Savitribai Phule Pune University

(Formerly University of Pune)

Three Year B.Sc. Degree Program in Nanoscience and Nanotechnology

(Faculty of Science & Technology)

T. Y. B. Sc. Nanoscience and Nanotechnology Syllabi in NEP

(Level 5.0)

National Education Policy Syllabus

To be implemented from Academic Year 2026-2027

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

1) Programme Objectives:

The undergraduate (UG) degree course in Nanoscience and Nanotechnology aims to provide:

a) Knowledge and skills to undertake higher studies/research in Nanoscience and Nanotechnology and related interdisciplinary areas thereby enabling students' employment/entrepreneurship.

b) Critical and analytical thinking, scientific reasoning, problem-solving skills, communication skills and teamwork.

c) Competence and skill in solving both theoretical and applied Nanoscience and Nanotechnology problems.

d) In-depth knowledge in Nanoscience and Nanotechnology through understanding of key physical concepts, principles, theories and their manifestations.

e) Exposure to the latest advances in Nanoscience and Nanotechnology, allied disciplines and research.

f) A conducive learning environment to ensure cognitive development of students.

g) Sufficient subject matter competence and enable students to prepare for various competitive examinations such as UGC-CSIR NET/JRF, GATE, GRE, IIT-JAM, and Civil Services Examinations.

h) Moral and ethical awareness, leadership qualities, innovation and life-long learning.

i) Multicultural competence and multilinguist.

2) Program Outcomes:

The learning outcomes of the undergraduate degree course in Nanoscience are as follows:

1. Fundamental Knowledge: Students should acquire a solid understanding of the principles and concepts in nanoscience and nanotechnology. This includes knowledge of quantum mechanics, material science, chemistry, and physics at the nanoscale.

2. Experimental Skills: Students should gain hands-on experience in working with nanoscale materials and instruments, including microscopy techniques, nanofabrication, and characterization tools.

3. Interdisciplinary Approach: A B.Sc. program in Nanoscience and Nanotechnology should encourage interdisciplinary thinking and collaboration between various scientific fields, such as physics, chemistry, biology, and engineering.

4. Nanomaterials: Students should be able to identify and design nanomaterials with specific properties for various applications, such as electronics, medicine, and energy.

5. Safety and Ethical Considerations: Students should understand the safety and ethical implications of working with nanoscale materials and technologies.

6. Research Skills: The program should foster research skills, including the ability to design and conduct experiments, analyse data, and draw meaningful conclusions.

7. Problem-Solving: Graduates should be able to apply their knowledge and skills to solve real-world problems and address challenges in nanoscience and nanotechnology.

8. Communication: Students should develop strong communication skills, including the ability to present scientific findings and research effectively to both technical and non-technical audiences.

9. Nanotechnology Applications: Graduates should be familiar with various applications of nanotechnology in fields such as electronics, medicine, energy, and materials science.

10. Adaptability: Given the rapidly evolving nature of nanoscience and nanotechnology, students should be prepared to adapt to new technologies and discoveries in the field throughout their careers.

11. Advanced Education: The B.Sc. program may also prepare students for further education, such as pursuing a master's or Ph.D. in nanoscience or related fields.

3) Abbreviations Used

- PO : Programme Outcomes
- PS : Programme Structure
- TLP : Teaching-Learning Process
- AM : Assessment Method
- DSC : Discipline Specific Core
- DSE : Discipline Specific Elective
- OE : Generic Electives
- OP : Open Electives
- VSC : Vocational Skill Courses
- SEC : Skill Enhancement Courses
- VSC* : Vocational Skill Courses
- AEC : Ability Enhancement Courses
- IKS : Indian Knowledge System
- VEC : Value Education Courses
- OJT : On Job Training (Internship/ Apprenticeship)
- FP : Field projects
- CEP : Community engagement program
- CC : Co-curricular Courses
- RM : Research Methodology
- RP : Research Project

4) Introduction to Undergraduate Degree Course in Nanoscience and Nanotechnology:

As per the recommendations of UGC-F-2022, the undergraduate (UG) degree course in Nanoscience and Nanotechnology is a 6-semester course spread over 3-academic years The Teaching Learning Process (TLP) is students' centric. It involves both theory and practical components. It offers a flexibility of programme structure while ensuring that the student gets a strong foundation in the subject and gains in-depth knowledge. Besides the DSCs (Major Core), a student has options courses from the syllabus comprising of DSEs (Electives), Minor, OE/GEs, SECs, AECs, RPs, RMs, OJT, FP, CEP, IKSs, VECs, CCs and VSCs. Hence, this will be bring out the interdisciplinary as well as multidisciplinary approach and adherence to innovative ways within the curriculum framework. It also allow a students' maximum flexibility in pursuing his/her studies at the undergraduate (UG) level to the extent of having the liberty to eventually design the degree with multiple exit options. Students have these exits options depending upon the needs and aspirations of the student in terms of his/her goals of life, without compromising on the teaching learning, both in qualitative and quantitative terms. This will suit the present day needs of students in terms of securing their paths towards higher studies or employment.

5) Programme Duration and Exit Options:

The minimum credit to be earned by a student per semester is 18-credits and the maximum is 26 credits. However, students are advised to earn 22-credits per semester. This provision is meant to provide students the comfort of the flexibility of semester-wise academic load and to learn at his/her own pace. However, the mandatory number of credits which have to be secured for the purpose of award of Undergraduate Certificate/Undergraduate Diploma/Appropriate Bachelor's Degree in Nanosience and Nanotechnology are listed in Table-1.

S. No.	Type of Award	Stage of Exit	Mandatory Credits to be Secured for the Award
1	Undergraduate Certificate in Nanoscience and Nanotechnology	After successful completion of Semester II	**44** and an additional 4 credits core NSQF Course/Internship
2	Undergraduate Diploma in Nanoscience and Nanotechnology	After successful completion of Semester IV	**88** and an additional 4 credits core NSQF Course/Internship
3	Bachelor of Science Nanoscience and Nanotechnology	After successful completion of Semester VI	**132**

6) Programme Structure :

The detailed Credit framework of undergraduate degree programme in Nanoscience and Nanotechnology

Level /Difficulty	**Sem**	**Subject-1**	**Subject-2**	**Subject-3**	**GE/ OE**	**SEC**	**IKS**	**AEC**	**VEC**	**CC**	**Total**
4.5/100	I	2(T)+2(P)	2(T)+2(P)	2(T)+2(P)	2(T)	2(T/P)	2(T) Generic	2(T)	2	-	22
	II	2(T)+2(P)	2(T)+2(P)	2(T)+2(P)	2(P)	2(T/P)	-	2(T)	2	2	22
Exit Option: Award of UG Certificate in Major with 44 credits **and** an additional 4 credits core NSQF Course/Internship **OR** Continue with Major and Minor. **Continue Option:** Student will select one subject among the (Subject-1, Subject-2, and Subject-3) as major and another as minor **and** third subject will be dropped.											

Level /Difficulty	**Sem**	**Credits related to major**				**Minor**		**GE/ OE**	**SEC**	**IKS**	**AEC**	**VEC**	**CC**	**Total**
		Discipline Specific Core (DSC) **Major Core**	Discipline Specific Elective (DSE) **Major Elective**	**VSC**	**FP/ OJT /CEP**									
5.0/200	III	4(T)+2(P)	-	2(T/P)	2 (FP)	2(T)+2(P)	-	2(T)	-	2(T) Major Subject Specific	2(T)	-	2	22
	IV	4(T)+2(P)	-	2(T/P)	2(CEP)	2(T)+2(P)	-	2(P)	2(T/P)	-	2(T)	-	2	22
Exit Option: Award of UG Diploma in Major and Minor with 88 credits **and** an additional 4 credits core NSQF Course/Internship **OR** Continue with Major and Minor.														

5.5/300	V	8(T)+4(P)	2(T)+2(P)	2(T/P)	2 (FP/ CEP)	2(T)	-	-	-	-	-	-	-	22
	VI	8(T)+4(P)	2(T)+2(P)	2(T/P)	4(OJT)	-	-	-	-	-	-	-	-	22
Total 3 Years		44	8	8	10	18	8	8	6	4	8	4	6	132
Exit Option: Award of UG degree in Major with 132 credits **OR** Continue with Major and Minor.														

7) Assessment Methods :

The primary objective of assessment will be to assess the learning outcomes of the course in tune with the broad outcomes of strengthening core theoretical knowledge base, practical laboratory skills, and research. Assessment will be based on continuous evaluation (MCQs, Short Questions (SQ), Class Test (CT), Seminar, Presentation (PPT), Group Discussion (GD), Quiz, Assignment, Tutorials, etc.) and end of semester examination of Savitribai Phule Pune University, Pune.

(i) Internal Assessment or Continuous Evaluation:

During a semester, students' mastery of the various learning outcomes as described in the syllabus will be assessed through MCQs, Short Questions (SQ), Class Test (CT), Seminar, Presentation (PPT), Group Discussion (GD), Quiz, Assignment, Tutorials, etc. Each theory paper and practical paper will have 15 marks for internal assessment. The critical analysis of internal assessment or continuous evaluation outcomes will provide opportunities to improve the teaching-learning process by focusing on the areas that need conceptual strengthening, laboratory exposure or design of new experiments, and research.

(ii) End of Semester University Examinations:

The summative end-semester university examinations will be conducted for both theory and practical courses. Besides internal assessment, each theory paper and each practical paper will be of 35 marks for end of semester examination of the university.

8) Scheme of Examination :

The total marks for a 2-credits course is 50.

- Theory Paper of 02 Credits:
    - Internal Exam (15 M) + University Theory Exam (35 M) = Total 50 M
    - Duration: For Internal exam = 40 Min. and for University Exam = 02 hours.
- Practical Paper of 2 Credits:
    - Internal Exam (15 M) + University Practical Exam (35 M) = Total 50 M
    - Duration: For Internal exam = 40 Min. and for University Exam = More than 04 hours.

Internal exam will be conducted by particular college/institutes at the end of each semester.

External exam will be conducted by Savitribai Phule Pune University, Pune at the end of each semester.

Note:

a) Each semester comprises of 15 weeks.
(12 weeks Actual Teaching + 3 weeks for Continuous Internal Evaluation).

b) One Credit of the Theory is equal to15 clock hours (Teaching 1 hour per week for each credit).
(12 hours Actual Teaching + 3 hours Continuous Internal Evaluation – Assignments, Tutorials, Practice, Problem solving sessions, Group discussion, Seminars and Unit Tests.)

c) One Credit of Practical = 30 clock hours (2 Contact hours per credit per week)
(24 hours' Actual Table work + 6 hours for journal competition, and Continuous Internal Evaluation of each practical).

d) Practical for each course comprises of 02 Credits = 60 clock hours.

- Minimum 12 laboratory/ Filed sessions of 04 clock hours must be conducted in one semester.
- In case of short practical, two practical's should be conducted in one session.
  - Each practical of 04 clock hours in the laboratory should consist of table performance for concerned practical, careful observations, calculation, writing results and conclusion, and submission of practical in written form.
  - Pre-laboratory reading and post laboratory assignments should be given on each practical as a part of continuous internal evaluation.

Pattern for Internal Theory Assessment: (15 Marks)

Que-1: Choose correct option (MCQs) (10-MCQs with Multiple Options) – 5 marks

Que-2: Answer the following questions (Short answer questions) (any 5 out of 7) – 5 marks

Que-3: Answer the following questions (Short answer Definition/Problems/Diagram) (any 5 out of 7)–5 marks

Pattern for External Theory Assessment: (35 Marks)

Que-1: Answer the following questions (Short answer/Definition/Problems/Diagram, etc.) (any 5 out of 7)–**5 marks**

Que-2: A) Answer the following questions (Long answer questions) – **6 marks**

i) ----------

ii) ----------

B) Answer the following questions (Long answer questions/Problems) – **4 marks**

i) ----------

ii) ----------

Que-3: A) Answer the following questions (Long answer questions) – **6 marks**

i) ----------

ii) ----------

B) Answer the following questions (Long answer questions/Problems) – **4 marks**

i) ----------

ii) ----------

Que-4: Write a short notes on following. (any 4 out of 6) –**10 marks**

a) ----------

b) ----------

c) ----------

d) ----------

e) ----------

f) ----------

Structure of Four Year-degree Program

Structure of the course for Three years, the pattern of examination and question papers are as per Savitribai Phule Pune University:

Nanoscience and Nanotechnology as Major (Core) Subject and any other subject as Minor (each theory / practical paper has 2 credits).

Year	Sem	Code Number	Title of the paper (Theory / Practical)	Credits allotted
I 4.5/100	I	NS-101-TH	Introduction to Nanoscience	02
		NS-102-PR	Nanoscience and Nanotechnology Laboratory-I	02
	II	NS-151-TH	Material Science	02
		NS -152-PR	Nanoscience and Nanotechnology Laboratory-II	02
II 5.0/200	III	NS -201-MJ	Physical Techniques for synthesis of Nanomaterials	02
			Properties of Nanomaterials (Physical, chemical, Optical and	02
		NS -202-MJ	Magnetic)	02
			Nanoscience and Nanotechnology Laboratory-III	
		NS -203-MJ		
	IV	NS -251-MJ	Organic and polymer science of nanomaterials	02
		NS -252-MJ	Advanced Techniques for Characterization of Nanomaterials	02
			Nanoscience and Nanotechnology Laboratory-IV	
		NS -253-MJP		02
III 5.5/300	V	NS -301-MJ	Polymer and Composites	02
		NS -302-MJ	Nanophysics	02
		NS -303-MJ	Nanobiotechnology	02
		NS -304-MJ	Chemical and Biological Techniques for synthesis	02
			nanomaterials	
		NS -305-MJP	Nanoscience and Nanotechnology Laboratory-V	02
		NS -306-MJP	Nanoscience and Nanotechnology Laboratory-VI	02
	VI	NS -351-MJ	Polymer Hetero-structure and their applications	02
		NS -352-MJ	Functional Nanomaterials	02

		NS -353-MJ	Applications of Nanobiotechnology	**02**
		NS -354-MJ	Nanoelectronics	**02**
		NS -355-MJP	Nanoscience and Nanotechnology Laboratory -VII	**02**
		NS -356-MJP	Nanoscience and Nanotechnology Laboratory-VIII	**02**

List of major Electives:

Year	Sem	Code Number	Title of the paper (Theory / Practical)	Credits allotted
III 5.5/300	**V**	NS-310-MJ	Thin film technology	**02**
		NS-313-MJP	Practical (Thin film technology)	**02**
	VI	NS-360-MJ	Physics of Nanomaterials	**02**
		NS-361-MJP	Practical (Physics of Nanomaterials)	**02**

List of Vocational Skill Courses (VSC):

Year	Sem	Code Number	Title of the paper (Theory / Practical)	Credits allotted
I	**I**	NS-121-VSC	Environment- I	**02**
	II	NS-171-VSC	Environment- II	**02**
II	**III**	NS-221-VSC	Data Analysis & Computer Application	**02**
	IV	NS-271-VSC	C Programing Practical	**02**
III	**V**	NS-321-VSC	Basic Instrumentation in Nanotechnology	**02**
	VI	NS-371-VSC	Basic Instrumentation Skill Practical	**02**

Field Project (FP) / On Job Training (OJT)/ Community Engagement Project (CEP):

Year	Sem.	Code Number	Title of the paper (Theory / Practical)	Credits allotted
II 5.0/200	**III**	NS-231-FP	Field Project	**02**
	IV	NS-281-CEP	Community Engagement Project	**02**
III 5.5/300	**V**	NS-331-FP/CEP	Field Project / Community Engagement Project	**02**
	VI	NS-381-OJT	On Job Training	**04**

Nanoscience and Nanotechnology as Major Subject and any other subject as Minor (each theory / practical paper has 2 credits)

Year	Sem	Code Number	Title of the paper (Theory / Practical)	Credits allotted
II 5.0/200	**III**	NS-241-MN	Renewable Energy and Energy Harvesting	**02**
		NS-242-MNP	Data Analysis & Computer Application Practical	**02**
	IV	NS-291-MN	Basics of Industrial Nanotechnology-I	**02**
		NS-292-MNP	C Programming Practical	**02**
III 5.5/300	**V**	NS-341-MN	Basics of Industrial Nanotechnology-II	**02**

List of Generic / Open Electives (OE):

Year	Sem	Code Number	Title of the paper (Theory / Practical)	Credits allotted
I	**I**	OE-101-NS	Chemical and Biological technique for synthesis of nanomaterial	**02**

4.5/100	**II**	OE-151-NS	Basic Characterization Techniques	**02**
II **5.0/200**	**III**	OE-201-NS	Nanoscience and Nanotechnology in Daily Life	**02**
	IV	OEP-251-NS	Energy Conversion Devices and Applications	**02**

List of Skill Enhancement Courses (SEC):

Year	Sem	Code Number	Title of the paper (Theory / Practical)	Credits allotted
I **4.5/100**	**I**	SEC-101-NS	C-Programming	**02**
	II	SEC-151-NS	Basic Instrumentation Skill	**02**
II **5.0/200**	**IV**	SEC-251-NS	Sensors and Detection Technology	**02**

Indian Knowledge System (IKS):

Year	Sem	Code Number	Title of the paper (Theory / Practical)	Credits allotted
I **4.5/100**	**I**	NS-101-IKS	Generic	**02**
II **5.0/200**	**III**	NS-201-IKS	नॅनोविज्ञान (Nanoscience)	**02**

Semester: - V

Major

NS -301-MJ Polymer and Composites

Lectures: 30 **(Credits-02)**

Unit 1 - Synthesis of Polymer: (10 lectures)

Introduction to composite materials – Classification, Introduction to polymer composites – Nano, micro and macro scales – Reinforcements – Short fibre, long fibre and particulate fillers – Matrices – thermoplastics-thermosets and rubbers- Nano and micro composites, Applications of composites.

Unit 2 - Synthesis of metal –polymer nanocomposites: (10 Lectures)

Incorporation of reinforcements in polymer solution mixing- latex stage mixing-melt mixing and in-situ polymerization and precipitation – Dispersion and nucleating effects-Intercalation and exfoliation- Application of layered and nonlayered nano and micro particles in polymer modification- Different methods of preparation of composites.

Unit 3- Synthesis of Oxide/sulphide –polymer nanocomposites: (10 Lectures)

Carbon nanotubes- single walled and multi walled- preparation, treatment and functionalization Salient features of polymer modification with carbon nanotubes- nano silica and nano clay organically modified layered clays: various methods used for the incorporation of nano fillers in polymer matrix like solution mixing, latex stage mixing and melt mixing.

Reference Books

1. G. Lubin - Handbook of composites – (Van Nostrand, 1982)
2. M.O.W. Richarson - Polymer Engineering Composites – (Applied Science Publishers, 1995)
3. J. G. Mohr - SPIE Handbook of Technology and Engineering of Reinforced Plastics/Composites – (Van Nostrand, 1998)
4. R. Krishnamoorti and R.A. Vaia – Polymer nanocomposites: Synthesis characterization and modeling (Americal Chemical Society, 2002)
5. Pinnavaia T.J. and Beall G.W. – Polymer –clay Nanocomposites (John Wiley 2000)

NS -302-MJ Nanophysics

Lectures: 30 **(Credits-02)**

Unit 1 – Probability and distribution functions (6 lectures)

Elementary probability theory: Preliminary concepts, Binomial distribution, mean value, standard deviation, Gaussian distribution, Poisson distribution, mean value. Probability density and probability for continuous variables (brief).

Unit 2 – Statistical Distribution of Systems of Particles (8 Lectures)

Behaviour of density of states, Statistical equilibrium, ensemble, canonical ensemble, isolated systems, system in contact with heat bath. Quantum distribution function, Maxwell –Boltzmann statistics, Bose – Einstein statistics, Fermi-Dirac statistics.

Unit 3- Solid State Physics (8 Lectures)

Revision of band theory, band structure, intrinsic and extrinsic semiconductors, Fermi level, band gap in metals, semiconductors and insulators, band gap for bulk, atoms and nanoclusters, density of states, Bohr exciton radius, quantum size effect, nanostructures, quantum well and quantum dots.

Unit 4- Advanced spectroscopy (8 lectures)

Dynamic Light scattering (DLS), NMR spectroscopy, ESR and FMR spectroscopy, optical absorption and emission spectroscopy, Thermoluminescence,

Reference Books

1. Fundamentals of Statistical Mechanics, B. B. Laud, New age International Publication, India.
2. Statistical and thermal Physics, F. Reif, Levant book, Kolkata, India.
3. An introduction to Statistical Mechanics and Thermal Physics, Robert H. Swendsen, Oxford University press.
4. Statistical Mechanics, R K Pathria and Paul D Beale, Elsevier (India)
5. Introduction to solid states Physics - Charles, Kittle 7th Edition
6. Solid States Physics - S.O. Pillai (latest edition)
7. Elementary Solid-State Physics- M. Ali Omar
8. Fundamentals of Molecular Spectroscopy - C. N. Banwell,
9. Fundamentals of Molecular Spectroscopy - WALTER S. STRUVE

NS -303-MJ Nanobiotechnology

Lectures: 30 **(Credits-02)**

Unit 1 – Basic biomolecules [12 Lectures]

Development of nanobiotechnology – overview.

Basic biomolecules: • Carbohydrates: Classification, Occurrence, Properties and biological reactions, • Amino acids: Amino acids and peptides-classification, chemical reactions and physical properties. • Protein: Peptide bond, Primary Secondary Tertiary, Quaternary structure of protein with example diagram. Globular and Fibrous protein. • Lipids: Classification, Structure and Functions. Triglycerides; Phospholipids; Steroids and terpenes. Glycol and lipoproteins-structure and function. Lipid Membranes: Structure and Properties – Models, • Nucleic acids: Nucleoside's, Nucleotides. Structure of double stranded DNA (B, A, C, D, T and Z DNA). Physical properties of double stranded DNA, Types of RNAs and their biological significance.

• Enzymes: Structure, Mechanism of action, Classification.

Unit 2-Biological nanomaterial [8 Lectures]

• Biological nano-partials and its applications: Introduction to biological nanoparticles, Exosomes, lipoproteins, Ferritin, Biological nano-motors and machines, • Biological nano-machines: muscle myosin, ATPase, Hemoglobin, • Biological nanoparticles production - plants and microbial Biological nanometers: Bacterial Flagella, cilia: Structure and function. • Biological Nano-pores: Ion channels: bacteria-rhodopsin.

Unit 3– Recombinant DNA technology [5 Lectures]

• Introduction, Restriction enzymes, cloning vectors (plasmids, bacteriophages, cosmids, expression), • DNA sequencing: Sanger's Dideoxy method.

Unit 4- Nanomaterial in biotechnology (5 Lectures)

definition classification of nanomaterial (i) carbon-based materials (ii) metal-based materials (iii) dendrimers (iv) composites, Graphene, Nanotubes, Nanowires, Nano cones, Quantum dots.

List of Reference books:

1. Principles of Biochemistry, Lehninger , Nelson, Cox, CBS publishers and distributors, New Delhi, 2004.

2. Fundamentals of Biochemistry, Donald Voet, Akif Uzman, Judith G. Voet, Charlotte W. Pratt,

John Wiley and Sons, New York, 2008.

3. Biochemistry, Geoffrey L. Zubay , WCB publishers, 1998.

4. Biochemistry – Lubert Stryer, 1995. _

5. C. M. Niemeyer, C. A. Mirkin, ―Nanobiotechnology: Concepts, Applications and Perspectives‖, Wiley – VCH, (2004).

6. Nanoscience : Nanobiotechnology and Nanobiology, P. Boisseau, P. Houdy and M. Lahmani, Springer, 2007.

7. Handbook of Nanostructured Biomaterials and Their Applications in Nanobiotechnology, Hari Singh Nalwa, American Scintific Publishers, 2005.

8. Nanobiotechnology, C.M.Niemeyer, C.A. Mirkin, Wiley VCH, 2004.

9. Challa, S.S.R. Kumar, Josef Hormes, Carola Leuschaer," Nanofabrication Towards Biomedical Applications, Techniques, Tools, Applications and Impact", Wiley – VCH, 2005.

10. Nicholas A. Kotov, "Nanoparticle Assemblies and Superstructures", CRC, 2006.

11. T. Pradeep, ―Nano: The Essentials‖, McGraw – Hill education, (2007).

12. David S Goodsell, "Bionanotechnology‖, John Wiley & Sons, (2004).

13. Molecular Biology of the Gene, 6th Edition (2008), James D. Watson, Tania Baker, Stephen P. Bell, Alexander Gann, Michael Levine, Richard Lodwick, Pearson Education, Inc. and Dorling Kindersley Publishing, Inc. USA

14. Molecular Biotechnology: 4th edition. (2010), Glick B.R., Pasternak J.J., Patten C. L., ASM press, USA

NS -304-MJ Physical and Biological technique for synthesis of nanomaterial

Lectures: 30 **(Credits-02)**

Unit 1 – Synthesis of Nanomaterial (6 Lectures)

Colloids and colloids in solution, Nucleation and growth of nanoparticles, Synthesis of metal and semiconductor nanoparticle by colloidal routes, Langmuis- Blodgett (L-B) method, sol-gel method.

Unit 2 – Synthesis of nanomaterial (8 Lectures)

Hydrothermal synthesis, Solvothermal synthesis, Sonochemical Synthesis, Solvothermal synthesis, Sonochemical Synthesis methods, Microwave synthesis, Synthesis using micro-reactor or Lab-or-chip spray pyrolysis, successive ionic Layer adsorption and reaction (SILAR), Electrodeposition,

Unit 3 – Synthesis of nanomaterial (8 Lectures)

Chemical vapour deposition, Metallorganic chemical vapour deposition (MOCVD), Plasma enhanced chemical vapour deposition (PECVD), Vapour-Liquid- Solid (ULS) method, Metal Oxide frameworks (MoF), Kirkindall effect and method.

Unit 4 – Synthesis of nanomaterial (8 Lectures)

Introduction, Synthesis using microorganisms, Synthesis using plant extract, Use of proteins, Templates like DNA, S-tayer synthesis of nanoparticles using DNA.

Reference Books:

1. Hari Singh Nalwa, “Encyclopedia of Nanotechnology”, USA 2011

2. James A. Schwarz, Cristian I. Contescu, Karol Putyera,“Dekker encyclopedia of nanoscience and nanotechnology” CRC Press, 2004.

3. Introduction to Nanoscience and Nanotechnology, CRC Press, G. L. Hornyak, H. F. Tibbals, J. Dutta, J. J. Moore

4. Nanotechnology: Principles and practices, 3rd Edition, Sulabha K. Kulkarni, Capital Publishing Company

NS -305-MJP Nanoscience and Nanotechnology Laboratory-V

Lectures: 30 **(Credits-02)**

Sr. No	Title of the experiment
1	Synthesis of ZnO nano-particles by wet chemical method.
2	Synthesis of NiO nano-particles by wet chemical method.
3	Synthesis of NiO Nanoparticles by using Hydrothermal method.
4	Synthesis of ZnO Nanoparticles by using Hydrothermal method.
5	Preparation of TiO2 thick film by screen printing technique and measurement of thickness using weight difference method
6	Preparation of thin film by spray pyrolysis technique and measurement of thickness using weight difference method.
7	Study of reverse bias characteristic of Photo-diode for different intensity.
8	Characteristic of solar cell (calculation of fill factor, maximum power point and efficiency)
Activities	
1	Lab Visit (Equivalent to 2 Practical's)
2	Industrial Visit (Equivalent to 2 Practical's)

NS -306-MJP Nanoscience and Nanotechnology Laboratory-VI

Lectures: 30 **(Credits-02)**

Sr. No	Title of the experiment
1	Determination of band gap of TiO2 by using UV-Visible spectrophotometer.
2	Synthesis of Silver nanoparticles by using mango Plant Extract.
3	Preparation of CdS thin film by using CBD method.
4	Preparation of PbS thin film by using CBD method.
5	Preparation of Dye Synthesized Solar Cell using Nano TiO_2.
6	Study of Dye Synthesized Solar Cell in presence of sunlight.
7	Study of Dye Synthesized Solar Cell in presence of light source.
8	Study of absorption spectra of silver nanoparticles by using visible spectrophotometer.
Activities	
1	Lab Visit (Equivalent to 2 Practical's)
2	Industrial Visit (Equivalent to 2 Practical's)

Major Elective
NS 310 MJ Thin Film Technology

Lectures: 30 **(Credits-02)**

Unit 1: Basics of Thin Films (14 Lectures)

- Definition and importance of thin films
- Types: metal, dielectric, semiconductor
- Growth mechanisms:
  - Volmer–Weber
  - Frank–van der Merwe
  - Stranski–Krastanov
- Basic properties: structural, electrical, optical

Unit 2: Deposition Techniques (10 Lectures)

- **PVD**: Thermal evaporation, sputtering
- **CVD**: APCVD, LPCVD, PECVD
- Other methods: Spin coating, sol–gel, PLD
- Thickness measurement: Quartz crystal monitor, profilometer

Unit 3: Applications (6 Lectures)

- Devices: Solar cells, TFT, sensors
- Applications: Electronics, coatings, nanotechnology

Reference Books

K. L. Chopra – Thin Film Phenomena

Donald L. Smith – Thin-Film Deposition

Milton Ohring – Materials Science of Thin Films

A. Goswami – Thin Film Fundamentals

Major Elective

NS 313 MJP Practical (Thin Film Technology)

Lectures: 30 **(Credits-02)**

Sr. No	Title of the experiment
1	Preparation of thin film by spin coating
2	Preparation of thin film by dip coating
3	Preparation of thin film by sol–gel method
4	Thickness measurement using stylus profilometer
5	Thickness measurement using quartz crystal monitor (study)
6	Study of thermal evaporation method
7	Study of sputtering technique
8	Structural analysis using XRD
10	Surface morphology study using SEM
11	Optical characterization using UV-Visible spectroscopy
12	Electrical characterization using four probe method
13	Study of applications of thin films (report)

Minor

NS 341 MN Basics of Industrial Nanotechnology-II

Lectures: 30 **(Credits-02)**

Module 1: Fundamentals of Industrial Nanotechnology (8 Lectures)

- Definition, scope, and importance of nanotechnology in industry
- Historical development and industrial revolution impact
- Size-dependent properties of nanomaterials
- Classification: Nanoparticles, Nanotubes, Nanofilms, Nanocomposites

Module 2: Industrial Applications of Nanotechnology (8 Lectures)

- Electronics: Nanoelectronics, sensors, semiconductors
- Energy: Solar cells, fuel cells, supercapacitors
- Medicine: Drug delivery systems, nanomedicine, diagnostics
- Textiles: Smart fabrics, antimicrobial coatings

Module 3: Industrial Applications of Nanotechnology (6 Lectures)

- Food Industry: Nano-packaging, food safety
- Automobile & Aerospace: Lightweight nanocomposites
- Coatings & Paints: Anti-corrosion, self-cleaning surfaces

Module 4: Industrial Safety, Ethics & Regulations (8 Lectures)

- Nanotoxicology and occupational hazards
- Environmental impact of nanomaterials
- Risk assessment and management
- Regulatory bodies and guidelines (ISO, OECD, BIS)
- Ethical and societal issues

References

1. Introduction to Nanotechnology – Charles P. Poole Jr. & Frank J. Owens
2. Nanotechnology: Principles and Practices – S. K. Kulkarni
3. Handbook of Nanoscience, Engineering, and Technology – Bharat Bhushan
4. Industrial Applications of Nanomaterials – Chaudhery Mustansar Hussain
5. Nanotechnology: A Gentle Introduction to the Next Big Ide

VSC

NS 321 VSC Basic Instrumentation in Nanotechnology

Lectures: 30 **(Credits-02)**

Unit 1. Microscopy Techniques (12 Lectures)

- Optical Microscope (basic concept and limitations)
- Scanning Electron Microscope (SEM)
- Transmission Electron Microscope (TEM)
- Atomic Force Microscope (AFM)
- Scanning Tunneling Microscope (STM)

Unit 2. Spectroscopic Techniques (6 Lectures)

- UV–Visible Spectroscopy
- Fourier Transform Infrared Spectroscopy (FTIR)
- Raman Spectroscopy

Unit 3. Diffraction & Particle Analysis Techniques (6 Lectures)

- X-ray Diffraction (XRD)
- Dynamic Light Scattering (DLS)
- Particle Size Analyzer

Unit 4. Surface & Elemental Analysis (6 Lectures)

- Energy Dispersive X-ray Analysis (EDX/EDS)
- X-ray Photoelectron Spectroscopy (XPS)
- Surface area analysis (BET method – basic idea)

References

1. Introduction to Nanotechnology" – Charles P. Poole Jr. & Frank J. Owens
2. "Nanotechnology: Principles and Practices" – Sulabha K. Kulkarni
3. "Introduction to Nanoscience and Nanotechnology" – K.K. Chattopadhyay & A.N. Banerjee
4. "Scanning Probe Microscopy and Spectroscopy" – Roland Wiesendanger
5. "Fundamentals of Molecular Spectroscopy" – C.N. Banwell
6. "Elements of X-ray Diffraction" – B.D. Cullity
7. "Nanomaterials: Synthesis, Properties and Applications" – A.S. Edelstein & R.C. Cammarata

SEMISTER-VI

Major

NS-351 MJ Polymer Hetro-structure and their Applications

Lectures: 30 **(Credits-02)**

Module 1: Introduction to Hetero-structures (10 Lecturers)

Introduction to p-n heterojunction n-n heterojunction and p-p heterojunction. Host Polymer characterization and Inorganic semiconductor characterization.

Module 2: Hetero-structures by Ex-situ Polymerization (12 Lecturers)

Synthesis and characterization of hetero-structure by Ex-situ polymerization using metals, metal oxides and polymers, Applications in electronics such as lasers, transistors and other optoelectronic applications.

Module 3: Hetero-structures by In-situ Polymerization (08 Lecturers)

Synthesis of hetero-structure by In-situ polymerization using metals, metal oxides and polymers, Application

References:

1. Nanotechnology: Technology Revolution of 21st Century by Rakesh Rathi, Published by S. Chand.
2. Introduction to Nanoscience, by Stuart Lindsay.
3. Introduction to Nanomaterials and Nanotechnology by Vladimir Pokropivny, Rynno Lohmus, Irina Hussainova, Alex Pokropivny and Sergey Vlassov.
4. Nanomaterials by A. K. Baandyopadhyay; New Age International Publishers.
5. Nanotechnology by Mark Ratner and Daniel Ratner, Pearson Education.
6. Nano Essentials- T. Pradeep/TMH.
7. Bharat Bhusan, “Springer Handbook of Nanotechnology”, springer, Newyork, 2007.
8. Hari Singh Nalwa, “Encyclopedia of Nanotecnology”, USA 2011.
9. James A. Schwarz, Cristian I. Contescu, Karol Putyera, “Dekker Encyclopedia of Nanoscience and Nanotechnology” CRC Press, 2004.
10. Introduction to Nanoscience and Nanotechnology, CRC Press, G. L. Hornyak, H. F. Tibbals, J. Dutta, J. J. Moore.
11. Nanotechnology: principles and practices, 3rd Edition, Sulabha K. Kulkarni, Capital Publishing Company.

NS-352 MJ Functional Nanomaterials

Lectures: 30 **(Credits-02)**

Module 1: Semiconductor quantum dots (10 Lectures)

Growth mechanism, shape andcomposition control of semiconductor nanocrystals, Synthesis of semiconductor nanocrystals in organic solvents, Aqueous synthesis of semiconductor nanocrystals,Layer-by-layer (LBL) assembly with semiconductor nanoparticles and Nanowires, Applications of quantum dots

Module 2: Nanotubes and nanowires (10 Lectures)

Fabrication of TiO_2 Nanotube Arrays by, Electrochemical Anodization: Four Synthesis Generations, MaterialProperties of TiO_2 Nanotube Arrays: Structural, Elemental, Optical, and Electrical, Applications, Boron Nitride,Nanotubes: Synthesis and Structure, One-Dimensional ,Oxide Nanostructures

Module 3: Nanofibers and Metal Oxide Frameworks (10 Lectures)

Introduction, The Electrospinning Process, Key Processing Parameters, Nanofiber Yarnsand Fabrics Formation, Potential Applications of Electrospun Fibers, Nanocomposite Fibers and their Structural Applications, Metal Oxide Frameworks, definitions, advantages, disadvantages, methods of synthesis, Structural originality of MOFs, properties, Applications.

Reference Books:

1) TiO_2 Nanotube Arrays: Synthesis, Properties, and Applications by Craig A. Grimes and Gopal K. Mor, Springer Publisher
2) Nanotubes and Nanofibers; Advanced Materials Series, Series Editor: Yury Gogotsi, Drexel University, Philadelphia, Pennsylvania, USA, Nanotubes and Nanofibers by Yury Gogotsi
3) Hybrid porous solids: past, present, future by Gerard Ferey, Chemical Society Reviews, 37 (2008) 191-214. DOI: 10.1039/b618320b
4) Semiconductor Nanocrystal, Quantum Dots: Synthesis, Assembly, Spectroscopy and Applications by Andrey L. Rogach (Ed.), Springer Publisher
5) Nanotubes and Nanowires, CNR Rao and Govindraj, RSC Publishers
6) Quantum well, wires and dots, Paul Harison, Wiley Publisher
7) Joel R. Fried; Polymers Science and Technology, Prentice-Hall of India Pvt. Ltd. New Delhi, 2002.
8) Vasant R. Gowariker, N. V. Viswanathan, Jayadev Sreedhar; Polymer Science, New Age International Pvt. Ltd., New Delhi, Reprint 2005.
9) Joseph H. Koo, Polymer Nanocomposites: Processing, Characterization, and Applications, McGraw-Hill, New Delhi, 2006.

NS-353 MJ Applications of Nanobiotechnology

Lectures: 30 **(Credits-02)**

Module 1: Functional Principles of Nanobiotechnology (08 Lectures)

• Information driven nanoassembly, Energetic, Role of enzymes in chemical transformation, allosteric motion and covalent modification in protein activity regulation,.Structure and functional properties of Biomaterials. • Bimolecular motors: ATP Synthetase and flagellar motors. • Traffic across membranes: Potassium channels and Bactreriorhodapsin.

Module 2: Nanomolecular and nanobiotechnological Diagnostics and detection system r– Array and Chips (08 Lectures)

• Nanoarrays Definition, Properties. • Nanofluidic: Definition, Properties. • Microfluidic Chips; Definition, Properties • Protein Microarray: Definition, Properties. • Electrochemical, Optical and mechanical transducer: Principle and Application only • Magnetic transducer and Piezoelectric transducer: Only introduction and use • Biosensor: Introduction, Characteristics, types (CNTs, QD, NPs. Graphene, Dendrimers) • Use of gold nanoparticles as biosensor: Heavy metal cation detection, Detection of small molecules in various samples such as blood., DNA detection, Enzymatic activity assay • Nanobiotechnology in Food Preservation: Food processing, Food preservation, Food contamination determination.

Module 3: Nanopharmaceuticals (08 Lectures)

• Small scale system for drug delivery system (DDS): Intelligent pills, Wobbling gels, Use of patches, Magnetically retainable drug delivery system, DES. • Applications of nanobiotechnology in the treatment of infectious disease Viral infectious disease, Fungal infectious disease. • Application of nanobiotechnology in the treatment of chronic disease, Diabetes, Hypertension • Application of gold nanoparticles in drug delivery. • Functionalized gold nanoparticles for protein delivery.

Module 4: Applications in Cancer Therapy and diagnosis (06 Lectures)

• Cancer: Carcinogens, properties of cancer cells and development of cancer cell. • Introduction and Rationale for Nanotechnology in Cancer; Application in Breast cancer. Application in brain cancer. Pancreatic cancer. Target delivery of anticancer drug.

Reference Books:

1. C. M. Niemeyer, C. A. Mirkin, ―Nanobiotechnology: Concepts, Applications and Perspectives‖, Wiley – VCH, (2004).

2. T. Pradeep, ―Nano: The Essentials‖, McGraw – Hill education, (2007).
3. Challa, S.S.R. Kumar, Josef Hormes, Carola Leuschaer, ‖Nanofabrication Towards Biomedical Applications, Techniques, Tools, Applications and Impact‖, Wiley – VCH, (2005).
4. Nicholas A. Kotov, ―Nanoparticle Assemblies and Superstructures‖, CRC, (2006).
5. David S Goodsell, "Bionanotechnology‖, John Wiley & Sons, (2004).
6. Kewal K. Jain, The Handbook of Nanomedicine ‖Humana Press, (2008).
7. Zhang, ‖Nanomedicine: A Systems Engineering Approach" 1st Ed., Pan Stanford Publishing, (2005).
8. Robert A. Freitas Jr., ―Nanomedicine Volume IIA: Biocompatibility‖, Landes Bioscience Publishers, (2003).

NS-354 MJ Nanoelectronics

Lectures: 30 **(Credits-02)**

Module 1: Introduction to Semiconductor technology (08 Lectures)

Survey of modern electronics and trends towards nanoelectronics, Discussion of the International Technology, Roadmap of Semiconductor (ITRS) characteristics, Need for new concept in electronics, From microelectronics towards biomolecules electronics, Moores low and CMOS scaling, Atoms-up approaches: Molecular electronics involving single molecules as electronic devices, transport in molecular structures, molecular interconnects.

Module 2: Fabrication process flow for nano device (08 Lectures)

Environment for VLSI Technology: Clean room and safety requirements. Wafer cleaning processes and wet chemical etching techniques; Impurity incorporation: Solid State diffusion technology; Ion Implantation; Oxidation: Kinetics of Silicon dioxide growth for thin and ultrathin films. Characterizations of oxide films; High k and low k dielectrics for ULSI.

Module 3: Lithography (08 Lectures)

Photolithography, E-beam lithography and newer lithography techniques for VLSI/ULSI; Mask generation. CVD techniques for deposition of polysilicon, silicon dioxide, silicon nitride and metal films; Epitaxial growth of silicon; modeling and technology. Metal film deposition: Evaporation and sputtering techniques for metal film. Multi-level metallization schemes.

Module 4: Nano-devices and Theoretical Modeling (06 Lectures)

Shrink-down approaches: Introduction, The nanoscale MOSFET, Vertical MOSFETs, limits to scaling, system integration limits (interconnect issues etc.), Single electron transistors, new storage, optoelectronic, and spintronics devices.

Reference Books:

1 C.Y. Chang and S.M.Sze (Ed), ULSI Technology, McGraw Hill Companies Inc, 1996.
2. S.M. Sze (Ed), VLSI Technology, 2nd Edition, McGraw Hill, 1988.
3. Nanoelectronics and Information Technology (Advanced Electronic Materials and Novel Devices), Waser Ranier, Wiley-VCH (2003)

NS 355 MJP Nanoscience and Nanotechnology Laboratory-VII

Lectures: 30 **(Credits-2)**

Sr. No	Title of the experiment
1	Study the X-ray diffraction method and to determine the grain size of given material.
2	Analysis of Surface Morphology using SEM/FESEM.
3	Analysis of structural Morphology using TEM/HRTEM.
4	Characterization of Graphene using Raman Spectroscopy.
5	Synthesis of TiO2- Chemical route method
6	Preparation of ZnO thick films by screen printing techniques
7	Gas sensing performance of pure ZnO thick films.
8	Gas sensing performance of pure ZnO thick films.
9	IV characteristics of pure TiO2 thick films.
10	IV characteristics of pure ZnO thick films.
Activities	
1	Lab Visit (Equivalent to 2 Practical's)
2	Use of Anti plagiarism Software (Equivalent to 2 Practical's)

NS 356 MJP Nanoscience and Nanotechnology Laboratory-VIII

Lectures: 30 **(Credits-2)**

Sr. No	Title of the experiment
1	Study of absorption spectrum of FeCl3 solution.
2	Synthesis of Silver nanoparticles by using curry leaves plant extract and study of absorption spectra.
3	Study of Photolithography techniques.
4	Preparation of thin film by using spin coating techniques.
5	Measurement of thickness of thin film using weight difference method (prepared by using spin coating)
6	Electrochemical deposition of Cu thin films.
7	Study of IR Spectroscopy.
8	Study of Atomic Absorption Spectrophotometer.
9	Study of Thermal gravimetric analysis.
10	Preparation plates using hydraulic press and study of its electrical properties.
Activities	
1	Lab Visit (Equivalent to 2 Practical's)
2	Industrial Visit (Equivalent to 2 Practical's)

Major Elective

NS-360 MJ Physics of Nanomaterials

Lectures: 30 **Credit 2**

Unit 1: Basics of Nanomaterials (10 Lectures)

- Introduction to nanoscience and nanotechnology
- Classification: 0D, 1D, 2D nanomaterials
- Quantum confinement and size effects
- Surface-to-volume ratio
- Top-down and bottom-up approaches

Unit 2: Physical Properties of Nanomaterials (10 Lectures)

- Electronic properties: Density of states, quantum wells, wires, dots
- Optical properties: Surface plasmon resonance, absorption, photoluminescence
- Magnetic properties: Superparamagnetism
- Mechanical properties: Strength and hardness

Unit 3: Nanomaterials, Devices and Applications (10 Lectures)

- Carbon nanomaterials: Carbon nanotubes (CNTs), graphene
- Semiconductor nanomaterials: Quantum dots, nanowires
- Nanodevices: Nanoelectronics, nanosensors
- Applications:

a) Energy (solar cells, batteries)
b) Medicine (drug delivery)
c) Environment (water purification)

Reference Books

1) C. P. Poole Jr. & F. J. Owens – Introduction to Nanotechnology
2) K. K. Chattopadhyay & A. N. Banerjee – Introduction to Nanoscience and Nanotechnology
3) Charles Kittel – Introduction to Solid State Physics
4) Bharat Bhushan – Springer Handbook of Nanotechnology
5) T. Pradeep – Nano: The Essentials

Major Elective

NS-361 MJP Practical (Physics of Nanomaterials)

Lectures: 30 **Credit 2**

Sr. No	Title of the experiment
1	Study of size and scale of nanomaterials (nm to m conversion)
2	Plotting and analysis of quantum confinement effect (energy vs size)
3	Study of density of states in quantum wells, wires, and dots (graphical)
4	Study of optical absorption of nanoparticles using UV–Visible spectroscopy (demo/data analysis)
5	Determination of band gap using absorption data (Tauc plot method)
6	Study of surface plasmon resonance in metal nanoparticles (theoretical/data-based)
7	Study of superparamagnetism using magnetization vs temperature graph (data analysis)
8	Comparative study of mechanical properties at nanoscale (case study/report)
9	Study of structure and properties of carbon nanotubes (model/report)
10	Study of graphene properties and applications (assignment/model)
11	Study of nanoelectronic devices (TFT, nanosensors) – report/demo
12	Study of applications of nanomaterials in energy, medicine, and environment (report)

VSC

NS-371 VSC Practical (Basic Instrumentation Skill)

Lectures: 30 **Credit 2**

Sr. No	Title of the experiment
1	Study of Optical Microscope: Working and limitations
2	Study of Scanning Electron Microscope (SEM)
3	Study of Transmission Electron Microscope (TEM)
4	Study of Atomic Force Microscope (AFM)
5	Study of Scanning Tunneling Microscope (STM)
6	Study of UV–Visible Spectroscopy
7	Study of FTIR Spectroscopy
8	Study of Raman Spectroscopy
9	Structural analysis using X-ray Diffraction (XRD)
10	Particle size analysis using Dynamic Light Scattering (DLS)
11	Particle size measurement using Particle Size Analyzer
12	Study of surface and elemental analysis techniques (EDX/XPS/BET)