DR. BABASAHEB AMBEDKAR MARATHWADA UNIVERSITY, AURANGABAD.

Curriculum under Choice Based Credit & Grading System

M.Sc. I & II Year

Nano-Technology

Semester–I to IV

run at college level from the Academic Year 2015-16 & onwards

Dr. Babasaheb Ambedkar Marathwada University
Aurangabad 431004, Maharashtra, India

Department of Nanotechnology

M. Sc. Nanotechnology
Syllabus
(Choice Based Credit System)

(Academic Autonomy)

(Effective from June 2011 onwards)

Course Structure:

First Year Course

Semester I

Course	Course Title	Teaching Hours/week	Max Marks	Credits
NAN 401	Quantum Physics I	4 Hours	100	4
NAN 402	Solid State I	4 Hours	100	4
NAN 403	Chemistry I	4 Hours	100	4
NAN 404	Bioscience I	4 Hours	100	4
NAN 441	Practical I	4 Hours	100	4
NAN 442	Seminar-I Fundamental Topics in Nanotechnology	4 Hours	100	4

Semester II

Course	Course Title	Teaching Hours/week	Max Marks	Credits
NAN 405	Quantum Physics II	4 Hours	100	4
NAN 406	Solid State II	4 Hours	100	4
NAN 407	Chemistry II	4 Hours	100	4
NAN 408	Biosciences II	4 Hours	100	4
NAN 443	Practical II	4 Hours	100	4
NAN 444	Seminar-II Fundamental Topics in Nanotechnology	4 Hours	100	4

Second Year Course

Semester III

Course	Course Title	Teaching Hours/ week	Max Marks	Credits
NAN 501	Quantum Confinement I	4 Hours	100	4
NAN 502	Advances in Nanotechnology-I	4 Hours	100	4
NAN 503	Applications of Nanotechnology-I	4 Hours	100	4
NAN 541	Practical III	6 Hours	100	4
NAN 542	Project I	6 Hours	100	4
NAN 543	Seminar-III Advanced Topics in Nanotechnology	4 Hours	100	4
NAN 521	Compulsory Service Course from Other Department	4 Hours	100	4

Semester IV

Course	Course Title	Teaching Hours/week	Max Marks	Credits
NAN 504	Quantum Confinement II	4 Hours	100	4
NAN 505	Advances in Nanotechnology-II	4 Hours	100	4
NAN 506	Applications of Nanotechnology-II	4 Hours	100	4
NAN 544	Practical IV	6 Hours	100	4
NAN 545	Project II	6 Hours	100	4
NAN 546	Seminar-IV Advanced Topics in Nanotechnology	4 Hours	100	4
NAN 521	Compulsory Service Course from Other Department	4 Hours	100	4

Nanotechnology Service Course for Other Departments Only
Following courses will be offered to other departments as service courses (subject to approval by the Departmental Committee). The time table for the service course will be arranged on Friday and Saturday (every week).

Course	Course Title	Teaching Hours/week	Max Marks	Credits
NAN 522	Service Course (Fundamentals of Nanotechnology and its General Applications)	4 Hours	100	4

Notes: (1) Tutorials consists of conceptual as well as numerical problems / questions based on the respective theory courses in the semester covering all five (05) units. Total marks assigned for tutorials will be 80 (20 for each theory course). Remaining 20 marks are assigned for seminar based on laboratory course.
(2) Each course / paper should be taught for 40 to 45 contact hours.
(3) Teaching duration for LAB COURSES in first and second semesters should be of 4 hours and for those in third and fourth semesters and project should be 06 hours per week per batch
(4) Each of the courses is divided into five units.
(5) The content of theory course / paper as well laboratory (practical) course may be modified time to time (with the approval DC) to keep pace with the recent developments and trends in the subject.

Attendance:

Students must have 75 % of attendance in each core, specialized, elective and laboratory course for appearing examination otherwise he / she will not be strictly allowed for appearing the examination of each course. However, students having 65 % attendance with medical certificate may request Head of the Department for the condo-nation of attendance. Monthly attendance of the students for each course will be displayed on the notice board.

Registration for Service Course:

- Students will have to register themselves for the service course of his / her interest after the start of semester in the department on official registration form. The teacher in-charge of the respective course will keep the record of the students registered. Maximum fifteen days period will be given from the date of admission for completion of registration procedure. The departmental committee shall follow a selection procedure after counseling to the students to avoid the overcrowding to a particular course at the expense of some other courses.
- No student shall be permitted to opt more than one service course in a semester.
- Normally no service course shall be offered unless a minimum of 10 students are registered.
- Students will have to pay the prescribed fees per course per semester /year for the registration as decided by the university.

Departmental Committee:

The existing Departmental Committee (DC) will monitor the smooth functioning of M. Sc. programme.

Results Grievances / Redressal Committee

Grievances / redressal committee will be constituted in the department to solve all grievances relating to the evaluation. The committee shall consist of Head/Co-ordinator of the Department and the concerned teacher of a particular course.

Evaluation Methods:

- The **grades for courses will be based on 20: 80 ratio** of continuous internal assessment (CIA) and semester end examination (SEE).

Internal Evaluation Method:

- There will be two mid semester examinations (20 marks each) as a part of continuous internal assessment (CIA), first based on 40 percent of the syllabus taught and second based on 60 percent of the syllabus taught. The setting of the question paper and the assessment will be done by the concerned teacher who has taught the course. **Average score obtained out of two mid semester examinations will be considered for the preparation of final sessional marks / grades.**

Term end Examination and Evaluation:

- Semester end examination (SEE) time table will be declared by the departmental committee and accordingly the concern course teacher will have to set question paper, conduct theory examination, conduct practical examination with external expert, evaluate, satisfy the objection /query of the students (if any) and submit the result to DC in one week time from the date of examination of that particular course / paper.
- The semester end theory examination in each theory course /paper will be of 80 marks. The total marks shall be 100 for each theory course / paper (80 marks semester end exam + 20 marks internal tests) and this is equivalent to 4 credits.
- Pattern of semester end question paper will be as below:
  - The semester end examination of theory course / paper will have two parts (20+60 = 80 Marks)
  - Part A will carry short questions of 2-3 marks (fill in the blanks/ answer in sentence / multiple choice questions) as compulsory question and it should cover entire syllabus (20 Marks)
  - Part B will carry 7 questions (12 marks each) out of which there shall be at least one question from each unit. Students will have to attempt any five questions (60 Marks).
  - 20 to 30% weightage can be given to problems wherein use of non-programmable scientific calculator may be allowed.
  - Number of sub questions (with allotment of marks) in a question may be decided by the examiner.

- Semester end practical examination will be of 50 marks each (semester end examination only). Student must perform at least eight experiments from each lab course. The final practical / project examination will be conducted at the end of each semester along with the theory examination. Students will be examined by one external and one internal examiner.

- At the end of each semester the Departmental Committee will assign grades to the students. The result sheet will be prepared in duplicate.

- Every student shall have the right to scrutinize answer scripts of mid semester /semester end examinations and seek clarifications from the teacher regarding evaluation of the scripts immediately thereafter or within 3 days of receiving the evaluated scripts.

- The Head of the Department shall display the grade points and grades for the notice of the students.

- The Head of the Department shall send all records of evaluation for safekeeping to the Controller of Examination in two week time after declaration of results.

Earning Credits:

At the end of every semester, a letter grade will be awarded in each course for which a student had registered. A student's performance will be measured by the number of credits that he/she earned by the weighted Grade Point Average (GPA). The SGPA (Semester Grade Point Average) will be awarded after completion of respective semester and the CGPA (Cumulative Grade Point Average) will be awarded at the end of the 4th semester.

Grading System:

- The grading reflects a student-own proficiency in the course. A ten point rating scale shall be used for the evaluation of the performance of the students to provide letter grade for each course and overall grade for the Master Programme. Grade points are based on the total number of marks obtained by him / her in all heads of the examination of the course. The grade points and their equivalent range of marks are shown in Table-I

Table – 1 : Ten point grade and grade description

Sr No	Marks Obtained (%)	Grade Point	Grade	Description
1	90-100	9.00- 10	O	Outstanding
2	80-89	8.00-8.90	A^{++}	Excellent
3	70-79	7.00-7.90	A^{+}	Exceptional
4	60-69	6.00-6.90	A	Very Good
5	55-59	5.50-5.90	B^{+}	Good
6	50-54	5.00-5.40	B	Fair
7	45-49	4.50-4.90	C^{+}	Average
8	41-44	4.1-4.40	C	Below Average
9	40	4.0	D	Pass
10	< 40	0.0	F	Fail (Unsatisfactory

- Non appearance in any examination / assessment shall be treated as the students have secured zero marks in that subject examination / assessment.
- Minimum D grade (4.00 grade points) shall be the limit to clear / pass the course / subject. A student with F grade will be considered as 'failed" in the concerned course and he / she has to clear the course by appearing in the next successive semester examinations. There will be no revaluation or recounting under this system.
- Every student shall be awarded grade points out of maximum 10 points in each subject (based on 10 point scale). Based on the grade points obtained in each subject, Semester Grade Point Average (SGPA) and then Cumulative Grade Point Average (CGPA) shall be computed. Results will be announced at the end of each semester and CGPA will be given on the completion of M. Sc. programme.

Computation of SGPA (Semester Grade Point Average) and CGPA (Cumulative Grade Point Average)

Grade in each subject / course will be calculated based on the summation of marks obtained in internal and semester end examination.

The computation of SGPA and CGPA will be as below

- Semester Grade Point Average (SGPA) is the weighted average points obtained by the students in a semester and will be computed as follows

$$SGPA = \frac{\text{Sum (Course Credit X Number of Grade Points in concern Course Gained by the Student}}{\text{Sum (Course Credit)}}$$

The SGPA will be mentioned on the mark sheet at the end of every semester.

- The Cumulative Grade Point Average (CGPA) will be used to describe the overall performance of a student in all semester of the course and will be computed as under.

$$CGPA = \frac{\text{Sum (All four Semester SGPA)}}{\text{Total Number of Semester}}$$

The SGPA and CGPA shall be rounded off to the second place of decimal.

Grade Card

Results will be declared by the Physics Department and the grade card (containing the grades obtained by the student along with SGPA) will be issued by the university after completion of every semester. The grade card will be consisting of following details.

- Title of the courses along with code opted by the student.
- Credits associated with the course.
- Grades and grade points secured by the student.
- Total credits earned by the student in a particular semester.
- Total credits earned by the students till that semester.
- SGPA of the student.
- CGPA of the student (at the end of the IVth semester).

Cumulative Grade Card

The grade card sheet showing details grades secured by the student in each subject in all semester along with overall CGPA will issued by the University at the end of IVth semester.

Course Syllabus of M.Sc. Nanotechnology

Semester-I

Course	Course Title	Teaching Hours/week	Max Marks	Credits
NAN 401	Quantum Physics I	4 Hours	100	4
NAN 402	Solid State I	4 Hours	100	4
NAN 403	Chemistry I	4 Hours	100	4
NAN 404	Bioscience I	4 Hours	100	4
NAN 441	Practical I	4 Hours	100	4
NAN 442	Seminar-I Fundamental Topics in Nanotechnology	4 Hours	100	4

Course syllabus of M.Sc. Nanotechnology
Semester I Syllabus (2011)

NAN 401: Quantum Physics-I Marks: 100 (80+20), Credit 4
Course : - NAN 401, Quantum Physics-I (Quantum mechanics for Nano particles)

Unit-I: Introduction to Quantum mechanics, Nanostructural Materials and Low dimensional structures.
Basic principles of Quantum mechanics (why and how classical mechanics fails), probability amplitude, wave functions, eigenstates and eigensvalues, Quantum wells, Quantum wires, Quantum dots, Nano clusters and Nano crystals.

Unit-II: Nano Mechanics
Nano scale mechanical properties of solid surfaces and thin films, scale effects in mechanical properties, mechanics of Biological Nanotechnology.

Unit-III: Quantum mathematical concepts for Nano particles.
Theory of linear differential, non linear differential, Partial Differential Equations and Ordinary Differential Equations, Basic concepts of statistics (M-B, B-E, and F-D statistics), data collection and measurement, Probability, Probability distributions and probability densities, Functions of random variables, Graphical and tabular displays of data, Numerical summaries of data, Partition function and its application for electrical, optical, magnetic and low temperature phenomena .

Unit-IV: Properties of Quantum nano material
Structural, optical, magnetic and electronic properties of nanocrystallites, Vibrational properties of nanocrystallites, Quantum mechanical properties of nano structural materials.

Unit-V : Quantum mechanical application of Nanotechnology
Quantum well and quantum dot lasers, ultra-fast switching devices, nano magnets for sensors and high density data storage, photonic integrated circuits, long wave length detectors, carbon nanotube, luminescence from porous silicon, spin-tronic devices.

References:

1. Nanomaterials : Synthesis, Properties and Applications:- Edited by A.S.Edelstein, R.C.Cammarata (IOP publication) .
2. Physics of low dimensional semiconductors:- John H Davies (Cambridge University Press),
3. Optical properties of Metal Clusters : - Uwe Kreibig and Michael Vollmer (Springer).
4. Nanostructural Materials : Processing Properties and Applications: - Carl C. Koch (Noyes Publications).
5. Magnetic Properties of Fine particle: - edited by J.L.Dorman and D.Fiorani (North-Holland publications).
6. Magnetic Multilayers and Giant Magnetoresistance: Fundamentals and Industrial applications:- Edited by Uwe Hartmann (Springer).
7. Quantum mechanics: - Schiff, Ghatak & Loknathan, Chatwal & Anand and M.L.Bellac, Cambridge University Press, 2006
8. Mathematical Physics:- Arfken and B.D.Gupta & Rajput
9. Introduction to the Practise of Statistics, Third Edition:- D.S.Moore and G.P.McCabe, W.H.Freeman and Co.

10. Mathematical Statistics :- Johh E.Freund's 6th Ed. By Miller & Millers, Pearson Education, Canada.
11. Numerical Analysis:- R.L.Burden and J.D.Faires, Brooks/Cole, 7th Ed. (2001)

NAN 402: Solid State-I Marks: 100 (80+20), Credit 4
Course : - NAN 402, Solid State I (Solid State and Nano Material Science)

Unit-I: Introduction
Classification of materials: crystalline, non-crystalline, nano-phase solid, Lattice translation vectors and lattices, basis crystal structure, Primitive and non-primitive cell fundamental types of lattices, characteristics of cubic lattices closed packed structures, Miller indices, symmetry elements, point groups and space groups, examples of simple crystal structures.

Unit-II: Zero-Dimensional Nanostructures: Nanoparticals
Introduction , Nanoparticles through Homogeneous Nucleation, Fundamentals of Synthesis of semiconductor nanoparticles, Synthesis of oxide,nanoparticles, Vapor phase reactions, Solid state phase segregation, Heterogeneous Nucleation and Growth, i.Fundamentals of heterogeneous nucleation, ii.Synthesis of nanoparticles, Kinetically Confined Synthesis of Nanoparticles, i. Synthesis inside micelles or using microemulsions, ii. Aerosol synthesis, iii. Growth homogeneous nucleation, ii.Subsequent growth of nuclei, iii.Synthesis of metallic nanoparticles,iv termination, iv. Spray pyrolysis, v. Template-based synthesis, Epitaxial Core-Shell Nanoparticles.

Unit-III One-Dimensional Nanostructures: Nanorods and Nanowires
Introduction, Spontaneous Growth, Evaporation (or dissolution) condensation, Vapor (or solution or solid)–liquid–solid growth, Stress-induced recrystallization, Template-Based Synthesis, Electrochemical deposition, Electrophoretic deposition, Template filling, Electrospinning, Lithography

Unit-IV- Two-Dimensional Nanostructures: Thin Film
Introduction,Fundamentals of Film Growth, Vacuum Science, Physical Vapor Deposition (PVD) i.Evaporation, ii. Molecular beam epitaxy, iii. Sputtering; Chemical Vapor Deposition (CVD), i. Types of chemical reactions, ii. Reaction kinetics, iii. Transport phenomena, iv. CVD methods, v. Diamond films by CVD; Atomic Layer Deposition (ALD), Superlattices, Self-Assembly, Langmuir-Blodgett Films, Electrochemical Deposition, Sol-Gel Films, Solution growth, SILAR films.

Unit-V- Special Nanomaterials and applications
Introduction; Carbon Fullerenes and Nanotubes: Carbon fullerenes, Fullerene- derived crystals, Carbon nanotubes; Micro and Mesoporous Materials: Ordered mesoporous materials, Random mesoporous materials, Crystalline porous materials (zeolites); Core-Shell Structures: Metal-oxide structures, Metal-polymer structures, Oxide-polymer structures; Organic-Inorganic Hybrids: Class I hybrids, Class II hybrids; Intercalation Compounds; Nanocomposites and Nanograined Materials.
Molecular Electronics and Nanoelectronics; Nanobots; Biological Applications of Nanoparticles; Catalysis of Gold Nanocrystals; Bandgap Engineered Quantum Devices: Quantum well devices, Quantum dot devices; Nanomechanics; Carbon Nanotube Emitters; Photoelectrochemical Cells; Photonic Crystals and Plasmon Waveguides.

References:
1. C. Kittle, "Introduction to solid state physics", all editions.
2. S. O. Pillai, "Solid state physics".
3. Saxena, Gupta, Saxena, "Solid state physics".
4. R. M. Matrin, "Electronic structures, basic theory and practical methods".
5. K. Sneppen and G. Zocchi, "Physics in molecular biology".
6. Gregory Timp, "Nanotechnology", AIP papers.
7. Journal of nanotechnology and articles.

NAN 403: Chemistry-I Marks: 100 (80+20), Credit 4
Course : - NAN 403, Chemistry-I (Nanochemistry and naostructured systems)

Unit-I: Introduction of Bonding in solid Material
Homonuclear and heteronuclear diatomic molecules - orbital diagrams, bond order, bond energy and magnetic properties. Ionic/covalent character/dipole moments - HX type molecules. Main group elements - shapes and structures using VSEPR. Bonding in transition metal complexes - coordination compounds, introduction, crystal field theory. Cubic, Octahedral, tetrahedral and distorted square planar shapes from octahedral complexes - stabilization energies and magnetic properties.

Unit-II: Chemical Bonds and phase studies in solid chemical materials
Chemical bonds, ionic, metallic, covalent and shearing bonds in solid materials. Different phases studies of conductor, semiconductor, insulator and polymers in nano phase, phase equilibrium and phase transitions, chemical reaction and their mechanism, engineering of chemical reactions for nano particle growth, thermodynamics and kinetic considerations for nanoparticles, rate limiting factors

Unit-III: Synthesis and types of nano particles
Nanocontainers, Nanoshells, Nanohorns, Nanowires, Nanosprings, Nanorods, Nanofilters, Nanopens, Nanopencils, Nanopipettes, Nanopens, Nanoplotter, Nanobalance, Nanobeads, Nanoguitar:

Unit-IV: Characterization and Properties of Nanomaterials
Introduction, Structural Characterization, X-ray diffraction (XRD), Small angle Xray scattering (SAXS), Scanning electron, microscopy(SEM), Transmission electron microscopy (TEM), Scanning probe microscopy (SPM) Gas adsorption. Chemical Characterization, Optical spectroscopy, Electron spectroscopy, Ionic spectroscopy, Physical Properties: Thermal stability and lattice constant, Mechanical properties, Optical properties, Electrical conductivity, Ferroelectrics and dielectrics, Superparamagnetism, Emission spectroscopy, luminescence spectroscopy, Raman spectroscopy.

Unit-V: Application of nano chemistry
Semiconductor and Microelectronics including MEMS, Optical Magnetic including memory, read-write, flash, bubble memories etc. Mechanical including Nanocomposites, thermal barriers etc.Biomedical including Pharmacology, Virology etc.

References:

1. P .W. Atkins, Physical Chemistry, Sixth Edition, Oxford University Press, 1998.
2. F. A. Cotton, G. Wilkinson and P. L. Gaus, Basic Inorganic Chemistry, Third Edition, John-Wiley, 1995.
3. A. R. West, Basic Solid State Chemisry, John-Wiley, 1991.
4. G. Friedlander, J. W. Kennedy, E. S. Macias and J. M. Miller, Nuclear & Radio Chemistry, 4th Edition, John Wiley, 1985.
5. C. Baird and Freeman, Environmental Chemistry, W. H. & Company, 1995.
6. Journals of Nanotechnology 2006., Nanomaterials: Synthesis, Properties and Applications- edited by A.S. Edelstein, R C. Cammarata (IOP publication)

NAN 404: Biosciences-I Marks: 100 (80+20), Credit 4
Course : - NAN 404, Biosciences-I (Nano Biosciences, Biomedical & Biotechnonoy)

Unit-I: Cellular Structure and Function, Inheritance, Molecular Biology and Biotechnology, Microbial and Plant Bioscience, Animal Bioscience and Statistics for Bioscience.

Unit-II: Nutrition and Metabolism, Cell Biology, Molecular Biology and Genetics, Introductory Microbiology and Human Physiology.

Department of Nanotechnology
Dr. Babasaheb Ambedkar Marathwada University
Aurangabad 431004, Maharashtra, India

Semester II Syllabus (2011)

Course	Course Title	Teaching Hours/week	Max Marks	Credits
NAN 405	Quantum Physics II	4 Hours	100	4
NAN 406	Solid State II	4 Hours	100	4
NAN 407	Chemistry II	4 Hours	100	4
NAN 408	Biosciences II	4 Hours	100	4
NAN 443	Practical II	4 Hours	100	4
NAN 444	Seminar-II Fundamental Topics in Nanotechnology	4 Hours	100	4

NAN 405 Quantum Physics II,
Course: NAN 405 Quantum & Statistical Mechanics (4 credits) Marks: 100 (80+20)

Unit-I: Introduction to Quantum Mechanics: Failures of Classical Mechanics; Brief discussion of general ideas such as "Wave particle duality", uncertainty principle, superposition principle etc.; solutions to Schrödinger Equation for 1-D and 3-D square wells and potential barriers, H-atom.

Unit-II: Matrix Mechanics: Operators, change of basis, Eigen Values and Eigen vectors; Simultaneous Eigenvectors, Harmonic oscillator in matrix mechanics; Exchange operator and identical particles.

Unit-III: Angular momentum: Introduction to angular momentum operators; Eigen values and eigenvectors of L^2, L_2 Spin and J^2 and J_2

Unit-IV: Approximation Methods: Non-Degenerate and degenerate perturbations theory and applications to anharmonic oscillator; Variational method with application to the ground states of harmonic oscillator and hydrogen atom; General expression for the probability of transition from one state to another, constant and harmonic perturbations.

Unit-V: Scattering Theory: Scattering Cross-section and scattering amplitude, partial wave analysis, Born approximation and its application to simple potentials. *Theory of Ensembles:* The microcanonical ensemble theory and its application to ideal gas of monatomic particles; The canonical ensemble and its thermodynamics; Partition function, energy fluctuations, equipartition; A system of harmonic oscillators as canonical ensemble; The grand canonical ensemble and significance of statistical quantities.

Unit-VI: Quantum Statistics: Quantum states and phase space, the density matrix, few examples; An ideal gas in quantum mechanical ensembles; statistics of occupation numbers. Basic concepts and thermodynamic behavior of an ideal Bose gas, Bose-Einstein condensation; Discussion of a gas of phonons (The Debye field); Thermodynamics of an ideal fermi gas, heat capacity of a free-electron gas at low temperatures; Pauli paramagnetism.

References:

1. Khanna, M.P. Quantum Mechanics Har Anand, New Delhi.
2. Sakurai, J.J., Modern Quantum Mechanics, Addison Wesley, Reading
3. Schiff, L.I., Quantum Mechanics
4. Loknathan & Ghatak, Quantum Mechanics
5. Dirac PAM, Principles of Quantum mechanics
6. Merzbacher, E., Introduction to Quantum Mechanics
7. Pathria, R.K., Statistical Mechanics, Pernamon, Oxford.
8. Bhatia, V.S., Statistical Mechanics

NAN 406 - Solid State II
Course: NAN 406 Physics of Semiconductor Devices (4 credits) Marks: 100 (80+20)

Unit-I: Semiconductor Electronics: Physics of Semiconductor materials, Drift velocity, Mobility, Scattering, Diffusion current, Band model.

Unit-II: Metal Semiconductor Contacts: Metal-Semiconductor system, (V-I) and (C-V) equations for a Shottky – Barrier – Diode, Diode construction, Device analysis using surface – states, applications as mixer and detection in microwave region, Ohmic contacts, Surface effects.

Unit-III: PN Junctions: Step junction, linearly graded junction, (V-I) and (C-V) characteristics, Junction Breakdown, Tunneling effect, avalanche multiplication, transient behaviour and noise. Use of Junction diode as a rectifier, Voltage regulator, resister varistor and fast recovery diode.

Unit-IV: Bipolar Junction Transistors: Transistor action, Current- Voltage equation, Output Characteristics, breakdown voltage, Ebers-Moll and Gummel-Poon Model, Early effect, Charge control model, small-signal transistor model, Simulation model.

Unit-V: Metal-oxide-silicon System: MOS structure, Energy Band Diagrams, Interface Charges, Surface effects, MOS Capacitors.

Unit-VI: MOS Transistors: Basic Theory, structure and operation, MOSFET Parameters, Threshold voltage and its control, Geometric effects on threshold, Ion- Implanted MOSFETs, Complementary MOSFET, Sub-threshold Conduction, Velocity saturation, hot carriers, small geometry considerations.

References:

1. McKelvey, J.P.1966. Introduction to Solid State and Semiconductor Physics, Harper and Row and John Weathe Hill.
2. Sze, S.M. 1981. Physics of Semiconductor Devices, 2nd edition, John Wiley.
3. Sah, C.T.1991. Fundamentals of Solid State Electronic Devices, Applied Publishers & World Scientific.
4. Yang, Edward S. 1988. Fundamentals of Semiconductor Devices, McGraw Hill.
5. Ng, K.K.1995. Complete Guide to Semiconductor Devices, McGraw Hill.
6. Nicollian, E.H. and Brews, J.R.1982. MOS Physics and Technology, John Wiley.

NAN 407 - Chemistry II
Course: NAN 407 Chemical synthesis of Nanomaterials and Instrumentation Techniques for Nanotechnology (4 credits) Marks: 100 (80+20)

Unit-I: Chemical Synthesis of Nanomaterials- Different types and processes for synthesis of nanomaterials using wet chemical approaches. Fabricating nanomaterials with different morphology intended for specific applications.

Unit-II: Fundamentals of Instrumental Analytical Techniques- UV-vis spectroscopy (liquid and solid state), Infrared spectroscopy, Raman spectroscopy, Mass spectrometry, Thermal Analysis Methods etc

Unit-III: Molecular Nanotechnology- Low Energy Electron Diffraction (LEED), Scanning Probe Microscopy-principle of operation, instrumentation and probes, Low temperature Scanning Probe Microscopy, Auger, SEM, TEM, XRD (Powder/Single crystal), Atomic Force Microscopy (AFM), Scanning Tunneling Microscopy (STM), EDAX, XRF, ESCA, Optical microscope, UPS (UV Photo electron spectroscopy).

and circuits; Universal quantum gates; Quantum Fourier Transform; Phase Estimation; Shor's algorithm; Grover's algorithm. Decoherence & Quantum Error Correction: Decoherence; Errors in quantum computation & communication; Quantum error correcting codes Physical Realization of Quantum Computers: Ion trap quantum computers; Solid state implementations (Kane proposal as an example); NMR quantum computer.

Reference:

1. Physical Review B 80, (2009) 193410.
2. Physical Review Letters 73(1994)3266.
3. Applied Physics letters 85 (2004) 3833.
4. Fundamental of atomic and molecular spectroscopy, Dr. Ramphal Sharma, Himalaya publication House, India, 2008.
5. Encyclopedia of Nanoscience and Nanotechnology, Ingenta Select: Electronic Publishing Solutions 1, 1 (2004) 135.
6. Nanoscale Materials in Chemistry, Wiley, 2001

NAN 502: Advances in Nanotechnology-I Marks: 100 (80+20), Credit 4

Course: NAN 502 Nanoscale Processing and Characterization for advanced devices

Unit-I:

Processing and fabrication: Si processing methods; cleaning/etching, oxidation, gettering, doping, epitaxy. Sputtering, Chemical vapor deposition (CVD), Plasma-enhanced CVD. Reactive ion etching (RIE). Moores Law; Design rules for CMOS at 90nm, 45nm, 32nm and beyond; Semiconductor device roadmap; Silicon-on-insulator technology. Gate dielectrics, poly-Si, high-k dielectrics. Thermal matching. Beyond CMOS – the material challenges of ultra-thin body (UTB), MOSFETs for sub-15nm gate technologies. 3-D interconnect technologies. Moving to 450mm silicon substrate technologies.

Unit-II:

Top-down approach to nanolithography; immersion lithography, EUV photolithography, phase shifting masks, X-ray lithography including plasma-X-ray sources, e-beam lithography, focused ion beams; photoresist technologies for the nanoscale; metrology and defect inspection. Costing and yield. Assembly and packaging.

Unit-III:

Processing III-V semiconductors including nitrides; molecular-beam epitaxy (MBE), chemical beam epitaxy (CBE), metal-organic CVD (MOCVD), quantum wells. Si-Ge, SiC, Diamond: synthesis, defects and properties on the nanoscale. Micromixers and microcontactors for single phase and multiphase systems. Microreactors for catalytic, single phase, and multiphase reactions. Microseparation systems.

Unit-IV:

Bottom-up approach. Chemical self-assembly. Spontaneous formation and ordering of nanostructures. Synthesis and properties of nanoparticles, nano-clusters, nanotubes, nanowires and nanodots. Nano-fluidics to build silicon devices with features comparable in size to DNA, proteins and other biological molecules; Control and manipulation of microfluidic and nanofluidic processes for lab-on-a-chip devices. Role of surfaces in nanotechnology devices; surface reconstruction; dangling bonds and surface states.

Unit-V:

Characterisation: UHV methods; UV and X-ray photoelectron spectroscopy (UPS, XPS); Auger electron spectroscopy (AES); low energy electron diffraction (LEED) and reflection high energy electron diffraction (RHEED), secondary ion mass spectrometry (SIMS); Electron energy loss spectroscopy (EELS) and high resolution EELS (HREELS); Nanoscale I-V/C-V; Hall, quantum Hall, fractional quantum Hall effects; Kelvin-probe measurements; photoluminescence (PL).

References

1. Hall Effect Sensing and Applications, Honeywell

2. The Quantum Hall Effect (Springer, 1989)
3. Deep level transient spectroscopy (DLTS, D.V. Lang, J. Appl. Phys. 45, 3023 (1974))
4. The Electrical Characterization of Semiconductors: Majority Carriers and Electron States, edited by P. Blood and J. Orton (Academic, London, 1992)
5. Theory of electrical characterization of semiconductors, Peter Stallinga, Universidade do Algarve
6. Electron Spectroscopy and Related Spectroscopies M De Crescenzi and MN Paincastelli (World Scientific, Singapore 1996)
7. Electron Microscopy and Analysis PJ Goodhew, J Humphreys, R Beanland (Taylor and Francis, London, 2001)
8. Electronic Thin Film Science K Tu, JW Mayer, LC Feldman (Macmillan, New York 1992)
9. Mico-Nanofabrication Z Cui (Springer, 2005)
10. Semiconductor Material and Device Characterization D. K. Schroder (John Wiley & Sons, New York, 1998)

NAN 503: Applications of Nanotechnology-I Marks: 100 (80+20), Credit 4
Course: NAN 503 Applications of Nanotechnology-I (Application of Nanotechnology in Healthcare Sector)

Unit-I: Biosensors - Present state of art and future potential: Devices for testing in the Doctor's Office, e.g. of blood and urine samples, for Home Monitoring; for Ambulance Monitoring; for Bedside Monitoring. Blocks to a full present implementation of such sensors: Technical Problems, Business constraints, Regulatory constraints. The potential of nanotechnology to remove these blocks.

Unit-II: Underpinning Electronic and Optical Techniques:
Amperometric sensors; Potentiometric sensors, including chemically sensitive field effect transistors; Optical sensors, including Evanescent field sensors; Optical waveguide sensors; Surface Plasmon Resonance sensors; Capillary Fill devices; Electrochemical Impedance Spectroscopy; Electro-mechanical devices, e.g. cantilever sensors.

Unit-III: Underpinning Biological Techniques
Enzyme-based assays; Antibody-based assays; Nucleic-acid based techniques, e.g. Polymerase Chain Reaction (PCR) Synthesis of the above onto a 'lab-on-a-chip' system. Nanotechnology research on medical diagnostic applications.

Hospital Environment:
Unit-IV: Imaging and targetted drug delivery This section will address the novel nanoscale imaging and drug delivery agents now arising at the research level. Recent trend and progress in MRI contrast agents. Recent trend and progress in bioimaging. Recent trend in diagnosis and treatment of diseases.

Unit-V: Stem cell research This section will examine some of the techniques arising from nanotechology processing that may contribute to such aspects of tissue engineering as better stem cell scaffolds.

References

<u>1. General background reading</u>
Vision Paper for NanoMedicine
Nanotechnology for Health, European Technology Platform on NanoMedicine, September 2005 ftp://ftp.cordis.europa.eu/pub/nanotechnology/docs/nanomedicine_visionpaper.pdf
2. Strategic Research Agenda for Nanomedicine
Nanomedicine: Nanotechnology for Health, European Technology Platform, November 2006 ftp://ftp.cordis.europa.eu/pub/nanotechnology/docs/nanomedicine_bat_en.pdf
3. Biomaterials for Delivery and Targeting of Proteins and Nucleic Acids, Edi. Ram I. Mahato, CRC Press, Boca Raton, Florida, 2005
4. The journal ***Nature: Nanotechnology*** is an excellent source for recent advances in Nanotechnology including medical and biological applications.
5. Molecular Biology of the Cell, B Alberts, A Johnson, J Lewis, M Raff and P Walter; Garland; 5th Edn. New York, 2007.

6. Principles of Bacterial Detection: Biosensors, Recognition Receptors and Microsystems, Zourob, Mohammed; Elwary, Sauna; Turner, Anthony P. F. (Eds.), Springer, 2008.
7. Biosensors and modern biospecific analytical techniques, Volume 44 of Wilson & Wilson's Comprehensive Analytical Chemistry; Ed. L Gorton; Elsevier, Amsterdam, London; 2005
8. The journal *Biosensors and Bioelectronics* is an excellent source for recent advances in the area.
9. Principles and Practice of Immunoassay; Eds. *Christopher P Price, David J Newman; Macmillan Press, New York : Stockton; 1996*
10. The Immunoassay Handbook; Ed. David Wild; 3rd ed.; Amsterdam : Elsevier; 2005
11. Alternative Immunoassays; Ed. W P Collins; Chichester : Wiley; 1985
12. Electrochemical Methods : Fundamentals and Applications; Allen J Bard and Larry R Faulkner; Wiley, New York, Chichester : 2nd ed.; 2001
13. Fundamentals of Semiconductor Devices; Edward S Yang; McGraw-Hill, New York, London; 1978
14. Optical Waveguide Sensors (Evanascent Field Sensors) Refer to the book Biosensors and
15. Molecular Probes e.g. Fluorescent Labels Invitrogen - http://probes.invitrogen.com/
16. Drug delivery systems, Vasant V. Ranade, Mannfred A. Hollinger.2nd ed. CRC Press, Boca Raton, Florida, 2003
17. Suface Plasmon Resonance (SPR) see the book Biosensors and Bioelectronics
18. Surface Plasmon Resonance Based Sensors in Springer Series on Chemical Sensors and Biosensors; Volume Four; Ed.Jiri Homola; Springer, Berlin; 2006
19. Electrochemical Impedance Spectroscopy (EIS) Ultrathin Electrochemical Chemo- and Biosensors: Technology and Performance in Springer Series on Chemical Sensors and Biosensors; Volume Two, Ed. Vladimir M. Mirsky; Springer, Berlin; 2004
20. The Polymerase Chain Reaction (PCR) Animation
http://www.sumanasinc.com/webcontent/anisamples/molecularbiology/pcr.html
21. DNA Profiling http://www.ipn.uni-kiel.de/eibe/UNIT02EN.PDF
22. Real time PCR *A Real-Time PCR Analyzer Compatible with High-Throughput Automated Processing of 2-μL Reactions in Glass Capillaries*, Patrick N. Ngatchou, Mark R. Holl, Member, Charles H. Fisher, Mohan S. Saini, Jianchun Dong, Timothy and Deirdre R. Meldrum, IEEE Transactions on Automation and Science Engineering, 3, 141-151 (2006)
23. Cantilever Sensors Cantilever Array Sensors, H P Lang, M Hegner & C Gerber, MaterialsToday, April 2005, 30-36; *Multiple label-free biodetection and quantitative DNA binding assays on a nanomechanical cantilever array*, R A McKendry, J Zhang, Y Arntz, T Strunz, M Hegner, H-P Lang, M K Baller, U Certa, H-J Guntherodt, & Ch Gerber, Proc. Natl. Acad Sci. U.S.A. 99, 9783-9788 (2002).
24. Targetted Drug Delivery: Magnetic Nanoparticles, Q A Pankhurst, J Connolly, S K Jones & J Dobson http://www.iop.org/EJ/abstract/0022-3727/36/13/201/ J. Phys. D: Appl. Phys. **36** (2003) R167-R181
25. Cancer cell targeting The Michigan Nanotechnology Institute
http://nano.med.umich.edu/about/news.html Cancer cell targetted drug delivery programme
26. Stem Cell Scaffolds, N D Evans, E Gentleman & J M Polak, MaterialsToday, **9**, Issue 12 , December 2006, 26-33.

NAN 541: Practical-III **Marks: 100 (50+50), Credit 4**
Course: NAN 541 Practical Course (Experimental Techniques for Nanotechnology)

1. Introduction to AFM and AFM imaging
In this practical the students will be trained to image samples in contact and non-contact modes.
2. Introduction to STM and STM imaging
In this practical the students will be trained to image standard graphite or silicon samples in addition to other samples.
3. AFM force spectroscopy
In this practical the students will be trained for nanometre-scale surface characterization using the AFM to produce and compare force-distance plots for samples of contrasting mechanical properties.
4. Advanced AFM: Tip characterization
In this practical the students will be trained to investigate the importance of tip morphology in AFM image formation.
5. Advanced AFM: Bio-imaging
Examples of biological applications and imaging with the AFM.

6. Synthesis and Characterization of Carbon Nanotubes

In this practical the students will be trained to synthesize carbon nanotubes (single walled/multiwalled) using CVD/ Arc Discharge technique which would be characterized using SEM, XRD and/or Raman spectroscopy.

7. Synthesis of Nanomaterial using biotemplates

In this practical the students will be trained to synthesized metal/metal oxide nanomaterial using biological templates e.g. protein, organism, or plant species and characterization of the same by SEM, XRD, and UV-vis spectroscopy.

8. Synthesis of Thin-Film using Vacuum Deposition

In this practical the students will be trained to synthesized metal oxide/chalcogenide thin-film on glass/ITO substrate using Vacuum Deposition System.

9. Synthesis of metal oxide nanomaterial based Thin-Film on glass substrate for fabricating gas sensor and its characterization.

In this practical the students will synthesize metal oxide/chalcogenide thin-film on glass substrate, fabricate gas sensor device and characterize for its sensing property.

10. Synthesis of metal/metal oxide nanoparticles (aqueous dispersion) using chemical/biological approach and estimate its size using particle size analyzer.

In this practical, a simple chemical/biological method will be employed for the synthesis of metal/metal oxide nanoparticles. The size of the spherical nanoparticles would be estimated using particle size analyzer and then the size would be compared with that derived from XRD.

11. Application of TGA/DTA in nanotechnology.

In this practical, the nanomaterial samples like carbon nanotubes (commercial), carbon nanotubes synthesized using simple approach of burning oil, and other nanomaterials would be analyzed by TGA/DTA to find their stability and purity.

12. Fabrication of solid-state thin film solar cells, characterization using solar energy simulator and calculating the conversion efficiency.

In this practical the students will be trained to fabricate solid state solar cell, their characterization and calculation of their solar to electrical energy conversion efficiency.

13. Synthesis of antibacterial nanoparticles using simple chemical approach and testing their antibacterial properties.

In this practical, the students will synthesize semiconductor based antibacterial nanoparticles in dispersed/or in thin film form and further characterized for antibacterial property using standard method.

14. Introduction to Hall Effect and its significance in nanotechnology.

In this practical, the students will synthesize semiconductor thin-films and characterize using Hall effect measurement equipment. The electronic properties of the thin film will be estimated.

NAN 542 : Project-I **Marks: 100 Credit 4**

Course: NAN 542 Project - I

The research project is a key component of the M. Sc, and gives students the opportunity to work in one of the nanotechnology research groups on a project at the forefront of nanotechnology research. Students will have access to the state-of-the-art facilities in our Laboratory, Central Facility of the University, surrounding Universities and Research Institutes. Students can also avail the option of choosing the topics of their interest with individual contacts with in India and even reputed Universities abroad. Research groups at Nanotechnology cover an exceptionally broad spectrum of research, from fundamental theory to novel nanomaterials and devices extending to technological applications.

NAN 543: Seminar-III Advanced Topics in Nanotechnology **Mark: 100 credit: 4**

Course: Seminar-III Advanced Topics in Nanotechnology

This will include assignments, tutorials and seminar on Advanced Topics in Nanotechnology.

NAN 521: Compulsory Service Course from Other Department **Mark: 100 Credit: 4**

Course: Compulsory Service Course from Other Department

Department of Nanotechnology
Dr. Babasaheb Ambedkar Marathwada University
Aurangabad 431004, Maharashtra, India

Semester IV Syllabus (2011)

Course	Course Title	Teaching Hours/week	Max Marks	Credits
NAN 504	Quantum Confinement II	4 Hours	100	4
NAN 505	Advances in Nanotechnology-II	4 Hours	100	4
NAN 506	Applications of Nanotechnology-II	4 Hours	100	4
NAN 544	Practical IV	6 Hours	100	4
NAN 545	Project II	6 Hours	100	4
NAN 546	Seminar-IV Advanced Topics in Nanotechnology	4 Hours	100	4
NAN 521	Compulsory Service Course from Other Department	4 Hours	100	4

NAN 504: Quantum Confinement II Marks 100 (80+20), Credit 4
Course: NAN 504: Quantum confinements effect on nano materials properties.

Unit-I: Nano-structure dependent on quantum confinement effect:
Structure dependent formula for the quantum confinement effect for metal, semiconductor, composite nanoparticals, nanodiamond (ND) clusters, carbon nanotubes, Hydrogen-terminated carbon ND clusters, and structural factor of ND clusters. An extended 'quantum confinement theory: surface-coordination imperfection modifies the entire band structure of a nano solid. Quantum-confinement effects in chalcogenides core–shell nanodot, nanowires and medical applications.

Unit-II: Nano-optical properties dependent on quantum confinement effect:
Comparison of quantum confinement effect on the electronic absorption spectra of direct and indirect band gap semiconductors nanocrystals. The size dependent electronic absorption spectra of II-VI compound nanocrystals. The absorption spectra of quantum dots, quantum wires and quantum wells. Quantum confinement induced photoluminescence in nano materials.

Unit-III: Nano-electronic properties dependent on quantum confinement effect:
Quantum confinement effects on electronic properties of quantum dots, wires and wells. Size dependent of quantum Hall effect. Size dependent effect on electronic properties of organic, inorganic and hybrids nanostructures materials.

Unit-IV: Nano-magnetic properties dependent on quantum confinement effect:
Quantum confinement effects on magnetic properties of quantum dots, wires and wells. Quantum confinement effects on magnetic nano materials (graphene, ferrites and doped ferrites and nanocomposites materials etc).

Unit-V: Nano-biochemical and biological properties dependent on quantum confinement effect:
Quantum confinement effects on nano-biochemical and biological properties of quantum dots, wires and wells. Application in genetics, neurological treatments, DNA hybridization, pathogen and toxin detections, in vivo imaging and pharmacological products.

References:
1. Handbook of nanotechnology by Bharat Bhushan, published by Springer.
2. Journal of Applied Physics 108 (2010) 943303 by Jun Jiang et.al.
3. Optical properties and quantum confinement of nanocrystalline II-VI semiconductor particles by Dijken Albert van, Meteen samenvatting in het Nederlands

4. Biological applications of quantum dots, Biomaterials 28(2007)4717.
5. Journal of Physics and Chemistry B 110(2006) 21528.
6. Journal of magnetism and magnetic materials 251(2002)245.
7. Journal of Physics and Chemistry C 114(2010)4841.
8. Joournal of Physics: Condens Matter 19(2007)295219.
9. Journal of American Chemistry Society 132(2010)132.
10. Physical Review Letters 73 (24)(1994)3266.
11. Journal Physics D: Applied Physics 34(2001)3470.
12. Physica E 41(2009)668.
13. Physical Review B 79(2009) 201302 (R).

NAN 505: Advances in Nanotechnology-II Marks: 100 (80+20), Credit 4

Course: NAN 505 Advances in Nanotechnology-II (Carbon Nanotubes and its Technological Applications)

Unit-I: Carbon Nanotubes (CNTs)-Introduction to CNTs and significance in R&D, different carbonaceous material, difference in carbon and CNTs. Synthesis (types), processing, properties and characterization. Chemical Vapour Deposition of CNTs using structural nanoparticle catalysts and its role in single walled carbon nanotubes (SWNTs) by chemical vapour deposition (CVD).

Unit-II: Charge transport in CNT Films and Fibers, Electrical and magneto transport properties of various types of carbon nanotubes arrays. Doped CNTs and the effect of doping (Aluminum, Boron, Nitrogen and Phosphorous on the models of CNTs. Characteristic properties of doped CNTs. Fundamentals of Carbon Nanotube Transistors (carbon nanotube field effect transistors -CNT-FETs). The I-V characteristics of CNT-FETs. Compact models for carbon nanotube transistors and interconnects for nanoelectronics. Interconnect challenges.

Unit-III: Affinity of CNT for metal - Its importance to application: Molecular dynamics approach, Carbon nanotube field emitters, CNTs as sensor material and their sensing mechanisms. Gas sensors based on decorated carbon nanotubes, Applications in Physical Sensors and Actuators, study of CNT-FETs for NEMS, CNT-FET nanoelectronics can achieve significantly greater performance than Silicon technology.

Unit-IV: Solid phase (micro) extraction tools based on carbon nanostructures (nanotubes, fullerenes, and nanocones) for analytical methods, sorbent for analysis of environmental pollutants, liquid crystal dispersions of CNTs: dielectric, electro-optical and structural peculiarities, functionalization of carbon nanotubes with luminescent silicon nanocrystals, functionaliation of CNTs (fluorinated single-walled (F-SWCNTs) and multiwalled (F-MWCNTs), characteriation and electronic structure. Nucleic acid interaction and interfaces with single-walled CNTs (biosystems), DNA-protein wrapped CNTs from Synthesis to Application, Microwave Dielectric Properties of Carbon Nanotube Composites. The environmental effects on the optical properties of SWNTs and MWNTs. Hydrogen storage by carbon materials, CNTs as a new type of electrode materials for Supercapacitors, CNTs Membrane Solar Sails for Extremely Fast Space Flight. Carbon Nanotube-Nanoparticle Hybrid Structures, Superconductivity in carbon nanotubes.

Unit-V: Nanotoxicology: Nanotechnology is poised to make the nano-revolution a reality in the manufacturing sector and on the verge of commercialization. From these perspectives, exploring the developments in nanotechnology are transforming areas as diverse as medicine, advanced materials, energy, electronics and agriculture. Nanotechnology: Health and Environmental Risks introduces risk analysis as a tool for responsible environmental decision making in nanotechnology development and provides examples of past, present, and future technologies that demonstrate the need for and benefits of evaluating the risks of nanotechnology. Risks, Regulation and Management strategies.

References

1. Carbon Nanotubes, Edited by Jose Mauricio Marulanda, Intech Publisher, Croatia, 1st Edn (2010).
2. P. M. Ajayan, Nanotubes from Carbon, Chem. Rev. 1999, 99, 1787-1799.

Batteries: General introduction, Basic battery theory, Definition of fundamentals quantities, Battery fundamental characteristics, Different types of battery arrangement, Classification of batteries and Advantages of batteries for bulk Energy storage.

Unit-V: Hydrogen energy: General introduction to Hydrogen energy and production, Electrolysis, Thermo-chemical methods, Fossil fuel methods and Solar energy methods. Hydrogen storage, transportation, utilization as an alternative fuel for motor vehicles. Hydrogen technology development in India, its safety and management.

Unit-VI: Energy storage and distribution: Introduction to Energy storage systems, Types of storage systems (Mechanical energy, Pumped hydroelectric, Compressed air, Energy storage via hydrogen, Ammonia, Reversible chemical reactions, Electromagnetic energy, Thermal energy storage, Sensible heat storage, Latent heat and Biological storage).
Distribution of energy: General Introduction, Gas pipelines, Electricity transmission, Batch transport, Heat, Chemical heat pipe etc.
Energy conservation: Economic concept of energy, renewable energy sources/device, Instrumentation and control.

References

1. Non-Conventional Energy Sources by G. D. Rai, 4th Edn., Khanna Publishers, Delhi (2009).
2. Solar Energy by Radu D. Rugescu, InTech Publisher, Croatia, 1st Edn. (2010).
3. Renewable Energy by T. J. Hammons, InTech Publishers, Croatia, 1st Edn. (2010).
4. Solar energy : renewable energy and the environment by Robert Foster, Majid Ghassemi, Alma Cota, CRC Press, Boca Raton, FL 1st edn. (2010).
5. Biofuel Technology Handbook by Dominik Rutz and Rainer Janssen, WIP, Germany, 2nd Edn. (2008).
6. Articles and Review articles from leading specialized journals.

NAN 544: Practical-IV **Marks: 100 (50+50), Credit 4**
Course: NAN 544 Practical Course (Current Topics in Nanotechnology)

This course is preparative component of the Research Project to be executed by the M. Sc. Students. In this course, the students are expected to read and present research papers on current topics in Nanotechnology leading to advances in Nanotechnology or relevant to their projects. Each student is expected to present minimum of 10 lectures of 30 min each followed by questions and discussion. Background knowledge related to the topic would be considered as the part of the presentation. Each presentation will carry 10 marks accounting for the annual grade on the scale of 100. The presentations should be in form of PPT files.

NAN 545: Project-II **Marks: 100 Credit 4**
Course: NAN 545 Project II

In this course, the students are expected to complete one project, the title of which should be finalized after discussions with their respective project guides. The project, project report and project presentation would be accounted for the annual grade on the scale of 100.

NAN 546: Seminar-IV Advanced Topics in Nanotechnology **Mark: 100 Credit: 4**
Course: NAN 546: Seminar-IV Advanced Topics in Nanotechnology
This will include assignments, tutorials and seminar on Advanced Topics in Nanotechnology.

NAN 521: Compulsory Service Course from Other Department **Mark: 100 Credit: 4**
Course: NAN 521: Compulsory Service Course from Other Department