N. D. Mermin, Solid State Physics, Saunders College Publishing, 1976
4. J. S. Blakemore, Solid State Physics, 2nd Edition, Cambridge University Press, 1974
5. Mendel Sachs, Solid State Theory, McGraw-Hill, 1963
6. A. O. E. Animalu, Intermediate Quantum Theory of Solids, Prentice Hall, 1977
7. Fröhlich, H. (1950). Theory of Dielectrics: Dielectric Constant and Dielectric Loss. United Kingdom: At the Clarendon Press.
8. Lines, M. E., Glass, A. M. (2001). Principles and Applications of Ferroelectrics and Related Materials. United Kingdom: OUP Oxford
9. Coey, J. M. D. (2010). Magnetism and Magnetic Materials. United Kingdom: Cambridge University Press.
10. Azároff, L. V. (1986). Introduction to Solids. India: Tata McGraw-Hill.
11. Sander, L. M. (2009). Advanced Condensed Matter Physics. United Kingdom: Cambridge University Press.

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Computational Nanoscience**					
Type of Course	Elective					
Course Code	NSM21E28					
Semester	Second Credit: 3					
Course Summary & Justification	This course brings about introduction to a vast repertoire of numerical algorithms and software that would be relevant to matter at the nanometer scale. Essential introduction to numerical methods is provided in the beginning. Since the computing power of powerful computing machines far exceed that of human imagination, the contents of this course would guide the student to the realm of computer algorithms.					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	40	40	-	40	120
Pre-requisite	Basic mathematical knowledge of linear algebra and differential equations					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	Upon completion of this course, students will be able to;		
1	Understand some of the numerical techniques underlying many simulation algorithms.	U, R	1, 4

2	Comprehend the boundary conditions and theoretical formalism of numerical simulation techniques.	E	1, 4
3	Learn the heuristics based techniques such as Monte Carlo and genetic algorithm	A	4, 8
4	Investigate physical and chemical properties of nanomaterials using quantum mechanical and classical mechanics based software.	A/An	4, 8
5	Select the appropriate software according to the scale and resolution of the problem.	E,S	4, 9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module no.	**Module content**	**Hours**	
1	**Numerical techniques:** Numerical solutions for simple Hamiltonian and Lagrangian equations, classical molecular dynamics, various integration schemes, periodic boundary conditions, long range interactions.	15	1,2
2	**Heuristics based methods:** Classical Monte Carlo method, Metropolis algorithm, applications to nano and biological systems, Numerical solutions of Schrodinger equation, electronic structure methods, application to simple molecules, clusters and solids.	15	3,4
3	**Atomistic methods:** Fields of application; Basics of Different methods: Ab initio, Density functional, Semi-empirical, Molecular Mechanics and Molecular Dynamics: Potential Energy Surfaces: Stationary points, saddle point, local and global minima, their significance, Examples: PES for water.	15	4, 5
4	**Molecular Mechanics:** Concept of Force Field, its components for bond stretching, bending, torsional motion, non-bonded and electrostatic interactions, Examples for force fields: MM, CFF, ECEPP, GROMOS, AMBER and CHARMM, Molecular Mechanics: Areas of application.	15	5

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative
Assessment Types	**Mode of Assessment** **Continuous Internal Assessment (CIA)** **1. *Internal Test* -** **2. *Assignment*** – Every student needs to write an assignment on a given topic based on the available published literature – 3. ***Seminar Presentation*** – A topic needs to be presented and discussed with the class- **A. Semester End Examination – 60 marks**

REFERENCES

1. Allen M. P. and Tildesley D. J, Computer Simulation of Liquids, Clarendon Press, Oxford, 2017
2. Wong S. S. M., Computational Methods in Physics and Engineering, World Scientific, 1997
3. J. H. Jensen, E. G. Lewars, Computational Chemistry: Introduction to the Theory and Applications of Molecular and Quantum Mechanics, 2nd Edn., Springer, 2011
4. Jensen, Introduction to Computational Chemistry, 2nd Edn., John Wiley & Sons, 2007

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Nanoelectronics and Electrochemistry**					
Type of Course	Elective					
Course Code	NSM21E29					
Course Summary & Justification	The students will be able to understand the basic concepts of nanoelectronic devices and nanotechnology. This course enables the learners to be capable of understanding the fundamentals of electrochemistry.					
Semester	2		**Credit**	3		
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite	Solid state devices, Semiconducting nanostructures, VLSI					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	Upon completion of this course, students will be able to;		
1	understand the basic and advance concepts of nanoelectronics.	U	1, 5
2	understand the methods of fabrication of nano-layers	U	1, 5
3	Understand the basic principles of Electrochemistry	U	1, 3
4	Understand the working of 2 dimensional nanoelectronic system and basic nanoelectronic devices	U	1, 3

***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)**

COURSE CONTENT

Module No:	Module Content	Hrs	CO.No.
1	**Introduction to nanoelectronics**: Introduction to nanotechnology, Impacts, Limitations of conventional microelectronics, Trends in microelectronics and optoelectronics Mesoscopic physics, trends in microelectronics and optoelectronics, characteristic lengths in mesoscopic systems, Quantum mechanical coherence, Classification of Nano structures, Low dimensional structures Quantum wells, wires and dots, Density of states and dimensionality, Basic properties of two dimensional semiconductor nanostructures, square quantum wells of finite depth, parabolic and triangular quantum wells, Quantum wires and quantum dots, carbon nano tube, graphene	15	1
2	**Introduction to methods of fabrication of nano-layers:** Introduction to methods of fabrication of nano-layers, different approaches, physical vapour deposition, chemical vapour deposition, Fabrication of nano particle-grinding with iron balls, laser ablation, reduction methods, sol gel, self assembly, precipitation of quantum dots. Molecular Beam Epitaxy, Ion Implantation, Formation of Silicon Dioxide- dry and wet oxidation methods.	15	2
3	**Fundamentals of Electrochemistry:** Fundamental Equations - Nernst equation, Equilibrium constant, Mass-transfer limiting current, Cottrell equation, Faraday's law, Equations governing modes of mass transfer - Nernst–Planck equation, Fick's laws of diffusion, General cell designs, Electrochemical cells and its applications. Electrochemical cells, concentration cells and activity coefficient determination, liquid,Fuel cells- Theory and working of fuel cells- methanol fuel cell, H2-O2 fuel cell and solid oxide fuel cells, Corrosion and methods of prevention, Pourbaix diagram and Evans diagrams.	10	3

4	**Two dimensional nano electronic system:** Two dimensional behaviour, MOSFET structures, Heterojunctions. Transport of charge in Nanostructures under Electric field - parallel transport, hot electrons, perpendicular transport. Quantum transport in nanostructures, Coulomb blockade. Transport of charge in magnetic field - Effect of magnetic field on a crystal. Aharonov-Bohm effect, the Shubnikov-de Hass effect, the quantum Hall effect.The concept of super lattices Kronig - Penney model of super lattice.	10	4
5	**Nanoelectronic devices:** MODFETS, heterojunction bipolar transistors, Resonant tunnel effect, RTD, RTT, Hot electron transistors,Coulomb blockade effect and single electron transistor, CNT transistors,Heterostructure semiconductor laser,Quantum well laser, quantum dot LED, quantum dot laser, Quantum well optical modulator, quantum well sub band photo detectors, principle of NEMS.	10	4

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments A. Semester End examination

REFERENCES

1. Chattopadhyay, Banerjee, Introduction to Nanoscience & Technology, PHI, 2012
2. George W. Hanson, Fundamentals of Nanoelectronics, Pearson Education, 2009.
3. K. Goser, P. Glosekotter, J. Dienstuhl, Nanoelectronics and nanosystems, Springer 2004.
4. Murty, Shankar, Text book of Nanoscience and Nanotechnology, Universities Press,2012.
5. Poole, Introduction to Nanotechnology, John Wiley, 2006.
6. Supriyo Dutta, Quantum Transport- Atom to transistor, Cambridge, 2013.
7. S. Glasstone, Introduction to Electrochemistry, Biblio Bazar, 2011
8. D. R. Crow, Principles and Applications of Electrochemistry, 4th Edn., S. Thornes, 1994.
9. B. K. Sharma, Electrochemistry, Krisna Prakashan, 1985
10. John O’M Bockris and Amulya K. N. Reddy, Modern Electrochemistry Vol I & II Springer International Edn., 2006

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School Name	School of Nanoscience and Nanotechnology					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Nanophotonics**					
Type of Course	Elective					
Course Code	NSM21E30					
Course Summary & Justification	This course aims to impart knowledge about the physics of photonics. This course also aims to provide knowledge about photonic crystals and applications of photonic crystal devices.					
Semester	2		**Credit**	3		
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	30	110
Pre-requisite	Solid state devices, Semiconducting nanostructures, VLSI					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	Upon completion of this course, students will be able to;		
1	understand the basic and advance concepts of nanophotonics.	U,R	1
2	Understand the concepts of near- field optics and near-field scanning optical microscopy,	U	3, 4
3	understand the basic concepts of plasmonics	U	4
4	understand the concepts of photonic crystals	U	3, 4
5	understand the applications of photonic crystals	U	3, 4
**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*			

COURSE CONTENT

Module No:	Module Content	Hrs	CO.No.
1	**Fundamentals of photonics and photonic devices:** lasers, LEDs, optical modulators (acoustic -optic and electro- optic), optical fibers and fiber optic components, frequency conversion, propagation and confinement of photons and electrons, tunneling, band gap, Quantum confinement effects, interaction dynamics, electronic energy transfer and emission.	**10**	1
2	**Near- field optics and Near- field scanning optical microscopy**: Quantum Dots, Single molecular spectroscopy, and Nonlinear Optical processes, Time resolved studies, Heterostructures, Metallic Nanoparticles and Nanorods, Metallic Nanoshells, Local Field Enhancement, Subwavelength Aperture Plasmonics, Plasmonic Wave Guiding, Applications of Metallic Nanostructure, Radiative Decay Engineering.	**15**	2
3	**Introduction to plasmonics**: Metallic nanoparticles and nanorods, metallic nanoshells, local field enhancement, sub-wavelength aperture plasmonics, plasmonic waveguiding, applications of metallic nanostructures, Evanescent wave excitation, dielectric sensitivity, radioactive decay engineering, metal dipole interaction.	**15**	**3**
4	**Photonic crystals**: Introduction to photonic crystals, Modelling of photonic crystals, Photonic crystal optical circuitry, Non-linear photonic crystals, Photonic crystal fibers, photonic band gap materials	**10**	**4**
5.	**Applications of Photonic crystals:** Applications in communication and sensing, Near field imaging of biological systems, Nanoparticles for optical diagnosis, upconverting nanopores for bioimaging.	**10**	**5**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments A. Semester End examination

REFERENCES

1. Nanophotonics: Paras N. Prasad, Wiley, 2004
2. Nanophotonics with Surface Plasmons: Valdimir M. Shalaev, Stoshi Kawata, Elsevier Science, 2006
3. Principles of Nanophotonics, Motoichi Ohtsu, Kiyoshi Kobayashi, Makato Naruse, Taylor & Francis, 2008
4. Photonic devices, Jia Ming Liu, Cambridge University Press; Reissue edition, 2009
5. Integrated Photonics: Fundamentals, Gines Lifante, Wiley, 2003
6. Photonic crystals, Kurt Busch, Stefan Lolkes, Wiley, 2006
7. Nanophotonics, Arthur McGurn, Springer Cham, 2018
8. Fundamentals and Applications of Nanophotonics, Joseph W. Haus (Editor), Woodhead Publishing Series in Electronic and Optical Materials, Elsevier, 2016

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School Name	School of Nanoscience and Nanotechnology					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Nanocomposites**					
Type of Course	Elective					
Course Code	NSM21E31					
Course Summary & Justification	Students will gain knowledge of the main types of nanocomposite materials and their specific physical and chemical properties required in applications. Graduates will become familiar with the methods of preparation and characterization of specific physical properties of nanocomposite materials. The current state of theory and modeling of nanocomposites will be presented. At the end of the course, students will have enough understanding of the main concepts in nanocomposites physics to allow them read and understand the most important research papers in this field.					
Semester	2		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	30	110
Pre-requisite	Basics of solid-state physics (Undergraduate)					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	Upon completion of this course, students will be able to;		
1	Understand Metal based nanocomposite: preparation techniques and their final properties and functionality (Module 1)	U, A	1
2	Study of Ceramic based nanocomposites: some preparation techniques, properties and applications.	U, A	1,7

	(Module 2)		
3	Introduction of Polymer based nanocomposites, Diblock Copolymer based nanocomposites: preparation, properties and applications. Carbon nanotubes-based nanocomposites: functionalization of CNTs will also be discussed. (Module 3).	An, E	7
4	Introduction of new kind of nanocomposites, Design of super hard materials, Super hard nanocomposites, its designing and improvements of mechanical properties will also be discussed. (Module 4)	E	7, 9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO.No.
1	Metal based nanocomposites: Metal- oxide or metal-ceramic composites: different aspects of their preparation techniques and their final properties and functionality. Metal -metal nanocomposites: some simple preparation techniques and their new electrical and magnetic properties.	15	1
2	Ceramic based nanocomposites: some preparation techniques, properties and applications.	15	2
3	Polymer based nanocomposites: Diblock Copolymer based nanocomposites: preparation, properties and applications. Polymer- carbon nanotubes-based nanocomposites: functionalization of CNTs, preparation, properties and applications.	15	3
4	New kind of nanocomposites: Fractal based glass-metal nanocomposites, its designing and fractal dimension analysis, Electrical property of fractal-based nanocomposites, Core-shell structured nanocomposites, Design of super hard materials, Super hard nanocomposites, its designing and improvements of mechanical properties.	15	4

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 4. Continuous Internal Assessment (CIA) 5. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 6. Assignments B. Semester End examination

REFERENCES

1. Nanocomposites Science and Technology – P. M. Ajayan, L. S. Schadler, P. V. Braum, Wiley, 2003
2. Physical properties of Carbon nanotube- R. Satio, Imperial College Press, 1998
3. Polymer nanocomposites, Edited by Yiu-Wing Mai and Zhong -Zeng Yu, Woodhead Publishing, 2006
4. Processing and properties of Nanocomposites, Suresh Advani, World Scientific Publishing, 2007
5. Polymer- Layered Silicate and Silicate and Silica Nanocomposites, Y. C. Ke and P. Stroeve, Elsevier Science, 2005
6. Novel synthesis and characterization of Nanostructured materials, Annelise Kopp Alves, Carlos P. Bergmann, Felipe Amorim Berutti, Springer, 2013
7. Hybrid Nanocomposites for Nanotechnology; Electronic, Optical, Magnetic and Biomedical Applications, Lhadi Merhari (Ed), Springer, 2009
8. Functional Polymer Nanocomposites for Wastewater Treatment, M J Hato, S S Ray (Eds), Springer Cham, 2022

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Physics Lab**					
Type of Course	**Practical -Core**					
Course Code	NSM21C41					
Course Summary & Justification	At the end of this course students should acquire skills in doing experiments in physics as well as advanced physics.					
Semester	2		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	0	0	25	0	25
Pre-requisite	Strong theoretical knowledge in					

Others- Library, seminar and assignment preparations, test, journal, discussion etc.

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	Upon completion of this course, students will be able to;		
1	To recognize various magnetic properties of materials and to get ability to determine the various magnetic parameters of ferromagnetic substances.	A, An, S	1, 4
2	To determination of both the sign of the charge carriers, e.g. electron or holes, and their density in a given sample.	A, An, S	1, 4
3	To determine reverse saturation current, temperature coefficient of junction voltage and energy gap.	A, An, S	1, 4
4	To find the wavelength and velocity measurement of ultrasonic waves in a liquid sensing ultrasonic diffractometer	A, An, S	1, 4
5	To determine the wavelength of He-Ne laser or diode laser beam.	A, An, S	1, 4

PART-B			
1	to ascertain the molecular structure of a crystalline material by diffracting x-rays through the sample. It helps to calculate crystalline size of the particles and lattice parameters of the crystalline samples.	A, An, S	1, 4
2	to measure how much a chemical substance absorbs light. To calculate the wavelength of measurement, absorbance (A) or Transmittance (%T) or Reflectance (%R), and its change with time	A, An, S	1, 4
3	to measure the inductance (L), Capacitance (C), and resistance (R) of a material. From the capacitance values students can calculate the dielectric permittivity of the material.	A, An, S	1, 4
4	To use a particle beam of electrons to visualize specimens and generate a highly-magnified image. TEMs can magnify objects up to 2 million times.	A, An, S	1, 4
5	to confidently measure the size distribution profiles of particles in the sub-micron range.	A, An, S	1, 4
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

sl no:	Experiments	Course outcome
	PART A - General Physics	
1	Magnetic Hysteresis loop tracer	1
2	Hall effect experiment	2
3	Study of P-N junction	3
4	Ultrasonic Diffractometer	4
5	Michelson Interferometer	5
Part B		

Advanced Physics Practical		
1	X-Ray Diffractometer	6
2	UV-Visible spectrometer	7
3	Impedance Analyser	8
4	Transmission Electron Microscopy (TEM)	9
5	Dynamic Light Scattering (DLS) analysis	10

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** **Continuous Internal Assessment (CIA)** 1. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 2. Assignments A. Semester End examination

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Numerical Methods & Programming**					
Type of Course	Core					
Course Code	NSM21C42					
Semester	Third Credit: 3					
Course Summary & Justification	The use of algorithms and ever increasing computing power over humans lead to some unsettling differences between numerical analysis and other branches of mathematics and science. This course provides a solid foundation to the numerical analysis as well as programming language and numeric computing.					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	40	40	-	40	120
Pre-requisite	Basic mathematical knowledge of linear algebra and differential equations					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
	Upon completion of this course, students will be able to;		
1	Learn the direct and iterative methods for finding the roots of transcendental and polynomial equations.	U, An	2, 3
2	Reiterate the methods for the solution of a system of linear algebraic equations and learn the decomposition procedure.	E, R	2, 4
3	Accomplish error analysis and convergence of iterative methods along with methods for numerical differentiation and integration as well as extrapolation procedures.	E, A	2, 4

4	Solve ordinary differential equations both analytically and using approximation methods such as finite element method	An, U	2, 4
5	Study the numerics of approximation methods using computing platform Matlab	E,S	2, 4, 9
***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)**			

COURSE CONTENT

Module no.	**Module content**	**Hours**	**CO. No:**
1	**Approximation Methods and Errors:** Truncation and round-off errors, Accuracy and precision Roots of Equations: Bracketing Methods (false position, bisection) Iteration Methods (Newton- Raphson and secant), Systems of linear algebraic equations inversion and LU decomposition methods, Gauss elimination matrix.	10	1
2	**Curve fitting:** Least squares regression, Linear, multiple linear and nonlinear regressions, Cubic spline, Interpolation Methods: interpolating polynomials, Newton's divided difference and Lagrange Fourier approximation: Curve fitting with oscillatory functions Frequency and time domains, Discrete Fourier and Fast Fourier transforms, Numerical differentiation and integration: Divided difference method for differentiation, Newton-Cotes formula, Trapezoidal and Simpson's rules, Romberg and Gauss quadrature methods.	20	2,3
3	**Ordinary differential equations:** Euler's method and its modifications Runge-Kutta methods, Boundary value and Eigenvalue problems, Partial differential equations: Finite difference equations, Elliptic equations, Laplace's equation and solutions, Parabolic equations, Solution of the heat conduction equation, Finite element method: General approach, Application to 1-dimensional and 2- dimensional problems.	20	4
4	**Matlab:** Basics of MATLAB.	10	5
Total credits of the course		60	

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:,

	Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative
Assessment Types	**Mode of Assessment** **Continuous Internal Assessment (CIA)** ***1. Internal Test* -20 marks** ***2. Assignment*** – Every student needs to write an assignment on a given topic based on the available published literature – **10 marks** 3. ***Seminar Presentation*** – A topic needs to be presented and discussed with the class- **10 marks** **A. Semester End Examination – 60 marks**

REFERENCES

1. Numerical Mathematical Analysis, J. B. Scarborough, John Hopkins, 1966
2. Introductory Methods of Numerical Analysis, S. S. Sastry, Prentice Hall of India, 1983
3. Numerical Methods for Engineering, S. C. Chapra and R. C. Canale, McGraw-Hill, 1989
4. Electromagnetics and Calculation of Fields, Nathan P-Ida and J. P. A Bastos, Springer-Verlag, 1992
5. Numerical Methods for Scientific and Engineering Computation, M. K. Jain, S. R. K. Iyengar and R. K. Jain, Wiley Eastern, 1992
6. Introduction to Linear Algebra, Gilbert Strang, 5th Edition, Wellesley-Cambridge Press, 2016
7. Brian D. Hahn and Daniel T. Valentine, Essential MATLAB® for Engineers and Scientists, Third edition, Elsevier, 2007

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School Name	**School of Nanoscience and Nanotechnology**
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**

Course Name	**Mathematical Physics II**					
Type of Course	Core					
Course Code	NSM21C43					
Semester	Third Credit: 3					
Course Summary & Justification	The use of mathematical techniques in physics contexts is inevitable though the physical understanding is inexact and imprecise. This course provides some advanced topics in applied mathematics relevant to express physical reality and the governing laws. Partial differential equations and complex analysis encompass estimation, approximation and limiting process.					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	40	40	-	40	120
Pre-requisite	Basic mathematical knowledge of complex variables, group theory and differential equations					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
	Upon completion of this course, students will be able to;		
1	Grasp the Cauchy-Riemann equations, which give the conditions a function must satisfy in order for a complex generalization of the derivative.	U	1, 4
2	Identify the general qualitative features of solutions such as existence and smoothness of solutions of various partial differential equations appearing in physics	E	1, 8, 9
3	Use calculus of variations which seeks to find the path, curve, surface, etc., for which a given function has a stationary value (usually a minimum or maximum).	U, A	7, 9
4	Apply approximation methods such as Rayleigh-Ritz to reduce the number of degrees of freedom (DOF)	A	7, 9

5	Emphasize the role of group theory as the mathematical framework for labelling symmetry properties of classical and quantum mechanical systems.	U, An	7, 9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module no.	**Module content**	**Hours**	**CO. No:**
1	**Complex Variables**: Analytic functions of a complex variable, Cauchy-Riemann conditions, Power series, Cauchy's integral theorem, Conformal mapping, Singularities: poles, essential singularities, Residue theorem, Contour integration and examples, Analytic continuation, Multiple-valued functions, branch points and branch cut integration.	20	1
2	**Partial Differential Equations:** Partial differential equations in Physics: Laplace, Poisson and Helmholtz equations; diffusion and wave equations, Applications.	15	2
3	**Integral transforms:** Laplace transforms and Fourier transforms, Parseval's theorem, Convolution theorem, Applications, Calculus of Variations Functionals, Natural boundary conditions, Lagrange multipliers, Rayleigh-Ritz method.	15	3,4
4	**Group theory:** Elements of group theory, Discrete groups with examples, Continuous groups (Lie groups) [rotation group in 2 and 3 dimensions, U (1) and SU (2)], Generators, Representations, Character tables for some point groups and the orthogonality theorem.	10	5

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative
Assessment Types	**Mode of Assessment** **Continuous Internal Assessment (CIA)** **1. *Internal Test*** -**20 marks** **2- *Assignment*** – Every student needs to write an assignment on a given topic based on the available published literature – **10 marks**

	3. ***Seminar Presentation*** – A topic needs to be presented and discussed with the class- **10 marks** **A. Semester End Examination – 60 marks**

TEXT BOOKS

1. George B. Arfken, Hans J. Weber, Frank E. Harris, Mathematical Methods for Physicists, 7th Edition, Academic Press, 2012
2. P. Dennerey and A. Kryzwicki, Mathematics for Physicists, Dover (Indian Edition), 2005
3. K. F. Riley, M. P. Hobson and S. J. Bence, Mathematical Methods for Physics and Engineering, Cambridge University Press (Cambridge Low-priced Edition), 1999

REFERENCES

1. Schaum's outline series, McGraw Hill, 1964: (i) Complex Variables, (ii) Laplace Transforms, (iii) Group Theory
2. M. Boas, Mathematical Methods in Physical Sciences, 2nd Edition, Wiley International Edition, 1983
3. E. Kreyszig, Advanced Engineering Mathematics, Wiley Eastern, 5th Edition, 1991
4. L. A. Pipes and L. R. Harwell, Applied Mathematics for Engineers and Physicists, McGraw-Hill, 1995
5. M. Artin, Algebra, Prentice-Hall India, 2002
6. I. N. Sneddon, The Use of Integral Transforms, Tata McGraw Hill, 1985
7. D. H. Sattinger and O. L. Weaver, Lie Groups and Algebras with Applications to Physics, Geometry and Mechanics, Springer, 1986
8. M. Tinkham, Group Theory and Quantum Mechanics, Dover, 2003

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Nuclear and Particle Physics**					
Type of Course	Core Credit: 3					
Course Code	NSM21C44					
Course Summary & Justification	This course looks at physics within the nucleus, exploring the consequences of quantum physics at the high energies, and short distances, explored by nuclear and particle physics. It begins with a review of relativistic and quantum mechanics, the symmetries of fermions and bosons, and the forces of nature. Further, it goes on to explore the nature of these forces in the nuclear and particle physics domain, and see how they are related to decays and scattering processes. This course will introduce the fundamental particles and composite states, including nuclei, which appear on subatomic scales and investigate the quantum numbers and symmetries associated with the interactions of these particles. We will discuss the models used to describe the phenomena observed on the subatomic scale, and explore both their many successes and their shortcomings. Also discuss the experimental methods used to explore the subatomic world.					
Semester	3		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite	Basics of Atomic stucture, Nuclear physics, Quantum mechanics (Undergraduate)					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	Upon completion of this course, students will be able to;		
1	The module encompasses a detailed exposure to nuclear structure and models. A qualitative study on estimation of transition rates also be discussed (Module 1)	U, A	1, 6
2	This module discusses different nuclear interaction problems (Module 2)	U, A	1, 6
3	The student will get knowledge about nuclear reactions and decay (Module 3).	An, E	1, 6
4	The student will get theoretical understandings of elementary particles and its interactions (Module 4)	E	1, 4
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO.No.
1	**Nuclear Structure and Models** Basic properties of nuclei: Masses and relative abundances, mass defect, size and shape, binding energy, magnetic dipole moments and electric quadrupole moments, Liquid drop model - Semi-empirical mass formula of Weizsacker - Nuclear stability Mass parabolas - Bohr-Wheeler theory of fission – Fermi gas model Shell model - Spin-orbit coupling - Magic numbers - Angular momenta and parities of nuclear ground state - qualitative discussion and estimates of transition rates - Magnetic moments and Schmidt lines - Collective model of Bohr and Mottelson - Nilsson Model - oblate and Prolate.	15	1
2	**Nuclear Interactions** Nuclear forces - Two body problem - Ground state of deuteron - Magnetic moment - Quadruple moment - Tensor forces - Meson theory of nuclear forces - Yukawa potential - Nucleon-nucleon scattering, scattering cross	15	2

	section - Low energy n-p scattering-phase shift - proton-proton scattering - Effective range theory - Characteristics of nuclear force - Spin dependence, charge independence and charge symmetry - Isospin formalism.		
3	**Nuclear Reactions and Nuclear Decay** Reaction dynamics, the Q value of Nuclear reaction, Scattering and reaction cross sections Compound nucleus formation and breakup, nuclear fission and heavy ion induced reactions, fusion reactions, types of nuclear reactors, Beta decay - Fermi's theory - Fermi-Curie Plot - Fermi and Gamow - Teller selection rules - Allowed and forbidden decays - Decay rates - Theory of Neutrino - Helicity of neutrino - Helicity measurement - Theory of electron capture - Non-conservation of parity - Gamma decay - Internal conversion - Multipole transitions in nuclei - Nuclear isomerism - Angular correlation in successive gamma emissions.	15	3
4	**Particle Physics** Types of interactions between elementary particles - Hadrons and leptons, their masses, spin parity decay structure, the quark model, the confined quarks, colored quarks, Experimental evidence for quark model, The quark-gluon interaction, Gellmann- Nishijima formula, Symmetries and conservation laws, C, P and CPT invariance and applications of symmetry arguments to particle reactions, parity non conservation in weak interactions, Exchange Bosons of the weak interaction, electroweak unification.	15	4

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** **Continuous Internal Assessment (CIA)** **1.** ***Internal Test*** -**20 marks** **2-** ***Assignment*** – Every student needs to write an assignment on a given topic based on the available published literature **– 10 marks** 3. ***Seminar Presentation*** – A topic needs to be presented and discussed with the class- **10 marks**

	A. Semester End Examination – 60 marks

REFERENCES

1. Introductory Nuclear Physics, Kenneth S. Krane, Wiley, New York, 1987
2. Introduction to Elementary Particles, D. Griffiths, Wiley, 1987
3. Nuclear Physics, R. R. Roy and B. P. Nigam,New Age International, New Delhi, 1983
4. The Particle Hunters, Yuval Ne'eman& Yoram Kirsh, Cambridge University Press, 1996
5. Concepts of Nuclear Physics, B. L. Cohen, TMH, New Delhi, 1971
6. Theory of Nuclear Structure, M. K. Pal, Scientific and Academic Edn., 1983
7. Atomic Nucleus, R. D. Evans, McGraw-Hill, New York, 1955
8. Nuclear Physics, I. Kaplan, 2nd Edn, Narosa, New Delhi, 1989
9. Introduction to Nuclear Physics, H. A. Enge, Addison Wesle, London, 1975
10. Introductory Nuclear Physics, Y. R. Waghmare, Oxford-IBH, New Delhi, 1981
11. Elementary Particles, J. M. Longo, McGraw-Hill, New York (1971)
12. Particles and Nuclei, B. Povh, K. Rith, C. Scholz & F. Zetche, Springer, 2002

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Atomic and Molecular Physics**					
Type of Course	Core					
Course Code	NSM21C45					
Course Summary & Justification	This course provides an introduction to the field of atomic and molecular physics. This will include a description of classic historical experiments and results and theoretical concepts from quantum mechanics. The first half of this course deals principally with atomic structure and the interaction between atoms and fields. It covers electronic transitions, atomic spectra, excited states, hydrogenic and multi-electron atoms. The second half of the course deals with the binding of atoms into molecules, molecular degrees of freedom (electronic, vibrational, and rotational), elementary group theory considerations and molecular spectroscopy.					
Semester	3		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite	Basics of Atomic stucture and Quantujm mechanics (Undergraduate)					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
	Upon completion of this course, students will be able to;		
1	The module encompasses a detailed exposure to Hydrogen atom and time independent perturbation	U, A	2, 3, 6

	theory. Also discuss the relativistic corrections for the energy levels of the hydrogen atom and their effect on optical spectra and derivation of the energy shifts due to these corrections using first order perturbation theory. (Module 1)		
2	This module discusses different interactions associated with Hydrogen atom and review of time dependent perturbation theory. (Module 2)	U, A	2, 3, 6
3	The student will get knowledge about Quantization of the electromagnetic field and Raman effect. (Module 3).	An, E	2, 3, 5
4	The student will get theoretical understandings of Hartree Fock SCF method, proof of Koopmans theorem, Slater's approximation to exchange, Total Hamiltonian of a molecule, Born -Oppenheimer approximation, Rotational and Vibrational Spectra of molecules etc. (Module 4)	E	2, 3, 5
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO.No.**
1	**Hydrogen atom:** Review of the Bohr atom model, solution of the Schrodinger equation, spectra of hydrogen and hydrogen-like atoms, Review of time-independent perturbation theory, Fine structure of the hydrogen atom: spin-orbit coupling and relativistic correction to the kinetic energy, Review of the Dirac equation, Dirac equation in the non-relativistic limit.	15	1
2	Zeeman and Stark Spectroscopy Hyperfine interaction in atomic Hydrogen, Spectroscopy with the 21 cm emission line, Review of time-dependent perturbation theory, Interaction of electromagnetic radiation with a two-level atom, Rabi flopping, The dipole approximation, electric dipole, magnetic dipole and electric quadrupole transitions, Selection rules, Transition probabilities and intensity of spectral lines.	15	2

3	Line broadening mechanisms, Spontaneous and stimulated emissions and Einstein coefficients, masers and lasers, Lamb shift, Quantization of the electromagnetic field, The Raman effect, Introduction to NMR and ESR, Review of Pauli's exclusion principle, The spin-statistics theorem, The Helium spectrum, Many electron systems: Electron configurations and spectroscopic notation, equivalent and non-equivalent electrons and Hund's rules.	15	3
4	Hartree Fock SCF method, proof of Koopmans theorem, Slater's approximation to exchange, Total Hamiltonian of a molecule, Born -Oppenheimer approximation, Rotational and Vibrational Spectra of molecules, Anharmonicity, Franck-Condon principle, Electronic, Infrared and Raman Spectra analysis, Symmetry of atomic and molecular systems, Group theoretical treatment, proof of the Great Orthogonality Theorem. Optional Advanced Topics: Saturation absorption spectroscopy, Atomic clocks, Laser-cooling and Bose-Einstein Condensation, Synchrotron radiation spectroscopy, Photofragmentation of molecules.	15	4

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** **Continuous Internal Assessment (CIA)** **1.** ***Internal Test*** -**20 marks** **2-** ***Assignment*** – Every student needs to write an assignment on a given topic based on the available published literature – **10 marks** 3. ***Seminar Presentation*** – A topic needs to be presented and discussed with the class- **10 marks** **A. Semester End Examination** – **60 marks**

REFERENCES

1. B. H. Bransden and C. J. Joachain, Physics of Atoms and Molecules Longman Inc. New York, 1983
2. E. U. Condon and G. H. Shortley, The Theory of Atomic spectra, Cambridge University Press, 1989
3. G. Herzberb, Molecular Spectra and Molecular Structure -I Spectra of Diatomic Molecules, D. Von Nostrand Inc., 1956
4. G. Herzberg, Molecular Spectra and Molecular Structure -II Infrared and Raman Spectra of Polyatomic Molecules, D. Von Nostrand Inc., 1956
5. G. Herzberg, Atomic Structure and Atomic Spectra, Dover Pub. Go. 2nd Edition, 1944
6. H. E. White, Introduction to Atomic Spectra, McGraw-Hill, 1954
7. P. S. Sindhu, Molecular Spectroscopy, Tata McGraw-Hill, 1985
8. E. U. Condon and H. Odabasi, Atomic Structure, Cambridge Universtiy Press, 1980
9. H. A. Bethe and E. E. Salpeter, Quantum Mechanics of One- and Two- Electron Atoms, Plenum Press, 1977
10. M. Tinkham, Group Theory and Quantum Mechanics, Courier Dover Publications, 2004
11. D. J. Griffiths, Introduction to Quantum Mechanics (2nd Edition), Pearson Education 2005
12. Peter F. Bernath, Spectra of Atoms and Molecules, Oxford University Press, 1995
13. J. J. Sakurai, Modern Quantum Mechanics, Pearson Education, 2009
14. J. J. Sakurai, Advanced Quantum Mechanics, Pearson Education,2009

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School Name	School of Nanoscience and Nanotechnology					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Mini Project/Review Report**					
Type of Course	Core					
Course Code	NSM21C46					
Course Summary & Justification	Train the student to assimilate research problems and research attitude and to acquire hands-on experience in either experimental/computational physics or both. Relevance of scientific literature in knowledge addition and problem identification would be emphasised. Encourage the student to initiate the process of literature review and use of online research repositories. Research literature documentation and rudimentary writing is envisaged in this course.					
Semester	3		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning			60	60	120
Pre-requisite	Fundamental understanding and knowledge of nanotechnology and nanomaterials.					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	Upon completion of this course, students will be able to;		
1	Conceive a research problem in the area of nanoscience by the application of scientific methodologies	U, C	1, 2,3, 7,8

2	Apply scientific methodologies to solve the problem either through experiments or simulation or applying both.	C, A	1,2,3,4, 7,8
3	Perform experiment or simulation or both to accomplish the outcome of the research.	An, E	5,7
4	Analyse results and arrive at inferences and conclusions drawn out of it. Also understand the documentation procedure for project report writing.	An, E	3, 7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – prepare mini project/review report and present in the seminar

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Nanotechnology for Energy Applications**					
Type of Course	Elective					
Course Code	NSM21E32					
Course Summary & Justification	This main objective of this course is to give a theoretical and practical overview of nanotechnology with applications in energy conversion and storage. The specific objectives of this course are to familiarize with nanomaterials, manufacturing processes, characterization and also reliability characteristics. Upon completion of the course on Application of Nanotechnology for Batteries, Solar and Fuel cells, students will understand the fundamental laws governing energy conversion and storage efficiency, the importance of favourable nanomaterials in the energy conversion, and storage application and reliability of materials. The modules are selected in order to have hierarchy in student learning in three different areas (fuel cells, batteries and solar photovoltaics) of alternative energy technologies.					
Semester	3		**Credit**		2	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	30	20	-	30	80
Pre-requisite	Basics of Energy storage systems and Nano based materials(Under graduate)					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
	Upon completion of this course, students will be able to;		

1	The module encompasses a detailed exposure to the alternative energy production technologies with a special focus on solar-photovoltaic, batteries and hydrogen-fuel cell technologies. Nanotechnology in Energy production (Module 1)	U, A	1, 9
2	To study the role of nanotechnology in Energy storage applications (Module 2)	U, A	1, 9
3	Detailed study of Carbon-based nanomaterials and its energy applications (Module 3).	An, E	1, 5
4	The students will understand energy sustainability: Green approaches to nanofabrication (Module 4)	E	1, 5
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO.No.**
1	Nanotechnology in Energy production- Photovoltaics-Semiconductor and optical absorption, Dye molecular engineering, Hydrogen production- Photochemical cells, Semiconductors with specific morphology, Sensitization, Fuel Cells- Low temperature fuel cells, cathode and anode reaction, electrolytes, Membrane electrode assembly, high temperature fuel cells, Thermo-electricity- Bulk thermoelectric materials, Size effects, Thermionics, Thermoelectric nanocomposites.	10	1
2	Energy Storage: Hydrogen storage by physisorption, Nanostructured Carbon, Zeolites, Metal-organic Frameworks, Chemisorption- Metal and complex hydrides, chemical hydrides, nanocomposites, Electrochemical energy storage: Nanostructured electrodes and interfaces, Current collectors/Active film interface: self-supported electrodes, current collectors, Active material / Electrolyte interfaces.	10	2

3	Carbon based nanomaterials: Nanostructure and surface functionality of sp3 carbon, supercapacitance, Psuedocapacitive oxides and conducting polymers, Lithium-ion batteries, Nanomaterials for superconductors, Flux pining, the grain boundary problem, anisotropic current properties, enhancing naturally occurring nanoscale defects, Artificial introduction of flux pinning nanostructures.	10	3
4	Energy sustainability: Green approaches to nanofabrication: Molding and embossing, Printing, Edge lithography by nanoskiving, Shadow evaporation, Electrospinning: Scanning and uniaxial, Self-assembly.	10	4

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 7. Continuous Internal Assessment (CIA) 8. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 9. Assignments C. Semester End examination

REFERENCES

1. Javier Garcia-Martinez, Nanotechnology for the energy Challenge, Wiley-VCH (2010)

2. Baldev Raj, Marcel Van De Voorde, Yashwant Mahajan, Nanotechnology for Energy Sustainability, Wiley-VCH (2017)

3. Kaufui Vincent Wong, Pan Stanf, Nanotechnology and Energy, Pan Stanford, 2017

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Computational Nanoscience and Applications**					
Type of Course	Elective					
Course Code	NSM21E33					
Semester	Third Credit: 3					
Course Summary & Justification	This course brings about introduction to a series of numerical algorithms and software. Computer simulation spanning from coarse, molecular to quantum mechanical scales are studied in this course. The characteristics of nanoscale devices can be quantified and predicted by efficiently bridging scales in the simulation procedures mentioned in this course.					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	40	40	-	30	110
Pre-requisite	Basic knowledge of quantum mechanics and differential equations					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Determine the dynamics of atomic- and molecular-level phenomena that cannot be observed directly and physical properties of potential nanotechnological devices	U	1, 4

2	Attempt solution of the electronic Schrödinger equation, by computation, given the positions of the nuclei and the number of electrons in order to yield useful information such as electron densities, energies and other properties of the system.	E	1, 4
3	Emphasize the inclusion of electron correlation which is a more accurate way of appropriating the repulsions between electrons than in the customary Hartree–Fock method where repulsions are only averaged.	U, A	1, 5
4	Familiar with semi-empirical quantum chemistry methods where the properties of a many-electron system can be determined by using functionals.	A	1, 5
5	Assimilate density functional theory (DFT) which is among the most popular and versatile semi-empirical quantum mechanical methods available in condensed-matter physics	U, An	1, 4, 5
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module no.	**Module content**	**Hours**	**CO. No:**
1	**Molecular Dynamics:** General Principles of MD simulations, General Principles of MD simulations, Design constraints: Microcanonical, Canonical, isothermal-isobaric, generalized ensembles; Applications and limitations of MD 75.	15	1
2	**Ab initio Quantum Methods:** Concept of Basis Sets, types and nomenclature; Slater and Gaussian functions; Hartree-Fock Methods: Basic concepts for Hartree-Fock (HF), Restricted open-shell Hartree-Fock (ROHF) and Unrestricted Hartree-Fock (UHF) methods.	15	2

3	**Introduction to post-Hartree-Fock methods:** Møller-Plesset perturbation theory, Configuration Interaction (CI), Coupled Cluster (CC), Quadratic Configuration Interaction.	15	3
4	**Semi-empirical Quantum Chemistry Methods:** Basic Concepts, Density Functional Methods: General Principles, Hohenberg-Kohn theorem, Kohn-sham model (derivations not expected), Types of electron density functional.	15	4

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative
Assessment Types	**Mode of Assessment** **Continuous Internal Assessment (CIA)** **1. *Internal Test* -20 marks** **2. *Assignment*** – Every student needs to write an assignment on a given topic based on the available published literature – **10 marks** 3. ***Seminar Presentation*** – A topic needs to be presented and discussed with the class- **10 marks** **A. Semester End Examination – 60 marks**

Text books

1. J. H. Jensen, E. G. Lewars, Computational Chemistry: Introduction to the Theory and Applications of Molecular and Quantum Mechanics, 2nd Edn., Springer, 2011
2. F. Jensen, Introduction to Computational Chemistry, 2nd Edn., John Wiley & Sons, 2007
3. A. R. Leach, Molecular Modelling: Principles and Applications, 2nd Edn., Pearson Education Ltd., 2001

REFERENCES

1. J. P. Fackler Jr., L. R. Falvello (Eds.), Techniques in Inorganic Chemistry: Chapter 4, CRC Press, 2011
2. K. I. Ramachandran, G. Deepa, K. Namboori, Computational Chemistry and Molecular Modeling: Principles and Applications, Springer, 2008
3. A. Hinchliffe, Molecular Modelling for Beginners, 2nd Edn., John Wiley & Sons, 2008
4. C. J. Cramer, Essentials of Computational Chemistry: Theories and Models, 2nd Edn., John & Sons, 2004
5. D. C. Young, Computational Chemistry: A Practical Guide for Applying Techniques Real-World Problems, John Wiley & Sons, 2001

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School Name	School of Nanoscience and Nanotechnology						
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**						
Course Name	**Nanomagnetic Materials**						
Type of Course	Elective						
Course Code	NSM21E34						
Course Summary & Justification	Advantage of artificial nanomagnetic materials and nanostructures is their ability to surpass the performance of naturally occurring magnetic compounds. Nanomagnetic materials and magnetic nanostructures are vital areas of nanoscience with many present and emerging applications, including permanent magnets, soft magnets, magnetic recording media, sensors, and materials for spintronics. This course provides a broad but brief coverage of key aspects of magnetism and magnetic materials explained from the macroscopic through nanometer scale. Size-effect which governs the peculiar properties of this class of materials at the nanometer scale would be presented in this course.						
Semester	3		Credit		3		
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours	
	Authentic learning Collaborative learning Case based learning	40	40	-	30	110	
Pre-requisite	Strong mathematical background in graduation level is desirable.						
Others- Library, seminar and assignment preparations, test, journal, discussion etc.							

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Learn the theory of ferromagnetism and magnetic moments as well as domain structure. Comprehend the specifics of magnetic nanostructured materials too.	U, An	1, 7

2	Get to know giant magneto resistance (GMR) and GMR materials which exhibits an extraordinarily large change of the electrical resistance of antiferromagnetically coupled thin film structures upon application of an external magnetic field.	U, Ap	1, 7
3	Order-disorder type phase transitions taking place in magnetic materials would be explained.	U, An	1, 7
4	Grapple with many critical sizes, specifically the grain-size effect that control the behaviour of magnetic materials.	U, An	1, 5, 7
5	Explain the concept of Magneto-electrics that exhibits both electric and magnetic orders in one material.	U,An	1, 5, 7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hours**	**CO: No:**
1	Basics of ferromagnetism, Effect of bulk structuring of Magnetic properties, Dynamics of Nanomagnets, Nanopore containment of magnetic properties, Nanocarbon ferromagnets	15	1
2	Giant Magneto resistance, GMR, Applications in data storage, Ferro fluids, Band structure in magnetic fields, Parallel and perpendicular field Magnetic susceptibilities, Disorder–order transformations. Spintronics	15	2
3	Super paramagnetism, Effect of grain-size, Magneto-transport, Fermi’s golden rule and mean free path, Ballistic vs. diffusive regimes, Persistent currents, Magnetization, Ferroelectrics	15	3
4	Electronic Properties and Quantum Effects, Magneto-electronics: Magnetism and Magnetotransport in Layered Structures, Magneto optics, magnetoelectrics.	15	4,5

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments A. Semester End examination

REFERENCES

1. Principles of Nanomagnetism: Alberto P. Guimarães, Springer Berlin, Heidelberg, 2009
2. Nanomagnetism and Spintronics: Fabrication, Materials, Characterization and Applications, Farzad Nasirpouri and Alain Nogaret, World Scientific, 2011
3. Fine Particle Magnetism, Bandyopadhyay Bibek, Atlantic Publishers and Distributors, 2002
4. Magneto-optics: S. Sugano, N. Kojima (Editors), Springer Berlin, Heidelberg, 2000
5. Magnetic Materials: Fundamentals and Applications (2nd ed.), Spaldin, N., Cambridge University Press, Cambridge, 2010.
6. Introduction to Magnetic Materials, 2nd Edition, L. C. Cullity and C. D. Graham, IEEE Press, Willey.
7. Nanomagnetism: Applications and Perspectives, Claude Fermon, Marcel Van de Voorde (Eds) Germany: Wiley, 2017.
8. Nanomagnetism: Fundamentals and Applications, Chris Binns (Ed), Netherlands: Elsevier Science, 2014.
9. Nanomagnetic Materials: Fabrication, Characterization and application, Akinobu Yamaguchi, Atsufumi Hirohata, Bethanie Stadler (Eds.), Netherlands: Elsevier Science, 2021.

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Dissertation**					
Type of Course	Core					
Course Code	NSM21C47					
Course Summary & Justification	The candidate shall do a research project in any of the research institute. This follows discussion with the Examination Board consisting of the Chairman, the Internal Examiner and the External Examiner.					
Semester	4		**Credit**		12	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning					
Pre-requisites	Aptitude for research work in one of the interdisciplinary areas in the realm of interface between physical science and nanotechnology. Literature survey. Should complete semester I, II and III.					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	At the end of the course the students are expected to		
1	Clearly present and discuss the research objectives, methodology, analysis, results and conclusions effectively.	A	1, 2, 3, 4, 5
2	Acquire a comprehensive knowledge of the area subject of study	Ap	1, 7
3	Gain deeper knowledge of methods in the topic of study.	A	6
4	Able to contribute to research and development work.	U	3

5	Undertake independent, original and critical research on a relevant topic.	U	5
6	Able to plan and use adequate methods to conduct specific tasks in given frameworks and to evaluate this work.	U	6
7	Create, analyse and critically evaluate different problems and their solutions.	C, An	7,8
8	Gain consciousness about the ethical aspects of research.	E	6,9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** E-learning, interactive Instruction: Seminar, Authentic learning, , Library work, laboratory work, Team work, independent learning and Group discussion, Presentation of research work.
Assessment Types	**Mode of Assessment** Evaluation of the presentation by both internal and external examiners.

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School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M. Sc. Physics (Nanoscience and Nanotechnology)**					
Course Name	**Viva-Voce**					
Course Credit	**4**					
Type of Course	**CORE**					
Course Code	NSM21C48					
Course Summary & Justification	The Examination Board consisting of the Chairman and examiners shall conduct the comprehensive viva-voce. Thorough understanding of all the M. Sc. level course contents and of the recent trends in the broad area of Physics and Nanotechnology are evaluated					
Semester	**4**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Classroom studies, lab work, library work, independent learning etc.	-	-	-	-	-
Pre-requisite	Basic as well as in-depth knowledge in the courses he/she studied					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	At the end of the course the students are expected to;		
1	Achieve fundamental and in-depth knowledge of the subject	U, A	1, 3
2	Acquire more profound knowledge of the methods of all the major areas of the programme	Ap	1,2,3,4, 5,6, 7
3	Obtain objective understanding and knowledge of physics with an emphasis on nanotechnology	A	1, 4
4	Be able to contribute to research and development work.	U, S	3, 8, 9
***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)**			

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** E-learning, interactive Instruction:, Seminar, Authentic learning, , Library work , laboratory work, Team work, independent learning and Group discussion, Presentation of research work
Assessment Types	**Mode of Assessment** Thorough understanding of all the M. Sc. level course contents and recent trends in the broad area of chemical sciences are evaluated. The candidate will be asked questions based on the whole syllabus he/she studied in the entire programme. How he/she answered or responded the questions asked will be considered for evaluation.

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MODEL QUESTION PAPER

SCHOOL OF NANOSCIENCE & NANOTECHNOLOGY

MAHATMA GANDHI UNIVERSITY

SEMESTER

PROGRAMME

EXTERNAL EXAMINATION (YEAR/ MONTH)

COURSE CODE: COURSE NAME

Time: 3 Hours **Max. Marks: 60**

Part A. Answer any 10 Questions (Each question carries 2 marks)

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Part B. Answer any 4 Questions (Each question carries 5 marks)

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Part C. Answer any 2 Question (Each question carries 10 marks)

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2. ………………………………………………………………………………………
3. ………………………………………………………………………………………
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