MAHATMA GANDHI UNIVERSITY

School of Nanoscience and Nanotechnology

Priyadarsini Hills P.O. Kottayam–686560,

Kerala, India

Learning Outcomes-based Curriculum Framework (LOCF) for Post Graduate Programme

M. Tech. Nanoscience & Technology

Under the CSS scheme for University

(EFFECTIVE FROM 2021 ADMISSION ONWARDS)

PREFACE

I am happy to present the revised curricula and syllabi of the following M.Tech. 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 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 par with the outcome-based approach. The Programme Specific Outcomes (PSOs) and the Course Outcomes (COs) are presented in the syllabus. The PSOs and the COs are well correlated in the syllabus of each course. The draft curricula and syllabi for all the M.Tech. Nanoscience and Nanotechnology programmes were discussed in a very effective manner in the Board of Studies of the School of Nanoscience and Nanotechnology. The Board of Studies has also modified the scheme, curricula and syllabi for the MTech. Programme in conformity with the Revised CSS Regulations 2020 by the Mahatma Gandhi University to suit the Credit and Semester System.

The BOS feels that appreciable updating could be done in keeping with the current developments and trends in chemistry 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.

Forward

OBE is an educational approach and a learning philosophy, focusing and organizing the entire academic program (curriculum) and instructional efforts around clearly defined ‘outcomes’ that an institution wants all students to demonstrate when they complete the program.

The induction of India in the Washington Accord in June 2014 with the permanent signatory status has triggered the implementation Outcome-Based Education (OBE) in Higher Education Institutions in India. This is considered a significant step of progress for the higher education sector in India and encourages and facilitates the mobility of graduates and professionals at the international level.

The National Assessment and Accreditation Council (NAAC) has incorporated OBE into the Accreditation process for promoting international quality standards for higher education in India. Through OBE, the Internal Quality Assurance Cell (IQAC) of Mahatma Gandhi University puts forward this document for University teaching departments to prepare the Learning Outcomes-based Curriculum Framework (LOCF) for Postgraduate programs.

OUTCOME-BASED EDUCATION (OBE)

ASSESSMENT PLAN

FOR THE ACADEMIC YEAR 2021-22

1. Introduction

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

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

2. Benefits of OBE

The OBE Framework is a paradigm shift from the traditional education system into the OBE system, where there is a greater focus on program and course outcomes. It guarantees that curriculum, teaching and learning strategies, and assessment tools are continuously enhanced through continuous improvement. All decisions, including curriculum, delivery of instruction, and assessment, are based on the best way to achieve the predetermined 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)

3. Outcome-Based Education (OBE) process

OBE is a comprehensive approach to organizing and operating a curriculum focused on and defined by the successful demonstrations of learning sought from each learner. The term means focusing and organizing 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 program or a course. Each student should have achieved the results by the end of the educational experience.

One of the main objectives of OBE is to ensure continuous improvement of programs in terms of maintaining the relevance of the curriculum and responding to the stakeholders' requirements. In other words, it provides that the Postgraduate program next year is better than the Postgraduate program this year offered by a department.

An OBE system has been proposed and implemented at various Departments of Mahatma Gandhi University as a quality-assurance approach to improving teaching and learning outcomes and processes. This OBE plan incorporates the "outcomes assessment" process to be followed in the departments. OBE should be a vital driver of curriculum management in all the university departments.

The OBE is a 6 step process, as shown in figure 1.

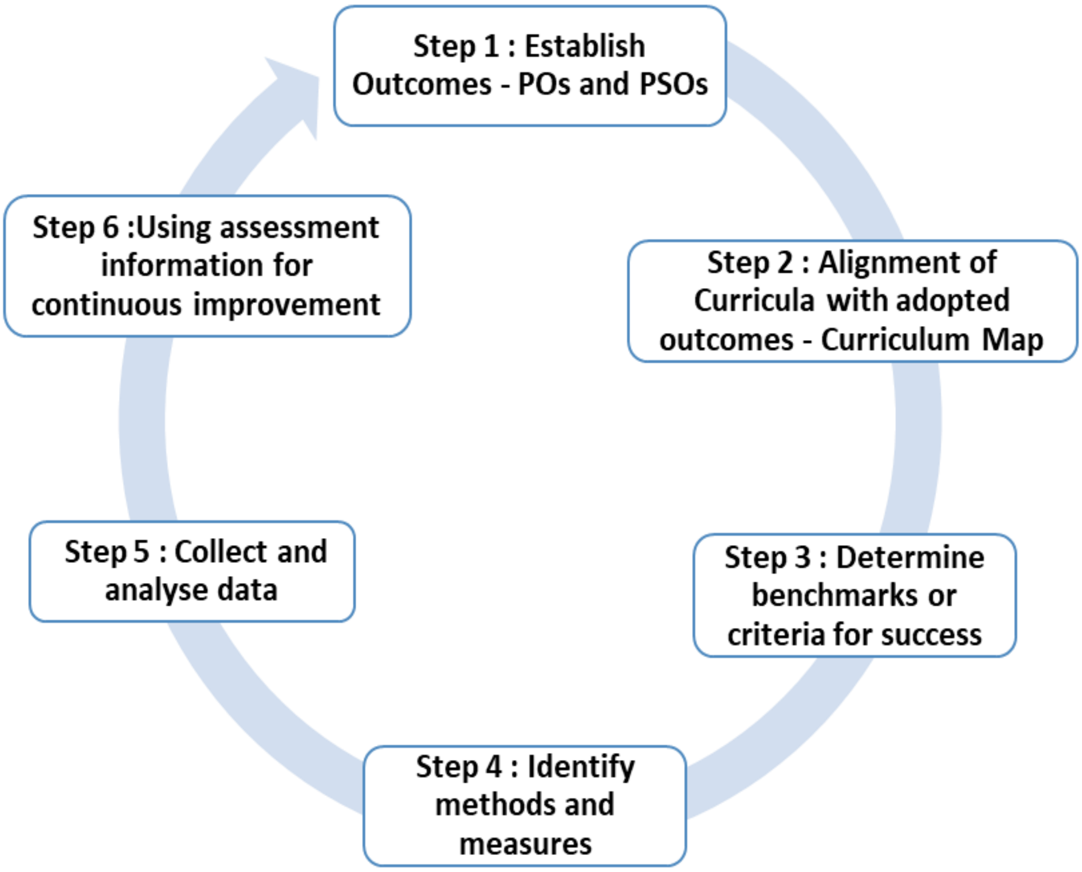

Figure 1: OBE Process

The process is presented as a cycle or a loop. The bike represents the continuous nature of assessing learning outcomes.

4. Department

This department has been addressing critical and demanding issues in all areas of science and technology through research using the most advanced Nanotechnology. The department has formed scientific teams among faculties. Each scientific team has a mission and specific scientific issues they address. The teams fulfil the team mission and achieve scientific solutions through constant international participation. The department then collaborates with industries to establish the research and make it available as products.

These scientific teams are responsible for different courses in the student's coursework. Thus, the curriculum is based on the latest progress in the course area. Students enrolled are trained in such a consistently changing curriculum and attaining training in research under the research teams of their interest.

The department carries out Master's degree to make experts in various professional areas in particular field of nanotechnology. We channel the students to the various felids at the later stage of the first semester through the compulsory reading of research articles throughout the months of the first semester as part of first-semester coursework assignments.

At the end of first-semester coursework and their latest article reading assignments, students become aware of all fields, and they will be given the freedom to be channelled to the various teams. Though the first semester's coursework dealt with the basic sciences of nanotechnology, the second semester's coursework focused on the different fields of nanotechnology. The students will get to study the areas they have chosen. The department's motives for the second semester are to make students excel in knowledge of their field through various team activities and weekly discussions throughout the second semester. The completion of the first and second semesters marks the end of the first year of MTech Nanotechnology. At this end, a final presentation is made compulsory for students to display their vast advanced knowledge in the field they choose.

In the scientific field, a professional is known for their competency through the number of publications. The more the publication at hand, the greater is their future in Research and Scientific work in industries. Secondly, a professional is unknown when they have expertise in a particular area.

In the second year, the faculties of each team would recommend all their students to various Research Labs and Universities all around the world for their exposure to research work. They are encouraged to gain expertise in a particular field. The student's performance in the third and fourth semester of the second year is accounted for as project grades for their respective research work and publication made during their work in the lab they would work in.

At the end of the third semester, arrangements would be made for students to be interviewed by various companies that would hire them. If students would prefer to study further, students are asked to start applying at this juncture. Recommendation letters to look further can be obtained from the university professors and the labs they would work in the second year.

By the fourth semester, students will start hearing about placement results and results from Universities they wish to study further. Thus, the department's success lies in the students' successful results.

Members of Experts at School of Nanoscience and Nanotechnology

1. Prof. Sabu Thomas (Chairman)
2. Prof. Nandakumar K
3. Dr. Sreekala M.S.
4. Dr. Ditty Dixon

5. Programme Outcomes (POs) :

Program Outcomes are the abilities that, the students acquire at the end of the program. POs reflect broad educational expectations for each degree program. They also reflect the major intellectual and behavioral competencies a program intends to instill in its students due to the total educational experience across a given program. Mahatma Gandhi University Programme Outcomes are driven by the mission and graduate attributes of the university.

Program Outcomes (POs) of Mahatma Gandhi University

PO 1: Critical thinking and analytical reasoning

Capability to analyze and evaluate evidence, arguments, claims, and beliefs based on empirical evidence; identify relevant assumptions or implications; formulate coherent ideas; critically evaluate practices, policies, and theories to develop knowledge and understanding; critical sensibility to lived experiences, with self-awareness and reflexivity of both self and society.

PO 2: Scientific reasoning and Problem solving

Ability to analyze, interpret and draw conclusions from quantitative/qualitative data; and critically evaluate ideas, evidence, and experiences from an open-minded and reasoned perspective; capacity to extrapolate from what one has learned and apply their competencies to solve different kinds of non-familiar problems, rather than replicate curriculum content knowledge; and apply one's learning to real-life situations.

PO 3: Multidisciplinary/interdisciplinary/transdisciplinary Approach

Acquire an interdisciplinary /multidisciplinary/transdisciplinary knowledge base due to the learning they engage with the program of study; develop a collaborative-multidisciplinary/interdisciplinary/transdisciplinary- approach for formulating constructive arguments and rational analysis for achieving common goals and objectives.

PO 4: Communication Skills

Ability to express thoughts and ideas effectively in writing and orally; Communicate with others using appropriate media; 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 to different groups.

PO 5: Leadership Skills

Ability to work effectively and lead respectfully with diverse teams; setting direction, formulating an inspiring vision, building a team who can help achieve the vision, motivating and inspiring team members to engage with that vision, 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 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 (caste, ethnicity, gender and marginalization), 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, avoid unethical behaviour

PO 9: Networking and Collaboration

Acquire skills to be able to collaborate and network with educational institutions, research organizations and industrial units 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 workplace place through knowledge/skill development/reskilling.

6. Programme Specific Outcomes (PSOs)

PSOs are statements that describe what the graduates of a specific educational Programme should be able to do. Program outcomes are broad statements and, taken alone, are not suitable for assessment. Therefore, each program outcome can be translated into one or more Programme Specific Outcomes (PSOs), which describe a measurable attribute of the overall program outcome. M.Tech. Nanotechnology Programme Specific Outcomes (PSOs) are created by a faculty team and reviewed by the entire faculty after getting suggestions from the relevant stakeholders.

The following section gives the PSOs of the Nanotechnology program:

PSO number	**Intended Program Specific Outcomes (PSO)** *Upon completion of the MTech Nanotechnology program, the graduates will be able to*	**MGU PO No.**
PSO 1	Understanding of science concept and problem solving	PO 1,2
PSO 2	Evaluate and make choices among alternatives that indicate a deep comprehension of the research problem.	PO 2,3,8
PSO 3	Practice team leadership through active team participation.	PO 4,5,7,9
PSO 4	Identify and evaluate different strategies for responding to scientific issues.	PO 6
PSO 5	Promoting research interest in students and enabling them to plan and execute research in frontier areas of nanosciences.	PO 2,3
PSO 6	Gain deep knowledge of the topic and have a strong foundation in Nanotechnology.	PO 1
PSO 7	Acquiring characterization skill	PO 1
PSO 8	Knowledge of the State of Art	PO 7,10
PSO 9	Make oral presentations effectively in a professional context.	PO 4,5,9

7. Course Outcomes (COs) : COs are statements that describe what students should be able to do at the end of a course; it should be measurable. A course can have at least one outcome per module of the course syllabus. Course outcome of each course is mentioned along with each course's description.

8. M.Tech. Nanoscience and Technology

Course Materials

SEMESTER I (24 credits)						
Course Code	**Course Title**	**Hours/Week**			**Credit**	**Total credits**
		L	T	P		
CORE COURSES						18
NSM21C01	Quantum Mechanics of Nanostructures	2	2	-	4	
NSM21C02	Synthesis and processing of Nanomaterials	2	2	-	4	
NSM21C03	Research Methodology and Intellectual Property Rights	2	2	-	3	
NSM21C04	Thermodynamics of Nanomaterials	2	2	-	4	
NSM21C05	Synthesis of Nanomaterials and Characterization of Nanomaterials Lab (Practical)			6	3	
***ELECTIVE COURSES (Choose any three)**						6
NSM21E01	Nanotechnology in Toxicology, food, and	2	-	-	2	
NSM21E02	Nano Magnetism	2	-	-	2	
NSM21E03	Semiconducting Nanostructures	2	-	-	2	
NSM21E04	Advanced Computing in Nanotechnology: Mathematical Modelling and Simulation	2	-	-	2	
NSM21E05	Nanotechnology for Corrosion Science and	2	-	-	2	
NSM21E06	Polymer Nano composites	2			2	

SEMESTER II (24 credits)						
Course Code	**Course Title**	**Hours/Week**			**Credit**	**Total credits**
		L	T	P		
CORE COURSES						18
NSM21C06	Advanced Characterisation techniques of nanomaterials	2	2	-	3	
NSM21C07	Design and fabrication of Nanodevices	2	2	-	3	
NSM21C08	Advanced nano-biotechnology	2	2	-	3	
NSM21C09	Advanced Characterization of Nanomaterials Lab -2	-	-	-	3	
NSM21C10	Mini Project and Comprehensive Viva	-	-	-	3	
NSM21C11	Industrial Visit /Case Study	-	-	-	3	
***ELECTIVE COURSES (Choose any three)**						6
NSM21E07	Nanoelectronics and Nanophotonics	2	-	-	2	
NSM21E08	Nanotechnology in Energy	2	-	-	2	
NSM21E09	Nanotechnology in Colloids, Surface Science & Catalysis	2	-	-	2	
NSM21E10	Environmental Nanotechnology	2	-	-	2	
NSM21E11	Advanced carbon-based nanomaterials	2	-	-	2	
NSM21E12	Computation and Simulation Lab	2			2	

SEMESTER III (16 credits)						
Course Code	**Course Title**	**Hours/Week**			**Credit**	**Total credits**
		L	T	P		
NSM21C12	Interim Project Evaluation				16	16

SEMESTER IV (18 credits)						
Course Code	**Course Title**	**Hours/Week**			**Credit**	**Total credits**
		L	T	P		
NSM21C13	Final Project Evaluation and Viva-Voce				18	18

MAHATMA GANDHI UNIVERSITY

NSM21C01 Quantum Mechanics of Nanostructures

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech.**
Course Name	**Quantum Mechanics of Nanostructures**
Type of Course	**Core**
Credit Value	**4**
Course Code	**NSM21C01**

Justification of Course in Programme	This course aims to impart basic knowledge on the principles of quantum mechanics, giving an overall view of the various aspects of it. It covers the foundation and gives them strong ground for them to build upon in their future for their research. Along with the foundation, a coverage is given of the various advancements made using this science. All the physical aspects of a nanomaterial formation is completely taken into picture and taught.					
Course Summary	Quantum-mechanical laws and principles can determine the properties of nanoscale materials, their manufacture and uses, as well as the operating principles of nanodevices and systems. The principles of quantum mechanics, such as basic principles of quantum mechanics, uncertainty relations, the Schrödinger equation, particle in a box problems, step potentials, and tunnelling, are covered in this course. These are then applied to predict the nanoscale properties, such as thermal, electrical, electronic, mechanical, optical, and magnetic properties. Nanoscale objects with higher dimensionality, such as quantum wires, quantum wells, and core-shell quantum dots, are introduced. Chemistry aspects of nanomaterials such as curvature and neighbouring-charge effects, Classical Colloid Theory, homogeneous vs. heterogeneous nucleation, and kinetics are also included. The surface and interfacial properties of diffusion and surface defects are also discussed. The development and application of quantum devices such as single electron transfer devices (SETs), electron spin transistors, resonant tunnel diodes, and tunnel FETs is also covered.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research article studies, Independant Learning etc.	40	40	0	40	120
Pre-requisite	Basic knowledge of mathematical methods in physics, chemistry, and materials science. Basic knowledge of nanostructures, properties, and applications.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To understand the basics and advanced applications of quantum mechanics in nanoscience and technology	U	1
2	Will be able to calculate atoms, molecules, and nanoparticles' energy states and band gaps based on quantum theory	U,A	1
3	Acquire knowledge on utilization of various nanostructures such as, quantum wells, quantum wires, quantum dots, , quantum rings for fabrication of nanoelectronic and optical devices.	U,R	2
4	To understand the basics of chemistry aspects of nanomaterials such as, interfacial chemical processes, chemical diffusion, Classical Colloid Theory, curvature and neighbouring-charge effects, adsorption and desorption kinetics, Hhomogeneous vs. heterogeneous nucleation, kinetics, and self-assembly and fictionalisation.	U	6
5	Acquire knowledge on principle and operation of various nanoscale devices such as, single electron transfer devices (SETs) – Electron spin transistor – resonant tunnel diodes, tunnel FETs - quantum interference transistors (QUITs) - quantum dot cellular automata.	U	6,8
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module I

<u>Basics of quantum mechanics</u>

Introduction to Quantum Mechanics - Schrodinger equation – time dependent and time independent equations –Solutions of the Schrodinger equation – free particle - particle in a box – one and three dimensions - particle in a finite well - Penetration through a barrier – Tunnel effect – Single step barrier, Size effect on thermal, electrical, electronic, mechanical, optical and magnetic properties of nanomaterials- surface area and aspect ratio- band gap energy- quantum confinement size effect.

Module II

Quantum confined materials

Inorganic semiconductors, quantum wells, quantum wires, quantum dots, quantum rings. Manifestation of quantum confinement: Optical properties nonlinear optical properties. Quantum confined stark effect. Dielectric confinement effect, superlattices. Core-shell quantum dots and quantum-dot-quantum wells. Quantum confined structures as Lasing media. Organic Quantum-confined structures.

Module III

Chemistry aspects of nanomaterials

Chemistry of small surfaces: Curvature and neighbouring-charge effects on chemical reactivity and equilibria (pKa's, redox potentials)-Classical Colloid Theory: Nucleation and growth, Adsorption and Desorption Kinetics- Ostwald ripening- Homogeneous vs. heterogeneous nucleation- Anisotropic growth and shape control-Catalyzed (seeded) growth - Effect of Capping Agents on Growth Kinetics - self-assembly and fictionalisation,

Module IV

Quantum devices

Charge and spin in single quantum dots- Coulomb blockade– Electrons in mesoscopic structures- single electron transfer devices (SETs) – Electron spin transistor – resonant tunnel diodes, tunnel FETs - quantum interference transistors (QUITs) - quantum dot cellular automata (QCAs) - quantum bits (qubits).

Module V

Diffusion and surface defects

Fick's Law-mechanisms of diffusion - influence of pressure and temperature- Kirkendall effect - surface defects in nanomaterials - effect of microstructure on surface defects - interfacial energy.

Teaching and Learning Approach	**Classroom Procedure** **Learning Approach Consists of** Direct Instruction: Brain storming Lecture, Explicit Teaching, E-learning Interactive Instruction, Seminar, Group Assignments, Flipping, Progressive tests, Blended learning, Quizzes
Assessment Types	**Mode of Assessment** **A. Continuous Internal Assessment (CIA)**(40%) • Internal Test • Seminar Presentation in a related topic and review a journal paper in a particular area and present before peers **B. Semester End examination**(60%)

REFERENCE

1) Bransden. B.H, and Joachain. C.J “Quantum Mechanics”, Pearson, 2007.
2) David. J, Griffiths, “Introduction to Quantum Mechanics”, Pearson, 2009.
3) Richard. L, Liboff, “Introductory Quantum Mechanics”, Pearson, 2003.
4) Mark Lundstrom, “Fundamentals of Carrier Transport”, Cambridge University Press, 2000.
5) Yoav Peleg, Reuven Pnini, Elyahu Zaarur, and Eugene Hecht, “Schaum’s Outline of Quantum Mechanics”, Tata McGraw Hill, 2010.
6) Eugen Merzbacher, “Quantum Mechanics”, John Wiley & Sons, 1999.
7) Mathews. P.M and Venkatesan. K, “Quantum Mechanics”, Tata McGraw Hill, 2010.
8) Ajoy Ghatak and S. Lokanathan, “Quantum Mechanics”, Macmillan, 2009.
9) Michael. A, Nielsen & Isaac. L, Chuang, “Quantum Computation and Quantum Information”, Cambridge University Press, 2002.
10) Processing & properties of structural nanomaterials - Leon L. Shaw, Nanochemistry: A Chemical Approach to Nanomaterials, Royal Society of Chemistry, Cambridge UK 2005.
11) Rao. C. N, Muller. A, Cheetham. A. K “Nanomaterials chemistry”, Wiley-VCH, 2007

	MAHATMA GANDHI UNIVERSITY
	NSM21C02 Synthesis and Processing of Nanomaterials

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech.**
Course Name	**Synthesis and Processing of Nanomaterials**
Type of Course	**Core**
Credit Value	**4**
Course Code	**NSM21C02**

Justification of Course in Programme	This course aims to impart basic knowledge on nanomaterials, different synthetic procedures and the application of nanotechnology for future large-scale applications in diverse will be discussed. It introduces basic concepts on nanomaterials and its unique physic-chemical properties nanomaterials in different dimensions, various possible structures of nanomaterials etc will be studied. To familiarize different synthetic procedures of nanomaterials. The course will also provide a deep awareness on different processing techniques of nanomaterials and will give an in depth knowledge of the application of nanostructured materials in various field of science.					
Course Summary	This course aims to give a general vision of the different procedures for preparation of nanometric materials: bottom up and top down. It imparts basic knowledge on nanostructured materials and the application of nanotechnology for future large-scale applications. To consolidate knowledge of multiple techniques to obtain nanomaterials following the bottom up approach. To know the importance of the synthesis method in the material properties. It give a general vision of applications of nanomaterials in diverse fields. The course will also provide an in depth knowledge of different processing techniques of nanostructured materials which will be useful in medical field, energy conversion and storage, agriculture and water treatment will be studied.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	40	40	0	40	120
Pre-requisite	Basic knowledge on chemistry.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To understand the fundamental and the current state of art in the synthesis methods of nanomaterials.	U	6
2	To analyse each synthesis technique and apply it in the making of desired nanomaterial.	An, A	1,8,9
3	To acquire skill in formulating the perfect synthesis method through rigorous literature survey.	S	4, 9
4	To analyse the end result and characteristic of each synthesis route.	An	2
5	To remember the fundamental approach and science behind every synthesis route.	R	6
6	To create interest and appreciation for the efforts of scientist and encourage them to create great functional nanomaterials.	I, Ap	6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module I

Physical Approaches

Bottom-Up versus Top-Down; Top-down approach with examples. Ball milling synthesis, Arc discharge, RF-plasma, Plasma arch technique, Inert gas condensation, electric explosion of wires, Ion sputtering method, Laser pyrolysis, Molecular beam epitaxy and electrodeposition. Electrospinning, Physical Vapor Deposition (PVD) – Chemical Vapour Deposition (CVD) - Atomic Layer Deposition (ALD) – Self Assembly- LB (Langmuir-Blodgett) technique.

Module II

Chemical Approaches

Chemical precipitation methods- Coprecipitation, Arrested precipitation, Sol-gel method, Chemical reduction, Photochemical synthesis, Electrochemical synthesis, Microemulsions or Reverse Micelles, Sonochemical synthesis, Hydrothermal, Solvothermal, Supercritical fluid process.

Module III

Biological Approaches

Use of bacteria, fungi, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Mechanism of formation; Viruses as components for the formation of nanostructured materials; Natural and artificial synthesis of nanoparticles in microorganisms; Use of microorganisms for nanostructure formation, Role of plants in nanoparticle synthesis, synthesis of nanoparticles using proteins and DNA templates

Module IV

Self-Assembly and catalysis

Process of self-assembly, semiconductors islands, monolayers, nature of catalysis, porous materials, pillared clays, colloids, and biometrics. Nanoporous Materials – Silicon - Zeolites, mesoporous materials - nanomembranes and carbon nanotubes transparent conducting oxides –molecular sieves – nanosponges.

Module V

Wafer Growth, Epitaxial Deposition, lithography

Crystal Growth - CZ, Float zone technique; Basic Properties of different substrates (e.g. semiconductor, glass); Wafer cutting; Sources and related effects of various contamination; Wafer processing; Epitaxial growth- Growth kinetics of epitaxy, Doping, Growth modes, M based nanolithography and nanomanipulation, E beam lithography and SEM based Nano lithography and Nano manipulation, Ion beam lithography, Deep UV lithography, X-ray based lithography.

TeachingandLearningApproach	**Classroom Procedure** **Learning Approach Consists of** Direct Instruction: Brain storming Lecture, Explicit Teaching, E-learning Interactive Instruction, Seminar, Group Assignments, Flipping, Progressive tests, Blended learning, Quizzes
Assessment Types	**Mode of Assessment** **B. Continuous Internal Assessment (CIA)**(40%) • Internal Test • Seminar Presentation in a related topic and review a journal paper in a particular area and present before peers **B. Semester End examination**(60%)

REFERENCE

1) Guozhong Cao. Ed Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, World Scientific Series in Nanoscience and Nanotechnology, 2011.

2) G.A. Ozin and A.C. Arsenault, Nanochemistry: A chemical approach to nanomaterials, Royal Society of Chemistry, 2009.

3) Microfabrication and Nanomanufacturing- Mark James Jackson

4) Chemistry of nanomaterials: Synthesis, properties and applications by CNR Rao et.al.

5) Nanoparticles: From theory to applications – G. Schmidt, Wiley Weinheim 2004.

6) Fabrication of fine pitch gratings by holography, electron beam lithography and nano-imprint lithography (Proceedings Paper) Author(s): Darren Goodchild; Alexei Bogdanov; Simon Wingar; Bill Benyon; Nak Kim; Frank Shepherd

7) A Three Beam Approach to TEM Preparation Using In-situ Low Voltage Argon Ion Final Milling in a FIBSEM

8) Instrument E L Principe, P Gnauck and P Hoffrogge, Microscopy and Microanalysis (2005), 11: 830- 831 Cambridge University Press.

9) Processing & properties of structural naonmaterials - Leon L. Shaw (editor)

10) Nanochemistry: A Chemical Approach to Nanomaterials – Royal Society of Chemistry, Cambridge UK 2005. 1. Nanocomposite science and technology – P.M. Ajayan, L.S. Schadler, P.V. Braun, Wiley, New York.

11) G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties &Applications, Imperial College Press, 2004

MAHATMA GANDHI UNIVERSITY

NSM21C03 Research Methodology and Intellectual Property Rights

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Research Methodology and Intellectual Property Rights**
Type of Course	**Core**
Credit Value	**3**
Course Code	**NSM21C03**

Justification of Course in Programme	Research Methodology and Intellectual Property Rights are very important topics in the field of research and it the researchers should be aware about it. This course is designed to give a clear and deep knowledge on Research Methodology and Intellectual Property Rights. The syllabus has been designed to cover the fundamental understanding of research and research methods. One of objective of this course is make the researcher (student) familiarise research approaches, scientific method, and research process to be aware of various data collection and analysis using qualitative methods and modern data processing tools. In this course special emphasis is on ethical research which is a very important requirement of a scientific research thereby enable the students to conduct the research ethically.					
Course Summary	This course deals with following topics; how to develop hypothesis and methodology for research, comprehend and deal with complex research issues in order to communicate their scientific results clearly for peer review, measurement and scaling techniques, features of good design, Sampling fundamentals, Research ethics, fundamentals of documentation and Intellectual Property Rights (IPR). The syllabus covers the significance of various research methodology and Intellectual Property Rights. This course further offers an awareness and understanding on the analysing and understanding the Interpretation of IP laws, need for protecting IP. After the completion of this course, students will be able to understand the basics associated with Research Methodology and Intellectual Property Rights.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research article studies, Independant Learning etc.	40	40	0	40	120
Pre-requisite	Basic understanding on science.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To understand the types of research	U, A	2
2	To familiarise research approaches, scientific method, research process.	U, A, An	4
3	be aware of various data collection and analysis using qualitative methods and modern data processing tools	A, An, E	1
4	develop hypothesis and methodology for research	An, E, C	4
5	comprehend and deal with complex research issues in order to communicate their scientific results clearly for peer review	An, E, C, S	8,9
6	To learn different measurement and scaling techniques	U, A, An,	1,6
7	To get a clear understanding on good research design	U, A, An, E, C, S	3
8	To understand the Sampling fundamentals	U, A	5
9	To get a clear understanding on research ethics and fundamentals of documentation	U, A	6
10	To design and conduct research efficient and ethically.	A, An, E, C, S	4
11	To have a clear understanding on the Interpretation of IP laws, need for protecting IP, Forms of IPR, application of different forms of IPR.	U, A, An, E, C, S	6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module I

Introduction to research methodology

Definition of research, motivation for research, types of research, research approaches, scientific method, research process. Defining the Research Problem. Problem Formulation and Statement of Research.

Module II

Introduction to Research design

Features of good design, important concepts, different research designs. Basic principles of experimental design, sampling design, sample survey, sampling design, implications and steps, characteristics and criteria for sampling design, types of sampling designs, random sampling, complex random sampling designs.

Module III

Measurement and scaling techniques

Sources of error in measurements, tests of good measurement. Scaling: scaling techniques, measurement uncertainty, uncertainty estimation. Methods of data collection: observation, interview, questionnaire, selection of appropriate methods, processing and analysis of data, types of analysis. Statistics in research. Regression analysis.

Module IV

Sampling fundamentals

Definitions, sampling distributions, central limit theorem, sampling theory, Sandler's A-test, standard error estimation, estimating population mean, proportion, sample size and determination, determination of sample size. Testing hypotheses: basic concepts, procedure and flow diagram, measuring the power of a hypothesis test, tests of hypotheses.

Module V

Research ethics, fundamentals of documentation

Ethics of research, ethical standards, authorship of paper, scientific misconduct, fabrication, obfuscation, plagiarism, misappropriation of data, responsibilities of authors and institutions. Data interpretation and Report writing – techniques of interpretation, precautions, significance of report writing, guidelines for writing research papers and reports.

Intellectual Property Rights (IPR) – Analysing and understanding the Interpretation of IP laws, need for protecting IP. Forms of IPR, application of different forms of IPR

REFERENCE

1. Management Research: Guide for Institutions and Professionals, Roger Bennett, Nitish
2. De, 3rd Edn., International Labour Office (1983)
3. Research Methodology, Methods and techniques C. R. Kothari, New Age International Publishers, New Delhi (2004)
4. Research Methodology, R. Panneerselvam, Prentice Hall of India, New Delhi (2011)
5. Research Methodology, A step by step approach, Ranjit Kumar, Pearson Publishers, New Delhi (2005)
6. Exploring Research, 9th Edn., Neil J. Salkind, Pearson Education (2016).

MAHATMA GANDHI UNIVERSITY

NSM21C04 Thermodynamics of Nanomaterials

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Fundamentals of Thermodynamics**
Type of Course	**Core**
Credit Value	**4**
Course Code	**NSM21C04**

Justification of Course in Programme	This course aims to impart basic knowledge on laws of thermodynamics, entropy, energy changes, energy analysis. To familiarize different types of cycle analysis and optimization, thermodynamic optimization of irreversible systems. To give the concept of Finite time thermodynamics principles. Understanding the relationship between properties of heat, temperature, energy, and work. This course is designed at providing students concepts of thermodynamics, entropy, energy changes, energy analysis. In depth knowledge on thermodynamic optimization, thermodynamic principles. Concept on thermodynamic reactive system, properties of gas mixtures, changes in entropy. Knowledge on laws of thermodynamics, energy analysis of industrial systems, cycle analysis and optimization.

Course Summary	Review of basic thermodynamics; thermodynamic equilibrium; phase equilibria and phase diagrams; reactions and reaction kinetics; heat transport; mass transport in solids and fluids; thermodynamic size effects.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research article studies, Independant Learning etc.	40	40	0	40	120
Pre-requisite	Basics of laws and principles of thermodynamics,entropy and energy changes of a system.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the concept of thermodynamics, entropy, energy analysis	U	1
2	To learn about various thermodynamic laws, principles, optimization of systems	U, R	1, 4
3	Understand the concept of energy, energy transformation of system	R	1, 4
4	To impart knowledge on engines, phase transitions, chemical reactions, transport phenomena	U, E	6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1

Introduction to energy

Definition and importance of entropy, entropy balance for closed and open systems, laws of thermodynamics, concept of reversible work & irreversibility, second law efficiency, energy change of a system, energy transfer by heat, work and mass, energy destruction, energy balance in closed & open systems, energy analysis of industrial systems, power systems and refrigerator systems.

Module 2

Cycle analysis and optimization

Regenerative reheat, Rankine cycle and Brayton cycle, combined cycle power plants, multi-stage refrigeration systems.

Module 3
Thermodynamic optimization of irreversible systems
Finite time thermodynamics principles, optimization studies of various thermal systems, Minimization of entropy generation principle. Thermodynamics of Reactive System: Conditions of equilibrium of a multiphase, multicomponent system; Second law applied to a reactive system; Condition for reaction equilibrium.

Module 4
Properties of Gas Mixtures
Equation of state and properties of ideal gas mixtures; Change in entropy on mixing; Partial molal properties for non-ideal gas mixtures; Equations of state.

REFERENCE

1. Ragone. D. V "Thermodynamics of Materials", John Wiley & Sons, 1994.
2. David. R, Gaskell, "Introduction to the Thermodynamics of Materials", Taylor & Francis, 2002.
3. Michael Rieth and Wolfram Schommers, "Handbook of Theoretical and Computational Nanotechnology", American Scientific Publishers, 2005.
4. Lupis. C. H. P, "Chemical Thermodynamics of Materials", Prantice Hall, 2000.
5. Christian. J. W,"Theory of Phase Transformations in Metals and Alloys", Pergamon Press, 2001.
6. Günter Radons, Benno Rumpf and Heinz Georg Schuster, "Nonlinear Dynamics of Nanosystems", Wiley publishers, 2010.

	MAHATMA GANDHI UNIVERSITY
	NSM21E01 Nanotechnology in Toxicology, food, and agriculture

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Nanotechnology in Toxicology, food, and agriculture**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E01**

<table>
<tr><td>Justification of Course in Programme</td><td colspan="6">Nanotechnology holds great promise for improving lives and protecting the environment. It is important to learn to evaluate whether there are risks associated with specific nanomaterials and determine whether a particular application is safe. In this course, the best tools developed and applied appropriately to evaluate these materials are taught. The science behind the toxic levels in all types of nanomaterials are also taught. The various effects of nanotoxicology is understood in the fields of agriculture and food. Application and development of Nanotechnology in food and agriculture are elaborately taught in this course.</td></tr>
<tr><td>Course Summary</td><td colspan="6">In this course, the effects of nano particles and materials on human health and, stress, disease and death responses of the organisms and cells to nano particles and materials will be analyzed and discussed from a molecular biology perspective. Nano particles/materials in industry and in the environment, methods to study nanotoxicology, organismal responses to nanomaterials, entry-uptake, fate of nano particles in cells and cellular and molecular stress and death responses against them will be covered during the course. The characteristics of a nanomaterial used in food and agriculture and how they can be applied in such application is also covered.</td></tr>
<tr><td>Semester</td><td colspan="6">I</td></tr>
<tr><td>Total Student Learning Time (SLT)</td><td>Learning Approach</td><td>Lecture</td><td>Tutorial</td><td>Practical</td><td>Others</td><td>Total Hours</td></tr>
<tr><td></td><td>Others include: Research, Fieldworks, Independant Learning etc.</td><td>40</td><td>40</td><td>0</td><td>40</td><td>120</td></tr>
<tr><td>Pre-requisite</td><td colspan="6">Fundamentals of nanoscience.</td></tr>
</table>

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To understand the fundamental and the current state of art in the tools developed to understand nanotoxicology.	U	1
2	To analyse each synthesis technique and apply it in the making of desired nanomaterial with least toxicity.	An	2
3	To acquire skill in formulating the perfect synthesis method through rigorous literature survey with least toxicity.	S, U, A	4
4	To remember the fundamental science behind every functional property of nanomaterials used in food and agriculture.	U, A	6
5	To create interest and appreciation for the efforts of scientists and encourage them to create great functional nanomaterials in food and agriculture with least toxicity.	U	5
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module I

Nanotoxicology - overview

Concept of Nanotoxicology- Entry Routes into the Human Body Lung, Intestinal Tract, Skin, Nano particle Size - Surface and Body Distribution; - Nanoparticles and Cellular Uptake, Methodology for Nanotoxicology- Toxicity testing Experimental Models in Nanotoxicology - In vitro Models, In Vivo Models, Toxicological Studies and Toxicity of Manufactured CNTs-case study; Toxicity of CNTs and Occupational Exposure Risk; Toxicity of MWCNTs/SWCNTs and Impact on Environmental Health.

Module II

Toxicology of Nanoparticles in Environmental Pollution

Toxicology of Airborne and Manufactured Nanomaterials in the Environment, Effects of Nanoparticle on the Cardiovascular System, Nervous system- Liver and gastrointestinal tract. Endothelial Dysfunction and Endogenous Fibrinolysis- coagulation and thrombosis, Ethical-Legal and social implications- Nanoparticle Toxicology and Ecotoxicology, The Role of Oxidative Stress- Development of Test Protocols for Nanomaterials- Regulation of Engineered Nanomaterials in Europe, USA and India

Module III

Dosimetry, Toxicology and Epidemiology of Nanoparticles

Epidemiological Evidence for Health Effect Associations with Ambient Particulate Matter; Toxicological Evidence for Ambient Particulate Matter Induced Adverse Health Effects; Toxicological Plausibility of Health Effects Caused by Nanoparticles; Inhaled Nanoparticle Dosimetry; Integrated Concept of Risk Assessment of Nanoparticles.

Module IV

Nanotechnology in Agriculture

Nanotechnology in Agriculture, Precision farming, Smart delivery systems, Insecticides using nanotechnology, Potential of nano-fertilizers, Potential benefits in Nanotechnology in Food industry, Global Challenges, Product innovation and Process improvement, Consumer benefits

Module V

Nanotechnology in food

Food processing, Packaging, Packing materials; physical properties, Improvements of mechanical and barrier properties, Antimicrobial functionality, Active packaging materials,

Information and communication technology, Sensors, RF identification, Food safety, Intelligent packaging, Nanoengineered Food ingredients, Potential risks to Nanofood to consumers

REFERENCE

1. Challa. S. S. R, Kumar, "Nanomaterials - Toxicity, Health and Environmental Issues", Wiley-VCH publisher, 2006.
2. Nancy. A, Monteiro-Riviere, Lang Tran. C, "Nanotoxicology: Characterization, Dosing and Health Effects", Informa healthcare, 2007.
3. Drobne. D, "Nanotoxicology for safe and Sustainable Nanotechnology", Dominant publisher, 2007.
4. Zafar Nyamadzi. M, "A Reference handbook of nanotoxicology", Dominant publisher, 2008.
5. Jennifer Kuzma and Peter VerHage, Nanotechnology in agriculture and food production, Woodrow Wilson International Center, (2006).
6. Lynn J. Frewer, Willehm Norde, R. H. Fischer and W. H. Kampers, Nanotechnology in the Agri-food sector, Wiley-VCH Verlag, (2011).
7. Q. Chaudry, L.Castle and R. Watkins Nanotechnologies in Food, RSC Publications, 2010.

	MAHATMA GANDHI UNIVERSITY
	NSM21E02 Nanomagnetism

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech.**
Course Name	**Nanomagnetism**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E02**

Justification of Course in Programme	This course introduces fundamental concepts in magnetism and spintronics through lectures and exercises, and it provides an overview of recent developments in science and technology that take place through the nanotechnology. The course elaborately covers the property changes of magnetic materials at nanoscale and the various phenomena at such scales. Various applications are also covered .					
Course Summary	The magnetism course aims to present an understanding of the origins of diamagnetism, paramagnetism and ferromagnetism and the magnetisation process. This fundamental knowledge is then applied to the design of soft and hard magnetic materials, magnetic nanoparticles, magnetic thin films and multilayers; and their applications. The module extends into the development of the modern magnetic technologies of magnetic data storage, memory and spintronics.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	45	20	0	25	90
Pre-requisite						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To evaluate the magnetism of a given nanomaterial.	E	2
2	To understand the magnetic properties in each reaction route for the synthesis of nanomaterials.	U	1
3	To analyse the magnetic property change outcomes of a nanomaterial in comparison with a macromaterial.	An	6, 5
4	To learn, and analyze the applications of nano-magnetic materials of choice.	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 I

Nanostructure magnetism, magnetostriction, Effect Bulk nanostructuring of magnetic property, Nanomagnetic materials, Classical and Quantum Magnetism, Magnetism of Atoms, Magnetic Ordering, Micromagnetism, Domain and Hysteresis, Paramagnetism, Ferromagnetism, Anti-ferromagnetism, Ferrimagnetism, Landau theory of Ferromagnetism Magnons, Exchange Interactions, superparamagnetism, blocking temperature, magnetic ultrathin films, magnetic surface and interface anisotropies, Physiological aspects - Toxic effects of magnetic nanoparticles

Module II

Magnetic Nanostructures and Applications

Magnetic sensors and Optically transparent materials, Soft ferrites- Nanocomposite magnets, Magnetic refrigerant, Ferro/biofluids, Biomedical applications of magnetic nanoparticles, Diagnostic applications, Therapeutic applications, Nuclear Magnetic Resonance, Magnetic Resonance Imaging. Neutron Diffraction, SQUID.

Module III

Introduction to spin electronics

Magnetoresistance, Giant Magnetoresistance mechanism of GMR, spin dependent scattering of electrons, interlayer exchange coupling (RKKY coupling), exchange biasing, spin valves, quantum tunnelling, tunnelling magnetoresistance (TMR), magnetic oxides and phase transformations: colossal magnetoresistance (CMR), magnetic semiconductors, multiferroics.

Module IV

Fabrication and Imaging

Molecular nanomagnets, Mesoscopic magnetism, Particulate nanomagnets, Geometrical nanomagnets, Fabrication techniques scaling, Characterization using various techniques, Neutron Diffraction, SQUID. Imaging magnetic micro spectroscopy, Optical Imaging, Magnetic Resonance Imaging Lorentz Microscopy, Electron Holography of Magnetic Nanostructures, Magnetic Force Microscopy

Module V

Magnetic data storage

Magnetic recording overview, recording medium, particulate recording media, thin film recording materials, longitudinal versus perpendicular recording, write heads, read heads, magnetic random-access memory (MRAM), outlook and fundamental limits to recording, patterned media.

REFERENCE

1. Coey, J. M. D., Magnetism and Magnetic Materials, (Cambridge University Press, 2009).
2. Cullity, B. D. and Graham C. D., Introduction to Magnetic Materials, 2nd Edition, (Wiley IEEE Press, 2008).
3. Peddie, W., Molecular Magnetism, (Nabu Press, 2011). 2. Spaldin, N. A., Magnetic Materials: Fundamentals and Applications, 2nd Edition, (Cambridge University Press, 2010)
4. Molecular Nanomagnets by Dante Gatteschi, Roberta Sessoli, Jacques Villain, OUP Oxford, ISBN10: 0199602263.
5. Nanofluids: Synthesis, Properties and Applications by SohelMurshed, C A Nieto Castro, Nova Science Publishers ISBN-10: 1633216772.
6. Nanofluids Properties and Their Applications byDebendra Das Devdatta Kulkarni LAP Lambert Academic Publishing, ISBN-10: 365916609X.
7. Introduction to Magnetism and Magnetic Materials by D.C. JilesSpringer, ISBN 10: 0412386402 5. Magnetic Materials by Rainer Hilzinger, Werner Rodewald, Wiley VCH, ISBN10: 389578352

	MAHATMA GANDHI UNIVERSITY
	NSM21E03 Semiconducting Nanostructures

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Semiconducting Nanostructures**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E03**

Justification of Course in Programme	This elective course will help the students to learn the basic understanding of nano electronics and the advanced understanding of the nano-micro fabrication. It provides a advanced level vast understanding to the device electronics for integrated circuits, a foundation for the device fabrication and various application in the field of sensors technology, optoelectronics, communication and nanotechnology .					
Course Summary	This course shall give a detailed understanding of nanoelectronics and its applications, and the role of semiconductors in them.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	45	20	0	25	90
Pre-requisite	Basic understnading of nanotechnology.					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	To provide an insight into the basic semiconductor concepts and basics of nanoelectronics.	U, R	6
2	To provide a sound understanding of current semiconductor devices and technology to appreciate its applications to electronics circuits and systems.	Ap, I, U	1
3	To understand the fundamental concepts of Microfabrication process.	U	1,9

4	To introduce nanodevices and nanosystems with applications.	U, A	7,9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module I

Introduction to Nanoelectronics

Technology roadmap of nano-electronics, Scaling of devices and technology jump, Challenge of the CMOS technologies, More-Moore and More-than-Moore. Review of semiconductor devices, Quantum statistical mechanics, Energy bands in silicon, Metal Oxide Semiconductor Field Effect Transistors (MOSFET), MOSFET Operation, Threshold Voltage and Subthreshold Slope, Current/voltage characteristics, Finite Element Modelling of MOS, CMOS technology, Challenges of the CMOS technologies, High-k dielectrics and Gate stack, Future interconnect.

Module II

Semiconductor processing and microfabrication

Introduction to semiconductor device processing, Necessity and different types of clean rooms-construction and maintenance of a clean room, Microfabrication process flow diagram, Chip cleaning, coating of photoresists, patterning, etching, inspection, Process integration, Etching techniques, Reactive Ion etching, RIE reactive ion etching-Magnetically enhanced RIEIBE Ion beam etching.

Module III

Two-terminal junction transistors

Basic CMOS process flow; MOS scaling theory; Issues in scaling MOS transistors; Requirements for non-classical MOS transistor; PMOS versus NMOS; Design and construction of MOS capacitor; Integration issues of high-k MOS, interface states, bulk charge, band offset, stability, reliability; MOS transistor and capacitor characteristics. UNIT III GATE TRANSISTORS 9 Metal gate transistors, motivation, basics and requirements; quantum transport in nano MOSFET; Ultrathin body silicon on insulator (SOI) , double gate transistors, Vertical transistors, FinFET and surround gate FET; compound semiconductor MOSFET, Hetero-structures MOSFET.

Module IV

Sensors and actuator characteristics

Types and working principles of sensors and actuators; Characteristic features: Range, Resolution, Sensitivity, Error, Repeatability, Linearity and Accuracy, Impedance, Nonlinearities, Static and Coulomb Friction, Eccentricity, Backlash, Saturation, Dead-band, System Response, First Order System Response, Under-damped Second Order System Response, Frequency Response.

Module V

Memory devices

Nano ferroelectrics, Ferroelectric random-access memory, Fe-RAM circuit design, ferroelectric thin film properties and integration, calorimetric sensors, electrochemical cells, surface and bulk acoustic devices, gas sensitive FETs, resistive semiconductor gas sensors, electronic noses, identification of hazardous solvents and gases, semiconductor sensor array.

REFERENCE

1. Fundamentals of nano electronics by George W Hanson Pearson publications, India 2008
2. Introduction to photoelectron Spectroscopy (Chemical Analysis Vol. 67) by P.K. Ghosh; Wiley Interscience
3. Nanophotonics by P. N. Prasad – Springer Education series.
4. Nanotechnology and Nano Electronics – Materials, devices and measurement Techniques by WR 19 Fahrner – Springer
5. K.E. Drexler, "Nano systems", Wiley, (1992).
6. M.C. Petty, "Introduction to Molecular Electronics"1995.
7. W. Ranier, "Nano Electronics and Information Technology", Wiley, (2003).

	MAHATMA GANDHI UNIVERSITY
	NSM21E04 Advanced Computing in Nanotechnology: Mathematical Modelling and Simulation

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Advanced Computing in Nanotechnology: Mathematical Modelling and Simulation**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E04**

Justification of Course in Programme	This course allows the students to assimilate mathematical foundations of computational techniques pertaining to nanosystems. A considerable body of background knowledge of mathematical and numerical techniques is essential for understanding and learning the theory behind every physical phenomena. This course would equip the students with standard numerical techniques of solving physical problems as well.					
Course Summary	This course is designed to understand nanoscience and their systems through the help of computing and modelling. Students will be taught to understand each method involved and understand its applications.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	45	20	0	25	90
Pre-requisite	Basic mathematics and nanoscience.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Comprehend the linear algebra underlying many of the numerical simulation algorithms	E	1
2	Acquire skills of applying numerical approximation methods and interpolation schemes to solve equations	U,S	8,4,5
3	Customize differential equations to depict various real-world problems	A	2
4	Identify the applicability of approximation methods and numerical integration	A/An	6
5	Develop skills for describing uncertainty in terms of probabilistic models and for probabilistic reasoning	E,S	5
6	Gain experience in learning and implementing heuristics based numerical simulation techniques	A/An	9,4
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module I

Matrices and linear systems of equations

Linear Systems: Cramer's Rule - Gaussian elimination and Gauss Jordon methods - Cholesky decomposition method – Gauss Seidel iteration method - Eigenvalue problems: Power method with deflation for both symmetric and non-symmetric matrices and Jacobi method for symmetric matrices.

Module II

Interpolation, differentiation and integration

Lagrange's interpolation - Newton's divided differences - Hermite's interpolation – Newton's forward and backward differences – Numerical differentiation – Numerical integration: Trapezoidal and Simpson's 1 3 rules - Gaussian quadrature: 2 and 3-point rules.

Module III

Differential equations

Initial value problems for first and second order ODEs: Single step methods - Taylor's series method – Euler's and modified Euler's methods, Runge - Kutta method of fourth order - Multi step methods: Milne's and Adam Bash forth methods - Boundary value problems: Finite difference approximations to derivatives - Finite difference method of solving second order ODEs. Formation of partial differential equations – Classification of second order partial differential equations

Module IV

Probability

Introduction to probability: Probability, Sample space and events- Probability- the axioms of probability, some elementary theorems-conditional probability Bayes' theorem Random Variables- Discrete and continuous – distribution- distribution function Distribution Binomial and poison distributions and normal distribution – related properties, Neural networks.

Module V

Simulation and monte carlo methods

Random numbers: Random number algorithms and generators – Estimation of areas and volumes by Monte Carlo techniques - Numerical integration - Computing volumes – Simulation: Loaded Die Problem - Birthday problem - Buffon's needle problem - Two dice problem and Neutron shielding problem.

REFERENCE

1. Advanced engineering mathematics, by Erwin Kreyszig, wiley publications
2. Probability and statistics, scham series, Arnold o. allen, academic press
3. Probability and statistics for engineers, miller and john e. freund, prentice hall of india.
4. A primer for the monte carlo method, llya M. Sobol' CRC Press
5. The monte carlo method, popular lectures in mathematics by sobol.i.m. Burden, R.L. and Faires, J.D.
6. "Numerical Analysis", 9th Edition, Cengage Learning, Delhi, 2016.
7. Cheney, W and Kincaid D., "Numerical Mathematics and Computing", 7th Edition, Cengage Learning, Delhi, 2014.
8. Jain, M.K., Iyengar, S.R.K. and Jain R.K. "Numerical Methods for Scientific and Engineering Computation", 5th Edition, New Age International Pvt. Ltd., Delhi, 2010.
9. Landau, D.P. and Binder, K., "A Guide to Monte - Carlo Simulations in Statistical Physics", 3rd Edition, Cambridge University Press, Cambridge, 2009.
10. Maki, D P and Thompson, M., "Mathematical Modelling with Computer Simulation", Cengage Learning, Delhi, 2011.
11. Taha, H.A. "Operations Research", 9th Edition, Pearson Education India, Delhi, 2016.

	MAHATMA GANDHI UNIVERSITY
	NSM21E05 Nanotechnology for Corrosion Science and Engineering

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Nanotechnology for Corrosion Science and Engineering**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E05**

Justification of Course in Programme	Nanocoatings are used effectively to lessen the impact of a corrosive environment due to its various preferences, such as surface hardness, adhesive quality, long haul and, additionally, high-temperature corrosion opposition, and to improve its tribological properties, and so forth. Understanding the science and characteristics of such nanomaterials is important. It plays an important role in the technologies of future.					
Course Summary	The comparison of nanomaterials in corrosion application is compared to other materials and their characteristics is well taught. All nanomaterials used in this application is discussed along with their properties.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	45	20	0	25	90
Pre-requisite	Basics of nanoscience.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To remember the fundamentals of the science of corrosion in nanomaterials.	R	6
2	To analyse the best nanocoating materials,	An	2
3	To understand the other physical and chemical properties of nanocoatings.	U	1
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module I

Introduction to corrosion

Principle of corrosion, types of corrosion, electrochemical aspect of corrosion, environmental effects, forms of corrosion, corrosion testing, factors affecting corrosion.

Module II

Nanotechnology and corrosion

Corrosion/oxidation behaviour of nanostructured materials, nanomaterials in corrosion prevention, thermodynamic and kinetic factors affecting corrosion.

Module III

Corrosion protection of metals using nanostructured alloys. Corrosion resistance of nanostructured metals and alloys, corrosion resistance of electrodeposited nanomaterials.

Module IV

Corrosion protection of metals using nano inhibitors and self-assembled monolayers. Surface modified nanoparticles as corrosion inhibitors, functionalised nanoparticles and nanostructures as carriers, self-assembled nanofilms as corrosion inhibitors

Module V

Corrosion protection of metals using nanocoating’s

Introduction to anticorrosion coatings, metallic nanocomposite coatings, ceramic nanocomposite coatings, organic nanocomposite coatings, polymeric nanocomposite coatings, sol-gel coatings.

REFERENCE

1. Corrosion Protection and Control Using Nanomaterials, R. M. Cook, Elsevier Science (2012)
2. Corrosion Protection at the Nanoscale, Susai Rajendran, Tuan Anh Nguyen, SaeidKakooei, Elsevier Science (2020)
3. Corrosion Science and Engineering, Pietro Pedeferri, Springer International publication (2019)
4. Corrosion for science and engineering, Kenneth Richard Trethewey, John Chamberlain, Longman (1995).

MAHATMA GANDHI UNIVERSITY

NSM21E06 Polymer Nanocomposites

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Polymer Nanocomposites**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E06**

Justification of Course in Programme	This course is designed to understand the basics of polymer science and their property change at nanoscale and its effective combination in a composite. Their importance and application are also elaborately discussed.					
Course Summary	The brief synthesis, characterisation and property of all polymer annocomposites along with their application is discussed. The physical and chemical science of all polymer nanocomposites is discussed.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	40	40	0	40	120
Pre-requisite	Basics of nanoscience.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To gain ability to design nano systems, component or process as per need and specification.	S,I	7,4,2
2	To understand the role of nanotechnology in polymer and nano-composities.	U	1,6
3	To gain knowledge of polymer and nano composites used in recent advances of polymer.	U,R	6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module I

Introduction to nanocomposites

Composite materials, classification, introduction to polymer composites, Classification based on the dimensionality: nanoparticles, nanoclusters, nanorods, nanotubes, nanowires, nanofibers and nanodots. Polymeric matrices, thermoplastics, thermosets and rubbers. Polymer nanocomposites: reinforcement, polymer-filler interactions, use of coupling and bonding agents.

Module II

Polymer /Ceramic nanocomposites

Introduction of ceramic nanomaterials: TiO_2, SiO_2, ZnO, nanoclay, hBN, MoS_2, WS_2, preparation of polymer/ceramic nanocomposites. Modification of nanomaterials like CNT, Graphene and Clay for polymer nanocomposites.

Module III

Synthesis techniques for Polymer nanocomposites

Solution techniques, latex stage mixing, melt mixing and in-situ polymerization, precipitation. Polymer nanocomposite preparation by emulsion and suspension polymerization. Dispersion and nucleating effects, intercalation and exfoliation. Application of layered and nonlayered nano particles in polymer modification. Electrospinning of polymer nanocomposites.

Module IV

Elastomeric nanocomposites

Different types of elastomers: NR, SBR and TPE, nanofillers for elastomer reinforcement, reinforcement mechanism. Preparation of bucky paper and fiber spinning of CNT and Graphene for reinforcing polymer nanocomposite. Mechanical and thermal properties of elastomeric polymer nanocomposite. Advantages and disadvantages of nanosized fillers in polymer nanocomposite, 2D polymers: Synthesis and applications.

Module V

Properties and applications of polymer nanocomposites

Enhancement in thermal, physical, chemical, electrical, gas barrier properties, factors affecting properties of polymer nanocomposites. Applications of polymer nanocomposites: energy, environment, space, biomedical, defence and structural applications.

REFERENCE

1. Handbook of composites, G. Lubin, Van Nostrand, (1982)
2. Chemical Functionalization of CarbonNanomaterials:Chemistry and Applications, Vijay Kumar Thakur, Manju Kumari Thakur, Taylor & Francis Group (2015)
3. Nanomaterials Handbook, YuryGogotsi, CRC Press (2006).
4. Polymer nanocomposites: Synthesis characterization andmodeling, R. Krishnamoorti and R.A. Vaia,Americal Chemical Society (2002)
5. Polymer Clay Nanocomposites, Pinnavaia T.J. and Beall G.W., John Wiley (2000)

MAHATMA GANDHI UNIVERSITY

NSM21C05 Synthesis and Characterization of Nanomaterials Lab 1

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Synthesis and Characterization of Nanomaterials Lab 1**
Type of Course	**Laboratory**
Credit Value	**3**
Course Code	**NSM21C05**

Justification of Course in Programme	This course aims to develop the practical skills for the synthesis and characterization of different types of nanoparticles for varying applications. The students will get opportunity for familiarising different synthesis techniques of top down and bottom-up approaches for nanoparticle synthesis as well as the characterization techniques usually using for the analysis of nanostructured materials.					
Course Summary	The course summarises different synthetic methods includes bulk synthesis, chemical methods, physical methods and synthesis of various nanoporous materials. Bulk synthesis includes top down and bottom-up approaches, Mechanical alloying and mechanical ball milling, Mechano chemical process etc. Chemical approaches include different sol gel methods like solvothermal, hydrothermal, spray pyrolysis etc. and physical methods like vapor deposition and different types of epitaxial growth techniques.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	-	-	100	20	120
Pre-requisite	Understanding of basics and principles of different synthesis methods in nanoscience.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To gain expertise in synthesis techniques of nanomaterials	U, A,S	2,4
2	Understand the advantages and limitations of different types of top down and bottom up approaches of nanoparticle synthesis	A, An, S	3,4
3	Understand different chemical and physical methods of nanoparticle synthesis	A, S, Ap	5, 6
4	Understand the synthesis of nanoporous materials like zeolites, carbon nanotubes, core-shell and hybrid nanocomposites.	U, A, Ap	5,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1

Bulk synthesis

Top down and bottom up approaches, Mechanical alloying and mechanical ball milling, Mechano chemical process, Inert gas condensation technique, Arc plasma and laser ablation.

Module 2

Chemical approaches

Sol gel processing-Solvothermal, hydrothermal, precipitation, Spray pyrolysis, Electro spraying and spin coating routes, Self-assembly, self-assembled monolayers (SAMs). Langmuir Blodgett (LB) films, micro emulsion polymerization- templated synthesis, pulsed electrochemical deposition.

Module 3

Physical approaches

Vapor deposition and different types of epitaxial growth techniques (CVD, MOCVD, MBE, ALD)- pulsed laser deposition, Magnetron sputtering, lithography: Photo/UV/EB/FIB techniques, Dip pen nanolithography, Etching process: Dry and Wet etching, micro contact printing.

Module 4

Nanoporous materials

Zeolites, mesoporous materials, nanomembranes, Carbon nanotubes and graphene , Core shell and hybrid nanocomposites.

Module 5

Characterization of Nanomaterials

UV Visible Spectroscopy, XRD, Raman Spectroscopy, DLS, Post processing of row data using Softwares.

REFERENCE

1. A S Edelstien, RC Cammarata, Nanomaterials: Synthesis, Properties and Application; Taylor & Francis. 1996.
2. G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties & Applications, Imperial College Press, 2004.
3. J.George, Preparation of Thin Films, Marcel Dekker, Inc., New York. 2005.
4. K. Barriham, D.D. Vvedensky, Low dimensional semiconductor structures: fundamental and device applications, Cambridge University Press, 2001.
5. S.P. Gaponenko, Optical Properties of semiconductor nanocrystals, Cambridge University Press, 1980.
6. W.Gaddand, D.Brenner, S.Lysherski and G.J.Infrate(Eds.), Handbook of NanoScience, Engg. and Technology, CRC Press, 2002.

SEMESTER II

MAHATMA GANDHI UNIVERSITY

NSM21C06 Advanced Characterisation Techniques of Nanomaterials

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Advanced Characterisation techniques of nanomaterials**
Type of Course	**core**
Credit Value	**3**
Course Code	**NSM21C06**

Justification of Course in Programme	The objective of the course is that the student acquires knowledge of the different existing experimental techniques for the nanostructural and physicochemical characterizations of materials.Students gain knowledge about the principles of various techniques.					
Course Summary	This course covers a review of materials characterization techniques, which can be used to analyse nanomaterials also. This course includes optical characterization techniques such as Raman and Fourier Transform Infrared Spectroscopy and, Spectroscopic ellipsometry; electron microscopy techniques such as transmission electron microscopy and field effect scanning electron microscopy (FESEM) and its sample preparation processing and, X-ray diffraction (XRD), atomic force microscopy, surface area analysis and nano-indentation techniques. Course also covers particle size analyzer, confocal microscope, optical profiler, rheometer and microhardness tester.					
Semester	**2**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	40	40	0	40	120
Pre-requisite	Basics of nanoscience and characterization methods					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	The knowledge gained from this subject help students to optimize material research.	U	6
2	Depending on the problem or needs of each case, the student must have sufficient criteria to select the most appropriate technique, as well as the interpretation of their results.	E, C,S	4,2,3
3	To remember the principle behind each technique for their efficient use.	U,S, R	1,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module I

Spectroscopic Techniques

Introduction to Molecular Spectroscopy and Differences-With Atomic Spectroscopy-Infrared (IR) Spectroscopy and Applications- Microwave Spectroscopy- Raman Spectroscopy, Surface enhanced Raman Spectroscopy, UV-Vis Spectroscopy, and Photoluminescence, Electron Spin Resonance Spectroscopy; NMR Spectroscopy; Dynamic Nuclear Magnetic Resonance; Dynamic light scattering (DLS).

Module II

X-Ray methods

X-ray powder diffraction, single crystal diffraction techniques, Quantitative determination of phases; Structure analysis, Determination of accurate lattice parameters, particle size analysis using Scherer formula, electron and neutron diffractions- X-Ray Photoelectron Spectroscopy, Energy Dispersive Analysis of X-rays.

Module III

Morphological Analysis

Matter-electron beam interaction; Principle, Basic instrumentation and applications of Transmission electron microscopy (TEM),Specimen preparation for TEM, Application of HR-TEM in Nano-structures, SAED, Instrumentation principle and application of Scanning electron Microscopy (SEM), Field emission Scanning electron Microscopy (FESEM), Scanning Tunnelling Microscopy (STM), Atomic Force Microscopy, static and tapping mode, advanced mode of AFM, Conductive AFM; Scanning force microscopy (SFM), BET-surface area analysis for nanomaterials.

Module IV

Mechanical and electrical properties measurement

Nanoindentation principles, elastic and plastic deformation, mechanical properties of materials in small dimensions, Hardness testing of thin films and coatings, Principle and applications of Cyclic voltammetry, Impedance Spectroscopy, Measurement of resistivity by 4-prob method.

Module V

Thermal and Magnetic Properties measurement

Instrumentation, working principle and applications of Thermogravimetric Analysis (TGA), Differential Thermal Analysis (DTA), Differential Scanning calorimetry (DSC), Thermomechanical analysis (TMA), Vibration Sample Magnetometer, PPMS, Measurement of Magnetic and electrical properties of nanomaterials.

REFERENCE

1. Elements of X-ray Diffraction B. D. Cullity, Addison Wesley, 1977
2. Transmission Electron Microscopy: A Textbook for Materials Science David B Williams, C Barry Carter, (1996) Plenum Press, New York
3. Impedance Spectroscopy: Theory, Experiment, and Applications, E. Barsoukov and J. Ross Macdonald (Editors) (2000) John Wiley & Sons (P) Ltd.
4. Fundamentals of Fourier Transform Infrared Spectroscopy, Brian C Smith, (1995) CRC Press
5. Nanoindentation, By Anthony C Fischercripps, Anthony C., Springer science and Bussiness media publications, 2011
6. Nanomaterials, Nanotechnologies and Design: An Introduction for Engineers, Daniel L. Schodek, Paulo Ferreira, Michael F. Ashby, Elsevier, 2009.
7. Principles of Instrumental analysis by D.A. Skoog, F.J. Hollen and T.A. Nieman
8. Characterization of nanostructured materials by Z.L. Wang
9. Introduction to Magnetic Materials, 2nd Edition, L. C. Cullity and C. D. Graham, IEEE Press, Willey.
10. Principles of Nanomagnetism, Guimarães, Alberto P., Springer, 2009.

MAHATMA GANDHI UNIVERSITY

NSM21C07 Design and Fabrication of Nanodevices

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Design and fabrication of Nanodevices**
Type of Course	**core**
Credit Value	**3**
Course Code	**NSM21C07**

Justification of Course in Programme	For most of the future applications that are in the background of today's basic research, both the functional units and the material used for interfacing the micro/macro-world to the nanosized systems will have to be structured in the nanoscale. This course teaches various techniques employed for design and fabrication of nanosized systems and devices. It provides a detailed study and various aspects of the key application area of nanosensors. Future nanodevices are introduced and discussed in this course in order to guide the students to the current research trends in nanotechnology.					
Course Summary	The course provides an in-depth understanding of top-down device fabrication. Focus is the unit processes typically used in micro & nanofabrication of devices. Both concepts and practical aspects are covered. Topics include crystal growth, doping, chemical vapor deposition, physical vapor deposition, photolithography, wet etching, dry etching, and packaging. The course is accessible to students from diverse backgrounds, such as materials, physics, chemistry, mechanical engineering, and electrical engineering.					
Semester	**2**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	40	40	0	40	120
Pre-requisite	Basics of nanoscience and device developments by using nanostructured materials.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Understand the requirement of miniaturization in order to manufacture ever smaller mechanical, optical and electronic products and devices	U, E	2, 3
2	Learn various experimental techniques employed for fabrication micro/nano devices	U,S	2, 5
3	Learn important features of sensors that aid in the progression of various fields such as medical technology, precision agriculture, urban farming, etc. as well as many industrial applications.	A	3, 4
4	Gain knowledge of the different kinds of physical and solid state mechanisms/phenomena which are precursors to the sensor technology.	A/An	4, 5, 6
5	Be introduced to the multifunctional nanosystems and devices which can. revolutionise the engineering and scientific world and thereby the society as a whole	E,S	5, 6, 7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module I

The science of miniaturization

The Science of Miniaturization of Electrical and Electronic Devices, Moore ‘s law and technology road map, Quantum Mechanical Aspects, Simulation of the Properties of Molecular Clusters, Formation of the Energy Gap, Confinement Effects, Discreteness of Energy Levels, Tunnelling Currents. Nanofabrication by Photons, Nanofabrication by Ion Beam, Nanofabrication by Scanning Probes

Module II

Fabrication of micro/nano devices microfluidic devices

Microchannels, Microfilters, Microvalves, Micropumps, Microneedles, Microreserviors, Microreaction chambers. Lithium Ion Battery and Super capacitors device fabrication, Operating and structure of Solar cells, CIGS solar cells, Dye-Sensitized solar cells, and Perovskite solar cell. MEMS and NEMS based devices

Module III

Introduction &sensor characteristics

Nanotechnology, Sensors, Nanotechnology Enabled Sensors, Sensor Characteristics and Terminology, Static Characteristics, Dynamic Characteristics, Physical Effects Employed for Signal Transduction, adsorption studies.

Module IV

Sensors & physical effects

Photoelectric Effect, Photo-dielectric Effect, Photoluminescence Effect, Electroluminescence Effect, Chemiluminescence Effect, Doppler Effect, Barkhausen Effect, Hall Effect, Nernst/Ettingshausen Effect, Thermoelectric (Seebeck/Peltier and Thomson) Effect, Thermoresistive Effect, Piezoresistive Effect, Piezoelectric Effect, Pyroelectric effect, MagnetoMechanical Effect (Magnetostriction), Mangnetoresistive Effect, Faraday-Henry Law. Introduction-types of sensors-Mechanical, optical, spintronic, electrochemical, thermal and magnetic sensors-surface modification-surface materials, bioreceptors and interactions

Module V

Future Nano systems

Nano machines, nano robots, electronics based on carbon-based materials, molecular Electronics. Quantum Computation: Future of Meso/Nanoelectronics, Interfacing with the Brain, towards molecular medicine, Lab-on-Biochips- Guided evolution for challenges and the solutions in Nano, Manufacturing technology

REFERENCE

1. Mark. J Jackson, “Micro and Nanomanufacturing”, 2007.
2. Edelstein. A. S, and Cammarata, “Nanomaterials: Synthesis, Properties and Applications Institute of Physics”, Bristol, Philadelphia: Institute of Physics, 2002.
3. Mahalik. N. P, “Micro manufacturing and Nanotechnology”, Springer Berlin Heidelberg New York 2006.
4. Zheng Cui, “Nanofabrication, Principles, Capabilities and Limits”, 2008.
5. Sergey Edward Lyshevski, Lyshevski Edward Lyshevski, “Micro-Electro Mechanical and Nano-Electro Mechanical Systems, Fundamental of Nano-and Micro-Engineering “– 2nd Ed., CRC Press, 2005.
6. Kalantar–Zadeh. K, “Nanotechnology Enabled Sensors, Springer,” 2008.
7. Serge Luryi, Jimmy Xu, Alex Zaslavsky, “Future trends in MicroElectronics”, John Wiley & Sons, Inc. Hoboken, New Jersey 2007.
8. Chemical Sensors-An Introduction for Scientists and Engineers, Peter Gr¨undler, Springer publications (2006)

	MAHATMA GANDHI UNIVERSITY
	NSM21C08 Advanced Nanobiotechnology

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Advanced Nanobiotechnology**
Type of Course	**core**
Credit Value	**3**
Course Code	**NSM21C08**

Justification of Course in Programme	The course aims to make the learner understand the nanobio interphase as well as the implications and applications of nanotechnology in biomedical sector. The objective of the course content is to create a sound awareness about the recent developments in biomedical sector in the areas of therapeutic and diagnostic strategies through the intervention of Nanotechnology.					
Course Summary	The course covers the advancement in biotechnology that took place through nanoscience and how the number of applications increased. Each application is taught in detail and the future prospects of nanomaterials and the advancements needed are discussed.					
Semester	**2**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	40	40	0	40	120
Pre-requisite	Strong understanding of basics of nanoscience and characteristic properties of nanostructured materials for their applications in health and medicine.					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Understand the challenges and opportunities associated with nanoscale materials and biological structures	R, U, E	1, 2, 3

2	Learn various experimental techniques for the fabrication of nanoengineered materials for biomedical applications.	U, A, I	3, 4
3	Learn the physiological interaction of nanostructured materials when used as therapeutics or scaffolds for tissue engineering applications	U, Ap, C	4
4	Understand the applications and implications of different nanomaterials using as tissue constructs or implants.	U, A, S	5, 6
5	Learn different types of nanotherapeutics beneficial for targeted drug delivery, hyperthermia, gene delivery etc.	U, A, I	6
6	Understand the current applications of nanoparticles in clinics for different diseased conditions.	U, E, Ap	7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module I

Biological nanostructures

Nanobiotechnology, Challenges and opportunities associated with biology on the Nanoscale, biologically relevant molecular nanostructures, Carbon nanotubes, quantum dots, metal-based nanostructures, nanowires, polymer-based nanostructures, protein and DNA based nanostructures, Nano bioelectronic devices and polymer nanocontainers. Microbial based inorganic nanoparticles.

Module II

Nanotechnology in regenerative engineering

Basics of regenerative engineering, Factors affecting regeneration, Scaffolds for tissue regeneration, Materials for scaffold fabrication, scaffolds fabrication techniques: particulate leaching, phase separation, three-dimensional pore formation, nano fibers, nanocomposite scaffolds, micro and nanopatterned scaffolds, Engineering of biomaterial to control cell function, Engineering of nanomaterials as implant material: Physico-chemical, in vitro and in vivo evaluations.

Module III

Implant Nanobiotechnology

Advantages of nanomaterials as implants-biological response of implanted materials, desirable and undesirable reactions of the body with implanted materials. Bioactive nanomaterials as bone implants, cartilage implants, bladder implants, dental implants, skin implants, Muscle implants, neural implants, Tendon implants, Ligament implants, cardiac implants, anti-adhesive membranes.

Module IV

Nanopharmaceuticals

Types of therapeutic nanoparticles, Types of nanostructured nanoparticles, Nanoparticle based drug delivery. Gold nanoparticles for drug discovery, Use of Quantum Dots and Nano lasers for Drug Discovery, Cells Targeting by Nanoparticles with Attached Small Molecules. Self-assembled nanoparticles for Intracellular Drug Delivery, Nanoparticle Combinations for Drug Delivery, Multi-targeted drugs, Delivery of nucleic acids, Dendrimers and Fullerenes as Drug Candidates. Barriers to therapeutic applications, interaction of organic molecules of the drug with pathological tissue, biocompatible core-shell nanoparticles for medicine.

Module V

Current Application of Nanoparticles in Clinics

Nanoparticles for Cancer Therapy, Nanoparticles for Infectious Disease Therapy, Nanoparticles for Autoimmune Disease Therapy, Nanoparticles for Cardiovascular Disease Therapy, Nanoparticles for Neurodegenerative Disease Therapy, Nanoparticles for Ocular Disease Therapy, Nanoparticles for Pulmonary Disease Therapy, Nanoparticles for Regenerative Therapy.

REFERENCE

1. Kewal K. Jain,_*The Handbook of Nanomedicine* _Humana Press, (2008).
2. Zhang, _*Nanomedicine: A Systems Engineering Approach"* 1st Ed., Pan Stanford Publishing, (2005).
3. Robert A. Freitas Jr., ―*Nanomedicine Volume IIA: Biocompatibility*_, Landes BiosciencePublishers, (2003).
4. Challa Kumar- Biological and pharmaceutical Nanomaterials, Wiley-VCH Verlag GmbH & Co. KGaA.
5. Cato T. Laurencin and Lakshmi S. Nair, Nanotechnology and Tissue Engineering the Scaffold, CRC Press taylor& Francis Group.
6. K.K.Jain, Nano Biotechnology, Horizions Biosciences, 2006 5.
7. C. Kumar, Nanomaterials for medical diagnosis and therapy, Wiley –VCH, 2007, USA
8. Nano bio-technology: Concepts, Applications and Perspectives, Christ of M. Niemeyer, Wiley, 2004

	MAHATMA GANDHI UNIVERSITY
	NSM21E07 Nanoelectronics and Nanophotonics

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Nanoelectronics and Nanophotonics**
Type of Course	**elective**
Credit Value	**2**
Course Code	**NSM21E07**

Justification of Course in Programme	The students will be able to understand basic concepts of nanoelectronic devices and nanotechnology. The course enables the learners capable of understanding the fundamentals of nanophotonics.					
Semester	**2**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	40	40	0	40	120
Pre-requisite	Basic understanding of electronics and photonics.					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Understand the basic and advance concepts of nanoelectronics.	U	1
2	To apply the methods of fabrication of nano-layers	A	6
3	Remember the basic principles of nanophotonics	R	6
4	Understand the working of 2 dimensional nanoelectronic systemS and basic nanoelectronic devices	U,A	4

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

COURSE CONTENT

Module I

Overview of nano-electronics

Introduction to Nanoelectronics Technology roadmap of nano-electronics, Scaling of devices and technology jump, Challenge of the CMOS technologies, More-Moore and More-than-Moore. Review of semiconductor devices, Quantum statistical mechanics, Energy bands in silicon, Metal Oxide Semiconductor Field Effect Transistors (MOSFET), MOSFET Operation, Threshold Voltage and Subthreshold Slope, Current/voltage characteristics, Finite Element Modelling of MOS, CMOS technology, Challenges of the CMOS technologies, High-k dielectrics and Gate stack, Future interconnect

Module II

Advances in Nanoelectronics

Molecular nanoelectronics, Electronic and optoelectronic properties of molecular materials, TFTs OLEDs- OTFTs, logic switches, SPINTRONICS: Spin tunnelling devices - Magnetic tunnel junctions- Tunnelling spin polarization, spin diodes, Magnetic tunnel transistor, Memory devices and sensors, ferroelectric random-access memory- MRAMS

Module III

Fundamental of Nanophotonics

Photons and electrons: similarities and differences, freespace propagation. Confinement of photons and electrons. Propagation through a classically forbidden zone: tunnelling. Localization under a periodic potential: Band gap. Cooperative effects for photons and electrons. Nanoscale optical interactions, axial and lateral nanoscopic localization. Nanoscale confinement of electronic interactions, Quantum confinement effects, Optical properties nonlinear optical properties, nanoscale interaction dynamics, nanoscale electronic energy transfer. Cooperative emissions.

Module IV

Nanophotonic Devices

Resonant cavity quantum well lasers and light-emitting diodes, Fundamentals of Cavity QED, strong and weak coupling regime, Purcell factor, Spontaneous emission control, Application of microcavities, including low threshold lasers, resonant cavity LED. Microcavity-based single photon sources.

Module V

Photonic crystals

Important features of photonic crystals, Presence of photonic bandgap, Anomalous Group Velocity Dispersion, Microcavity, Effects in Photonic Crystals, Fabrication of photonic crystals, Dielectric mirrors and interference filters, Photonic Crystal Laser, PC based LEDs, Photonic crystal fibers (PCFs), Photonic crystal sensing.

REFERENCE

1. M.C. Petty, “Introduction to Molecular Electronics”1995.
2. W. Ranier, “Nano Electronics and Information Technology”, Wiley, (2003).
3. Yuan Taur and Tak H. Ning, Fundamentals of Modern VLSI Devices, Cambridge
4. Karl Goser, Peter Glosekotter, Jan Dienstuhl, ―Nanoelectronics and Nanosystems, Springer (2004)
5. Cyril Prasanna Raj P., Designing with FINFETs and CNTFETs, MSEC E-Publication (2016)
6. SadamichiMaekawa, ―Concepts in Spin Electronics‖, Oxford University Press (2006)
7. Lucas Novotny and Bert Hecht, "Principles of Nano-Optics”, Cambridge University Press, 2012.
8. B.E.A. Saleh and A.C.Teich, Fundamentals of Photonics, John-Weiley & Sons, New York, 1993.
9. M.Ohtsu, K.Kobayashi, T.Kawazoe, and T.Yatsui, Principles of Nanophotonics (Optics and Optoelectronics), University of Tokyo, Japan, 2003.
10. K.E. Drexler, “Nano systems”, Wiley, (1992).

MAHATMA GANDHI UNIVERSITY

NSM21E08 Nanotechnology in Energy

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech.**
Course Name	**Nanotechnology in Energy**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E08**

Justification of Course in Programme	This main objective of this course is to give a theoretical and practical overview of nanotechnology with applications in energy production, 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 Nanotechnology in Energy, 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.					
Course Summary	This paper encompasses a detailed exposure to the alternative energy technologies with a special focus on solar-photovoltaic, batteries and hydrogen-fuel cell technologies. The proposed course will be one of the elective courses to introduce students to applications of nanotechnology through five different modules. The modules are selected in order to have hierarchy in student learning in three different areas (renewable energy technologies, batteries, fuel cells, hydrogen storage and solar photovoltaics) of alternative energy technologies.					
Semester	**2**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	40	40	0	40	120
Pre-requisite	Basics of nanoscience.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	The module encompasses a detailed exposure to energy challenges, development and implementation of renewable energy technologies. Nanotechnology enabled renewable energy technologies are also be discussed (Module 1)	U, A	6
2	This module discusses Nanomaterials for Energy Storage Systems. The student will able to understand principles and material design of different nanostructured carbon-based materials. Current status and future trends on energy storage systems are also	U, A	6,1

	discussed. (Module 2)		
3	This module is to designed to help the students to provide adequate knowledge regarding nanomaterials in fuel cells, hydrogen Storage, thermoelectric materials (in nano scale), supercapacitors (Module 3).	An, E	4,9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1

Renewable Energy Technology

Energy challenges, development and implementation of renewable energy technologies, nanotechnology enabled renewable energy technologies, Energy transport, conversion and storage- Nano, micro, and poly crystalline and amorphous Si for solar cells, Nano-micro Si-composite structure, various techniques of Si deposition

Module II

Nanomaterials for Energy Storage Systems

Issues and Challenges of functional Nanostructured Materials for electrochemical Energy Storage Systems, Primary and Secondary Batteries (Lithium ion Batteries), Cathode and anode materials, Capacitor Electrochemical supercapacitors, electrical double layer model, Principles and materials design, Nanostructured Carbon-based materials, Nano-Oxides, Novel hybrid electrode materials, Current status and future trends.

Module III

Nanomaterials in Fuel Cell and Storage Technology

Micro-fuel cell technologies, integration and performance for micro-fuel cell systems, thin film and microfabrication methods, design methodologies, micro-fuel cell power sources, Supercapacitors, Specific energy, charging/discharging, EIS analysis.

Module IV

Nanomaterials for Hydrogen Storage and Photocatalysis

Hydrogen storage methods, metal hydrides, size effects, hydrogen storage capacity, hydrogen reaction kinetics, carbon-free cycle, gravimetric and volumetric storage capacities, hydriding/dehydriding kinetics, multiple catalytic effects, degradation of the dye, nanomaterials based photocatalyst design, kinetics of degradation.

Module V

Nanomaterials for Photovoltaic Solar Energy Conversion Systems

Principles of photovoltaic energy conversion (PV), Types of photovoltaics Cells, Physics of Photovoltaic cells, Organic photovoltaic cell cells, thin film Dye Sensitized Solar Cells, Quantum dot (QD) Sensitized Solar Cells (QD-SSC), Organic- Inorganic Hybrid Bulk Hetero Junction (BHJ-SC) Solar cells, Current status and future trends.

REFERENCE

1. Twidell. J. and Weir. T “Renewable Energy Resources”, E & F N Spon Ltd, 1986.
2. Martin A Green, “Solar cells: Operating principles, technology and system applications”, Prentice Hall Inc, Englewood Cliffs, 1981.
3. Moller. H J “Semiconductor for solar cells”, Artech House Inc, 1993. 4. Ben G Streetman, “Solid state electronic device”, Prentice Hall of India Pvt Ltd.,1995
4. D. Linden Ed., Handbook of Batteries, 2nd edition, McGraw- Hill, New York (1995).
5. Handbook of fuel cells: Fuel cell technology and applications by Vielstich. Wiley, CRC Press
6. G.A. Nazri and G. Pistoia, Lithium Batteries: Science and Technology, Kulwer Acdemic Publishers, Dordrecht, Netherlands (2004).
7. J. Larmine and A, Dicks, Fuel Cell System Explained, John Wiley, New York (2000).
8. Science and Technology of Lithium Batteries-Materials Aspects: An Overview, A. Manthiram, Kulwer Academic Publisher (2000).
9. Hydrogen from Renewable Energy Sources by D. Infield 2004

	MAHATMA GANDHI UNIVERSITY
	NSM21E09 Nanotechnology in Colloids, Surface Science & Catalysis

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Nanotechnology in Colloids, Surface Science & Catalysis**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E09**

Justification of Course in Programme	The objective of the course on Nanotechnology in Colloids, Surface Science & Catalysis is to equip the M.Tech. students with the concepts related to the surface of nanomaterials, colloidal nanoscience, adsorption phenomenon and catalysis that he/she needs for understanding different courses taught in this class and for developing a strong background if he/she chooses to pursue research in Nanoscience & Nanotechnology as a career.					
Course Summary	This course illustrates the surface chemistry and colloidal properties of nanomaterials					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	40	40	0	40	120
Pre-requisite						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Describe the surface-interface concept and its properties especially surface energy and their states, and surface tension. The tsurface defects in nanomaterials and effect of microstructure on surface defects are also be discussed. (Module 1)	U, A	1, 6
2	Explain the colloidal materials, surface properties and its characterization. Some significant areas such as Brownian motion and Brownian flocculation are also be discussed. (Module 2)	An, E	4
3	This module is to designed to help the students to provide adequate knowledge regarding surfaces in multidisciplinary applications. Demonstrate the surface interface effects and application of colloids in drug delivery system. New coating concepts in multilayer structures, thermal barrier coatings are also discussed. (Module 3).	E	2, 4
4	Explain the binding of molecules to the surface, physio and chemio adsorptions and their kinetic models are discussed. (Module 4)	E	6
5	Discuss the Nanostructure catalytic materials like Pt, Pd and Fe, colloidal and porous materials and applications. (Module 5)	U	6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module I

Surface Nanoscience

Introduction to surface active agents. Theory and applications. Types of surfactants. Classification, synthesis of surfactant - Shape, size and structure of surfactants. Micelle, Emulsions, Microemulsions & Gels. Kraft temperature, surfactant geometry and packing. surface defects in nanomaterials, effect of microstructure on surface defects, interfacial energy.

Module II

Colloidal Nanoscience

Introduction to colloidal material, surface properties, origin of colloidal particles, preparation & characterization of colloidal particles. Brownian motion and Brownian Flocculation. Applications of super hydrophilic hydrophobic surfaces, self-cleaning surfaces. Surface viscosity, Applications of oil recovery.

Module III

Surfaces in Multidisciplinary Applications

Colloids, Optical and Electrical properties, Colloids in Drug Delivery, Electrical and Electronic properties of Surfaces, zeta potential, Corrosion, Coatings for corrosion protection, High temperature issues, New coating concepts in multilayer structures, thermal barrier coatings. Bioinspired materials, Tribology in Human Body, Artificial organs and Medical devices, Nano surfaces in Energy, Environmental, Automobile and Industrial Applications

Module IV

Adsorption phenomenon

Chemisorption & Physisorption, adsorption isotherms and methods of determination of pore size and surface area of materials using the adsorption isotherms, Adsorption isotherms (Langmuir and BET), Reaction Mechanism (Langmuir-Hinshelwood and Eley-Rideal). Intermolecular Forces, Van der Waals forces (Kessorn, Debye, and London Interactions). Dynamic properties of interfaces, Contact angle. Surface free energy.

Module V

Catalysis

Catalysis – Definition, Catalysis in environmental protection & green process, Industrial catalytic wet air oxidation processes, water purification, types of catalysis with suitable examples, Introduction to photocatalysis: Principle- Band energy engineering, characteristics of a catalyst, selectivity or specificity of the catalyst, activation and deactivation of catalysts, catalytic poisoning, Nanostructured metals like Pt, Pd and Fe, nanostructured ceramics like silica, silicate and alumina, pillared clays, colloids and porous materials (viz. mesoporous materials).

REFERENCE

1. Gabor A. Somorjai, Yimin Li, Introduction to Surface Chemistry and Catalysis, John Wiley & Sons, New Jersey, 2010.
2. HaraldIbach, Physics of Surfaces and Interfaces, Springer-Verlag, Berlin, 2006.
3. Peter J. Blau, Friction Science and Technology- From concepts to applications, Second Edition, CRC Press, Boca Raton, 2009
4. N. Birks, G. H. Meier, F. S. Pettit, Introduction to the high temperature oxidation of metals, Second edition, Cambridge University Press, 2006
5. P.C Hiemen and R.Rajgopalam, Principle of colloid and surface Chemistry, NY Marcel Dekker, 1997.
6. D.J.Shaw, Colloid and surface chemistry, Butterworth Heineman, Oxford, 1992.
7. Heterogeneous Catalysis, D.K. Chakrabarty and B. Viswanathan, New Age International (P) Limited, 2008

8. Nanoporous Materials: Synthesis and Applications, Edited by Qiang Xu, CRC Press, 2013
9. Catalysis: Principles and Applications, Edited by B. Viswanathan, S. Sivasanker, A.V. Ramaswamy, Narosa Publishing House, 2011
10. New and Future Developments in Catalysis, Edited by Steven L. Suib, Elsevier, 2013.

MAHATMA GANDHI UNIVERSITY

NSM21E10 Environmental Nanotechnology

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Environmental Nanotechnology**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E10**

Justification of Course in Programme	This course intends to understand the applications and implications of nanotechnology for environment safety and water security. The aim of this course is to mention the latest developments related to nanotechnology, environmentally friendly manufacturing procedures, possible effects on human and environment and scientific researches and regulations that should be done in the future related to nanotechnology and to develop a scientific infrastructure on environmental nanotechnology which is sensitive to human and environment.					
Course Summary	Introduction to Environmental Nanotechnology, Manufacture of materials using environmentally friendly procedures, Positive and negative effects of technologies at nanoscale on environmental pollution, Importance of nanotechnologies on environmental technology (Water treatment applications etc.), Nanosensors for detecting pollutants, Effects of nanoparticles to the environment, Effects of nanoparticles to human, Fundamental properties (transport, aggregation, deposition, etc.) of nanoparticles in different media (Water, air, soil, etc.), Characterization techniques of nanoparticles (SEM, AFM, TEM, VSI, etc.), Scientific researches and regulations that should be done in the future related to nanotechnology.					
Semester	**I**					
Total Student						Total

Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Hours
	Others include: Research, Fieldworks, Independant Learning etc.	40	40	0	40	120
Pre-requisite	Fundamentals of Nanomaterials, synthesis and characterization (Graduate level)					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	The student will able to understand		
2	Environmental applications of nanotechnology	U	1,2,7
3	Environmental effects of nanotechnology	U	2,3,7
4	Effects of nanotechnology to human body	U, A	3,4,7
5	Risk assessment	U	1,2,5
6	Regulations that should be done for nanotechnology	U	2,5

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

COURSE CONTENT

Module I

Environmental Nanotechnology

Introduction, properties of nanomaterials, major applications of nanotechnology, types of nanoparticles, types of engineered nanoparticles. Environmental uses of nanotechnology: air purification, water purification, nano monitoring: bio sensors for pesticide detection, biosensors for plant pathogen detection, Nanobioremediation, pesticide degradation, soil, structure and remediation.

Module II

Green Nanotechnology

Green synthesis of metal, metal oxide and organic nanoparticles, biological synthesis of nanomaterials: natural nanomaterials, natural polymers, natural adsorbents, nano biomaterials, clays, nanocomposites.

Module III

Applications of nanotechnology in waste water treatment

Techniques for water purification, nano-absorbents, membrane filtration, nanomaterials for water treatment, photocatalysts. Role of nanotechnology in energy sector, sustainable energy applications.

Module IV

Advanced Instruments: Characterisation of nanomaterials

Atomic absorption spectrometry, inductively coupled plasma spectrometry, chromatography, thermal methods, hyphenated techniques.

Module V

Nanoparticles: Health and Environmental effects

Health hazards, physicochemical properties of nanoparticles, toxicity of nanoparticles, toxicity to plants, exposure and risk assessment, dose-response, ecotoxicological impacts of nanomaterials.

REFERENCE

1. Environmental Nanotechnology, M. H. Fulekar, Bhawana Pathak, CRC Press (2017)
2. Environmental Nanotechnology: Applications andImpacts of Nanomaterials, Wiesner, M.R., Bottero, J.Y. (Ed.) McGraw-Hill, New York (2007)
3. NanotechnologyApplications for Clean Water, Diallo, M., Duncan, J., Savage, N., Street, A., Sustich, R. (Eds)., William Andrew (2008)
4. Environmental and Human Health Impacts of Nanotechnology, Lead J., and Smith, E., John Wiley & Sons (2009).
5. Introduction to Environmental Engineering and Science, Masters, G.M., Ela, W.P., Prentice Hall (2007)

	MAHATMA GANDHI UNIVERSITY
	NSM21E11 Advanced carbon-based nanomaterials

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Advanced carbon-based nanomaterials**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**NSM21E11**

Justification of Course in Programme	Advanced carbon-based nanomaterials is a distinctive topic in Nanoscience and Nanotechnology having many inter as well as multidisciplinary components. This course is designed as an interdisciplinary course that includes fundamental as well as in-depth knowledge of the carbon-based nanomaterials. The syllabus has been designed to cover the fundamental understanding of different carbon-based nanomaterials with special emphasis on fullerenes, carbon nanotubes (CNT) and graphene synthesis and related topics thereby enabling the students to work in frontier areas of carbon-based nanomaterials. This comprises of the history of carbon-based nanomaterials and its relevance in the development of human civilization.					
Course Summary	The syllabus covers the significance of different carbon-based nanomaterials, and their relation with the structure and property of various carbon-based nanomaterials. This course also covers a detailed study of the synthesis and properties of different carbon-based nanomaterials. This course further offers awareness and understanding of the contemporary trends and growth in the field of carbon-based nanomaterials. After the completion of this course, students will be able to understand the basics associated with different carbon-based nanomaterials and the method/mechanism of its synthesis and advanced applications.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	40	40	0	40	120
Pre-requisite	Basic Chemistry knowledge.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To understand the carbon based nanostructures and their characteristic properties	U, An	1
2	To gain in depth knowledge about Fullerenes and their applications	U	1, 4
3	Understand different types of carbon nanotubes and their characteristics beneficial for varying applications	U, A	4, 6
4	Learners will get in depth knowledge about Graphenes, different methods of synthesis, characteristic properties and characterizations.	U, A	6
5	Understand varying applications of different types of carbon nanostructures	U, A, I	6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module I

Introduction

Carbon molecules, nature of carbon bonds, structure and chemistry of different carbon allotropes. Classification of carbon nanomaterials: fullerenes, carbon nanotubes (CNT), graphene and other carbon nanomaterials.

Module II

Introduction to Fullerenes

Structure of Higher Fullerenes, Growth Mechanisms; Production and Purification: Pyrolysis of Hydrocarbons, Partial Combustion of Hydrocarbons, Arc Discharge Methods, Resistive Heating, Rational Syntheses. Physical Properties, Spectroscopic Properties, Thermodynamic Properties. Chemical Properties: Hydrogenation, Halogenation, Nucleophilic Addition to Fullerenes.

Module III

Introduction to Carbon nanotubes (CNT)

The Structure of Carbon Nanotubes, Single Walled Carbon Nanotubes, Multiwalled Carbon Nanotubes. Electrical, Vibrational, Mechanical Properties of CNTs, optical properties & Raman Spectroscopy of CNTs. Purification and Functionalization of CNTs by Flame, CVD, Laser & Arc-discharge process, Fluidized bed reactor.

Module IV

Introduction to graphene

Structure of graphene, synthesis of graphene: Modified Hummer's method, electrochemical exfoliation and CVD method., Electronic Properties Band structure of Graphene -Mobility and Density of Carriers - Quantum Hall Effect -Spectroscopic Properties of graphene.

Module V

Applications of Fullerene, CNT, Graphene and other carbon nanomaterials. Mechanical, Thermal, Electronic and biological Applications of carbon nanomaterials.

REFERENCE

1. Encyclopaedia of Nanotechnology, M.Balakrishna rao and K.Krishna Reddy, Vol I to XCampus books (2006).
2. Nano:The Essentials – Understanding Nano Scinece and Nanotechnology, T.Pradeep; TataMc.Graw Hill (2008).
3. Carbon Nanotubes: Properties and Application, Michael J. O'Connell, CRC Press (2018).
4. Nanotubes and Nanowires, CNR Rao and A Govindaraj, RCS Publishing (2005)
5. Carbon Nanotechnology: Recent Developments in Chemistry, Physics, Materials Science and Device Applications, Liming Dai, Elsevier Science (2006)

	MAHATMA GANDHI UNIVERSITY
	NSM21E12 Computation and Simulation - Lab

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Computation and Simulation – Lab**
Type of Course	**Laboratory**
Credit Value	**2**
Course Code	**NSM21E12**

Justification of Course in Programme	Simulation modeling solves real-world problems safely and efficiently. It provides an important method of analysis which is easily verified, communicated, and understood. Across industries and disciplines, simulation modeling provides valuable solutions by giving clear insights into complex systems.					
Course Summary	A modeling and simulation laboratory appropriate to sophomore-level study in materials science and engineering. Introduce students to visualizing data and mathematical functions, numerical and symbolic differentiation/integration, matrix operations, coupled algebraic equations, and elementary programming constructs related to materials science and engineering. Define limitations of models and simulations and methods by which to assess accuracy.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	40	40	0	40	120
Pre-requisite	Basic understanding of numerical methods.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	The student will able to understand;		
2	To introduce with the various system simulation and modeling techniques, and highlight their applications.	U	1,2,7
4	To introduce modeling, design, simulation, planning, verification and validation in the areas of simulation.	U, A	2,3,7
5	To develop skills among the learners of system simulation.	U	5,7
6	To make them able to solve real world problems, which cannot be solved by mathematical approaches.	U	1,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Basic Computational methods

Numerical programme to plot the first four Eigen functions of a one - dimensional rectangular potential well with infinite potential barrier. Numerical solution of the Schrodinger wave equation for a rectangular potential well with infinite potential barrier using numerical programme. Toy model in molecular electronics

MATLAB

Introduction to MATLAB Programming, Program assembly, Execution, Data processing and graphic analysis, Study of Fermi – Dirac distribution function, Introduction to symbolic math computations, MATLAB program to plot the one-dimensional rectangular potential well with infinite potential barrier, Introduction to Simulink and SimElectronics

	MAHATMA GANDHI UNIVERSITY
	NSM21C09 Advanced Characterization of Nanomaterials Lab -2

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Material Characterisation Lab**
Type of Course	**Laboratory (Core)**
Credit Value	**3**
Course Code	**NSM21C09**

Justification of Course in Programme	This course covers most important currently utilised techniques for the characterisation of nanostructures and nanoparticles. The techniques presented here are grouped into categories of topology, internal structure, and compositional investigation.					
Course Summary	This course covers a review of materials characterization techniques, which can be used to analyse nanomaterials also. This course includes optical characterization techniques such as Raman and Fourier Transform Infrared Spectroscopy and, Spectroscopic ellipsometry; electron microscopy techniques such as transmission electron microscopy and field effect scanning electron microscopy (FESEM) and its sample preparation processing and, X-ray diffraction (XRD), atomic force microscopy, surface area analysis and nano-indentation techniques. Course also covers particle size analyzer, confocal microscope, optical profiler, rheometer and microhardness tester.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	40	40	0	40	120
Pre-requisite						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Learn different characterization techniques used for characterizing nanomaterials	U, A, An	
2	Learners will get in-depth knowledge in various advanced tools and techniques	U, A, S	
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Morphological analysis, Thermal analysis, Spectroscopic methods and wet chemistry methods

Imaging Techniques SEM, TEM, AFM, STEM

	MAHATMA GANDHI UNIVERSITY
	NSM21C10 Mini Project and Comprehensive Viva

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech**
Course Name	**Mini Project and Viva**
Type of Course	**CORE**
Credit Value	**3**
Course Code	**NSM21C10**

Justification of Course in Programme	This course helps in the first major practical understanding of the programme.					
Course Summary	The candidate shall do a mini research project in any of the research institute. This follows discussion with the Examination Board consisting of the Chairman, minimum two Internal Examiners and one External Examiner. The comprehensive viva-voce shall be conducted by the Examination Board consisting of the Chairman, Internal Examiner and External Examiner. Thorough understanding of all the M.Tech. level course contents and recent trends in the broad area of nanoscience will be evaluated.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	40	40	0	40	120
Pre-requisite	Knowledge of the courses taught in programme.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Acquire a comprehensive knowledge of the area subject of study.	A	6
2	Gain deeper knowledge of methods in the topic of study.	R	6
3	Able to contribute to research and development work.	C, S	4
4	Create, analyse and critically evaluate different problems and their solutions.	C, E	2,1
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

	MAHATMA GANDHI UNIVERSITY
	NSM21C11 Industrial visit / Review

School Name	**School of Nanoscience and Nanotechnology**					
Programme	**M.Tech.**					
Course Name	**Industrial Visit / Review**					
Course Credit	**3**					
Type of Course	**CORE**					
Course Code	**NSM21C11**					
Course Summary & Justification	The Industrial visit/ Review shall be conducted by the School of Nanoscience and Nanotechnology. The students have to visit an industry in the presence of a faculty member of the School during the programme and submit a report on the same at the end of the fourth semester.					
Semester	**II**					
Total StudentLearnin gTi me (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total LearningH o urs
	Visiting the industry and interacting with the personnel	-	-	-	-	-
Pre-requisite	Basic knowledge in chemistry practicals and industrial chemistry					

1	Demonstrate the applications of chemical concepts and principles learned in classroom.	A	1, 2, 3
2	Illustrate processes and products manufactured in the chemical industries.	A	2, 4
3	Develop awareness of the principles and technological aspects in the chemical industries.	C	2
4	Improve interpersonal skill by communicating directly with industrial personnel.	S	5
5	Aware of the impacts of industrial processes on health, safety, environment and society.	E	6, 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)** Main aim of industrial visit is to provide an exposure to students about practical working environment. They also provide students a good opportunity to gain full awareness about industrial practices. Through industrial visit students get awareness about new technologies.
Assessment Types	**Mode of Assessment** The report shall be evaluated by the Examination Board consisting of the Chairman, the Internal Examiner and the External Examiner.

	MAHATMA GANDHI UNIVERSITY
	NSM21C12 Interim Project Evaluation

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech.**
Course Name	**Interim Project Evaluation**
Type of Course	**CORE**
Credit Value	**16**
Course Code	**NSM21C12**

Justification of Course in Programme	The candidate shall do a research project in any of the International Research Institute abroad. This follows discussion with the Examination Board consisting of the Chairman, the Internal Examiner and the External Examiner.					
Course Summary	The candidate shall give a seminar on the research project submitted. This follows discussion with the Examination Board consisting of the Chairman, the Internal Examiner and the External Examiner.					
Semester	**3**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Hours
	Others include: Research, Fieldworks, Independant Learning etc.	40	40	0	40	120
Pre-requisite	Knowledge of nanoscience.					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Acquire a comprehensive knowledge of the area subject of study	Ap	1, 7

2	Gain deeper knowledge of methods in the topic of study.	A	6
3	Able to contribute to research and development work.	U	3
4	Undertake independent, original and critical research on a relevant topic.	U	5
5	Able to plan and use adequate methods to conduct specific tasks in given frameworks and to evaluate this work.	U	6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

	MAHATMA GANDHI UNIVERSITY
	NSM21C13 Final Project Evaluation and Viva

SchoolName	**School of Nanoscience and Nanotechnology**
Program	**M.Tech.**
Course Name	**Phase II**
Type of Course	**CORE**
Credit Value	**18**
Course Code	**NSM21C13**

<table>
<tr><td>Justification of Course in Programme</td><td colspan="6">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.</td></tr>
<tr><td>Course Summary</td><td colspan="6">The candidate shall give a seminar on the research project submitted. This follows discussion with the Examination Board consisting of the Chairman, the Internal Examiner and the External Examiner.</td></tr>
<tr><td>Semester</td><td colspan="6">4</td></tr>
<tr><td>Total Student Learning Time (SLT)</td><td>Learning Approach</td><td>Lecture</td><td>Tutorial</td><td>Practical</td><td>Others</td><td>Total Hours</td></tr>
<tr><td></td><td>Others include: Research, Fieldworks, Independant Learning etc.</td><td>40</td><td>40</td><td>0</td><td>40</td><td>120</td></tr>
<tr><td>Pre-requisite</td><td colspan="6"></td></tr>
</table>

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Carry out literature survey-Familiarise with journal abstracting,inculate scientific temper and research interest and to make understand and aware recent trends in the topic chosen. Journal reading and writing skill.	A	2, 3, 4, 5
2	Acquire a comprehensive knowledge of the area subject of study	Ap	1, 7
3	Deeper knowledge of methods in the major subject 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
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

	MAHATMA GANDHI UNIVERSITY
	NSM21C14 Viva-Voce

<table>
<tr><td>School Name</td><td colspan="6">School of Nanoscience and Nanotechnology</td></tr>
<tr><td>Programme</td><td colspan="6">M.Tech.</td></tr>
<tr><td>Course Name</td><td colspan="6">Viva-Voce</td></tr>
<tr><td>Course Credit</td><td colspan="6">4</td></tr>
<tr><td>Type of Course</td><td colspan="6">CORE</td></tr>
<tr><td>Course Code</td><td colspan="6">NSM21C14</td></tr>
<tr><td>Course Summary & Justification</td><td colspan="6">The comprehensive viva-voce shall be conducted by the Examination Board consisting of the Chairman, the Internal Examiner and the External Examiner. Thorough understanding of all the Masters level course contents and recent trends in the broad area of chemical sciences are evaluated</td></tr>
<tr><td>Semester</td><td colspan="6">IV</td></tr>
<tr><td>Total Student Learning Time (SLT)</td><td>Learning Approach</td><td>Lecture</td><td>Tutorial</td><td>Practical</td><td>Others</td><td>Total LearningH o urs</td></tr>
<tr><td></td><td>Classroom studies, lab work, library Library work, independent learning etc.</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Pre-requisite</td><td colspan="6">Basic as well as in-depth knowledge in the coureses he/she studied</td></tr>
</table>

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	A	3
2	Acquire more in-depth knowledge of the major subject of study	Ap	1,2,3,4,5,6,7
3	Deeper knowledge of methods in the major subject of study.	A	1, 4
4	Able to contribute to research and development work.	U	3
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 Masters 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.

Pattern of Question papers for the End- Semester Written Examination

The question papers set for the end-semester written examination will have three sections and carry 60 marks as detailed below:

Section A – Fourteen short answer questions, minimum one from each Unit. Students will have to answer any ten. Each question will carry two marks (Total 20 marks).

Section B – Seven short essay questions, minimum one from each Unit. Students will have to answer any four. Each question will carry 5 marks (Total 20 marks).

Both sections will contain questions covering all the cognitive levels Remembering/ Understanding/Applying/Analysing/ Evaluating and Creating.

Section C - There will be questions of higher levels of learning for at least 10 marks. Students needs to answer any 2 out of 4 questions covering all the cognitive levels. Minimum one question from each module.

The End Semester Examination (ESE) will be of three hours duration and carry 60 marks. The ESE for the core and elective courses shall be conducted based on the following pattern of question paper.

Section	Cognitive level	Choice and Marks of questions	Question specification	Total Marks	Alignment with Course outcomes (COs)
Section A	Remembering/ Understanding/ Applying/Evaluating.	10 out of 14 questions; 2 marks each	Minimum one Question from each unit.	20	Aligned with COs
Section B	Applying/Analysing/ Evaluating/Creating	4 out of 7 questions; 5 marks each	Minimum one Question from each unit	20	Aligned with Cos
Section C	Applying/ Creating/Evaluating/ critical thinking	2 out of 4 questions: 10 marks each.	Minimum one Question from each module.	20	Aligned with Cos

The cognitive levels of questions in the End Semester Examinations are summarised as:

Lower levels of learning (Remembering/Understanding/Applying) :30 to 40%

Higher Levels of Learning (Analyzing/Evaluating/Creating) : 60 to 70%

The **difficulty levels** of questions in the End Semester Examinations are categorised as Low, Medium and High. The percentage of questions in each level of difficulty are given below:

- Low: 20 to 30%
- Moderate: 55 to 65%
- High: 15 to 25%

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)

1. ……………………………………………………………………………………
2. ……………………………………………………………………………………
3. ……………………………………………………………………………………
4. ……………………………………………………………………………………
5. ……………………………………………………………………………………
6. ……………………………………………………………………………………
7. ……………………………………………………………………………………
8. ……………………………………………………………………………………
9. ……………………………………………………………………………………
10. ……………………………………………………………………………………
11. ……………………………………………………………………………………
12. ……………………………………………………………………………………
13. ……………………………………………………………………………………
14. ……………………………………………………………………………………

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

1. ……………………………………………………………………………………
2. ……………………………………………………………………………………
3. ……………………………………………………………………………………
4. ……………………………………………………………………………………
5. ……………………………………………………………………………………
6. ……………………………………………………………………………………
7. ……………………………………………………………………………………

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

1. ……………………………………………………………………………………
2. ……………………………………………………………………………………
3. ……………………………………………………………………………………
4. ……………………………………………………………………………………