

University of Mumbai



No. AAMS_UGS/ICC/2024-25/140

CIRCULAR:-

Attention of all the Principals of the Affiliated Colleges, Directors of the Recognized Institutions and the Head, University Departments is invited to this office Circular No. AAMS_UGS/ICC/2023-24/23 dated 08th September, 2023 relating to the NEP UG & PG Syllabus.

They are hereby informed that the recommendations made by the Ad-hoc Board of Studies in Nanoscience & Nanotechnology at its meeting held on 8th August, 2024 and subsequently passed by the Board of Deans at its meeting held on 3rd September, 2024 vide item No. 6.13 (N) have been accepted by the Hon'ble Vice Chancellor as per the power confirmed upon him under section 12(7) of the Maharashtra Public Universities Act, 2016 and that in accordance therewith syllabus for M.Sc. (Nanoscience & Nanotechnology) Sem – III & IV is introduced as per appendix (NEP 2020) with effect from the academic year 2024-25.

(The Circular is available on the University's website www.mu.ac.in).

MUMBAI – 400 032
21st September, 2024

(Dr. Prasad Karande)
REGISTRAR

To

All the Principals of the Affiliated Colleges, Directors of the Recognized Institutions and the Head, University Departments.

BOD 6.13(N) 03/09/2024

Copy forwarded with Compliments for information to:-

- 1) The Chairman, Board of Deans,
- 2) The Dean, Faculty of Science,
- 3) The Chairman, Ad-hoc Board of Studies in Nanoscience & Nanotechnology
- 4) The Director, Board of Examinations and Evaluation,
- 5) The Director, Department of Students Development,
- 6) The Director, Department of Information & Communication Technology,
- 7) The Director, Centre for Distance and Online Education (CDOE) Vidyanagari,
- 8) The Deputy Registrar, Admission, Enrolment, Eligibility & Migration Department (AEM),

Copy forwarded for information and necessary action to :-	
1	The Deputy Registrar, (Admissions, Enrolment, Eligibility and Migration Dept)(AEM), dr@eligi.mu.ac.in
2	The Deputy Registrar, Result unit, Vidyanagari drresults@exam.mu.ac.in
3	The Deputy Registrar, Marks and Certificate Unit,. Vidyanagari dr.verification@mu.ac.in
4	The Deputy Registrar, Appointment Unit, Vidyanagari dr.appointment@exam.mu.ac.in
5	The Deputy Registrar, CAP Unit, Vidyanagari cap.exam@mu.ac.in
6	The Deputy Registrar, College Affiliations & Development Department (CAD), deputyregistrar.uni@gmail.com
7	The Deputy Registrar, PRO, Fort, (Publication Section), Pro@mu.ac.in
8	The Deputy Registrar, Executive Authorities Section (EA) eau120@fort.mu.ac.in He is requested to treat this as action taken report on the concerned resolution adopted by the Academic Council referred to the above circular.
9	The Deputy Registrar, Research Administration & Promotion Cell (RAPC), rapc@mu.ac.in
10	The Deputy Registrar, Academic Appointments & Quality Assurance (AAQA) dy.registrar.tau.fort.mu.ac.in ar.tau@fort.mu.ac.in
11	The Deputy Registrar, College Teachers Approval Unit (CTA), concolsection@gmail.com
12	The Deputy Registrars, Finance & Accounts Section, fort draccounts@fort.mu.ac.in
13	The Deputy Registrar, Election Section, Fort drelection@election.mu.ac.in
14	The Assistant Registrar, Administrative Sub-Campus Thane, thanesubcampus@mu.ac.in
15	The Assistant Registrar, School of Engg. & Applied Sciences, Kalyan, ar.seask@mu.ac.in
16	The Assistant Registrar, Ratnagiri Sub-centre, Ratnagiri, ratnagirisubcentar@gmail.com
17	The Director, Centre for Distance and Online Education (CDOE), Vidyanagari, director@idol.mu.ac.in
18	Director, Innovation, Incubation and Linkages, Dr. Sachin Laddha pinkumanno@gmail.com
19	Director, Department of Lifelong Learning and Extension (DLLE), dlleuniversityofmumbai@gmail.com

Copy for information :-	
1	P.A to Hon'ble Vice-Chancellor, vice-chancellor@mu.ac.in
2	P.A to Pro-Vice-Chancellor pvc@fort.mu.ac.in
3	P.A to Registrar, registrar@fort.mu.ac.in
4	P.A to all Deans of all Faculties
5	P.A to Finance & Account Officers, (F & A.O), camu@accounts.mu.ac.in

To,

1	The Chairman, Board of Deans pvc@fort.mu.ac.in
2	Faculty of Humanities, Dean 1. Prof.Anil Singh Dranilsingh129@gmail.com Associate Dean 2. Dr.Suchitra Naik Naiksuchitra27@gmail.com 3.Prof.Manisha Karne mkarne@economics.mu.ac.in
	Faculty of Commerce & Management, Dean 1. Dr.Kavita Laghate kavitalaghate@jbims.mu.ac.in Associate Dean 2. Dr.Ravikant Balkrishna Sangurde Ravikant.s.@somaiya.edu 3. Prin.Kishori Bhagat kishoribhagat@rediffmail.com

	Faculty of Science & Technology Dean 1. Prof. Shivram Garje ssgarje@chem.mu.ac.in Associate Dean 2. Dr. Madhav R. Rajwade Madhavr64@gmail.com 3. Prin. Deven Shah sir.deven@gmail.com
	Faculty of Inter-Disciplinary Studies, Dean 1. Dr. Anil K. Singh aksingh@trcl.org.in Associate Dean 2. Prin. Chadrashekhkar Ashok Chakradeo cachakradeo@gmail.com
3	Chairman, Board of Studies,
4	The Director, Board of Examinations and Evaluation, dboee@exam.mu.ac.in
5	The Director, Board of Students Development, dsd@mu.ac.in@gmail.com DSW directr@dsw.mu.ac.in
6	The Director, Department of Information & Communication Technology, director.dict@mu.ac.in

BOD – 3/9/2024
12 (7) of M.P.U.A. 2016
Item No. – 6.13 (N)

As Per NEP 2020

University of Mumbai



Title of the P.G. Program

M.Sc. (Nanoscience & Nanotechnology)

Syllabus for

Semester – Sem.- III & IV

Ref: GR dated 16th May, 2023 for Credit

Structure of PG

(With effect from the academic year 2024-25)

University of Mumbai



(As per NEP 2020)

Sr. No.	Heading	Particulars
1	Title of program O: _____	M.Sc. (Nanoscience & Nanotechnology)
2	Scheme of Examination R: _____	NEP 50% Internal 50% External, Semester End Examination Individual Passing in Internal and External Examination
3	Standards of Passing R: _____	40%
4	Credit Structure R: <u>SP- 90 B</u>	Attached herewith
5	Semesters	Sem. III & IV
6	Program Academic Level	6.5
7	Pattern	Semester
8	Status	New/Revised
9	To be implemented from Academic Year	2024-25

Sign of the BOS
Chairman
Dr. Vishwanath R. Patil
Ad-hoc BoS
Nanoscience &
Nanotechnology

Sign of the
Offg. Associate Dean
Dr. Madhav R. Rajwade
Faculty of Science &
Technology

Sign of the
Offg. Dean
Prof. Shivram S. Garje
Faculty of Science &
Technology

PREAMBLE

1. Introduction:

Considerable research over the past decade has shown that nanoscience played a vital role in developing new generation technologies commonly known as nanotechnology has crossed almost all boundaries of sciences. Hence to initiate cognizance of ongoing research activities in the said field, center has introduced two years post-graduation course work entitled “Masters of Science in *Nanosciences and Nanotechnology*”. The course work designed herewith not only provide the fundamental understanding of the subject to students but also offers them flexibility to work as an interdisciplinary approach to seek for possible solutions by developing in house technologies to address the problems society facing now a days. Looking at the ongoing demand of fourth generation industrial revolution, the course work designed herewith not only literate but also motivate young generation in this field to reduce the gap via scientific/research activities followed by in house technological breakthroughs. Care taken especially to train and develop the required skillsets in the students while designing the course work will definitely help students to prepare them for the next generation industrial opportunities.

2. Aims and Objectives:

- To provide exposure to students in various specializations of Nanosciences and Nanotechnology.
- To undertake the capacity building of human resource in the field of recent developments in Nanosciences and nanotechnologies.
- Collaborate with national and international researcher institutes and industries for the development of high-end new generation of technologies.
- Motivate young minds for taking up Nano Science R&D as career and their skill developments,
- Motivate students towards the conducive environment for creation and commercialization of in house technologies.

3. Learning Outcomes:

Students who complete the course will understand the following,

- The fundamental knowledge of various subjects essential to understand nanosciences.

- The knowledge of various nanomaterials, their properties, synthesis routes and characterization techniques.
- Provide exposure in various specialization of Nanotechnology.
- Develop skills on modern developments in materials at the nanoscale and their relationship with the classical concepts.
- Develop skills on modern and state of art equipment's to be used to characterize nanomaterials, pattern them via top down and bottom up approaches to design new nanotechnology based systems (especially MEMS and NEMS).
- Practical understanding of descriptive data analysis, sampling theory, testing of hypotheses, nonparametric methods and multivariate analysis.
- Develop skills to address various societal issues via developing in house technologies.
- Building of human resource development in Nano Science and nanotechnology.
- Motivate young minds for taking up Nano Science R&D as career.
- Motivate students towards the conducive environment for creation and commercialization of in house technologies.

4. Any other point (if any):

- During course work students will be provided hand on training on highly sophisticated state of art microscopy and spectroscopy equipment's.
- Students will be provided internship at various industries looking at their choice of preference.
- Via assigning short term and research projects students will be motivated to design and commercialization their in house technologies.
- Collaborate with national and international researchers/industries for the development of high-end new generation of technologies based on nanosciences.

5. Credit Structure of the Program (Sem I, II, III & IV)
(Table as per Parishisht 1 with sign of HOD and Dean)

Post Graduate Programs in University

Parishishta - 1

Year (2 Yr PG)	Level	Sem. (2 Yr)	Major		RM	OJT / FP	RP	Cum . Cr.	Degree
			Mandatory*	Elective s Any one					
I	6.0	Sem I	CNN 501: Physics of Materials (Cr. 4) CNN 502: Chemistry of Materials (Cr. 4) CNN 503: Bio-nano Materials Cr. 4) CNN 504: Practical Course I (Cr. 2)	CNN 505-A OR CNN 505-B (Cr. 4)	CNN 506 (Cr. 4)			22	PG Diploma (after 3 Year Degree)
		Sem II	CNN 511: Fundamentals of Nanomaterials (Cr. 4) CNN 512: Experimental Methods (Cr. 4) CNN 513: Micro-nano fabrication techniques (Cr. 4) CNN 514: Practical Course II (Cr. 2)	CNN 515-A OR CNN 515-B OR CNN 515-C OR CNN 15-D (Cr. 4)		CNN 516 Industrial visits (Cr. 4)		22	
Cum. Cr. For PG Diploma			28	8	4	4	-	44	

R: SP- 90 B**Exit option: PG Diploma (44 Credits) after Three Year UG Degree**

II	6.5	Sem III	CNN 601: Advanced Instrumentation techniques (Cr. 4)	CNN 605-A OR CNN 605-B OR CNN 605-C OR CNN 605-D (Cr. 4)			CNN 606 Short term project (Cr. 4)	22	PG Degree After 3- Yr UG
			CNN 602: Physics of semiconductors -I (Cr. 4)						
			CNN 603: Fundamentals of spectroscopy (Cr-4)						
			CNN 604: Practical III (Cr. 2)						
		Sem IV	CNN 611: Nanophotonics and Biophotonics (Cr. 4)	CNN 614-A OR CNN 614-B OR CNN 614-C OR CNN 614-D OR CNN-614-E (Cr. 4)			CNN 615 Research Project (Cr. 8)	22	
			CNN 612: MEMS/NEMS and Microsystems (Cr. 4)						
			CNN 613: Practical IV (Cr. 2)						
Cum. Cr. for 1 Yr PG Degree			26	8			10	44	
Cum. Cr. for 2 Yr PG Degree			54	16	4	4	10	88	

Electives Suggested

SEM I		SEM II		SEM III		SEM IV	
Course Code	Course Name	Course Code	Course Name	Course Code	Course Name	Course Code	Course Name
CNN-505-A	Essential Mathematics	CNN-515-A	Nanomaterial synthesis techniques (PVD and CVD)	CNN-605-A	Nanotechnology in space and defense	CNN-614-A	Quantum electronic devices
CNN-505-B	Numerical recipes methods for data analysis using python	CNN-515-B	Electronics and circuit designing	CNN-605-B	Nanotechnology in energy and power storage devices	CNN-614-B	Nanomagnetic Materials and Devices
		CNN-515-C	Computing nanomaterials	CNN-605-C	Nanotechnology in medical, food and agriculture sector	CNN-614-C	Nanotechnology in Electrochemical Water Desalination
		CNN-515-D	Thermodynamics and catalysis of nanomaterials	CNN-605-D	Interfacing and machine learning-I	CNN-614-D	Interfacing and machine learning-II

*Note: * The number of courses can vary for totaling 14 Credits for Major Mandatory Courses in a semester as illustrated.*

Sign of HOD

Name of the Head of the Department

Name of the Department

Sign of Dean,

Name of the Dean

Name of the Faculty

Program Educational Objectives (PSOs)
--

The two-year master's course in "Nanoscience and Nanotechnology" is designed with the focus to understand/develop various technologies in sectors for e.g. optoelectronics, electronics, space, energy sectors, agriculture, medicinal, biotechnology, etc. Considering the research over the past few decades that has shown that nanomaterials has played vital role in these sectors using various nano architectures/framework. The course proposed herewith provides a fundamental understanding towards the physical and chemical properties of these materials, methods to synthesize, characterize them. The micro and nanofabrication followed by hands on training provided to students on state of art instruments will provide enough confidence in the students to design/develop their own in house technologies.
--

Course Learning Outcomes (CLOs)

After the successful completion of each course the students are expected to

SEMESTER I

Mandatory Courses

CNN 501	Comprehensive exposure to students regarding various materials viz. crystalline, non-crystalline their crystal structure and defects. Fundamental understanding towards them with respect to physical and chemical properties.
CNN 502	Comprehensive exposure to students regarding chemistry behind the materials such as metals, polymers and ceramics followed fundamental understanding of chemistry and properties behind nanomaterials, nanocomposites, etc.
CNN 503	Comprehensive exposure to students regarding biology/biological system followed by basics of bio-nano science/technologies for futuristic applications.
CNN 504	Confidence for self-learning, education and provide hands on experience towards material science, physics, chemistry and nano-bio systems and technologies based on these subjects.
CNN 506	Develop focuses on the methods and strategies and the way of conveying information in way to activate the intellectual property rights.

Elective Courses (Any one)

CNN 505-A	Improved mathematical skill sets for describing materials and understand deep theory behind.
CNN 505-B	Improved inter-disciplinary concepts followed by possible computational simulation to interpret the natural phenomenon.

SEMESTER II

Mandatory Courses

CNN 511	Knowledge of advanced experimental/ theoretical methods used for measuring, observing and understanding various phenomenon that occurs at nanoscale and in various nano systems.
CNN 512	Skills development to know and design various physical and chemical synthesis techniques to grow nanomaterials in the laboratory as well as industries
CNN 513	Knowledge towards various lithography techniques followed by micro/nano fabrication processes.
CNN 514	Understanding how various electronic/semiconductor devices actually work followed by ability developed to analyze various electric circuits, design them to develop in house gadgets.
CNN 516	Comprehensive exposure to the industrial requirements and their functioning.

Elective Courses (Any one)

CNN 515-A	Knowledge of nano material synthesis techniques and routes.
CNN 515-B	Skills developed to analyze and design electrical circuits one of the key requirements to develop in house gadgets/nano technology based products.
CNN 515-C	Aptitude to perceive, measure, operate and build materials at the nanometer scale, the size of atoms and molecules using various computational software available.
CNN 515-D	Knowledge about the catalytic performances, synthesis and characterization of various nano catalysts used in diverse sectors.

SEMESTER III

Mandatory Courses

CNN 601	Comprehensive exposure to students regarding various advanced characterization techniques and fundamental understanding to know physical and chemical properties of materials/thin films/nanoparticles.
CNN 602	Knowledge about the fundamental understanding of semiconductor material, devices and their working principles.
CNN 603	Comprehensive exposure to students regarding various advanced spectroscopy techniques along with their principles to develop fundamental understanding of the materials/thin films/nanoparticles.
CNN 604	Understanding physical and chemical properties of various nano-materials using advanced characterization and spectroscopic techniques.
CNN 606	To develop the research methodology skills in the students by exposing them with various short term project that mainly include literature survey, using statistical tools, handling AI based tools, etc.

Elective Courses (Any one)	
CNN 605-A	Explore and make students aware about the principles and applications of nanotechnology especially in highly sophisticated fields for e.g. space and defense.
CNN 605-B	Explore and make students aware about the principles and applications of nanotechnology in energy storage and generation.
CNN 605-C	Explore and make students aware about the principles and applications of nanotechnology in food, agriculture and medicine.
CNN 605-D	Develop various skill sets in students for computing, modeling and interfacing various gadgets.
SEMESTER IV	
Mandatory Courses	
CNN 611	Explore and make students aware about the principles and applications of nanophotonics, bio photonics and their applications in various areas.
CNN 612	Explore and make students aware about new area of technologies based on MEMS/NEMS looking at great demands from the upcoming industries i.e. 4.0 and 5.0.
CNN 613	Understanding how various electronic/semiconductor devices actually work followed by ability developed to analyze various electric circuits, design them to develop in house gadgets.
CNN 615	To develop the research aptitude in the students by exposing them with various research based projects that includes synthesis of nanomaterials, characterize and analyze them using highly sophisticated tools and demonstrate their actual application if any
Elective Courses (Any one)	
CNN 614-A	Explore and make students aware about the principles and applications of quantum devices their applications in various areas.
CNN 614-B	Explore and make students aware about the principles and applications of nanomagnetism, magnetic devices and their applications in various areas.
CNN 614-C	Comprehensive understanding towards principles and applications of nanotechnology in electrochemical water desalination, focusing on capacitive deionization (CDI) technology.
CNN 614-D	Develop advanced skill sets in students towards computing, modeling and interfacing gadgets.

Syllabus for SEM III & IV

Semester III			
Mandatory Subjects			
Sr. No.	Course Name and Code:	Proposed syllabus	Credits
1	Advanced Instrumentation techniques (CNN 601)	Objective(s) of the course: The course aims to provide the student with an overview of the current techniques used for the physicochemical characterization of materials with special reference to the principles, practice and applications of X-ray diffraction, microscopic, electrical, magnetic and thermal techniques. Microscopic and spectroscopic characterization techniques (30L) Microscopy (30L): Overview of Optical Microscopy, Advancement in Optical Microscopic techniques such as Fluorescence Microscopy, Confocal Microscope, Super Resolution Microscopy (STED, RESOLFT). Applications of Optical Microscopy, Overview of Electron Microscopy (SEM & TEM), Instrumentation & Imaging in SEM, Image Artefacts and Troubleshooting, Specialized SEM Techniques, Introduction to Focused Ion Beam (FIB) SEM, Interaction Overview & Sputtering in FIB SEM, Instrumentation, Imaging & its Artefacts, Applications of FIB SEM, Environmental SEM (ESEM), Introduction to Energy Dispersive Spectroscopy (EDS), X -Ray generation, Kramer's Law, Moseley's Law, X - Ray detection by EDS, Qualitative & Quantitative EDS X - Ray microanalysis using SEM, Limitations of its analysis, X - Ray Mapping and its Artefacts, Atomic Probe Tomography (APT), AFM Instrumentation, Operation and Imaging, Force Spectroscopy, AFM imaging modes, Tip, Image and Scanner Artefacts, Phase Imaging, Overview of STM, STM of Clean surfaces and Applications of Scanning tunneling spectroscopy (fixed position, varying bias voltages) and Applications of STM. Overview of TEM, Instrumentation and its problems, Imaging in TEM, Diffraction in TEM, Kikuchi Diffraction, SAD patterns, CBED, HRTEM. Introduction to STEM, STEM detectors and its imaging modes, Electron Energy Loss Spectroscopy (EELS), TEM sample preparation. Methods of material characterization Techniques (30L): X-Ray Diffraction: Production & Absorption of X - Rays, X-ray diffraction: Principle, measuring system and applications for characterization of powdered materials. X-ray diffraction profile and analysis: FWHM and line broadening, Crystallite size effect and Scherrer formula, Effect of strain (tensile vs compressive, uniform vs. non-uniform), Basic Crystallography, Indexing and Identification of planes and Directions, X-Ray Reflectometry (XRR), Small Angle X Ray Scattering (SAXS), Grazing Incidence X-Ray Diffraction	4

		(GIXRD), Texture, Phi scans, Pole figures, High Resolution XRD, Reciprocal space mapping, High Temp XRD, Low Temp XRD Electrical Properties: Two Probe and Four Probe Resistivity technique, Impedance measurements at Low & High frequencies, Hall effect, Vander paw's method for Resistivity measurements. Thermal Measurements: Heat Capacity, Thermal Conductivity, Thermal transport measurements at Low & High temperatures. Thermo-electric Materials and their properties Magnetic Properties: Magnetic Materials, Microscopic picture of magnetic materials, Magnetic moment measurements, ZFC, FC measurements at different temperatures, AC Susceptibility, Torque magnetometry. Electrical and Thermal properties under the presence of magnetic field, Vibrating Sample Magnetometer (VSM), Kerr Effect Magnetometer (MOKE). List of Reference Books Suggested: 1. An Introduction to Electron Microscopy & Instrumentation, Imaging & Preparation, by Andres Kaech. 2. Principles of Instrumental Analysis, D. A. Skoog, F. J. Holter and S. R. Crouch, Thomson Brooks/Cole, 2007. 3. Instrumental Methods of Analysis, Hobart H. Willard, John A. Dean, Lynne L. Merritt D. Van Nostrand Company. 4. Elements of X-ray diffraction, B. D. Cullity, Creative Media Partners, LLC.	
2	Physics of semiconductors -I (CNN 602)	Objective(s) of the course: 1. To make students familiar with semiconductor materials and various devices fabricated using them. 2. To make students aware about various transport phenomena of different devices. Energy Band in Solids (15 Lectures) Energy spectra in atoms, molecules and solids, the Bloch theorem, band symmetry in k-space, Brillouin zones, free electron model, the energy gap, tight binding model, calculations of energy bands, metals, insulators and semiconductors, density of states, Fermi surface, charge dynamics in electric field, effective mass, electrical conductivity, charge dynamics in magnetic field, experimental methods to determine band structure. Theory of semiconductors (15 Lectures) Introduction, crystal structure and bonding, energy bands and energy gap, impurity states, semiconductor statistic, carrier concentration, mobility, carrier transport phenomena, electrical field effects, magnetic field effects, band structure of real semiconductor, high electric field and hot electrons, the Gunn effect, optical properties, absorption processes, photoconductivity, luminescence, other effects. Device Building Blocks I (15 Lectures): Phonon, optical and thermal properties, heterojunction and nanostructures, basic equations and examples, p-n junctions,	4

		depletion region, current-voltage characteristics, junction breakdown, transient behaviour and noise, thermal junctions, heterojunction, p-n junction rectifier, tunnel diode, Gunn diode Zinner diode. Device Building Blocks II (15 Lectures): Metal semiconductor contacts: formation of barrier, current transport process, measurement of barrier height, device structures, ohmic contacts Metal Insulator Semiconductor Capacitors: introduction, ideal MIS capacitor, silicon MOS capacitor Transistor: introduction, bipolar transistor, static characteristics, device structure List of Reference Books Suggested: 1. Physics of semiconductor devices, S. M. Sze and Knok J. NG, Wiley-Interscience, A John Wiley and Sons , INC Publication 2. Elementary solid state physics: Principles and Application, Ali Omar, Addison Wesley Publishing Company 3. Semiconductor Physics And Devices, Donald Neamen, McGraw-Hill Higher Education 4. Physics of Semiconductor Devices, Simon M. Sze, Yiming Li, Kwok K. Ng, John Wiley & Sons	
3	Fundamentals of spectroscopy (CNN 603)	Objective(s) of the course: 1. Understand the principles, techniques, and applications of various spectroscopic methods including UV-Vis, IR, NMR, and Mass Spectrometry. 2. Develop skills in interpreting spectroscopic data, determining molecular structures, and analyzing biomolecules, while staying updated with emerging trends in spectroscopy. Introduction to Spectroscopy (15L): Overview of spectroscopy techniques: Absorption spectroscopy, emission spectroscopy, fluorescence spectroscopy, Raman spectroscopy, X-ray spectroscopy; Historical development of spectroscopy: Contributions of notable scientists, evolution of instrumentation; Basic principles and concepts: Energy levels, transition probabilities, Beer-Lambert law, spectral resolution; Interaction of light with matter: Absorption, emission, scattering, reflection, transmission; Types of spectroscopy (UV-Vis, IR, NMR, Mass Spectrometry): Principles, applications, limitations; Spectroscopic instrumentation and techniques: Components of spectrometers, data acquisition methods, calibration techniques. Spectroscopic Methods and Applications (15 L) UV-Visible Spectroscopy: Beer's law, molar absorptivity, UV-Vis spectra interpretation, applications in quantitative analysis; Infrared Spectroscopy: Vibrational modes, IR spectra interpretation, functional group analysis, applications in organic chemistry and materials science; Nuclear Magnetic Resonance (NMR) Spectroscopy: Chemical shifts, coupling constants, NMR spectra interpretation, 1D and 2D NMR techniques, applications in structural elucidation; Mass Spectrometry:	4

		Ionization techniques, mass analyzers, fragmentation patterns, mass spectra interpretation, applications in molecular weight determination and identification; Application of spectroscopic techniques in chemical analysis, materials science, environmental science, and biochemistry: Case studies, real-world applications, interdisciplinary approaches Molecular Structure Determination (15 L) Molecular symmetry and spectroscopy: Symmetry elements, point groups, symmetry operations, group theory in spectroscopy; Interpretation of spectroscopic data: Peak assignments, spectral analysis software, databases; Structural elucidation using spectroscopic techniques: Combining spectroscopic data, spectroscopic structure determination workflow; Chemical shifts, coupling constants, and spectral analysis in NMR: Factors influencing chemical shifts, J-coupling patterns, 2D NMR correlation spectroscopy; Spectroscopic characterization of organic and inorganic compounds: Functional group analysis, spectral fingerprints, interpretation challenges; Spectroscopic methods in determining molecular geometry and electronic structure: Bond lengths, bond angles, hybridization states, electronic transitions Advanced Topics in Spectroscopy (15 L) Time-resolved spectroscopy: Ultrafast techniques, transient spectra, reaction kinetics studies; Surface-enhanced spectroscopy: Surface plasmon resonance, SERS, applications in nanotechnology and bio sensing; Spectroscopic imaging techniques: FTIR imaging, Raman imaging, fluorescence imaging, applications in materials characterization and biomedical imaging; Chiroptical spectroscopy: Circular dichroism, optical activity, applications in chirality determination and structural analysis; Spectroscopic studies of biomolecules (proteins, nucleic acids, carbohydrates): Protein folding studies, DNA/RNA conformation analysis, carbohydrate structure elucidation; Emerging trends and developments in spectroscopy: Single-molecule spectroscopy, quantum spectroscopy, spectroscopy in nanomaterials and nanomedicine. <u>List of Reference Books Suggested:</u> 1. Principles of Instrumental Analysis, 7 th Edition, Douglas A. Skoog, F. James Holler, Stanley R. Crouch, ISBN: 9789353506193 2. Fundamentals of Molecular Spectroscopy, Prabal Kumar Mallick, ISBN 978-981-99- 0790-8 3. Fundamentals of molecular spectroscopy, Colin N. Banwell and Elaine M. McCash, Tata McGraw Hill, 2006, 4 th Edition, ISBN: 0074620258	
--	--	---	--

4	Practical III (CNN 604)	Objective(s) of the course: 1. To give comprehensive exposure to the students regarding various materials; crystalline, non- crystalline materials, crystal structure and their defects. 2. To provide basic understanding to identify materials and their physical as well as chemical properties. List of practical's 1. Fabrication of electrical contacts for electronic 2. Understanding transport properties of two terminal devices for e.g. resistor, diode, photodiode, etc. 3. Deposition of active materials using various deposition techniques. 4. Characterization of nanomaterials using various techniques	2
5	Short Term Project (CNN 606)	Objective(s) of the course: 1. To develop the research methodology skills in the students by exposing them with various short term project that mainly include literature survey, using statistical tools, handling AI based tools, etc.	4
Electives			
6	Nanotechnology in space and defense (CNN 605-A)	Objective(s) of the course: 1. Explore the principles and applications of nanotechnology in space exploration, satellite technology, and defense systems. 2. Develop expertise in nanomaterials, nanosensors, and nanoelectronics for space missions, spacecraft construction, and military defense applications. Introduction to Nanotechnology in Space and Defense: (15 Lectures) Overview of nanotechnology applications in space exploration and defense systems; Historical development and milestones in nanotechnology for aerospace and defense; Fundamentals of nanomaterials: Nanoparticles, nanocomposites, nanofibers, nanotubes, and their properties; Nanoscale characterization techniques: Scanning electron microscopy (SEM), transmission electron microscopy (TEM), atomic force microscopy (AFM); Nanostructured materials for space applications: Lightweight materials, thermal protection systems, radiation shielding; Nanotechnology in defense: Nanosensors, nanomaterials for ballistic protection, stealth technology. Nanomaterials for Spacecraft and Satellite Applications: (15 Lectures) Nanomaterials for spacecraft construction: Carbon nanotubes, graphene, nanocomposites; Nanostructured materials for thermal management in space vehicles: Nanofluids, phase change materials, thermal barrier coatings; Nanotechnology in space propulsion: Nanofuels, nanoscale thrusters, propulsion systems optimization; Nanomaterials for satellite technologies:	4

	Miniaturization, lightweight components, radiation-hardened materials; Nanoscale electronics for space applications: Nanocircuits, MEMS devices, radiation-resistant electronics. Nanotechnology in Space Exploration: (15 Lectures) Nanoscale sensors and instruments for space missions: Remote sensing, environmental monitoring, planetary exploration; Nanomaterials for space habitats and life support systems: Water purification, air filtration, waste management; Nanobiotechnology in space: Biomedical applications, drug delivery systems, regenerative medicine; Nanoscale robotics and automation for space exploration: Nanobots, autonomous systems, space assembly technologies; Nanotechnology-enabled spacecraft propulsion: Solar sails, ion thrusters, advanced propulsion concepts Nanotechnology in Defense and National Security: (15 Lectures) Nanosensors and nanomaterials for defense applications: Chemical, biological, radiological, and explosive (CBRE) detection; Nanotechnology in military equipment and vehicles: Lightweight armor, smart textiles, energy-efficient systems; Nanomaterials for ballistic protection and impact resistance: Bulletproof materials, impact-absorbing structures; Nanotechnology in cybersecurity and information warfare: Quantum cryptography, secure communication systems; Future trends and challenges in nanotechnology for space and defense: Ethical considerations, regulatory frameworks, global collaborations List of Reference Books Suggested: 1. Nanotechnology in Space, 1st Edition, Maria Letizia Terranova, Emanuela Tamburri, ISBN 9789814877541 2. Nanotechnology in the Defense Industry: Advances, Innovation, and Practical Applications, Madhuri Sharon, Angelica Silvestre, Lopez Rodriguez, Chetna Sharon and Pio Sifuentes Gallardo, ISBN 978-1-119-46012-1	
Nanotechnology in energy and power storage devices (CNN 605-B)	Objective(s) of the course: 1. Explore the principles and applications of various energy and power storage devices. Basics of Electrochemistry: (15 Lectures) Introduction and overview of electrode process, potential and thermodynamics of cell, kinetics of electrode reaction, mass transfer by migration and diffusion, basic potential step methods, potential sweep methods, polarography and pulse voltammetry, controlled current techniques, concept of impedance. The Governing Equations: Faraday Nernst and Butler Volmer , Chlor Alkali and Electrolysis, Corrosion, Pourbaix diagrams. Batteries:: (15 Lectures)	4

		[A] Batteries with Aqueous electrolyte – General Aspect, Types of batteries including Pb, Ni, cad, NIMH, Lithium batteries, Electrical Characterization of batteries, Miscellaneous batteries (reserve batteries, compound batteries etc.), Design parameters including scale factor, separators, sealing, Ohmic losses, thermal process in batteries. General aspect of battery maintenance. [B] Batteries with non-aqueous electrolytes: Different kind of electrolytes, 1) Primary Li Battery- design, fundamentals, electrical and operational characterizations. 2) Li-Ion Batteries- basics, characterizations. 3) Alternative to Li-Ion batteries- Li-Air, Li-Sulphur and Na ion batteries. 4) Solid state batteries, 5) batteries with molten salt electrolytes. Supercapacitors: (15 Lectures) Electrochemical capacitors and supercapacitors: ideal electrostatic capacitor, electrolytic capacitor, double layer capacitor, pseudo-capacitor, and impedance of supercapacitor, electrochemical Transducers. Fuel Cells and other electrochemical systems: (15 L) Introduction, efficiency and open circuit voltage, operational fuel cell voltage, Details about various types of fuel cells including Proton exchange membrane fuel cell (PEMFC), Direct Liquid fuel cell with gaseous, liquid and/or solid reagents, Molten Carbonate fuel cell (MCFC), Solid oxide fuel cells (SOFC), Alkaline electrolyte fuel cells (AFC), Direct Methanol fuel cell, Medium and High Temperature fuel cells, other types of fuel cells. Fuel cells as electrolyzers, Applications of fuel cells. Concepts of electro-catalysis, Photo electrochemistry and bio-electrochemistry with an example. <u>List of Reference Books Suggested:</u> 1. J. Bard, and L. R. Faulkner, Electrochemical Methods: Fundamentals and Applications, Wiley, 2001. 2. R. Huggins, Advanced Batteries: Materials Science Aspects, 2008. 3. V. S. Bagotsky, Fundamentals of electrochemistry, 2nd ed., 2006. 4. J. Larminie and A. Dicks, Fuel Cell Systems Explained, 2nd ed., 2003. 5. J. Newman, and K. E. Thomas-Alyea, Electrochemical Systems, 3rd ed., 2004. 6. M. Mench, Fuel Cell Engines, Wiley, 2008. 7. G. A. Prentice, Electrochemical Engineering Principles, 1990. 8. M. Root, The TAB Battery Book: An In-Depth Guide to Construction, Design, and Use, Tab Electronics, 2011. 9. A.C. West, Electrochemistry and Electrochemical Engineering. An Introduction, 2012.	
--	--	---	--

5	Nanotechnology in medical, Nanotechnology in medical, food and agriculture sector food and agriculture sector (CNN 605-C)	Objective(s) of the course: 1. Explore the principles and applications of nanotechnology in medical, food and agriculture sectors. Agricultural Nanotechnology: (15 L) Conventional Farming: Issues and Limitations, Intensive Conventional Farming Affects Environment, Current Agricultural Production Systems, Nanotools -Nanoprocesses, and Nanomaterials Production of Bionanomaterials from Agricultural Wastes:Cellulose and Nanocellulose from Citrus and Orange Wastes, Synthesis of Graphene Oxide from Agrowastes, Production of Amorphous Silica Nanoparticles from Agrowastes, Carbon Nanomaterials from Agrowastes, Nanoengineering Superabsorbent Materials in Agriculture: Introduction, Formation and Structure of Cross-Linked Polyacrylates, Formation and Structure of Cross-Linked Polyacrylates; Statistical Models, Mechanisms of Swelling in Superabsorbent Polymers, Mechanisms of Swelling in Superabsorbent Polymers; Hydration, Hydrogen Bonds, Properties of Superabsorbent Polymers, Absorption of Aqueous Solution, Moisture Absorption Superabsorbent Polymers Application in Agriculture, Superabsorbent/Clay Nanocomposites. Nanotechnology in plant protection (15 L) Nanotechnology and Their Applications in Insect's Pest Control; Formulations of Nanoinsecticides- Nanoemulsions, Components, Preparation, Types and Methods, Nanoparticle-Based Plant Disease Management; Interactions between NPs, Pathogens, and Plants, Plant Disease Diagnosis Using different NPs, Nanotechnology in Microbial Plant Pathogen and insect Management, Nanoantimicrobials Mechanism of Action, Chitosan-Based Nanostructures in Plant Protection.; Synthesis and characterization of NPs and Nanocomposite Copper Nanostructures Applications in Plant Protection, Nanosensors for Monitoring Soil Conditions and Environmental Stresses; Carbon Nanotube, Nanoaptamers, Smart Dust Technology, Nanocapsules for Efficient Delivery of Pesticides, Fertilizers and Agrochemicals; Targeted Delivery of Agrochemicals Using Nanotechnology, Nanobased Pesticides in Agriculture, Nano-based Fertilizer Efficiency, Improving Plant Traits against Environmental Stresses Using Nanotechnology, Nanotechnology and Its Applications in Water Conservation Nanoparticles in food production and diagnostics (15 L) Food and New Ways of Food Production - Efficient Fractionation of Crops Efficient Product Structuring -Optimizing Nutritional Values - Applications of Nanotechnology in Foods : Sensing, Packaging, Encapsulation, Engineering Food Ingredients to Improve Bioavailability – Nanocrystalline 18 Food Ingredients -	4
---	---	--	---

		Nanoemulsions - Nano-Engineered Protein Fibrils as Ingredient Building Blocks Preparation of Food Matrices - Concerns about Using Nanotechnology in food production. Diagnostics Enzyme Biosensors and Diagnostics - DNA- Based Biosensors and Diagnostics Radiofrequency Identification- Integrated Nanosensor Networks: Detection and Response- Lateral Flow (Immuno) assay - Nucleic Acid Lateral Flow (Immuno) assay - Flow-Through (Immuno) assays - Antibody Microarrays Surface Plasmon Resonance Spectroscopy. Nanotechnology in food packaging (15 L) Crop improvement - Reasons to Package Food Products - Physical Properties of Packaging Materials - Strength - Barrier Properties Light Absorption – Structuring of Interior Surfaces – Antimicrobial Functionality - Visual Indicators – Quality Assessment - Food Safety Indication - Product Properties - Information and Communication Technology - Sensors - Radiofrequency Identification Technology- Risks - Consumer and Societal Acceptance. List of Reference Books Suggested: 1. Nanobiotechnology Applications in Plant Protection by Kamel A. Abd-Elsalam and Ram Prasad, Volume 2, Springer, 2018. 2. Nanotechnology an Agricultural Paradigm by Ram Prasad, Manoj Kumar, Vivek Kumar Springer, 2017. 3. Nanoscience in Food and Agriculture by Shivendu Ranjan, Volume 1, Springer, 2016. 4. Nanotechnology and Plant Sciences by Manzer H. Siddiqui, Springer, 2015. 5. Nanoparticle Assemblies and Superstructures by Nicholas A. Kotov, CRC, 2006. 6. Nanotechnology in agriculture and food production by Jennifer Kuzma and Peter VerHage, Woodrow Wilson International, 2006. 7. Bionanotechnology by David S Goodsell, John Wiley & Sons, 2004. 8. Nanobiomaterials Handbook by Balaji Sitharaman, Taylor & Francis Group, 2011.	
6	Interfacing and machine learning-I (CNN 605-D)	Objective(s) of the course: 1. Learn mathematical foundations of various machine learning techniques. Applications of these techniques for standard examples with Python codes. Learn fundamentals of digital electronics for controls and interfacing. Classification and Regression (15 Lectures): Supervised learning, Un-supervised learning, Binary classification, Various performance measures: Cross-Validation, Confusion Matrix, Precision and Recall, The ROC Curve, Linear regression, The Normal Equation, Computational Complexity.	4

		Training Models (15 Lectures): Gradient Descent, Batch Gradient Descent, Stochastic Gradient Descent, Mini-batch Gradient Descent, Polynomial Regression, Learning Curves, Regularized Linear Model, Ridge Regression, Lasso Regression, Elastic Net, Early Stopping, Regression for classification: Logistic Regression, Estimating Probabilities, Training and Cost Function, Decision Boundaries, Softmax Regression. Clustering and anomaly detection (15 Lectures): Support vector machines (SVM), linear SVM classification, soft margin classification, SVM regression, Training and Visualizing a Decision Tree, Making Predictions, Estimating Class Probabilities, The CART Training Algorithm, Regularization Hyperparameters, Random Forest classification. Flip-flops, Registers and Memories(15 Lectures): Digital gates: NOT, OR, AND, NOR, NAND, Flip-flops: RS, Gated, Edge triggered, JK Master-slave, Registers: serial in - serial out, serial in - parallel out, parallel in - serial out, parallel in - parallel out, Shift register, Memories: RAM, ROM, Static RAM, Dynamic RAM, Masked ROM, PROM, EPROM. Reference Books: 1. Hands-on Machine Learning with Scikit-Learn, Keras and Tensorflow by A. Geron Third Edition, O'reily Media Inc. 2. Practical Machine learning with Python by D. Sarkar, R. Bali and T. Sharma, Apress publications 3. Fundamentals of Machine Learning for Predictive Data Analytics by J. D. Kelleher, B. M. Namee, and A. D'Arcy, The MIT Press 4. Real World Instrumentation with Python: Automated Data Acquisition and Control Systems by John M. Hughes, O'reily Media Inc. 5. Digital Interface Design and Application by J. A. Dell, Wiley, UK	
Total Credits			22

Semester IV			
Sr. No.	Course Name and Code:	Proposed syllabus	Credits
Mandatory Subjects			
1	Nano- Photonics and Biophotonics (CNN 611)	Objective(s) of the course: 1. The course provides different opportunities to students having diverse background with a well-defined narrow focus. 2. The proposed course work can may students aware about the fusion of nanotechnology and photonics which is an emerging frontier providing challenges for fundamental research and opportunities towards building new technologies. Foundation of nanophotonics (15 L): Photons and Electrons (similarity and differences), Nanoscale Optical Interactions (Axial and lateral Nanoscopic Localization), Confinement of Electronic Interactions (quantum confinement effect, Interaction Dynamics, Electronic Energy Transfer, Emissions), Near field interactions (Near-Field Optics, Theoretical Modeling of Near-Field Nanoscopic Interactions, Near-Field Studies: Quantum Dots, Quantum wells, Quantum Wires, Quantum Ring, Quantum confinement (optical properties, Nonlinear Optical Properties, Quantum-Confined Stark Effect, Dielectric Confinement Effect) Photonic Crystals (15 L): Introduction, Basics Concepts, Theoretical Modeling of Photonic Crystals, Features of Photonic Crystals, Methods of Fabrication, Photonic Crystal Optical Circuitry, Nonlinear Photonic Crystals, Photonic Crystal Fibers (PCF), Photonic Crystals and Optical Communications, Photonic Crystal Sensors; Plasmonics (Introduction, Local Field Enhancement, Plasmonic Wave Guiding, Radiative Decay Engineering) Biomaterials and Nanophotonics (15 L): Bioderived Materials, Bioinspired Materials, Biotemplates, Bacteria as Biosynthesizers, Near-Field Bioimaging, Nanoparticles for Optical Diagnostics and Targeted Therapy, Semiconductor Quantum Dots for Bioimaging, Nanophores for Bioimaging, Biosensing, Nanophotonics for Optical Diagnostics, Targeted Therapy, Gene Delivery and Photodynamic Therapy Nano/bio photonics and their applications (15 L): Coating, Sunscreens, Self-Cleaning, Nano-barcodes, Lasers and Photonic devices, Near-Field Microscopy, Power Generation and Conversion, Information Technology, Sensor Technology, Nano-medicine List of Reference Books Suggested: 1. Nanophotonics, P Prasad, A John Wiley & Sons, Inc., publication. 2. Advances In Biophotonics, (Eds.) Brian C. WilsonValery V. Tuchin and Stoyan Tanev, IOS Press, ISBN 1-58603-540-1, (2005). 3. Biophotonics, Optical Science and Engineering for the 21st Century, (Ed.) Xun Shen and Roeland Van Wijk, ISBN-10: 0-	4

		387-24995-8; ISBN-13: 978-0387-24995-7; eISBN: 0- 387-24996-6. 4. Nano Biophotonics: Science and Technology, (Eds) Hiroshi Masuhara, Satoshi Kawata and Fumio Tokunaga, ISBN-13: 978-0-444-52878-0; ISBN-10: 0-444- 52878-4, Elsevier (2007).	
2	MEMS/NEMS and Microsystems (CNN 612)	Objective(s) of the course: 1. The students are expected to possess the knowledge a comprehensive overview about new area of technology which is in high demand looking at the great demands from the 4.0 industry. Overview of MEMS and microsystems: (15 Lectures) Introduction, MEMs and microsystems, fabrication of microsystem, microsystems and microelectronics, miniaturization of microsystems, application of microsystems in automotive, healthcare, aerospace, telecommunication, etc. Working of microsystems: (15 Lectures) Introduction, micro sensors (acoustic wave sensors, biomedical sensors and biosensors, chemical sensors, optical sensors, pressure sensors, thermal sensors); Micro-actuation (Actuation using thermal forces, shape memory alloys, piezoelectric crystals, electrostatic forces, magnetic forces); MEMS with micro actuators (Microgripper, micro-motors, micro-valves, micro-pumps); Micro-accelerometers, Microfluidics Materials for MEMS and manufacturing: (15 Lectures) Substrates and wafers, active materials for e.g. Si, quartz, GaAs, piezoelectric crystals, polymers, packaging materials, photolithography, ion implantation, diffusion, oxidation, bulk micro-manufacturing, surface micro-manufacturing, LIGA process Microsystem design and packaging: (15 Lectures) Design consideration (selection of material, manufacturing process, signal transduction), process design, mechanical design using finite element method, design of microfluidic network systems, computer added design, mechanical packaging of microelectronics, microsystem packaging, interfaces in microsystem packaging, essential packaging technologies (die preparation, surface bonding, wire bonding, sealing), 3-D packaging, assembling microsystems. List of Reference Books Suggested: 1. MEMS and Microsystems design and manufacture, T. R. Hsu, Tata McGraw Hill Publishing Company Ltd. 2. MEMS: A practical guide to design, analysis and applications, J. G. Korvink and O. Paul, William Andrew Publishing. 3. MEMS/NEMS Sensors Fabrication and Application, G. Koley, MDPI. 4. MEMS/NEMS Handbook Techniques and Applications, C. T. Leondes, Springer.	4

4	Practical III (CNN 613)	Objective(s) of the course: 1. To give comprehensive exposure to the students regarding various materials; crystalline, non- crystalline materials, crystal structure and their defects. 2. To provide basic understanding to identify materials and their physical as well as chemical properties. List of practical's 1. Understanding quantum hall effect. 2. Understanding various exchange interactions in magnetic materials 3. Synthesis of magnetic alloys by chemical route. 4. Synthesis of magnetic materials by sputtering method.	2
5	Research Project (CNN 616)	Objective(s) of the course: 1. To develop the research aptitude in the students by exposing them with various research based projects that includes synthesis of nanomaterials, characterize and analyze them using highly sophisticated tools and demonstrate their actual application if any	8
Minor (Electives)			
6	Quantum electronic devices (CNN 614-A)	Objective(s) of the course: 1. To make students familiar with the physics of various quantum structures. 2. To make students aware about principles and working of special quantum electronics devices. Quantum physics : (15 Lectures) Introduction, Schrodinger wave equations, Harmonic oscillator, Schrodinger equation in spherically symmetric potentials, Angular operators and eigen functions, matrix formation (representation of operators as matrices, transformation, deriving eigen functions and eigen values of an operators using matrix method, Heisenberg equation of motion, matrix elements as angular momentum operator, spin angular momenta, addition of angular momentum, time independent perturbation theory, density matrix), Lattice vibrations, electromagnetic fields and their quantization, Physics of quantum structures: (15 Lectures) Introduction to quantum structures (i.e. Quantum Dots, Quantum wells, Quantum Wires, Quantum Rings, etc.), Density of States of quantum structures, optical properties of quantum structures, quantum confinement, Nonlinear optical properties, Quantum-Confined Stark Effect, Dielectric confinement effect), Optical resonators, Laser oscillation Specific quantum systems I: (15 Lectures) Types of lasers (Introduction, optical pumping, He-Ne laser, ruby laser, Nd:YAG laser, Neodymium glass laser, CO ₂ laser, Organic dye laser, semiconductor diode lasers, quantum cascade laser, quantum well lasers, free electron lasers, etc.); Laser dynamics, Laser Stability and Relaxation, Laser Efficiency	4

		Specific quantum systems II: (15 Lectures) Short pulse generation by Q-Switching, Mode locking in homogeneous and inhomogeneous laser systems, oscillations in lasers, noise and spectra of laser amplifiers and oscillators, optical fibers (waveguide modes, characteristics of planer waveguide, propagation in optical fibers) List of Reference Books Suggested: 1. Quantum electronics, Ammon Yariv, A John Wiley and Sons. 2. Electronic and Photonic Quantum Devices, Erik Forsberg, Printed by Universitetsservice AB, Stockholm 2003, ISBN 91-7283-446-3. 3. Physical Foundations of Quantum Electronics, by David Klashko, Published by World Scientific Publishing Co. Pte. Ltd.	
	Nanomagnetic Materials and Devices (CNN 614-B)	Objective(s) of the course: 1. Explore the principles and applications of nanomagnetic materials for various devices. Introduction to Magnetism Introduction to magnetic materials, magnetic dipoles and dipole moments, Bohr magneton, magnetic susceptibility and permeability, classification of magnetic materials, temperature dependent susceptibility, classical considerations and magnetic moments, atomic diamagnetism and paramagnetism, Bohr-van Leeuwen theorem, quantum considerations: orbital and spin angular momentum, Hund's rule. Magnetic Interactions Model of free electrons, Pauli's paramagnetism, spontaneous spin split states, magnetic dipole interactions, direct and indirect exchange interactions (superexchange interactions, RKKY exchange interactions, double exchange interactions), excitations in electron gas, collective magnetism, ferromagnetic and anti-ferromagnetic ordering, ferrimagnetic ordering, helical ordering, spin glasses. Symmetry Broken symmetry: Different models of magnetic behaviour, Landau theory of ferromagnetism, Heisenberg Model, 1D 2D and 3D Ising model, consequences of broken symmetry, phase transition, rigidity, magnetic excitations: Magnons, Domains and domain walls, magnetization processes. Magnetic Devices and Applications Spintronic and spintronic materials and devices: Magnetoresistance, giant magnetoresistance, colossal magnetoresistance, hall effect, magnetic random access memory devices, read heads, sensors. List of Reference Books Suggested: 1. Fundamentals of magnetism, Mathias Getzlaff, Springer 2. Magnetism in condensed matter physics, Stephen Blundell, Oxford University Press. 3. Introduction to magnetism, B. D. Cullity and C. D. Graham, Wiley.	4
	Interfacing and machine learning-II (CNN-614-D)	Objective(s) of the course:	4

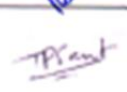
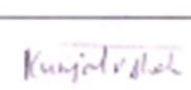
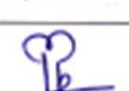
		1. Learn mathematical foundations of various machine learning techniques. Applications of these techniques for standard examples with Python codes. Learn fundamentals of digital electronics for controls and interfacing. Deep learning and neural networks (15 Lectures): From Biological to Artificial Neurons, Logical Computations with Neurons, The Perceptron, Multi-Layer Perceptron and Backpropagation, Training a Deep Neural Network, Fine-Tuning Neural Network Hyperparameters, Number of Hidden Layers, Number of Neurons per Hidden Layer, Activation Functions D/A, A/D converters, Counters and Timers (15 Lectures): Variable, Resistor networks, Binary ladders, D/A converters, A/D converters: different techniques, Synchronous, Asynchronous counters, Digital Clock, Serial I/O, Parallel I/O Physical Interfaces (15 Lectures): Connectors: DB-Type Connectors, USB Connectors, Circular Connectors, Terminal Blocks, Serial Interfaces, RS-232/EIA-232, RS-485/EIA-485, GPIB/IEEE-488, GPIB/IEEE-488 Signals and Connections, GPIB via USB, PC Bus Interface Hardware, Data Acquisition Cards, GPIB Interface Cards. Applications of Interfaces (15 Lectures): Text-Based Interfaces, The Console, ANSI Display Control Techniques, Graphical User Interfaces, Some GUI Background and Concepts, Using a GUI with Python, TkInter, wxPython, Serial Interfaces, Serial Interface Discrete and Analog Data I/O Devices, Serial Interfaces and Speed Considerations List of Reference Books Suggested: 1. Hands-on Machine Learning with Scikit-Learn, Keras and Tensorflow by A. Geron Third Edition, O'reily Media Inc. 2. Practical Machine learning with Python by D. Sarkar, R. Bali and T. Sharma, Apress publications 3. Deep Learning by I. Goodfellow, Y. Bengio, A. Courville, The MIT Press 4. Real World Instrumentation with Python: Automated Data Acquisition and Control Systems by John M. Hughes, O'reily Media Inc. 5. Digital Interface Design and Application by J. A. Dell, Wiley, UK 6. Digital Principles and Applications by Leach and Malvino, McGraw Hill publications 7. Introduction to Microprocessors and Microcontrollers by J. Crisp, Newnes Elsevier publications	
	Nanotechnology in Electrochemical Water Desalination (CNN-614-E)	Objective(s) of the course: 1. To provide students with a comprehensive understanding of the principles and applications of nanotechnology in electrochemical water desalination, focusing on capacitive deionization (CDI) technology. 2. To equip students with the knowledge and skills necessary to analyze, design, and optimize nanomaterial-based electrodes and CDI systems for efficient removal of ions and pollutants from water, addressing environmental challenges and promoting sustainable water treatment solutions.	4

	Introduction to Nanotechnology in Water Desalination: (15 Lectures) Overview of nanotechnology applications in water treatment and desalination; principles of electrochemical desalination and capacitive deionization (CDI), electrical double layer (EDL) concept, Gouy-Chapman-Stern (GCS) layer; electrosorption concept; electrosorption performance metrics, salt adsorption capacity, salt adsorption rate, salt removal efficiency, desorption capacity, selectivity, coulombic efficiency, energy consumption; importance of nanomaterials in enhancing desalination efficiency, environmental and sustainability aspects of nanotechnology-based water treatment Nanomaterials for Capacitive Deionization Electrodes: (15 Lectures) Introduction to capacitive deionization (CDI) electrodes; properties and characteristics of nanomaterials used in CDI electrodes (e.g., carbon-based materials, metal oxides, graphene); synthesis methods and characterization techniques for CDI electrode materials, specific capacitance calculations, role of nanoscale architecture in improving ion adsorption and desorption Design and Architecture of Capacitive Deionization Systems: (15 Lectures) Design principles and configurations of CDI systems, factors influencing the performance of CDI systems (e.g., electrode spacing, flow rate, operating voltage), Adsorption isotherm fitting, including Langmuir adsorption isotherm and Freundlich adsorption isotherm, modified Donnan model Nanotechnology for Pollutant Removal in Wastewater: (15 Lectures) Overview of pollutants in wastewater (e.g., heavy metals, organic compounds, microorganisms), nanomaterial-based strategies for pollutant removal (e.g., adsorption, catalysis, membrane technologies), integration of CDI with conventional wastewater treatment processes, Case studies and examples of successful CDI applications in water desalination. <u>List of Reference Books Suggested:</u> 1. Capacitive Deionization 1st Edition, Xingtao Xu, Likun Pan, ISBN-13: 978-1839162367 2. Nanotechnology for Water Treatment and Purification, Anming Hu, Allen Apblett, ISBN 978-3-319-06577-9 3. Nanotechnology in Water and Wastewater Treatment: Theory and Applications, Amimul Ahsan and Ahmad Fauzi Ismail, ISBN 978-0-12-813902-8	
Total Credits		22

Team for Creation of Syllabus

M.Sc. in (Nanosciences and Nanotechnology) (SEM III & IV)

Team for creation of syllabus

Name	Name of Dept./Institute	Sign
Prof. Vishwanath PATil	National Center for Nanoscience and Nanotechnology, University of Mumbai	
Dr. Suhas M. Jejurikar	National Center for Nanoscience and Nanotechnology, University of Mumbai	
Dr. Pravin Walke	National Center for Nanoscience and Nanotechnology, University of Mumbai	
Dr. Tushar Sant	National Center for Nanoscience and Nanotechnology, University of Mumbai	
Dr. Kunjal Shah	National Center for Nanoscience and Nanotechnology, University of Mumbai	
Dr. Bhavesh Sinha	National Center for Nanoscience and Nanotechnology, University of Mumbai	
Dr. Kalpesh Bhavsar	National Center for Nanoscience and Nanotechnology, University of Mumbai	
Dr. Shreerang Datar	National Center for Nanoscience and Nanotechnology, University of Mumbai	
Dr. Prajakta Borgaonkar	National Center for Nanoscience and Nanotechnology, University of Mumbai	

Sign of Director



Prof. Vishwanath Patil
National center for Nanosciences and
nanotechnology

Sign of Dean,

Prof. Shivram Garje
Dean (Science)
University of Mumbai

Annexure I

University of Mumbai
Two Year Degree Course of M.Sc. (Nanosciences and Nanotechnology)
As per Choice Based Credit System (CBCS)
(With effect from the academic year 2023-2024)
Examination pattern for Semester III and IV

Semester III:

- a) Theory Paper** : 100 marks for each paper (Total theory papers 4)
 i) Internal examination : Total marks 50 (in each theory paper)
 ii) External examination : Total marks 50 (in each theory paper) Duration:
2 1/2 Hours
- 1) Total number of questions to be framed for theory paper in external examination is 7 of 10 marks each.
 - 2) Out of total 7 questions, students are required to attempt **any five** questions.
- b) Practical Paper** : 50 marks for one paper (Cr. 2)
(Out of total 50 marks in two credits practical, 40 marks for practical examination, 10 marks for journal writing and viva.)
- c) Short Term Project** : 100 marks
 i) Internal examination : Total marks 50 (Presentation)
 ii) External examination : Total marks 50 (Presentation followed by submission of detailed report in front of experts in the respective areas of projects)
- d) Marking system:**
- i) Total marks for theory: 4 Credits *5 theory papers =20 credits
 - ii) Total marks for practical: 2 credits for one practical papers
 - iii) Grand Total for Semester I is 22 credits**

Semester IV

- a) Theory Paper** : 100 marks for each paper (Total theory papers 3)
 i) Internal examination : Total marks 50 (in each theory paper)
 ii) External examination : Total marks 50 (in each theory paper) Duration:
2 1/2 Hours
- 1) Total number of questions to be framed for theory paper in external examination is 7 of 10 marks each.
 - 2) Out of total 7 questions, students are required to attempt **any five** questions.
- b) Practical Paper** : 50 marks for one paper (Cr. 2)
(Out of total 50 marks in two credits practical, 40 marks for practical examination, 10 marks for journal writing and viva.)
- c) Research Project** : 200 Marks (Cr. 8)
The evaluation of research project will be done as per the guidelines provided by the University of Mumbai, for e.g. students have
- 1) Completion the research project from recognized institutes/industries/NGOs, etc.

2) Every individuals have to submit the research report

d) Marking system:

- i) Total marks for theory: 4 Credits *3 theory papers =12 credits
- ii) Total marks for practical: 2 credits for one practical
- iii) Research Project: 8 Credits
- iv) **Grand Total for Semester II = 22 credits**

Total credits earned at the end M.Sc. first year (Semester III and Semester IV) would be 44.

Letter Grades and Grade Points

Semester GPA/ Programme CGPA Semester/ Programme	% of Marks	Alpha-Sign/ Letter Grade Result	Grading Point
9.00 - 10.00	90.0 - 100	O (Outstanding)	10
8.00 - < 9.00	80.0 - < 90.0	A+ (Excellent)	9
7.00 - < 8.00	70.0 - < 80.0	A (Very Good)	8
6.00 - < 7.00	60.0 - < 70.0	B+ (Good)	7
5.50 - < 6.00	55.0 - < 60.0	B (Above Average)	6
5.00 - < 5.50	50.0 - < 55.0	C (Average)	5
4.00 - < 5.00	40.0 - < 50.0	P (Pass)	4
Below 4.00	Below 40.0	F (Fail)	0
Ab (Absent)	-	Ab (Absent)	0



Sign of the BOS
Chairman
Dr. Vishwanath R. Patil
Ad-hoc BoS
Nanoscience &
Nanotechnology

Sign of the
Offg. Associate Dean
Dr. Madhav R. Rajwade
Faculty of Science &
Technology

Sign of the
Offg. Dean
Prof. Shivram S. Garje
Faculty of Science &
Technology