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)

Choice Based Credit System Syllabus (revised in June 2021)

To be implemented from Academic Year 2021-2022

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	Basic Instrumentation Skill	2
				NS- 3511	C Programming	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 & Computer Application	2
				NS- 3611	Renewable Energy And Energy Harvesting	2

SEMISTER-V

Course code and title: NS-351 Polymer Nanocomposite

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

Unit 1 - Synthesis of Polymer: (12 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: (12 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.

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Unit 3- Synthesis of Oxide/sulphide –polymer nanocomposites: (12 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)

Course code and title: NS-352 Nanophysics

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

Unit 1 – Probability and distribution functions

(8 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, Liouville theorem, 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: (12 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)

Revision of electron probe microscopy, 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. Introductory Solid States Physics – H. P. Myers
7. Solid States Physics - S.O. Pillai (latest edition)
8. Elementary Solid State Physics- M. Ali Omar
9. Solid States Physics – A.J. Dekkar
10. Fundamentals of Molecular Spectroscopy - C. N. Banwell,
11. Fundamentals of Molecular Spectroscopy - WALTER S. STRUVE
12. Introduction to Nanomaterials and nanotechnology by Vladimir Pokropivny,
13. Bharat Bhusan, “Springer Handbook of Nanotechnology”, springer, Newyork, 2007
14. Hari Singh Nalwa, “Encyclopedia of Nanotechnology”, USA 2011

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

Course code and title: NS-353 Nanobiotechnology

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

Unit 1 – Basic biomolecules: **[15 Lectures]**

Development of nanobiotechnology – overview.

Basic biomolecules:

- Carbohydrats: 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. Glyco 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-particals and its applications : Introduction to biological nanoparticals, Exosomes, lipoproteins, Ferritin, Biological nano-moters 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: bactrio-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 . (8 Lectures)

definition classification of nanomaterial
(i) carbon based materials (ii) metal based materials (iii) dendrimers (iv) composites,Graphene, Nanotubes, Nanowires ,Nanocones, 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

Course code and title: NS-354 Carbon based Nanomaterials

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

Unit 1 - Forms of Carbon: (12 lectures)

Structure and bonding in Graphite, Diamond like Carbon(DLC) and other allotropes of carbon, carbon nanotubes and structure of C_{60}.

Unit 2 - Production of Carbon based nanomaterials: (12 Lectures)

Production of carbon nanotubes (Single walled and multi walled) , arc discharge method, Laser ablation, Chemical vapour deposition, Pyrolatic technique, purification and separation of carbon nanotubes, diamond synthesis routes, preparation of nanodiamond.

Unit 3- Applications of carbon based nanomaterials: (12 lectures)

Catalysis applications of nanoforms of carbon, supercapacitor, battery applications, water purification, solar cell applications, sensor and FET, Biological applications.

Reference Books

1.Carbon materials and nanotechnology – Anke Krueger, Wiley- VCH publication
2. Carbon-based Nanomaterials and Hybrids, Hans J. Fecht, Kai Brühne, CRC Press
3. Carbon Nanotube Science, Peter J. F. Harris, Cambridge University Pres

4. Introduction to nanoscience – S. M. Lindsay, OXFORD publication

5. Nanostructured materials, C. C. Koch, 2006, William Andrew Inc
6. The Chemistry of Nanomaterials: Synthesis, Properties and Applications. C. N. R. Rao, A. Muller, A. K. Cheetham (Eds.), (2004) WILEY-VCH Verlag GmbH & Co., Weinheim

7. Nanostructured Materials, Jackie Yi-Ru Ying, 2001, Academamic press

8. Nanostructured materials, Philippe Knauth, Joop Schoonman, 2002, Springer

Course code and title: NS-355 Energy Conversion Devices and applications

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

Unit I: Photovoltaic Solar cells: (9 lectures)

Introduction to solar energy, the greenhouse effect, properties of sunlight, energy of photon, p-n junction under dark and under illumination, Light generated current, I-V equation, Characteristics, Upper limits of cell parameters, losses in solar cells, equivalent circuit, effects of various parameters on efficiency, Solar cell design, Design for high Isc, Antireflective coating (ARC), Design for high Voc and fill factor. Minority carrier life time and diffusion length measurement. Design of Silicon solar cells, Thin film solar cells.

Unit 2: Sensitized Solar Cells: (9 lectures)

Introduction, Basics of photo-electrochemical cells, Construction, Mechanism of DSSCs, Energy band diagram, important parameters, properties of working electrode and counter electrode, properties of electrolytes and dyes, fabrication process, Operation, Efficiency, Advantages, Disadvantages, Introduction to quantum dot solar cells.

Unit 3: Polymer Solar Cells: (9 lectures)

Introduction, history of the polymer solar cells, planar heterojunction solar cells, bulk heterojunction solar cells, excitons in polymers, donor and acceptors polymers, mechanism of photon absorption and power generation, evolution of polymer solar cell designs, hybrid polymer solar cells.

Unit 4: Perovskite solar cells: (9 lectures)

Introduction, history of perovskite solar cells, operation, design and working principal of perovskite solar cells, advantage and disadvantages of perovskite solar cells, comparison of photon conversion efficiency of perovskite solar cells with other solar cells.

Reference Books:

1. Solar photovoltaics, Fundamentals, Technologies and Applications by Chetan Singh Solanki, PHI Learning Private Limited, Delhi-110092.
2. Polymer photovoltaics, a practical approach by Fredrik C. Krebs, Spie Press, Bellingham, Washington USA.
3. Organic Solar Cells, Theory, Experiment, and Device Simulation by Wolfgang Tress, Springer.
4. Dye Sensitized Solar Cells by K. Kalyansundaram, EPFL Press, A Swiss academic publisher distributed by CRC press.
5. Solar cells- Dye-sensitized Devices by Leonid A. Kosyachenko, Published by Intech, Janeza Trdine 9, 51000 Rijeka, Croatia.

Course code and title: NS-356 Environmental Nanotechnology and Applications

Unit 1 – Water Pollution: (12 lectures)

1) Water Pollution, sources and management of water pollution, need for water management, waste water collection, physicochemical properties of waste water, water and waste water treatment, physical, chemical and biological treatment process, activated sludge, oxidation ditches, trickling filter, rotating discs, rotating drums, oxidation ponds, Anaerobic digestions, anaerobic filters, up flow anaerobic sludge blanket reactor, treatment schemes for water of dairy, distillery, sugar and antibiotic industries.
2) Ground water pollution, Sources, effect control, consequences of ground water pollution.
3) Drinking water, domestic and industrial waste water, nanotechnologies used in water treatments, effluent treatment.
4) Environment (Protection) act-1986, the water (prevention and control of pollution) act-1974

Unit 2 – Air pollution: (12 Lectures)

1) Air pollution, methods for the measurement of air pollution and its control, pollution in the atmosphere.
2) Toxicity due to air-borne nanomaterials, engineered nanomaterials in the environment and health effects of nanoparticles through air, absorption, pulmonary deposition of nanoparticles, elimination of dust deposited in the lungs, nanoparticles.
3) Absorption in the air, effect of ultrafine dust
4) The air (prevention and control of pollution) act-1981, clean air act and nanotechnology.

Unit 3- Nanomaterials for sensing toxic gases: (12 Lectures)

Gas sensing materials and devices, Techniques used for gas sensing (resistance, capacitance and electrochemical), Sensor properties, advantages of nanomaterials, synthesis and characterization of nano-metal oxides (tin oxide, zinc oxide, indium oxide),

mixed oxides, nanoscale materials for sensors (quantum dots, CNTs, nanotubes, wires and belts), colloidal silver and gold, magnetic nanoparticles, application of nanomaterials in sensors, CNT-based sensors, Grapehe-based sensors, active devices based on Nanostructures.

Reference Books:

1) Environmental applications of Nanomaterials: Synthesis, sorbents and sensors (2nd Edition) Editors: Glen E.Fryxell and Guozhong Cao, Imperial College Press

2) Metal Oxide Nanostructures As Gas Sensing Devices, G. Eranna, Crc Press, A Taylor And Francis Book,

3) Environmental Chemistry, A. K. De, Wiley Western ltd. , New Delhi, 2003

4) Waste water Engineering- treatment, Disposal and reuse, Metcalf and Eddy, Inc., Tat McGraw Hill, 1999

5) Standard method by American public health association (APHA), 2005

6) Water and waste water analysis (Handbook of methods in environmental studies Col. 1 by S. K. Maiti, ABD Publication, Delhi, ISBN-978-81-8577-34-07

Course code and title: NS-357 Nanoscience and Nanotechnology Laboratory-3A

Credits-02

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 TiO_2 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)

9. Lab Visit (equivalent to two practical)

Course code and title: NS-358 Nanoscience and Nanotechnology Laboratory-3B

Credits-02

1 Determination of band gap of TiO_2 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.

9 Use of plagiarism software (equivalent to two practices)

B.Sc. (Nanoscience and Nanotechnology) (Semester-V)

Paper Code: NS-369

Paper Title: Project

Credits-02

PROJECT BASED ON NANOSCIENCE / NANOTECHNOLOGY / APPLICATIONS OF NANOMATERIALS

SKILL ENHANCEMENT COURSE

Course code and title: NS-3510

Basic Instrumentation Skills

Lectures : 36 **Credits: 2**

1) Basic of Measurement:

Instruments accuracy, precision, sensitivity, resolution range etc. Errors in measurements and loading effects. Principle and working of digital meters. Comparison of analog & digital instruments. Characteristics of a digital meter. Multimeter: Block diagram and working of a digital multimeter. Principles of measurement of dc voltage and dc current, ac voltage, ac current and resistance. Specifications of a multimeter and their significance. (8 Lectures)

2) Electronic Voltmeter

Principles of voltmeter, Construction (block diagram only). Specifications of an electronic Voltmeter and their significance. AC millivoltmeter: Type of AC millivoltmeters: Amplifier- rectifier, and rectifier- amplifier. Block diagram ac millivoltmeter, specifications and their significance. (4 Lectures)

3) Cathode Ray Oscilloscope:

Block diagram of basic CRO. Construction of CRT, Electron gun,electrostatic focusing and acceleration (Explanation only-no mathematical treatment), brief discussion on screen phosphor, visual persistence & chemical composition. Time base operation, synchronization. Front panel controls. Specifications of a CRO and their significance.

Use of CRO for the measurement of voltage (dc and ac frequency, time period. Special features of dual trace, introduction to digital oscilloscope, probes. Digital storage Oscilloscope: Block diagram and principle of working. (9 Lectures)

4) Signal Generators and Analysis Instruments:

Block diagram, explanation and specifications of low frequency signal generators. pulse generator, and function generator. Brief idea for testing, specifications. Distortion factor meter, wave analysis. (4 Lectures)

5) Impedance Bridges & Q-Meters: Block diagram of bridge. working principles of basic (balancing type) RLC bridge. Specifications of RLC bridge. Block diagram & working principles of a Q- Meter. Digital LCR bridges. (3 Lectures)

Activity **(8 Lecture)**

The test of lab skills will be of the following test items:

1. Use of an oscilloscope.
2. CRO as a versatile measuring device.
3.Circuit tracing of Laboratory electronic equipment,
4.Use of Digital multimeter/VTVM for measuring voltages
5.Circuit tracing of Laboratory electronic equipment
6. Winding a coil / transformer.
7.Study the layout of receiver circuit.
8. Trouble shooting a circuit
9. Balancing of bridges

Laboratory Exercises:

1. To observe the loading effect of a multimeter while measuringvoltage across a low resistance and high resistance.
2. To observe the limitations of a multimeter for measuring high frequency voltage and currents.
3. To measure Q of a coil and its dependence on frequency, using a Q- meter.
4. Measurement of voltage, frequency, time period and phase angle using CRO.
5. Measurement of time period, frequency, average period using universal counter/ frequency counter
6. Measurement of rise, fall and delay times using a CRO.
7. Measurement of distortion of a RF signal generator using distortion factor meter.
8. Measurement of R, L and C using a LCR bridge/ universal bridge.

Reference Books:

1) A text book in Electrical Technology - B L Theraja - S Chand and Co.

2) Performance and design of AC machines - M G Say ELBS Edn.

3) Digital Circuits and systems, Venugopal, 2011, Tata Mc Graw Hill. Logic circuit design, Shimon P. Vingron, 2012, Springer.

4) Electronic Devices and circuits, S. Salivahanan & N. S.Kumar, 3

2012, Tata Mc-Graw Hill

5) Electronic circuits: Handbook of design and applications, U.Tietze, Ch.Schenk, 2008, Springer

Electronic Devices, 7/e Thomas L. Floyd, 2008, Pearson India

SKILL ENHANCEMENT COURSE

Course code and title: NS-3511

C Programming

Lectures : 36 **Credits: 2**

1. Concepts of programming: **(6 L)**

Definition and Properties of algorithms, Algorithm development,

Flow charts- symbols and simple flowcharts.

Flow charts and Algorithms for Kinematic equations, Free fall, Equation of state, Factorial of a number.

Types of programming language: Lower, middle and higher level languages.

2. C Programming **(20 L)**

Structure of C program, Character set, key words, Constants andvariables, Variable names, Data types and their declarations, Symbolic Constants.

Input/output functions: scanf ( ), printf ( ), getchar ( ), putchar ( ), getch ( ), gets ( ), puts ( ). Operators and Expressions: Arithmetic Operators, Relational Operators, LogicalOperators, Assignment Operators, Conditional Operator.

Formatted input/output

Control statements: If, if else, while, do while for loop, nested control structures (nested if, nested loops), break, continue, switch- case statement, goto statement. Use of Library functions: e.g. mathematical, trigonometric, graphics.

3. Arrays and Pointers in C **(4 L)**

Arrays: 1-D, 2-D and String

Examples: Arranging numbers in descending and ascending order, Sum of matrices, multiplication of matrices.

Concept of Pointers

4.Graphics in C: **(6L)**

Some simple graphic commands- Line, Circle, Arc, Ellipse, Bar.

Activity

1) Program to find factorial of given number.

2) Program to find prime number in given range.

3) Program to draw line, arc, circle, ellipse, rectangle, bar using computer graphics program.

4) Program to find root of equation using Newton-Rapsons method.

5) Program to find integration of given equation using Trapezoidal rule.

5) Program to find integration of given equation using $1/3^{rd}$ rule.

Reference Books:

1. Programming in C- (Schaum's series) Gottfreid TMH

2. Programming in C- Balgurusami Prentice Hall publications

3. Let us C- YashwantKanetkar BPB publications

4. Programming with C- K.R. Venugopal, S. R. Prasad, TMH.

5. Introductory methods of numerical analysis-S. Sastry Prentice Hall

6. Computer oriented numerical methods – V. Rajaraman.

Semester-VI

Course code and title: NS-361
Polymer Hetro-structure and their Applications.

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

Unit 1- Introduction to Hetero-structures [12 Lectures]

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

Unit 2- Hetero-structures by Ex-situ Polymerization [12 Lectures]

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.

Unit 3- Hetero-structures by In-situ Polymerization [12 Lectures]

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

Reference Books:

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.

Course code and title: NS-362
Functional Nanomaterials.

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

Unit 1. Semiconductor quantum dots

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

Unit 2 Nanotubes and nanowires

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

Unit 3 Nanofibers and Metal Oxide Frameworks

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.
10) Suprakas Sinha Ray and Mosto Bousmina, Polymer Nanocomposites and Their Applications, American Scientific Publishers, 2006.

Course code and title: NS-363
Applications of Nanobiotechnology

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

UNIT - 1 Functional Principles of Nanobiotechnology: (4 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.

UNIT-2 Nanomolecular and nanobiotechnological Diagnostics and detection system r– Array and Chips: (15 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.

UNIT -3 Nanopharmaceuticals: (9 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 disesde, Diabets, Hypertension
- Application of gold nanoparticles in drug delivery.
- Functionalized gold nanoparticles for protein delivery.

UNIT-4 Applications in Cancer Therapy and diagnosis: (8 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.

References:

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).

Course code and title: NS-364
Nanoelectronics

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

Unit 1 - Introduction to Semiconductor technology: **(12 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.

Unit 2 Fabrication process flow for nano device **(8 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.

Unit 3 Lithography : **(8 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 metallisation schemes.

Unit 4- Nano-devices and Theoretical Modeling: **(8 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.

References:

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)

Course code and title: NS-365
Energy Storage Device and Applications

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

Unit 1 - Introduction To Energy Storage: **(12 lectures)**

What is mean by energy storage, Need of energy storage, Worlds scenario of energy storage, Development and technology overview, Functional nanomaterials for efficient energy storage device.

Unit 2 - Battery: **(8 Lectures)**

Battery as energy storage device, Construction and working of battery, Electrode design, Charging and discharging, Types of batteries.

Unit 3- Supercapacitor : **(8 Lectures)**

Fundamental, Construction and properties, Types of supercapacitors, Cycling and performance characteristic, Recent trend of nanotechnology in supercapacitors.

Unit 4- Application of energy storage: **(8 lectures)**

Scope of energy storage device, Methods: mechanical, thermal, electrochemical, electrical, Home and industrial energy storage.

References:

1) Energy storage device for electronic system: Rechargeable batteries and Supercapacitors by Nihal Kularatna, Academic press Elsevier

2)Advanced Batteries: Materials Science Aspects by Robert Huggins, springer Publication.

3)Supercapacitors: Materials, Systems and Applications, by Francois Beguin (Editor)

4) Energy: Sources, Utilization, Legislation, Sustainability, Illionois as model state by GA Mansoori, N Enayati, L B Agarkar, World Sci. Pub. Co. 2016

Course code and title: NS-366
Photocatalysis for Environmental Pollution Control

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

Unit 1 - Introduction To Catalysis : **(12 lectures)**

Introduction to catalysis, lock and key model, classifications, heterogeneous catalysis, reactionon the solid surfaces, adsorption isotherms ; Langmuir, Freundlich and Brunauer-Emmett-Teller(BET) (no derivation).Physisorption and chemisorption.

Unit 2 - Kinetics of Catalysis: **(12 Lectures)**

Catalytic activity (bulk and nanoscale), kinetics of catalytic reactions and determination. Catalytic rate constants: apparent rate constant and normalized rate constant (for pseudo-first order kinetics).Induction time, catalytic efficiency and turnover frequency, inhibition. Application of metal nanoparticles in organic reactions (Heck and Suzuki-Maurya reactions),environmental remediation.

Unit 3- Photocatalysis : **(12 Lectures)**

Introduction of photocatalysis, basics of photochemistry, principles of light over solid, Jablonskii diagram and photophysical processes in electronically excited state, solar spectrum analysis. Properties of good photocatalysts. Application of photocatalysis: self cleaning, purification of water and air.

References

(1) Y. Nosaka and A Nosaka, Introduction to Photocatalysis: from basic Sciences to Application, RSC Publications, 2016.

(2) J. G. Calvert, J. N. Pitts, Photochemistry, Wiley & Sons, New York, 1966.

(3) N. Serpone, E. Pelizzetti (Eds.), Photocatalysis. Fundamentals and Applications, Wiley, New York, 1989.

(4) K. K. Rohatgi-Mukherjee, Fundamentals of Photochemistry, Wiley, New York,3rd Edition, 2002.

(5) Photoelectrochemical solar cells, Suresh Chandra, Gordon and Breach Science Publishers, 1985.

(6) Physical Chemistry of Surfaces , W. Adamson, Wiley Intersciences,(5th edition), 1990.

(7) Physical chemistry - Peter Atkins, Julio de Paula , 7th Edition, Oxford University Press.

(8) Catalytic Chemistry, B.C. Gates, John Wiley and Sons Inc. (1992)

(9) Nanoparticles and Catalysis; D. Astruc, Wiley-VCH, 2008

Course code and title: NS-367
Nanoscience and Nanotechnology Laboratory-4A

Credits-02

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 TiO_2- 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 TiO_2 thick films.

10) IV characteristics of pure ZnO thick films.

Course code and title: NS-368
Nanoscience and Nanotechnology Laboratory-4B

Credits-02

1) Study of absorption spectrum of $FeCl_3$ 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.

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B.Sc. (Nanoscience and Nanotechnology)

Paper Code: NS-369

Paper Title: Project

PROJECT BASED ON NANOSCIENCE / NANOTECHNOLOGY / APPLICATIONS OF NANOMATERIALS

SKILL ENHANCEMENT COURSE

Course code and title: NS-3610
Data Analysis & Computer Application

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

UNIT I :

Basic statistical functions and analysis – mean, median, mode standard deviation, correlation, regression methods & techniques, estimation Linear trend and growth rate.

Measures of central tendency: mean, median and mode; arithmetic, geometric and harmonic mean. Measures of dispersion, skewness and kurtosis. Correlation and regression.

UNIT II :

Introduction to probability theory. Notions of random experiment, sample space, event, probability of an event. Conditional probability. Independence of events. Random variables and probability distributions. Binomial and normal distributions. Estimation of population parameters from sample data.

UNIT III :

Basic components and organization of a computer, Generation and classification of computers, Input/Output devices, Data representation, Computer Software, Programming languages and packages.

UNIT IV :

Familiarisation of MSExcel, Creating & Editing Worksheet, Formatting and Essential Operations, Formulas and Functions, and use of different Charts.

Readings

1. P.H. Karmel and M. Polasek (1978), Applied Statistics for Economists, 4th edition; Pitman.

2. M.R. Spiegel (2003), Theory and Problems of Probability and Statistics (Schaum Series).

3. Rajaraman, V. (1996) – Fundamentals of Computers, Prentice Hall (India) New Delhi

4. V.P.Jagi & S Jain (1996) – Computer for Beginners, Academic publisher, New Delhi

SKILL ENHANCEMENT COURSE

Course code and title: NS-3611
Renewable Energy and Energy Harvesting

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

UNIT I : Fossil fuels and Alternate Sources of energy:

Fossil fuels and nuclear energy, their limitation, need of renewable energy, non-conventional energy sources. An overview of developments in Offshore Wind Energy, Tidal Energy, Wave energy systems, Ocean Thermal Energy Conversion, solar energy, biomass, biochemical conversion, biogas generation, geothermal energy tidal energy, Hydroelectricity.

UNIT II : Solar energy:

Solar energy, its importance, storage of solar energy, solar pond, non plate collector, solar distillation, solar cooker, solar green houses, solar cell, absorption air conditioning. Need and characteristics of photovoltaic (PV) systems, PV models and equivalent circuits, and sun tracking systems.

UNIT III: Wind Energy harvesting: Fundamentals of Wind energy, Wind Turbines and different electrical machines in wind turbines, Power electronic interfaces, and grid interconnection topologies.

UNIT IV : Ocean Energy:

Ocean Energy Potential against Wind and Solar, Wave Characteristics and Statistics, Wave Energy Devices. Tide characteristics and Statistics, Tide Energy Technologies, Ocean Thermal Energy, Osmotic Power, Ocean Bio-mass.

Hydro Energy: Hydropower resources, hydropower technologies, environmental impact of hydro power sources.

References

1. Non-conventional energy sources - G.D Rai - Khanna Publishers, New Delhi

2. Solar energy - M P Agarwal - S Chand and Co. Ltd.

3. Solar energy - Suhas P Sukhative Tata McGraw - Hill Publishing Company Ltd.

4. Godfrey Boyle, “Renewable Energy, Power for a sustainable future”, 2004, Oxford University Press, in association with The Open University.