Savitribai Phule Pune University

(Formerly University of Pune)

Three Year B.Sc. Degree Program in

Nanoscience and Nanotechnology

(Faculty of Science & Technology)

S.Y.B.Sc.
(Nanoscience and Nanotechnology)

Choice Based Credit System Syllabus

To be implemented from Academic Year 2019-2020

Title of the Course: B.Sc. (Nanoscience and Nanotechnology)

Preamble:

The curriculum for the B. Sc. (Nanoscience and Nanotechnology) programme is designed to cater to the requirement of Choice Based Credit System following the University Grants Commission (UGC) guidelines. In the proposed structure, due consideration is given to Core and Elective Courses (Discipline specific - Nanoscience and Nanotechnology), along with Ability Enhancement (Compulsory and Skill based) Courses. Furthermore, continuous assessment is an integral part of the CBCS, which will facilitate systematic and thorough learning towards better understanding of the subject. The systematic and planned curricula from first year to the third year (comprised of six semesters) shall motivate the student for pursuing higher studies in Nanoscience and Nanotechnology and inculcate enough skills for becoming an entrepreneur.

Objectives:

- To foster scientific attitude, provide in-depth knowledge of scientific and technological concepts of Nanoscience and Nanotechnology.
- To enrich knowledge through problem solving, minor/major projects, seminars, tutorials, review of research articles/papers, participation in scientific events, study visits, etc.
- To familiarize with recent scientific and technological developments.
- To create foundation for research and development in Nanoscience and Nanotechnology.
- To help students to learn various experimental and computational tools thereby developing analytical abilities to address real world problems.
- To train students in skills related to research, education, industry, and market.
- To help students to build-up a progressive and successful career in Nanoscience and Nanotechnology.

Structure of the Course:

Subject Name	Year	Semester	Course Type	Course Code	Course Name	Credit
Nanoscience and Nanotechnology	1	I	Compulsory Course	NS-111	Fundamentals of Nanoscience	2
				NS-112	Materials Science	2
				NS-113	Nanoscience and Nanotechnology Laboratory-IA	1.5
		II	Compulsory Course	NS-121	Chemical and Biological Techniques for synthesis of nanomaterials.	2
				NS-122	Basic Characterization Techniques	2
				NS-123	Nanoscience and Nanotechnology Laboratory-IB	1.5
	2	III	Compulsory Course	NS-231	Physical Techniques for synthesis of Nanomaterials	2
				NS-232	Properties of Nanomaterials (Physical, chemical, Optical and Magnetic)	2
				NS-233	Nanoscience and Nanotechnology Laboratory-2A	2
			Ability Enhancement Compulsory Course	NS-2310	Environment –I	2
				NS-2311	Language-I	2
		IV	Compulsory Course	NS-241	Organic and polymer science of nanomaterials	2
				NS-242	Advanced Techniques for Characterization of Nanomaterials	2
				NS-243	Nanoscience and Nanotechnology Laboratory-2B	2
			Ability Enhancement Compulsory Course	NS-2410	Environment –II	2
				NS-2411	Language-II	2
	3	V		NS- 351	Polymer and Composites	2
				NS- 352	Nanophysics	2
				NS- 353	Nanobiotechnology	2
				NS- 354	Carbon Based Nanomaterials	2
				NS- 355	Energy Conversion Devices and Applications	2
				NS- 356	Elective I (Select any One)- Environmental nanotechnology and applications.	2
				NS- 357	Nanoscience and Nanotechnology Laboratory-3A	2

				NS- 358	Nanoscience and Nanotechnology Laboratory-3B	2
				NS- 359	Project	2
			Skill Enhancement Course	NS-3510	Data Analysis – I	2
				NS- 3511	Maintenance of Chemical synthesis lab. for Nanomaterials - I	2
		VI		NS- 361	Polymer Hetero-structure and their applications	2
				NS- 362	Functional Nanomaterials	2
				NS- 363	Applications of Nanobiotechnology	2
				NS- 364	Nanoelectronics	2
				NS- 365	Energy Storage Devices and Applications	2
				NS- 366	Elective II (Select any One) Photo catalysis for environmental pollution control	2
				NS- 367	Nanoscience and Nanotechnology Laboratory-4A	2
				NS- 368	Nanoscience and Nanotechnology Laboratory-4B	2
				NS- 369	Project	2
			Skill Enhancement Course	NS-3610	Data Analysis – II	2
				NS- 3611	Chemistry Lab. Safety protocols: Maintenance of Chemical synthesis lab. for Nanomaterials – II	2

Note:- Students should be complete at least one online course(2 credit) on basis of Nanoscience and Nanotechnology on swayam platform or any other National online platform(8 weeks) in entire 3 years.

SEMISTER-III

Course code and title: NS-231 Physical Techniques for Synthesis of Nanomaterials

Lectures: 36 **(Credits-02)**

Paper I (NS 211): PHYSICAL TECHNIQUES FOR SYNTHESIS OF NANOMATERIALS

Unit 1: Physical Methods **(24 Lecturers)**

a) Introduction

b) Mechanical techniques - Mechanical exfoliation using scotch tape, ultrasonic exfoliation, laser assisted exfoliation (mostly applicable to 2D nanomaterials), Ball Milling

c) Physical Vapour Deposition - Vacuum Evaporation, Sputter Deposition, Pulse Laser Deposition, Ion-beam Deposition (PLD), Molecular Beam Epitaxy (MBE) (mostly applicable for synthesis of nanostructures in thin film form), Electric-arc method (applicable for synthesis of nanostructures in powder form)

Unit 2: Hybrid Techniques (combination of physical, chemical, and/or biological methods) (12 Lectures)

Metallorganic Chemical Vapour Deposition (MOCVD), Plasma Enhanced Chemical Vapour Deposition (PECVD), Laser irradiation in liquids (liquid phase plasma synthesis)

Unit 3: Green Synthesis **(Lectures 12)**

Biological Synthesis of Nanoparticles, Microbial Routes for Nanoparticle Synthesis:- Actinomycetes, Algae, Bacteria, Fungi, Viruses, Yeasts,.

Biological Synthesis of Metal Nanoparticles via Plants.

Factors Affecting Biological Synthesis of Metal Nanoparticles:- Influence of pH, Influence of Reactant Concentration, Influence of Reaction Time, Influence of Reaction Temperature.

Major Nanoparticles Synthesized by Plant Extracts:- Gold and Silver Nanoparticles, Copper and Copper Oxide Nanoparticles, Palladium and Platinium Nanoparticles, Titanium Dioxide and Zinc Oxide Nanoparticles, Indium Oxide, Iron Oxide, Lead, and Selenium Nanoparticles.

Applications of Nanoparticles & Biologically Inspired Templates.

Reference Books:

- Nanotechnology: Principles & Practices. Sulbha K. Kulkarni, Capital Pub (3rd Edition)
- Nanostructures and Nanomaterials Synthesis, Properties and Applications, Guozhong Cao, imperials college Press, London.
- Nanaomaterils: Synthesis, properties and Applications. Edited by A. S. Edelstein & R. C. Commorata, Institute of Physics Publishing, Bristol & Philaldelphia.
- Nanotechnology, Technology revolution of 21st Century by Er.Rakesh Rathi(S.Chand & company Ltd.)

Course code and title: NS-232 Properties of Nanomaterials

Lectures: 36 **(Credits-02)**

Unit 1: Physics at Nanoscale (12 Lecturers)

Quantum size effect, Bohr radius, surface energy, variation in band gap energy of semiconducting nanomaterials (blue and red shift), exciton,

Unit 2: Properties of Nanomaterials:

Mechanical properties - Hardness, Tribology, Elasticity, strength, etc.) **(06 Lectures)**

Optical properties - Absorption, Transmission and Scattering of UV-visible radiation, Luminescence (Photoluminescence, Cathodoluminescence, Electroluminescence, etc) Surface Plasmon Resonance (SPR) **(08 lectures)**

Magnetic properties - Diamagnetism, Para magnetism, Ferromagnetism, Ferri magnetism, Antiferro magnetism, Superpara magnetism, Giant Magnetoresistance (GMR) and Colossal Magnetoresistance (CMR) (Lectures 10)

Unit 3: Introduction to Nanotoxicology: **(Lectures 12)**

Physicochemical determinants: Size Shape, Surface area Surface chemistry

Material composition, Redox cycling and catalytic chemistry, UV activation leading to radical formation, Surface coatings for protection, passivation, hydrophobicity, hydrophilicity

Effect of material synthesis methods, solvents etc

NPs Degradation

Routes of Exposure: oral respiratory tract, Skin, Gastrointestinal tract, injection

Risks evaluation both *in vitro* and *in vivo* studies, *In vivo* abnormal behavior, clinical signs, mortality, body weight changes, histological observation

Histopathology, Immunohistochemistry, SEM, TEM, AFM

Spectroscopic techniques: AAS, X-ray fluorescence, SEM-EDS

Reference Books:

- Nanotechnology: Principles & Practices. Sulbha K. Kulkarni, Capital Pub (3rd Edition)
- Nanostructures and Nanomaterials Synthesis, Properties and Applications, Guozhong Cao, imperials college Press, London.
- Nanaomaterils: Synthesis, properties and Applications. Edited by A. S. Edelstein & R. C. Commorata, Institute of Physics Publishing, Bristol & Philaldelphia.
- Nanomaterials by A.K. Bandyopadhyay (2nd Edition), International Publishers.

Course code and title: NS 233 Nanoscience and Nanotechnology Laboratory-2A

Practical: 15 **(Credits-2)**

Sr. No	Title of the experiment
1	Synthesis of SnO_2 nanoparticles by using Ball Milling method.
2	Preparation of TiO_2 thin films by using Spin Coating technique.
3	Preparation of CdS thin films by using Spray Pyrolysis method.
4	To determine Magnetic Susceptibility of $FeCl_3$ solution for different concentration
5	To determine band gap of TiO_2 using UV-Visible spectra.
6	Synthesis of Silver nanoparticles by using Plant Extract.
7	To study of X-ray Diffraction pattern to determine grain size of material. (Lattice Parameter)
8	Synthesis of ZnO nanoparticles by using Hydrothermal synthesis method.
9	To study of SAED (Selected Area Electron Diffratogram.)
10	To obtain porous silicon and study it's Photoluminescence.
11.	Synthesis of TiO_2 Using Sol-Gel method.
12.	Synthesis of ZnO using microwave synthesis method.
Activities	
1	Lab Visit (Equivalent to 2 Practical's)
2	Industrial Visit (Equivalent to 2 Practical's)

Note: Any Fifteen experiments from each section be conducted during the semester, with a total of 16 experiments.(12 experiments+ 2 activities (4 experiments)

SEMISTER-IV

Course code and title: NS-241 Organic and polymer science of nanomaterials

Lectures: 36 **(Credits-02)**

Unit 1: Basic Aspects Polymer Science: **(14Lecturers)**

Some basic definitions, Classification, Nomenclature

Polymerization methods: Mechanism of free radical, cationic and anionic polymerizations: Bulk, Solution, Suspension and Emulsion polymerizations, Interfacial condensation, Chemical (Oxidative) polymerization, electrochemical polymerization, Salient features of different polymerization techniques.

Molecular weight of polymers: Number average, weight average and viscosity average molecular weights of polymers- Determination of molecular weight of polymers by end group analysis and Viscometry methods.

Unit 2: Some Special polymers: **(14 Lecturers)**

Bio-polymers: Bio-degradable polymers, Fire retardant/Thermally stable polymers, and Liquid Crystalline polymers.

Conducting Polymers: Discovery, Classification of conducting polymers (intrinsic and extrinsic conducting polymers). Chemical and electrochemical methods of the synthesis of conducting polymers, Structural characteristics and doping concept, charge carriers and conducting mechanism, Applications of conducting polymers

Unit 3: Cabron Nanotubes and Graphene: **(12 Lecturers)**

Introduction to Carbon Nanotubes, Single-Wall Nanotubes, Multiwall Nanotubes, Synthesis of Carbon Nanotubes: Solid Carbon Source-Based techniques, Gaseous Carbon Source-Based techniques, Growth Mechanisms of Carbon Nanotubes: Catalyst-Free Growth, Catalyst-Free Growth, Activated Growth, Properties of Carbon Nanotubes, Applications

Introduction of Graphene and Reduced Graphene Oxide, Properties of Graphene, Applications

Unit 4: Polymer Nanocomposites: **(08 Lecturers)**

Definition of nanocomposites:- Nanofillers, Classification of nanofillers, Synthesis and properties of nanofilers-Types of nanocomposites, Synthesis of nanocomposites: Direct mixing, solution mixing, In-situ polymerization -Polymer Metal oxide nanocomposites, Polymer/CNTS and Polymer/Nanoclay based composites and their properties and functional applications.

References:

1. Bill Meyer, A Text Book of Polymer Chemistry, John Wiley & Sons, Singapore, 1994.

3. Gowariker and Visivanathan, Polymer Science, Wiley Eastern, 1986.

4. Nanostructured Conductive Polymers, Editor. Ali Efekhari, Wiley, 2010.

S. Nanocomposites Science and Technology M. Ajayan, L.S. Schadler, P. V. Braun Wiley-VCH, 2004

Course code and title: NS-242 Advanced Techniques for Characterization of Nanomaterials

Lectures: 36 **(Credits-02)**

Unit 1: TDA, DSC, Fluorescence, Confocal Microscopy: (12 Lectures)

Working Principle, Block diagram of instrument, function and role of each block, Output form and its analysis, applications, Illustration by giving at least one typical example.

Unit 2: Scanning Electron Microscope (SEM) and Energy Dispersive Analysis of X-rays (EDAX): (12 Lectures)

SEM: Working Principle, Block diagram of instrument, Function and role of each block, Interaction of electron beam, Output form and its analysis, limitations, applications. Different versions of SEM: FESEM, Environmental SEM, Biological sample preparation, Importance and applications.

EDAX: Working Principle data analysis and applications.

Unit 3: Transmission Electron Microscope (TEM): (12 Lectures)

Construction, Working Principle, Image formation, Different Operational Modes: Bright field and Dark field imaging, High Resolution (HR) / Lattice mapping imaging, Selected Area Electron Diffraction (SAED), Illustration by showing typical TEM images obtained using the various operational modes

Sample preparation for TEM, Sample preparation for cross sectional view, Applications.

Unit 4: Magnetic measurements (12 Lectures)

Vibrating Sample Magnetometer (VSM) – Construction, Working and applications, Introduction to Superconducting Quantum Interference Device (SQUID) – Construction, Working and Applications.

Reference Books:

1. Encyclopedia of Material Characterization Edited by C. Richard Brundle, Charles A. Evans, Shaun Wilson, Butterworth, London.
2. Handbook of Microscopy, Applications in Materials Science, Solid State Physics and Chemistry, Edited by D. van Dyck, J. van Landuyt and G. van Tendeloo VCH,UK.
3. Handbook of Instrumental Techniques for Analytical Chemistry, Edited by Frank A. Settle, Printice Hall, PTR, New Jersey, USA.
4. Instrumental Methods of Analysis, by Willard, Merritt, Dean and Settle, CBS Publishers & Distributors; 7th edition (2004)
5. Bharat Bhusan, “Springer Handbook of Nanotechnology”, springer, Newyork, 2007.
6. Hari Singh Nalwa, “Encyclopedia of Nanotechnology”,USA 2011.

7. James A. Schwarz, Cristian I. Contescu, Karol Putyera, “Dekker encyclopedia of Nanoscience and Nanotechnology” CRC Press, 2004.

Course code and title: NS 243 Nanoscience and Nanotechnology Laboratory-2B

Practical: 15 **(Credits-2)**

Sr. No	Title of the experiment
1	To obtain the design pattern on given substrate by using Photolithography.
2	Analysis of Surface morphology using SEM (Scanning Electron Microscopy).
3	Analysis of Surface morphology using TEM (Transmission Electron Microscopy).
4	Characterization of Graphene using Raman Spectroscopy.
5	Preparation of CdS Thin Film by using CBD method
6	Preparation of dye synthesized solar cell using Nano TiO_2 materials.
7	Study of dye synthesized Solar cell in the presence of Sunlight.
8	Synthesis of Copper and Copper Oxide Nanoparticles using plant extract.
9	Synthesis of Zinc Oxide Nanoparticles using plant extract.
10	Synthesis of Zinc Oxide by using Hydrothermal Method
11.	Study of elemental analysis by using EDAX
12.	Preparation of thick films by using screen printing techniques.
	Activities
1	Study of Atomic Absorption spectroscopy and FTIR (Equivalent to 2 Practical's)
2	Use of Anti plagiarism Software (Equivalent to 2 Practical's)

Note: Any Fifteen experiments from each section be conducted during the semester, with a total of 16 experiments.(12 experiments+ 2 activities (4 experiments)