VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM
CHOICE BASED CREDIT SYSTEM (CBCS)
B.E. Nano Technology

Semester: VI

Core Subjects

Quantum Mechanics and Simulation Techniques [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2015 -2016) Course: B.E. / Nano Technology Semester: VI			
Subject Code	15NT61	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03
CREDIT – 04			
Course Objective: • To understand the basic principles of quantum mechanics and simulation methods. • To learn the application of the simulation techniques in biology and biomedical fields.			
Modules		Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: **PHYSICAL BASIS OF QUANTUM MECHANICS** Experimental background, inadequacy of classical physics, summary of principal experiments and inferences, Uncertainty and Complementarity. Wave packets in space and time, and their physical significance. Schrodinger wave equation: Development of wave equation: One-dimensional and extension to three dimensions inclusive of forces. Ehrenfest's theorem.		10	L1, L2
Module 2: **THE BASIC PRINCIPLES OF QUANTUM MECHANICS** The fundamental postulates, expectation values and probabilities; quantum mechanical operators, explicit representation of operators, uncertainty principle. Matrix method solution of linear harmonic oscillator. Quantum dynamics: Equations of motion, Schrodinger, Heisenberg and Interaction pictures. Poisson brackets and commutator brackets.		10	L1, L2, L3
Module 3: **QUANTUM COMPUTATIONAL SIMULATION** Turing machines, logic gates, and computers – reversible vs. irreversible computation – Landauer's principle and the Maxwell demon – natural phenomena as computing processes – physical limits of computation – Moore's law – quantum computation – historical development of quantum computation – quantum bits – quantum logic. (Note: only qualitative approach)		10	L1, L2, L3, L4

Module 4: SURGICAL SIMULATION AND VIRTUAL ENVIRONMENT Need, technology, volume image data file, human resources, interface and applications. Virtual environment (VE), technology, applications of VE, advantages of simulators and after effects of VE participation. Millirobotics for remote surgery, Telesurgery, and endoscopy.	10	L1, L2, L3, L4
Module 5: SIMULATION METHODS AND BIOLOGICAL SYSTEMS Monte Carlo methods – Introduction, Integration, Simulation, Random Walk, Percolation, Ising Model, Markov. Simulations of Biological systems - Proteins: peptides, Alpha Helix, Beta Sheet, PDB, heme, ligands, Dock, HierDock. DNA: B, Z, A, sugar, PO4, ligands	10	L1, L2, L3

Course Outcome:
Students can able to learn

- Physical basics of quantum mechanics
- Basic principles of quantum mechanics
- Basics of Quantum computational simulation
- Basic principles of surgical simulation and virtual environment for biomedical applications
- Concepts of montecarlo simulation methods and biological systems

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. Basic Quantum Mechanics by -A. Ghatak (2009) ISBN 0-230-63916-X
2. Introductory Quantum Chemistry; A.K. Chandra; Tata McGraw Hill PublishingCompany Limited. New Delhi, 1998
3. Quantum Mechanics: B. K. Agarwal and Hariprakash (Prentice-Hall, 1997).
4. Medical Informatics: Computer applications in health care and biomedicine by E.H.Shortliffe, G. Wiederhold, L.E.Perreault and L.M.Fagan, Springer Verlag.Handbook of Medical Informatics by J.H.Van Bemmel, Stanford University Press
5. “Handbook of theoretical and computational Nanotechnology” eds. Michael Rieth and wolfram schommers, 2006.
6. Computational physics, R. C. Verma, K. C. Sharma & P. K. Ahluwalia.

REFERENCE BOOKS:

1. Text book of Quantum Mechanics: P. M. Mathews and K. Venkateshan (TMH, 1994).
2. Quantum Mechanics: F. Schwabl (Narosa, 1995).
3. Quantum Mechanics: V. K. Thankappan (Wiley Eastern, 1980).
4. Quantum Physics of Atoms, molecules, solids Nuclei and particles 2nd Ed by Eisberg, Robert, Resnick Robert
5. Jerrod H.Zar (1999) Biostatistical analysis by Prentice hall international Inc Press, London

Python Programming Language for Automation
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VI

Subject Code	15NT62	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03

CREDIT – 04

Course Objective:
- To understand the programming python programming language
- To study implementation of python programmes for automation

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: **PYTHON – OVERVIEW** History of Python, Python Features. PYTHON – BASIC SYNTAX: First Python Program, Python Identifiers, Lines and Indentation, Multi-Line Statements, Quotation in Python, Comments in Python, Using Blank Lines, Waiting for the User, Multiple Statements on a Single line, Multiple Statement Groups as Suites, Command Line Arguments, Accessing Command-Line Arguments, Parsing Command-Line Arguments, getopt.getopt method, Exception getopt.GetoptError.	10	L1, L2
Module 2: **PYTHON – BASIC OPERATORS** Types of Operators, Python Arithmetic Operators, Python Comparison Operators, Python, Python Assignment Operators, Python Bitwise Operators, Python Logical Operators, Python Membership Operators, Python Identity Operators, Python Operators Precedence.	10	L1, L2, L3
Module 3: **PYTHON – DECISION MAKING** If Statement, If else Statement, The elif Statement, Single	10	L1, L2, L3, L4

Statement Suites PYTHON – LOOPS While Loop, the Infinite Loop, Using else Statement with Loops, Single Statement Suites, For Loop, Iterating by Sequence Index, Using else Statement with Loops, Nested Loops, Loop Control Statements, Break Statement, Continue Statement, Pass Statement.		
Module 4: PYTHON – NUMBERS Number Type Conversion, Random Number Functions, Trigonometric Functions, Mathematical Constants. PYTHON – STRINGS Accessing values in strings, updating strings, escape characters, string special operators, string formatting operator, triple quotes, unicode string and built-in string methods – capitalize – center – count – decode - encode.	10	L1, L2, L3, L4
Module 5: PYTHON – LISTS Python Lists Accessing Values in Lists Updating Lists Deleting List Elements Basic List Operations Indexing, Slicing, and Matrixes Built-in List Functions – compare – length – max value - min value. PYTHON – TUPLES Accessing Values in Tuples Updating Tuples Deleting Tuple Elements, Basic Tuples Operations Indexing, Slicing, and Matrixes No Enclosing Delimiters, Built-in Tuple Functions – compare – length – max value - min value – tuple.	10	L1, L2, L3

Course Outcome:
Students can

- Understand the programming python programming language
- Study implementation of python programmes for automation

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. Mark Lutz, Learning Python, 5th Edition, ISBN: 978-1-449-35573-9
2. Allen Downey, Think Python: An Introduction to Software Design, ISBN: 1466367296, 9781466367296

REFERENCE BOOKS:
1. Python Programming Language, tutorialspoint, www.tutorialspoint.com

Molecular Biology and Genetic Engineering
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VI

Subject Code	15NT63	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03

CREDIT – 04

Course Objective:

- To develop skills of the students in understanding the basics of Molecular Biology and Genetic engineering.
- To provide basic knowledge on replication. Transcription and Translation
- To provide knowledge on methods of cloning, construction of DNA libraries and applications of rDNA technology.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: **MOLECULAR GENETICS** DNA as genetic material, classical experiments – Hershey and chase; AveryMcLeod& McCarty. Bacterial conjugation, transduction and transformation, prokaryotic andeukaryotic genome organization.	10	L1, L2
Module 2: **REPLICATION AND TRANSCRIPTION** Replication in prokaryotes and eukaryotes - D-loop and rollingcircle mode of replication, replication of linear viral DNA. Transcription- initiation, elongation,termination, features of promoters and enhancers, transcription factors, inhibitors, post-transcriptional modification - RNA splicing, ribozyme. RNA editing.	10	L1, L2, L3
Module 3: **TRANSLATION** Elucidation of genetic code, Process of translation in prokaryotes and eukaryotes, posttranslational modifications, Suppressor mutations, Regulation of gene expression - Lac and trp operons.	10	L1, L2, L3, L4

Module 4: RECOMBINANT DNA TECHNOLOGY DNA cloning, vectors, restriction enzymes, Construction of cDNA and genomic libraries. Screening of libraries with probes – Northern, Southern and Western blotting. PCR- Principle, application and types. RAPD, Site Directed Mutagenesis. Restriction mapping	10	L1, L2, L3, L4
Module 5: APPLICATIONS OF RECOMBINANT DNA TECHNOLOGY Cloning in plants, transgenic and knockout animals. Recombinant cytokines and antibodies, vaccines, gene-therapy, stem cell therapy. *In-vitro* fertilization, embryo transfer technology. GMO detection, identification and quantification methods.	10	L1, L2, L3
Course Outcome: • Students may obtain interest in Molecular biology research • Students may acquire knowledge about the methods of rDNA technology.		
Graduate Attributes (as per NBA): • Engineering Knowledge. • Problem Analysis. • Design / development of solutions (partly). • Interpretation of data.		
Question paper pattern: • The question paper will have ten questions. • Each full Question consisting of 16 marks • There will be 2 full questions (with a maximum of four sub questions) from each module. • Each full question will have sub questions covering all the topics under a module. • The students will have to answer 5 full questions, selecting one full question from each module.		
TEXT BOOKS: 1.Primrose SB &Twyman, "Principles Of Gene Manipulation, An Introduction To Genetic Engineering ", Blackwell Science Publications, 2006. 2. David Friefelder, Molecular Biology, Narosa Publ. House, 1999		
REFERENCE BOOKS: 1. SandhyaMitra, “Genetic Engineering Principles and Practice”, Rajiv Beri for Macmillan IndiaLtd publications, 2008. 2. P.K.Gupta, “Elements of biotechnology”, Rastogi publications,2004. 3. Gardner / Simmons / Snustad, Principles of Genetics, Eighth Edition, John Wiley, 2000.		

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM
CHOICE BASED CREDIT SYSTEM (CBCS)
B.E. Nano Technology

Micro Fluidics and Nano Fluids [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2015 -2016) Course: B.E. / Nano Technology Semester: VII			
Subject Code	15NT64	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03
CREDIT – 04			
Course Objective: • To study basic principles of micro and nano fluids • To understand the synthesis advantages and importance of micro and nanofluids			
Modules		Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: INTRODUCTION TO MICRO FLUIDICS AND NANO FLUIDS Microfluidics: Introduction, Benefits of size reduction, Benefits of automation and integration, Application areas; PDMS microfluidics: Introduction, PDMS microvalve architectures, elastomeric microfluidic valve, Multilayer device fabrication, Advantages of PDMS devices. Nano fluids: Properties of nanofluids; thermophysical characteristics of nanofluids and factors affecting; Experimental methods of preparation of nano fluids; Theoretical models for thermal conductivity of nanofluids.		10	L1, L2
Module 2: BASIC PRINCIPLES OF MICROFLUIDICS Laminar flow, Peclet number, Pressure driven flow, Electro-osmotic flow, Micropumps: Mechanical micropumps (Peristaltic pump, Centrifugal pump), Non-mechanical micropumps (Electrokinetic pump, Magneto-hydro dynamic (MHD) pump); Micromixers: Active micromixers (Planar laminar bubble mixer, MHD mixer), Passive micromixers (T-type mixers); Soft lithography and PDMS; Detection methods; Applications.		10	L1, L2, L3
Module 3: MICROFLUIDICS IN BIOMEDICAL RESEARCH Impact of microfluidics on biomedical research; microfluidics concepts: Laminar versus turbulent flow, Surface and interfacial tension, Capillary forces; Chemotaxis: Introduction, Agar-plate techniques, Two-chamber techniques, Boyden chamber, Bridge chambers, Capillary techniques, Other techniques, A case study in chemotaxis assays; Microfluidic device fabrication (polydimethylsiloxane (PDMS) based, Thermoplastics based, paper		10	L1, L2, L3, L4

based, and wax based); Diagnostics for low-resource settings; Rapidly assaying biofluids with microfluidics; Organ-on-a-chip; Biomimetic blood vessel and capillary networks.		
Module 4: MICRO AND NANO EMULSIONS Emulsion: Appearance and properties, Emulsifiers, Mechanisms of emulsification, Uses; Microemulsions: Definition and History, types of microemulsions, Interaction energies, Packing parameter and microemulsion structures, Hydrophilic–Lipophilic Balance, Phase Inversion Temperature; Surfactant film properties: Ultra-low interfacial tension, Spontaneous curvature; Nano emulsions: Introduction; formation; differences between macro-, micro-, and nano-emulsions; Preparation of nanoemulsions; Droplet size control; Stability: Destabilization mechanisms, Controlling stability of nanoemulsions; Properties: Droplet size and stability, Tunable rheology; Applications of nanoemulsions: in drug delivery, in food industry, as building blocks, in crystallization/pharmaceuticals industry.	10	L1, L2, L3, L4
Module 5: PREPARATION AND APPLICATIONS OF NANO FLUIDS Preparation of nano fluids: Preparation of non-metallic nanofluids: Aluminum nitride-nanofluids, Zinc oxide-nanofluids, Titanium dioxide-nanofluids, Silicon dioxide-nanofluids, Copper oxide-nanofluids, Aluminum oxide-nanofluids, Carbon nanotube-nanofluids; Preparation of metallic nanofluids: Gold & silver-nanofluids, Copper-nanofluids. Applications of nanofluids: Heat Transfer Applications, Industrial Cooling Applications, Nuclear Reactors, Extraction of Geothermal Power and Other Energy Sources; Automotive Applications: Nanofluid Coolant, Nanofluid in Fuel, Brake and Other Vehicular Nanofluids; Electronic Applications: Cooling of Microchips, Microscale Fluidic Applications; Biomedical Applications: Nanodrug Delivery, Cancer Theraupetics, Cryopreservation, Nanocryosurgery, Sensing and Imaging; Other Applications: Nanofluid Detergent; Oxide Nanofluids, Metallic Nanofluids, Nanofluids with Carbon Nanotubes.	10	L1, L2, L3
Course Outcome: Students can learn • To study basic principles of micro and nano fluids • To understand the synthesis advantages and importance of micro and Nano fluids		
Graduate Attributes (as per NBA): • Engineering Knowledge. • Problem Analysis. • Design / development of solutions (partly). • Interpretation of data.		
Question paper pattern: • The question paper will have ten questions. • Each full Question consisting of 16 marks • There will be 2 full questions (with a maximum of four sub questions) from each		

module. • Each full question will have sub questions covering all the topics under a module. • The students will have to answer 5 full questions, selecting one full question from each module.
TEXT BOOKS: 1. Nanofluids:Science and Technology, Sarit K. Das, Stephen U. S. Choi, Wenhua Yu, T.Pradeep, 2008 John Wiley & Sons, Inc. 2. PatricTabeling, "Introduction to Microfluids", Oxford U. Press, New York , 2005
REFERENCE BOOKS: 1.Eric K. Sackmann, Anna L. Fulton, David J. Beebe, The present and future role of microfluidics in biomedical research, doi:10.1038/nature13118 2. Ankur Gupta, H. BurakEral, T. Alan Hatton, Patrick S. Doyle, Nanoemulsions: formation, propertiesand applications, Soft Matter, Royal Society of Chemistry, DOI: 10.1039/c5sm02958a 3. R.Saidura, K.Y.Leongb, H.A. Mohammad, A review on applications and challenges of nanofluids, Elsevier, doi.org/10.1016/j.rser.2010.11.035

Professional Elective Subjects

Hybrid Circuits and Packaging
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VI

Subject Code	15NT651	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03

CREDIT – 03

Course Objective:
- To understand the basics of hybrid microcircuits, mathematical foundations and CAD design for hybrid microcircuits
- To learn packaging of electronic devices, techniques for nano and bio packaging, nanomaterials for packaging
- To design and develop 3D models for packaging

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: HYBRID MICROCIRCUIT INTRODUCTION Microcircuit family, need for hybrid microcircuits, applications of microcircuits, typical microelectronic products	08	L1, L2
Module 2:	08	L1, L2, L3

MATHEMATICAL FOUNDATIONS OF HYBRID CIRCUITS Mathematical foundations, circuit design and layout rules, Computer aided design and pattern generation		
Module 3: FUTURE OF PACKAGING Packaging for Electronic systems, system integration by advanced electronics packaging, nano and bio techniques for electronic device packaging	08	L1, L2, L3, L4
Module 4: 3D MODELLING AND DESIGN FOR NEMS 3D design, 3D data structures for nanoscale design	08	L1, L2, L3, L4
Module 5: NANOMATERIALS FOR MICROELECTRONIC AND BIO PACKAGING packaging of bio-micro-electro-mechanical systems (BIOMEMS) and microfluidic chips, packaging of miomolecular and chemical microsensors	08	L1, L2, L3

Course Outcome:
After successfully completing this course, students will be able to:

- Understand the fundamentalsof hybrid micro circuits and importance of hybrid circuits in various industries
- Evaluate and determine the standards, technological challenges and future trends of nano and bio techniques for electronic device packaging
- Initiate, innovate and develop nanotechnology based solutions in the field of electronics packaging

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. Tapan K. Gupta, Handbook of Thick and Thin Film Hybrid Microelectronics, Wiley Interscience, John Wiley & Sons, 2003.
2. http://onlinelibrary.wiley.com/doi/10.1002/0471723673.fmatter/pdf
3. Gerald Gerlach, Klaus-Jürgen Wolter, Bio and Nano Packaging Techniques for Electron Devices: Advances in Electronic Packaging, Springer, 2012.
4. C.P. Wong, Kyoung-Sik Moon, Yi (Grace) Li, Nano-Bio- Electronic, Photonic and MEMS Packaging, Springer Science & Business Media, 2014.

REFERENCE BOOKS:

1. Gerald Gerlach, K.-F. Arndt, Hydrogel Sensors and Actuators: Engineering and Technology,

Springer, 2009
2. Daniel Lu, C.P. Wong, Materials for Advanced Packaging, Springer, 2016
3. Yan Li, Deepak Goyal, 3D Microelectronic Packaging: From Fundamentals to Applications, Springer, 2017

Nanotechnology in Agriculture and Food Processing
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VI

Subject Code	15NT652	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03

CREDIT – 04

Course Objective:
- To study the basic interaction of different molecules which are helpful in both food and agricultural activities
- To understand the importance of nanomaterials and devices in precision farming, advanced materials used in agriculture and food industries.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: **INTERMOLECULAR INTERACTIONS AND SUPRAMOLECULAR STRUCTURES** Water - Hydrophobic and Hydrophilic Interactions - Dispersion Interaction - Electrostatic Interactions - Atoms and Small Molecules - Polymers, Particles, and Surfaces - Steric Interactions Involving Soluble Polymers - Depletion Aggregation of Particles by Non-adsorbing Polymers - Bridging Aggregation of Particles by Adsorbing Polymers - Stabilization of Dispersed Particles by Adsorbing Polymers - Polymer Brushes to Prevent Particle Aggregation and Particle Deposition at Surfaces - Plant Cells - Organized Self-Assembled Structures - Langmuir Layers - Lipid Bilayers - Solid-Supported Lipid Bilayers.	08	L1, L2
Module 2: **NANOPARTICLES IN AGRICULTURAL AND FOOD DIAGNOSTICS** Enzyme Biosensors and Diagnostics - DNA-Based Biosensors and Diagnostics - Radiofrequency Identification- Integrated NanosensorNetworks: Detection and Response- Lateral Flow	08	L1, L2, L3

(Immuno)assay - Nucleic Acid Lateral Flow (Immuno)assay - Flow-Through (Immuno)assays - Antibody Microarrays - Surface Plasmon Resonance Spectroscopy.		
Module 3: NANOTECHNOLOGY IN FOOD PRODUCTION Food and New Ways of Food Production - Efficient Fractionation of Crops - Efficient Product Structuring -Optimizing Nutritional Values - Applications of Nanotechnology in Foods: Sensing,Packaging, Encapsulation, Engineering Food Ingredients to Improve Bioavailability - Nanocrystalline Food Ingredients - Nano- Emulsions - Nano-Engineered Protein Fibrils as Ingredient Building Blocks - Preparation of Food Matrices - Concerns about Using Nanotechnology in Food Production.	08	L1, L2, L3
Module 4: NANOTECHNOLOGY IN FOOD PACKAGING Crop improvement - Reasons to Package Food Products - Physical Properties of Packaging Materials - Strength - Barrier Properties Light Absorption – Structuring of Interior Surfaces - Antimicrobial Functionality - Visual Indicators – Quality Assessment - Food Safety Indication - Product Properties - Information and Communication Technology - Sensors - Radiofrequency Identification Technology - Risks - Consumer and Societal Acceptance.	08	L1, L2, L3, L4
Module 5: TOXICOLOGY OF NANOMATERIALS IN FOOD Characterization of Engineered Nanomaterials: Unique Issues for Characterization of Engineered Nanomaterials for Food Applications - Safety Assessment of Oral- Exposure Engineered Nanomaterials for Food Application - Experimental Design Considerations for Toxicology Studies –Toxico-kinetics – ADME –Toxico-dynamics - In Vivo Toxicity - In Vitro Toxicity - Study Reliability.	08	L1, L2, L3, L4
Course Outcome: Students can • Study the basic interaction of different molecules which are helpful in both food and agricultural activities • Understand the importance of nanomaterials and devices in precision farming, advanced materials used in agriculture and food industries.		
Graduate Attributes (as per NBA): • Engineering Knowledge. • Problem Analysis. • Design / development of solutions (partly). • Interpretation of data.		
Question paper pattern: • The question paper will have ten questions. • Each full Question consisting of 16 marks • There will be 2 full questions (with a maximum of four sub questions) from each module. • Each full question will have sub questions covering all the topics under a module. • The students will have to answer 5 full questions, selecting one full question from		

each module.
TEXT BOOKS: 1. Nicholas A. Kotov, "Nanoparticle Assemblies and Superstructures", CRC, 2006. 2.Jennifer Kuzma and Peter VerHage, "Nanotechnology in agriculture and food production", Woodrow Wilson International, 2006.
REFERENCE BOOKS: 1. David S.Goodsell, "Bionanotechnology", John Wiley & Sons, 2004. 2. BalajiSitharaman "Nanobiomaterials Handbook", Taylor & Francis Group, 2011. 3 Food Processing, Management And Nanotechnology Author: Annish Chauhan, *et.al*.,; ISBN: 978 93 5056 796 8; Year: 2016; Pages: 198

Ceramic Materials and Their Applications [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2015 -2016) Course: B.E. / Nano Technology Semester: VI			
Subject Code	15NT653	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT – 03			
Course Objective: • A course designed to expose students to the fundamental knowledge and concept of different areas of ceramics and applications. • It is designed to introduce the special characteristics and fabrication methods of different classes of ceramics.			
Modules		Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: FUNDAMENTALS OF CERAMICS Definition & scope of ceramics and ceramic materials. Examples of ceramic crystals, short-range and long-range order, imperfections, polymorphism. Ceramic Binary and ternary systems, ceramic microstructures. Crystallization of glass and glass-ceramics.		08	L1, L2
Module 2: PROPERTIES, CLASSIFICATION AND APPLICATIONS OF CERAMICS Thermal, electrical, magnetic and optical properties of ceramics and application. Classification of ceramic materials conventional and advanced, Areas of applications.		08	L1, L2, L3
Module 3: CONVENTIONAL CERAMICS Refractories: Classification of Refractories, Modern trends and		08	L1, L2, L3, L4

developments, Basic raw materials, Elementary idea of manufacturing process technology, Flow diagram of steps necessary for manufacture, basic properties and areas of application. **Whitewares**: Classification and type of Whitewares, Elementary idea of manufacturing process technology including body preparation, basic properties and application areas. **Ceramic Coatings**: Types of glazes and enamels, Elementary ideas on compositions, Process of enameling& glazing and their properties. **Glass**: Definition of glass, Basic concepts of glass structure, Batch materials and minor ingredients and their functions, Elementary concept of glass manufacturing process, Different types of glasses. Application of glasses. **Cement & Concrete**: Concept of hydraulic materials, Basic raw materials, Manufacturing process, Basic compositions of OPC. Compound formation, setting and hardening. Tests of cement and concrete.		
Module 4: **RAW MATERIALS AND FABRICATION METHODS** Elementary ideas about the raw materials used in pottery, Heavy clayweres, Refractories, Glass, Cement, Industries. Raw materials clays and their classification, Quartz, Polymorphism of quartz, Feldspar and its classification, Talc, Steatite and Mica. Fabrication methods, Packing of Powders, Classification and scope of various fabrication methods. Dry and semi dry pressing, extrusion, Jiggering & jollying, Slip casting HP & HIP. Drying & Firing of ceramics: Biscuit firing and glost firing, fast firing technology, action of heat on triaxial body, Elementary ideas of various furnaces used is ceramic industries.	08	L1, L2, L3, L4
Module 5: **ADVANCED CERAMICS** Engineering ceramics, ceramics used in advanced applications, ceramics for medical and scientific products, ceramics for electrical and electronic, aerospace.	08	L1, L2, L3
Course Outcome: After completion of the course students will be exposed to: • The fundamental knowledge and concept of different areas of ceramics and applications. • The special characteristics and fabrication methods of different classes of ceramics.		
Graduate Attributes (as per NBA): • Engineering Knowledge. • Problem Analysis. • Design / development of solutions (partly). • Interpretation of data.		
Question paper pattern: • The question paper will have ten questions. • Each full Question consisting of 16 marks • There will be 2 full questions (with a maximum of four sub questions) from each module.		

• Each full question will have sub questions covering all the topics under a module. • The students will have to answer 5 full questions, selecting one full question from each module.
TEXT BOOKS: 1) Elements of Ceramics - F.H Norton 2) Fundamentals of Ceramics - Barsoum 3) Introduction to Ceramics - W.D Kingery 4) Smith - Materials Science 5) Industrial Ceramics - Singer & Singer. 4.2
REFERENCE BOOKS: 1) Refractories - J. H. Chester 2) Chemistry of Glasses - A. Paul 3) Ceramic Whitewares - SudhirSen 4) Chemistry of cement - F.M. Lea 5) Cera. Mat. for Electronics - R.C Buchanon

Surface Science and Thin Film Technology
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VI

Subject Code	15NT654	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT – 03			

Course Objective:
- To learn the science of surface and the technological aspects of thin films

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: **INTRODUCTION** Introduction to surface, classification, importance. Absorption and adsorption; physic-sorption and chemisorption; factors affecting the adsorption of gases on solid; Adsorption from the Solutions and its importance; applications of adsorption. Colloids: Introduction; differences between colloids and suspension; important properties of true solutions, colloids, and suspensions; types of colloidal solutions and their examples; classification of colloids based on the interactions; Applications of colloidal solutions; colloidal silver and its drawbacks; colloidal gold and its applications. Interfaces: introduction, types, surface energy and energetics, surface tension	08	L1, L2

and effect of surfactants, importance of surface tension in case of nanoparticles, atomic structure of clean surfaces and with adsorbates, surface defects (Terrace, Ledges, Kinks and Adatoms), surface property and bulk property.		
Module 2: **THIN FILMS AND COATING** Thin films:Introduction, importance; thin film growth modes: Frank-van-der-Merwe mode, Stranski-Krastanow mode, and Volmer-Weber mode. Coating: Functions of coating;Dip coating: Introduction, process, factors affecting.Spin coating: General theory, applications, advantages and disadvantages, special requirements for nanoparticles, thickness equation, speed, duration, DDSC, and SDSC techniques, ultra-low spin speeds and covered drying, spin coating with solvent blends, two step spin coating and edge/corner bead removal, visible assessment of drying and filmuniformity, cleaning and wash steps, avoiding a hole& vacuum warping of substrate, spin coating low viscosity solvents, ambient conditions and changes in drying time, incomplete coating of substrate, common spin coating defects.	08	L1, L2, L3
Module 3: **THIN FILM DEPOSITION: PHYSICAL VAPOUR DEPOSITION** Introduction to PVD; vacuum thermal evaporation: resistance heating technique, electron beam heating techniques, Advantages and limitations of vacuum thermal evaporation, applications; Sputter deposition: basic principle, magnetron sputtering, advantages and limitations of sputter deposition, applications; Evaporation (deposition): physical principle, equipment, optimization, applications, comparison.	08	L1, L2, L3
Module 4: **ATOMIC LAYER DEPOSITION AND CHEMICAL BATH DEPOSITION** Atomic layer deposition: Introduction; History; Surface reaction mechanisms: Thermal Al_2O_3 ALD, Metal ALD, Catalytic SiO_2 ALD; ALD applications: Microelectronics applications (Gate oxides, Transition-metal nitrides, Metal films, Magnetic recording heads, and DRAM capacitors), Biomedical applications, and Quality and quality control; Advantages and limitations (Economic viability, Reaction time, and Chemical imitations) of ALD. Chemical bath deposition: Introduction, reaction mechanism, advantages and limitations.	08	L1, L2, L3, L4
Module 5: **ANTI-REFLECTIVE COATING, SELF-CLEANING GLASS, AND NANO INDENTATION** Anti-reflective coating: Introduction, Applications: Corrective lenses, Photolithography; Types: Index-matching, Single-layer interference, Multi-layer interference, Absorbing, Moth eye, and Circular polarizer; Theory: Reflection, Rayleigh's film, Interference coatings, Textured coatings. Self-cleaning glass: Introduction, patterning of hydrophobic surfaces, thin film titania coating, use of titanium dioxide in self-cleaning applications: mechanism, and applications.	08	L1, L2, L3

Nano indentation: Introduction, process, applications.		

Course Outcome:
Students can understand

- surface science and interfaces,
- thin films and coating,
- thin film deposition,
- atomic layer deposition,
- mechanism of anti-reflective coating and self-cleaning glass, and
- nano indentation.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. S. Grainger and J. Blunt, Engineering Coatings: Design and Application, Woodhead Publishing Ltd, UK, 2nd ed., 1998, ISBN 978-1-85573-369-5
2. Functional Polymer Films Eds. R. Advincula and W. Knoll – Wiley, 2011, ISBN 978-3527321902.

REFERENCE BOOKS:

1. George, S.M. (2010). "Atomic Layer Deposition: An Overview". Chem. Rev. 110: 111–131. doi:10.1021/cr900056b

Open Elective Subjects

Nanotechnology in Electrical and Electronics Engineering
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM
CHOICE BASED CREDIT SYSTEM (CBCS)
B.E. Nano Technology

Semester: VI			
Subject Code	15NT661	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT – 03			

Course Objective:
- To understand the basics of nanotechnology and its perspective in electrical and electronics industry
- To comprehend and investigate role of nanotechnology in energy production, storage, distribution and conversion
- To study and review nanotechnology trends in telecommunication industry

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: ENERGY PRODUCTION Nanotechnology and Applications for Electric Power: The Perspective of a Major Player in Electricity, Lightweight Nanostructured Materials and Their Certification for Wind Energy Applications	08	L1, L2
Module 2: ENERGY STORAGE AND DISTRIBUTION Carbon Nanotube Wires and Cables: Near-Term Applications and Future Perspectives, Carbon Nanotube Materials to Realize High-Performance Supercapacitors	08	L1, L2, L3
Module 3: ENERGY CONVERSION AND HARVESTING Nanostructured Thermoelectric Materials: Current Research and Future Challenges. Energy Consumption in Information and Communication Technology: Role of Semiconductor Nanotechnology	08	L1, L2, L3, L4
Module 4: NANOENABLED MATERIALS AND COATINGS FOR ENERGY APPLICATIONS NanocrystallineBainitic Steels for Industrial Applications, Graphene and Graphene Oxide for Energy Storage	08	L1, L2, L3, L4
Module 5: NANOTECHNOLOGY IN TELECOMMUNICATIONS Impact of Nanotechnology on Telecommunications, Nanotubes and Their Applications in Telecommunications, Quantum Dot Cellular Automata: The Prospective Technology for Digital Telecommunication Systems	08	L1, L2, L3

Course Outcome:
After successfully completing this course, students will be able to:
- Understand the fundamentalsof nanotechnology and importance of nanotechnology

in electrical and electronics industry • Evaluate and determine the standards, technological challenges and future trends of nanotechnology in electronics and electrical engineering • Initiate, innovate and develop nanotechnology based solutions in the field of electronics and electrical engineering
Graduate Attributes (as per NBA): • Engineering Knowledge. • Problem Analysis. • Design / development of solutions (partly). • Interpretation of data.
Question paper pattern: • The question paper will have ten questions. • Each full Question consisting of 16 marks • There will be 2 full questions (with a maximum of four sub questions) from each module. • Each full question will have sub questions covering all the topics under a module. • The students will have to answer 5 full questions, selecting one full question from each module.
TEXT BOOKS: 1. Baldev Raj, Marcel Van de Voorde, YashwantMahajan, Nanotechnology for Energy Sustainability, Wiley-VCH Verlag GmbH & Co. KGaA, 2017 http://onlinelibrary.wiley.com/book/10.1002/9783527696109 2. Sohail Anwar, M. YasinAkhtar Raja, SalahuddinQazi, Mohammad Ilyas, Nanotechnology for Telecommunications, CRC Press, 2017 https://www.crcpress.com/Nanotechnology-for-Telecommunications/Anwar-Raja-Qazi-Ilyas/p/book/9781138113817
REFERENCE BOOKS: 1. ManijehRazeghi; Leo Esaki; Klaus von Klitzing, The Wonder of Nanotechnology: Quantum Optoelectronic Devices and Applications, SPIE PRESS BOOK, 2013 2. Puers Robert, BaldiLivio, Van de Voorde Marcel, van Nooten, Sebastiaan E., Nanoelectronics: Materials, Devices, Applications, Wiley-VCH, Weinheim, 2017

Nanotechnology in Civil and Environmental Engineering [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2015 -2016) Course: B.E. / Nano Technology Semester: VI			
Subject Code	15NT662	IA Marks	20

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM
CHOICE BASED CREDIT SYSTEM (CBCS)
B.E. Nano Technology

Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT – 03			

Course Objective:

- To learn the importance of nanotechnology in Civil Engineering.
- To understand how nanomaterials can be used in construction materials
- To understand the latest development nanotechnology for civil and environmental engineering application

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: INTRODUCTION Introduction to Nanoscience and Technology, basic principles and important Concept of Nanotechnology, Nanomaterial, Nano size effect, Surface area, Surface to volume ratio, Property of Nanomaterials- Mechanical, Electrical, optical, Thermal, Magnetic and Catalytic. Awareness and Existing activities of nanotechnology relevant to construction - desk study. Understanding phenomena of traditional construction materials at nanoscale.	08	L1, L2
Module 2: NANOTECHNOLOGY IN CONSTRUCTION MATERIALS Nanomaterials in Concrete and Cement, Introduction, different nanomaterials used in concrete, Development of nano concrete, Application of nanomaterials in UHPC, Nano silica, densification of cement using Nanosilica,Nano alumina, Carbon nanotube (CNT), the Effect of SWCNT and Other Nanomaterials on Cement Hydration and Reinforcement, Polycarboxylates, Titanium oxide, Nano kaolin, Nano clay. Nanomaterials-Enabled Multifunctional Concrete and Structures, Next-Generation Nano-based Concrete Construction Products: Optimization of Clay Addition for the Enhancement of Pozzolanic Reaction in Nano-modified Cement Paste	08	L1, L2, L3
Module 3: NANOTECHNOLOGY IN STRUCTURAL MATERIAL Nanotechnology and Steel, Applications in steel structures, for strength, corrosion resistance, improving strength of steel with nanomaterials, effect of copper nanoparticles of strength of steel. MMFX steel and application. Applications in welds and joints, weld ability, delayed fracture, strengthening of steel bolts, vanadium and molybdenum nanoparticles to improve delayed fracture. Wood as structural material, nanomaterials to improve the structural performance and serviceability of wood, nanocomposites, polymer - nanocomposite.	08	L1, L2, L3, L4
Module 4:	08	L1, L2, L3

NANOTECHNOLOGY AND COATINGS Nanomaterials based paints, insulatingProperties nanomaterials, Smart nanomaterials for building and Glass, Nanomaterials for Thermal or Fire Retarding, Functional coatings and thin films. Environment and performance monitoring sensors and devices. Nano sensors for structural health monitoring. Advances in instrumentation, Atomic force microscopy, Nanoindentation techniques, Neutron and X-ray scattering techniques for construction materials		
Module 5: NANOTECHNOLOGY IN ENVIRONMENTAL ENGINEERING Introduction, nanomaterials for clean water, waste water treatment, Nanomaterials as adsorbent for removal of pollutant, microorganisms, heavy metals. Removal of pesticides and fungicides with Nanomaterials. Nanomaterials for water disinfection, Nanofiltration. Nanomaterials as photo catalyst, catalyst. Nanomaterials for capturing CO_2. Nanomaterials for Air pollution remediation, Air purification and Emission mitigation using Nanomaterials. Nanotechnology for detection of pollutant in air and water, Nano sensors and application. Environmental risk due to Nanomaterials, Nanotoxicology.	08	L1, L2, L3, L4

Course Outcome:

- To learn the basic concepts of Nanotechnology.
- To understand nanomaterial properties useful in construction materials
- Able to understand nanotechnology application in civil engineering
- Use nanomaterials in Environmental engineering

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. Khitab Anwar, Advanced Research on Nanotechnology for Civil Engineering Applications, IGI Global, May 16, 2016 - Technology & Engineering - 339 pages
2. ZdenekBittnar, Peter J. M. Bartos, Jiri Nemecek, V. Smilauer, J. Zeman, Nanotechnology in Construction: Proceedings of the NICOM3, Springer Science & Business Media, Apr 21, 2009 - Technology & Engineering - 437 pages
3. M.S. Ramachandra Rao, Shubra Singh, Nanoscience and Nanotechnology: fundamentals to Frontiers, Wiley 2013

4. G Cao, Nanostructures and Nanomaterials synthesis, properties and applications, Imperial College press 2004.

REFERENCE BOOKS:

1. W. Zhu 1, P.J.M. Bartos 1 and A. Porro, Materials and Structures / Mat6riaux et Constructions, RILEM TC 197-NCM: 'Nanotechnology in construction materials' Application of nanotechnology in construction Summary of a state-of-the-art report Prepared 2 Vol. 37, November 2004, pp 649-658
2. Florence Sanchez, Konstantin Sobolev, Nanotechnology in concrete – A review, Construction and Building Materials 24 (2010) 2060–2071
3. G.A. Mansoori, T. Rohani. Bastami, A. Ahmadpour, Z. and Eshaghi, Chapter 2 Environmental Application Of Nanotechnology, Annual Review of Nano Research, Vol.2, Chap.2, 2008
4. Ian SofianYunus, Harwin, AdiKurniawan, DendyAdityawarman and Antonius Indarto, Nanotechnologies in water and air pollution treatment, Environmental Technology Reviews Vol. 1, No. 1, November 2012, 136–148
5. JieZhuang and Randall W. Gentry, Environmental Application and Risks of Nanotechnology: A Balanced View, In Biotechnology and Nanotechnology Risk Assessment: Minding and Managing the Potential Threats around Us; Ripp, S., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Nanotechnology in Mechanical Engineering

[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VI

Subject Code	15NT663	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03

CREDIT – 03

Course Objective:

- To learn the different aspects of nanotechnology which can improve the field of Mechanical Engineering
- To understand the designing, fabricating, developing and analysing the materials by nanotechnology

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1 NANOSTRUCTURES IN MECHANICAL ENGINEERING Introduction to Nanomaterials- Quantum dot, CNT, fullerenes,	08	L1, L2

buckyball, nanocomposites and nanoceramics, mechanical properties of nanomaterials, applications of nanomaterials in Mechanical engineering, Assembly of nanoparticles and functionalization - Nanoparticles arranged structures as Nanopores and Nanocomposites - Structure control of nanoparticle collectives by sintering and bonding - Self-assembly. Nanoparticle dispersion and aggregation behavior - Single nanoparticle motion in fluid – Brownian diffusion - Adsorption properties - Interactions between particles		
Module 2 MACHINING BRITTLE MATERIALS USING NANOSTRUCTURED DIAMOND TOOLS Introduction, Mechanisms of Tool Wear- classification of tool types, Machining Simulations, Experimental Method- Deposition cycles for TMCVD panel and TMCVD panel, characterization- Film characterization, Wear mechanisms- Crater wear and notching wear, Flank wear, Cutting forces and friction coefficient.	08	L1, L2, L3, L4
Module 3 ANALYSIS OF CONTACT BETWEEN CHIP AND TOOL USING NANOSTRUCTURED COATED CUTTING TOOLS Introduction, Computational Analysis of Machining Conditions- Loewen and Shaw's Method to Calculating Cutting Temperatures, Finite Element Studies of Machining Conditions- Coefficient of Friction, Shear Plane Temperature vs Coefficient of friction and Tool Face Temperature vs Coefficient of Friction.	08	L1, L2, L3
Module 4 FORMATION OF NANOSTRUCTURED METALS BY MACHINING Introduction, Chip Formation- Chip Curl Modelling and Shear Strains, Chip Formation with Modulation, Computational Analysis, Experimental Procedure- Finite Element Analysis, Micro-grinding Experiments, Chip Curl Modelling, Finite Element Modelling and Micro-grinding Observations.	08	L1, L2, L3, L4
Module 5 MANUFACTURE AND DEVELOPMENT OF NANOSTRUCTURED DIAMOND TOOLS Introduction, Analysis of Stress in a Loaded Wedge- Stress analysis of a single-point loaded wedge, Stress Analysis in a Wedge with a Distributed Load, Development of Wear Model, Computational Stress Analysis of Single Diamond Grains, Experimental Methods- Hot filament chemical vapor deposition, Measurement of wear of diamond tools.	08	L1, L2, L3
Course Outcome: • Students will learn the different aspects of nanotechnology which can improve the field of Mechanical Engineering • Students are able to understand the designing, fabricating, developing and analysing the materials by nanotechnology		
Graduate Attributes (as per NBA): • Engineering Knowledge.		

- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. Mark J. Jackson Jonathan S. Morrell "Machining with Nanomaterials" 2009 Springer ISBN 978-0-387-87659-7
2. Edward L. Wolf, "Nanophysics and Nanotechnology - An Introduction to Modern Concepts in Nanoscience" Second Edition, John Wiley & Sons, 2006.

REFERENCE BOOKS:

1. K.W. Kolasinski, "Surface Science: Foundations of Catalysis and Nanoscience", Wiley, 2002

Nanotechnology in Biomedical Engineering

[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VI

Subject Code	15NT664	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03

CREDIT – 03

Course Objective:

- To learn the basic importance and applications of Nanotechnology medical and biological fields.
- To understand techniques and design the nanostructures, nanodevices, nano based diagnostics techniques, therapeutics, and devices as implants, drug delivery devices etc.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: INTRODUCTION	08	L1, L2

Synthesis of nanomaterials by Physical, Chemical and Biological methods. Popular Characterization methods. Carbon nanotube and its bio-applications. DNA Nanotechnology, Protein and Glyco-Nanotechnology, Lipid Nanotechnology. Nanotoxicology.		
Module 2: IMPACT OF NANOTECHNOLOGY ON SURGERY Introduction, Surgical blades and suture needles. Nanoshell particles, minimally invasive surgery using catheters, optical tweezers. Bio-molecular motors, Nanorobotics, gold and silver nanoparticles for cancer therapy, chemotherapy, Immunotherapy, Vaccine immunotherapy, Radiotherapy, thermotherapy, photo dynamic therapy	08	L1, L2, L3
Module 3: SENSING APPLICATIONS Nanoprobes as BioPhotonics. Diagnostic Biosensors. Functionalized Metallic Nanoparticles and their Applications in Colorimetric Sensing, Dip stick Tests. Nanochip for HIV detection. Nanoparticles in Magnetic Resonance Imaging- Optical nanoparticles sensors for quantitative intracellular imaging. Cancer imaging- Nanophotonics.	08	L1, L2, L3, L4
Module 4: NANO-ARTIFICIAL CELLS AND BIONANOMACHINES Nano-materials in bone substitutes & Dentistry, Natural nanocomposite systems as spider silk, bones, shells; organic-inorganic nanocomposite formation through self-assembly. Implantable materials for vascular interventions, active implantable devices and bionics, Implantable materials for orthopaedic and dentistry. Wound care products. Polymeric nanofibres.	08	L1, L2, L3, L4
Module 5: NANOPARTICLES IN DRUG DELIVERY DEVICES Sustained and targeted drug delivery, delivery mechanism – Introduction, antibody conjugated nanoparticles and their interactions with biological surfaces, Biomedical nanoparticles – Liposomes, dendrimers, Nanoscale drug delivery devices, Nano vectors for gene therapy, mechanism of drug targeting, drug delivery carriers, Nanoparticulate delivery systems, nano-particle mediated drug delivery to solid tumors, colloidal nanosilver particles as an effective nano antibiotic.	08	L1, L2, L3
Course Outcome: Students can • Learn the basic importance and applications of Nanotechnology medical and biological fields. • Understand techniques and design the nanostructures, nanodevices, nano based diagnostics techniques, therapeutics and devices as implants, drug delivery devices, etc.		
Graduate Attributes (as per NBA): • Engineering Knowledge.		

- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. Malsch, N.H., "Biomedical Nanotechnology", CRC Press. (2005)
2. Mirkin, C.A. and Niemeyer, C.M., "Nanobiotechnology II: More Concepts and Applications", Wiley-VCH. (2007)
3. Kumar, C. S. S. R., Hormes, J. and Leuschner C., "Nanofabrication Towards Biomedical Applications: Techniques, Tools, Applications, and Impact", WILEY -VCH Verlag GmbH & Co. (2005)
4. Lamprecht, A., "Nanotherapeutics: Drug Delivery Concepts in Nanoscience", Pan Stanford Publishing Pte. Ltd. (2009)

REFERENCE BOOKS:

1. K.K.Jain, "The Handbook of Nanomedicine", Humana press. (2008)
2. M. Reza Mozafari, Nanomaterials and Nanosystems for Biomedical Applications, Springer. (2007)
3. P.P. Simeonova, N. Opopol and M.I. Luster, "Nanotechnology - Toxicological Issues and EnvironmentalSafety", Springer 2006.
4. VinodLabhasetwar and Diandra L. Leslie, "Biomedical Applications of nanotechnology", A John Willy& son Inc,NJ, USA, 2007.
5. Challa, S.S.R. Kumar, Josef Hormes,& CarolaLeuschaer, Nanofabrication Towards Biomedical Applications, Techniques, Tools, Applications and Impact, Wile- VCH, (2005)

Molecular Biology and Genetic Engineering Lab
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VI

Laboratory Code	15NTL67	IA Marks	20
Number of Lecture Hours/Week	01Hr Tutorial + 02 Hrs Laboratory	Exam Marks	80

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM
CHOICE BASED CREDIT SYSTEM (CBCS)
B.E. Nano Technology

		Exam Hours	03
CREDIT – 02			
Course Objective: • To understand the cell structure and organization of cell components. • To isolate the genetic materials like DNA and RNA from different microbes, plants and also learn molecular biology techniques.			
List of Experiments			Revised Bloom's Taxonomy (RBT) Level
1. Study of divisional stages in Mitosis			L2,L4,L5
2. Study of divisional stages in Meiosis.			L2,L3,L4
3. Study of Polytene and Lampbrush chromosomes using permanent slides			L2,L3,L4
4. Isolation and fusion of plant protoplasts			L5,L6
5. Isolation of plasmid DNA from *bacteria*			L5,L6
6. Isolation of genomic DNA (plant / microbial sources)			L2,L3,L4
7. Agarose gel electrophoresis and quantification of nucleic acids (colorimetric, ethidium bromide dot blot and standard DNA marker)			L5,L6
8. Competent cell preparations.			L2,L3,L4
9. Transformation and selection of recombinants			L2,L3,L4
10. Study of conjugation in *E.coli*			L5,L6
11. Amplification of DNA by PCR			L5,L6
12. Preparation of DNA for PCR applications- Isolation, purity & quantification			L2,L3,L4
Course Outcome: • Students can able to understand organization and different components at molecular scale level. • Students can also learn different techniques used for the isolation of the genetic materials like DNA and RNA. • Students can also learn the most advanced techniques like PCR, Gel Electrophoresis which are important techniques of molecular biology.			
Graduate Attributes (as per NBA): • Engineering Knowledge. • Problem Analysis. • Design / development of solutions (partly). • Interpretation of data.			
Question paper pattern: • The question paper will have ten questions. • Each full Question consisting of 16 marks • There will be 2 full questions (with a maximum of four sub questions) from each module. • Each full question will have sub questions covering all the topics under a module. • The students will have to answer 5 full questions, selecting one full question from each module.			
TEXT BOOKS: 1. Looking at Chromosomes by Darlington, Wiley. 2. Essentials of Molecular Biology by David Freifelder, Narosa Pub. House. 3. Molecular Biology of the Cell by Alberts et al., Garland Publishing. 4. Principles of Gene manipulation and Genomics by Primrose, Oxford University Press. 5. Molecular Biology of the Gene by James D Watson et al., Pearson Education.			

REFERENCE BOOKS:
1. Molecular Cell Biology by Darnell J Lodish& H Baltimore, Freeman Pub.
2. Biochemistry & Molecular Biology by William H Elliot and Daphane C Elliot, Oxford University Press.
3. Current protocols in molecular biology, edited by Frederick M. Ausubel et al., John Wiley & Sons.
4. Methods in enzymology by Berger S.L. & Kimmel A.R., Vol.152, Academic Press.
5. Cellular & Biochemical Science by G. Tripathi, IK Intl.

Quantum Mechanics and Simulation Lab
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VI

Laboratory Code	15NTL68	IA Marks	20
Number of Lecture Hours/Week	01Hr Tutorial + 02 Hrs Laboratory	Exam Marks	80
		Exam Hours	03

CREDIT – 02

Course Objective:
To understand the simulation at atomic and molecular level by using softwares
To study about the nucleic acids, proteins, superimposition of molecules and building the phylogenetic tree, etc.

List of Experiments	Revised Bloom's Taxonomy (RBT) Level
1. Modelling metal–semiconductor contacts: The Ag–Si interface using QuantumWise - Virtual NanoLab Software	L5,L6
2. Resistivity calculations using the MD-Landauer method using QuantumWise - Virtual NanoLab Software	L5,L6
3. Spin-orbit transport calculations: Bi2Se3 topological insulator thin-film device using QuantumWise - Virtual NanoLab Software	L5,L6
4. Opening a band gap in silicene and bilayer graphene with an electric field using QuantumWise - Virtual NanoLab Software	L5,L6
5. Building molecule–surface systems: Benzene on Au (111) using QuantumWise - Virtual NanoLab Software	L5,L6
6. Spin-dependent Bloch states in graphene nanoribbons using QuantumWise - Virtual NanoLab Software	L5,L6
7. Exploring graphene - Build a graphene sheet - Build a CNT - Transmission spectrum of a GNR using QuantumWise - Virtual NanoLab Software	L5,L6
8. Twisted nanoribbon - Transmission spectrum - Buckling a graphene sheet.	L5,L6
9. Sequence retrieval from nucleic acid and protein data base using NCBI	L2,L3,L4
10. Multiple alignment of sequence and pattern determination by NCBI and Clustal Omega Prosite software	L2,L3,L4

11. Evolutionary studies / phylogenetic analysis by phylowin software and Visualization by TreeView software	L2,L3,L4
12. Secondary structure prediction of proteins by Sopma software	L2,L3,L4
13. Identification of functional sites in gene / genome by Gen Sean and ORF finder software	L2,L3,L4
14. Super imposition of molecular structures and calculation of RMSD by SPDBV software	L2,L3,L4
15. PDB structure retrieval and visualization; analysis of homologous structure by RASMOL software	L2,L3,L4

Course Outcome:
Students can understand

- The simulation at atomic and molecular level by using softwares
- About the nucleic acids, proteins, superimposition of molecules and building the phylogenetic tree.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:
1. Lab manual

Semester: VII

Core Subjects

Nanocomposites and Their Applications
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VII

Subject Code	15NT71	IA Marks	20

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM
CHOICE BASED CREDIT SYSTEM (CBCS)
B.E. Nano Technology

Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03
CREDIT – 04			

Course Objective:

- Composites are a relatively wide used class of materials.
- In this course the students learn about the benefits of combining different materials to a composite to obtain desired properties.
- The motive of this course is to make the students to understand different processing methods, issues, properties and testing methods of different composite materials

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: INTRODUCTION TO COMPOSITES Definition and Fundamentals of composites and Nanocomposites. Need for composite materials. Classification of composites; Matrix: Polymer matrix composites (PMC), Metal matrix composites (MMC), Ceramic matrix composites (CMC); Reinforcement: particle reinforced composites, Fibre reinforced composites. Applications of composites. Fibre production techniques for glass, carbon and ceramic fibres.	10	L1, L2
Module 2: POLYMER MATRIX COMPOSITES Polymer resins: thermosetting resins, thermoplastic resins; reinforcement fibres: rovings, woven fabrics, non-woven random mats, various types of fibres. Processing of PMC: hand layup process, spray up process, compression moulding, reinforced reaction injection moulding, resin transfer moulding, Pultrusion, Filament winding, Injection moulding. Fibre reinforced plastics (FRP), Glass Fibre Reinforced Plastics (GFRP). Laminates: Balanced Laminates, Symmetric Laminates, Angle Ply Laminates, Cross Ply Laminates; applications of PMC in aerospace, automotive industries. Applications of polymer nanocomposites	10	L1, L2, L3
Module 3: METAL MATRIX COMPOSITES Characteristics of MMC, various types of metal matrix composites alloy vs. MMC, advantages of MMC, limitations of MMC, Reinforcements: particles, fibres. Effect of reinforcement: volume fraction, rule of mixtures. Processing of MMC: powder metallurgy process, diffusion bonding, stir casting, squeeze casting, a spray process, Liquid infiltration In-situ reactions, Interface-measurement of interface properties, applications of MMC in aerospace, automotive industries. Applications of Metal matrix nanocomposites.	10	L1, L2, L3, L4

Module 4: CERAMIC MATRIX AND SPECIAL COMPOSITES Engineering ceramic materials: properties, advantages, limitations, monolithic ceramics, need for CMC, Ceramic matrix: various types of ceramic matrix composites- oxide ceramics, non-oxide ceramics, aluminium oxide, silicon nitride; Reinforcements: particles, fibres, whiskers. Sintering, Hot pressing, Cold isostatic pressing (CIPing), Hot isostatic pressing (HIPing). Processing of Ceramic Matrix composites. Applications of ceramic matrix nanocomposites Applications of CMC in aerospace, automotive industries. Carbon/carbon composites, advantages of carbon matrix,limitations of carbon matrix. Carbon fibre – chemical vapour deposition of carbon on carbon fibre perform. Sol-gel technique	10	L1, L2, L3, L4
Module 5: MECHANICS OF COMPOSITES Lamina Constitutive Equations: Lamina Assumptions – Macroscopic Viewpoint. Generalized Hooke's Law. Reduction to Homogeneous Orthotropic Lamina – Isotropic limit case, Orthotropic Stiffness matrix (Qij), Definition of stress and Moment Resultants. Strain Displacement relations. Basic Assumptions of Laminated anisotropic plates. Laminate Constitutive Equations – Coupling Interactions, Balanced Laminates, Symmetric Laminates, Angle Ply Laminates, Cross Ply Laminates. Laminate Structural Moduli. Evaluation of Lamina Properties from Laminate Tests. QuasiIsotropic Laminates. Determination of Lamina stresses within Laminates.	10	L1, L2, L3

Course Outcome:

After completion of course, student can be able to

- Design composites using of different material
- Use different techniques to process different types of composites and know the limitations of each process
- Use Mathematical techniques to predict the macroscopic properties of different Laminates

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. Mathews F. L. and Rawlings R. D., "Composite Materials: Engineering and Science", 1 st Edition, Chapman and Hall, London, England, 1994.
2. Chawla K. K., "Composite materials", Second Edition, Springer – Verlag, 1998.

REFERENCE BOOKS:
1. Clyne, T. W. and Withers, P. J., "Introduction to Metal Matrix Composites", Cambridge University Press, 1993.
2. Strong, A.B., "Fundamentals of Composite Manufacturing", SME, 1989.
3. Sharma, S.C., "Composite materials", Narosa Publications, 2000.
4. Broutman, L.J. and Krock,R. M., "Modern Composite Materials", Addison-Wesley, 1967. 5. ASM Hand Book, "Composites", Vol.21, ASM International, 2001.

Microcontrollers and Interface [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2015 -2016) Course: B.E. / Nano Technology Semester: VI			
Subject Code	15NT72	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03
CREDIT – 04			
Course Objective: • To study basic principles of micro-controllers family • To understand designing and interfacing the devices with micro controllers			
Modules		Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: MICROPROCESSORS AND MICROCONTROLLER Introduction, Microprocessors and Microcontrollers, RISC & CISC CPU Architectures, Harvard & Von- Neumann CPU architecture, Computer software. The 8051 Architecture: Introduction, Architecture of 8051, Pin diagram of 8051, Memory organization, External Memory interfacing, stacks.		10	L1, L2, L3
Module 2: ADDRESSING MODES Introduction, Instruction syntax, Data types, Subroutines, Addressing modes: Immediate addressing, Register addressing, Direct addressing, Indirect addressing, relative addressing, Absolute addressing, Long addressing, Indexed addressing, Bit inherent addressing, bit direct addressing.		10	L1, L2, L3
Module 3:		10	L1, L2, L3,

8051 INSTRUCTION SET Instruction timings, 8051 instructions: Data transfer instructions, Arithmetic instructions, Logical instructions, Branch instructions, Subroutine instructions, Bit manipulation instruction. INTERFACING Interfacing stepper motor – program to rotate stepper motor, interfacing DC motor – program to control the speed of DC motor, interfacing serial A/D converter, interfacing D/A converter using parallel ports – program to generate square wave by interfacing DAC08 with parallel port.		L4
Module 4: MICROCONTROLLER PIC16F84 Introduction, CISC, RISC, Applications, Clock/instruction cycle, Pipelining, Pin description, Clock generator – oscillator, Reset, Central processing unit, Ports, Memory organization, Interrupts, Free timer TMR0, EEPROM Data memory. PIC16CXX INSTRUCTION SET Introduction to instruction set in pic16cxx microcontroller family, data transfer, arithmetic and logic, bit operations, directing the program flow, instruction execution period.	10	L1, L2, L3
Module 5: OVERVIEW OF THE AVR FAMILY History, AVR feature's, AVR family overview – classic AVR – Mega AVR – Tiny AVR – Special purpose AVR. AVR ARCHITECTURE The general purpose registers in the AVR, AVR data memory, instructions with the data memory, AVR status register, AVR data format and directives.	10	L1, L2, L3
Course Outcome: Students can • Study basic principles of micro-controllers family • Understand designing and interfacing the devices with micro controllers		
Graduate Attributes (as per NBA): • Engineering Knowledge. • Problem Analysis. • Design / development of solutions (partly). • Interpretation of data.		
Question paper pattern: • The question paper will have ten questions. • Each full Question consisting of 16 marks • There will be 2 full questions (with a maximum of four sub questions) from each module. • Each full question will have sub questions covering all the topics under a module. • The students will have to answer 5 full questions, selecting one full question from each module.		
TEXT BOOKS: 1. 8051 microcontroller : Hardware, software and applications by M S Mallikarjunaswamy and V Udayashankara		

2. PIC microcontrollers for beginners, by NebojsaMatic. 3.The AVR microcontroller and embedded system by Muhammad alimazidi.
REFERENCE BOOKS: 1. The 8051 microcontroller and embedded systems Using assembly and C, 2nd ed., by Muhammad Ali Mazidi. ISBN: 9780131194021 2. The 8051 microcontroller, 3rd ed. By Kenneth Ayala, ISBN: 108131502007

MEMS and NEMS [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2015 -2016) Course: B.E. / Nano Technology Semester: VII			
Subject Code	15NT73	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03
CREDIT – 04			
Course Objective: • To understand the basic components of MEMS and NEMS • To study, design the MEMS and NEMS based devices			
Modules		Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: **INTRODUCTION** Miniaturization, Integrated Circuits, Microsensors, Microactuators, Thermal MEMS, Micro-Opto Electro Mechanical Systems (MOEMS), Magnetic MEMS, Microfluidics, RF MEMS, Packaging. **MICRO SENSORS & ACTUATORS** Principle of sensing and actuation, silicon capacity sensors, piezo-resistive sensors, electrostatic comb drive, magnetic microrelay, piezo-ink jet printer, micromirrors, array sensors, microgrippers, gyroscopes, micro beams and cantilever.		10	L1, L2
Module 2: **TRANSDUCTION PLATFORMS** Introduction - Conductometric and Capacitive Transducers, Optical Waveguide based Transducers, Electrochemical Transducers, Solid State Transducers - Schottky Diode based Transducers - p-n Diodes or Bipolar Junction based Transducers - MOS Capacitor based Transducers, Acoustic Wave Transducers - Cantilever based Transducers - Quartz Crystal Microbalance - Film Bulk Acoustic Wave		10	L1, L2, L3

Resonator.		
Module 3: MICROMACHINING Types of wafers, orientation, Photolithography, Etching methods, Silicon polishing, surface and bulk micromachining, Thin film deposition techniques sputtering, CVD, epitaxial growth, thermal oxidation, wafer bonding. MEMS MATERIALS Single crystal silicon, poly silicon, SiO_2, SiN, Germanium based materials, metals, SiC, diamond III-V materials, piezoelectric materials.	10	L1, L2, L3, L4
Module 4: INTEGRATION OF MEMS DEVICES Microsystem packaging, packaging technologies, reliability, failure mechanisms, CMOS, stability, transient properties and performance, traceability and calibration, scaling effects, signal amplifiers, transmitters, signal conditioning, basics of control theory, case studies.	10	L1, L2, L3, L4
Module 5: NANOELECTROMECHANICAL SYSTEMS (NEMS) Introduction- Nano machining of NEMS based upon electron beam lithography, Nano electromechanical systems fabrication, nano imprint lithography, polymeric nano fibre templates, focused ion beam doping and wet chemical etching, stencil lithography and sacrificial etching, large scale integration, future challenges, applications.	10	L1, L2, L3
Course Outcome: Students can • understand the basic components of MEMS and NEMS • study, design the MEMS and NEMS based devices		
Graduate Attributes (as per NBA): • Engineering Knowledge. • Problem Analysis. • Design / development of solutions (partly). • Interpretation of data.		
Question paper pattern: • The question paper will have ten questions. • Each full Question consisting of 16 marks • There will be 2 full questions (with a maximum of four sub questions) from each module. • Each full question will have sub questions covering all the topics under a module. • The students will have to answer 5 full questions, selecting one full question from each module.		
TEXT BOOKS: 1. N.P. Mahalik, MEMS, Tata-McGraw Hill publication, 2009 2. V.K.Aatre, G.K.Ananthasuresh, K.J.Vinoy, Micro & Smart System, Wiley India, 2010. 3. Karlglosekotter, “Nanoelectronics and Nanosystems”,Springer, 2004		

KouroshKalantar-zadeh, Benjamin Fry, "Nanotechnology-Enabled Sensors", springer.
REFERENCE BOOKS: 1. Michael Stroscio, MitraDutta, Biological nanostructures and applications of nanostructures in biology, Kluwer academic publishers, 2004. 2. H. Fujita, Micromachines as Tools for Nanotechnology, Springer, 2003. 3. J.B. Park, Biomaterials Science and Engineering, Ed. 2, Narosa Publishers, New Delhi, 2005

Professional Elective Subjects

Data Analytics in Nanoscience [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2015 -2016) Course: B.E. / Nano Technology Semester: VII			
Subject Code	15NT741	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT – 03			
Course Objective: • To understand the basics of big data analytics, methods and tools that data scientists use • Tolearn the concepts, principles and practical applications of data analytics in nanotechnology • To learn the method and procedures of using open source software for big data analytics			
Modules		Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: INTRODUCTION TO BIG DATA ANALYTICS Big data overview, data structures, analyst prespective on data repositories, state of the practice in analytics, current analytical architecture, drivers of big data, emerging big data ecosystem, new big data ecosystem, examples of big data analytics		08	L1, L2
Module 2: DATA ANALYTICS LIFECYCLE Life cycle, discovery, data preparation, model planning, model building, communicate results, operationalize, global innovation networks and analysis, discovery		08	L1, L2, L3
Module 3: DATA ANALYTIC METHOD USING R Introduction to R, exploratory data analysis, statistical methods for		08	L1, L2, L3, L4

evaluation.		
Module 4: **ANALYTICAL THEORY AND METHODS** Introduction to clustering, association rules, regression, classification, time series analysis, text analysis, mapreduce and hadoop, in database analytics	08	L1, L2, L3, L4
Module 5: **CONVERGENCE OF NANOTECHNOLOGY AND BIG DATA ANALYSIS** Big Data; biosensors; computer-aided diagnosis; data analysis; data visualization; healthcare; nanotechnology	08	L1, L2, L3

Course Outcome:
After successfully completing this course, students will be able to:

- Understand the fundamentalsof data analytics and big data
- Develop structured lifecycle approach to data analytics problems
- Apply appropriate analytic technique and tools to analyse big data in nanotechnology

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. Data Science and Big Data Analytics: Discovering, Analyzing, Visualizing and Presenting Data, EMC Education Services, 2015. (http://as.wiley.com/WileyCDA/WileyTitle/productCd-111887613X.html)
2. Data Science and Big Data Analytics: Discovering, Analyzing, Visualizing and Presenting Data, EMC Education Services, 2015. (http://as.wiley.com/WileyCDA/WileyTitle/productCd-111887613X.html)
3. Rodrigues JF, Paulovich FV, de Oliveira MC, de Oliveira ON, On the convergence of nanotechnology and Big Data analysis for computer-aided diagnosis, Nanomedicine (Lond). 2016 Apr;11(8):959-82. doi: 10.2217/nnm.16.35. Epub 2016 Mar 16 (https://www.ncbi.nlm.nih.gov/pubmed/2697966)

REFERENCE BOOKS:

1. Ramona Nelson, Nancy Staggers, Health Informatics - E-Book: An Interprofessional Approach, Elsevier, 2014

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B.E. Nano Technology

Nanotechnology for Healthcare [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2015 -2016) Course: B.E. / Nano Technology Semester: VII			
Subject Code	15NT742	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT – 03			

Course Objective:

- To learn the basic principles and importance of Nanobiotechnology health care.
- To understand and design the nanostructures, nanodevices, nano based diagnostics techniques and devices as implants, drug delivery devices etc.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: **NANOTECHNOLOGY IN PHARMACEUTICAL APPLICATIONS** Human anatomy – Form function and physiology – Developmental prolog - principle of development – Neurophysiology – sensory physiology and muscle physiology – Trends in nanobiotechnology - Protein- and peptide-based compounds for cancer, diabetes, infectious diseases and organ transplant- therapeutic classes-focused pharmaceutical delivery systems.	08	L1, L2
Module 2: **NANOTECHNOLOGY AND DRUG DELIVERY** Introduction, Advantages of Nanostructured Delivery Systems: Localized and Targeted Delivery, Controlled Delivery, Enhanced Circulation Time and Bio distribution, Drug Solubility, Intracellular Drug Delivery, Ability to Cross Biological Membranes, Enhanced Surface Areas. Activation and Targeting of Nanotechnology-Based Drug Delivery Systems (Externally and Internally): Activation and Targeting through PhysicoChemical Stimuli and Drug Targeting through Targeting Molecules. Multifunctional Nanoparticle Systems: Multivalent Strategies and Exploiting Inherent Material Properties.	08	L1, L2, L3
Module 3: **MATERIALS AND METHODS FOR PREPARATION OF NANOCARRIER SYSTEMS** Materials: Introduction, materials used in preparation of nanoparticles as drug carrier systems: polylactic-co-glycolic acid (PLGA), poly lactic acid (PLA), polysaccharides, chitosan, alginate and their pharmaceutical applications, metal nanoparticles, iron oxide nanoparticles, metallic nanoparticles: Ag, Au, and stabilizers.	08	L1, L2, L3, L4

Methods: Polymer precipitation methods: emulsification-solvent evaporation, emulsification-solvent diffusion, salting out method, SLN: preparation methods, Hot homogenization vs Cold homogenization techniques, Encapsulation and Drug release studies.		
Module 4: SMART POLYMERS AS DRUG CARRIERS Smart polymers: Introduction, smart polymers for drug delivery applications with type of stimuli, phase transition of smart polymers and smart hydrogels, classification of smart polymers: external stimuli (//light) responsive polymers: electrically responsive polymers, magnetically responsive polymers, ultrasonic responsive polymers, light responsive polymers and internal stimuli responsive polymers.	08	L1, L2, L3, L4
Module 5: LIPOSOMES AS DRUG CARRIER Liposomes: Introduction, types of liposomes, materials used in liposome preparation: phospholipids and bilayer additives, Preparation of liposomes, characterization of liposomes, stability of liposomal delivery systems: chemical stability, stability testing, pharmacokinetics, Liposomes uses: fungal treatment, cancer treatment: long circulating liposomes, size and tumor delivery, Doxil (doxorubicin) carrying liposome, Liposome vaccines, immunoliposomes and gene delivery by liposomes.	08	L1, L2, L3

Course Outcome:

Students can learn

- Basic concepts and applications of Nanotechnology in pharmaceutics.
- The applications of Nanotechnology in drug delivery
- Materials and methods for preparation of nanocarrier systems
- Smart polymers as drug carriers
- Liposomes as drug carrier.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. "Nanotechnology in health care" edited by P.D. Gupta and N. Udupa, first edition, 2011
2. Chemical Sensors and Biosensors; Brian, R Eggins; Wiley; New York, Chichester; 2002.

3. Biomedical Nanostructures by Kenneth E. Gonsalves and Craig R. Halberstadt, John wiley& sons, inc., publication, 2007.
4. "Nanotechnology in biology and medicine" Methods, Devices, and Applications by Tuan Vo-Dinh, Taylor & Francis Group, LLC, 2007

REFERENCE BOOKS:

1. Electrochemical Methods: Fundamentals and Applications; Allen J Bard and Larry R Faulkner; Wiley, New York, Chichester: 2nd ed.; 2001.
2. 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

Engineering Materials and Surface Coatings

[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VII

Subject Code	15NT743	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03

CREDIT – 03

Course Objective:
The objective of this subject is to

- Understand the growth in the use of adhesives, especially in ever more technically demanding applications;
- The science and technology of additives, paints and lubricants, and the recent developments in nano technology towards engineering applications of adhesives, paints and lubricants.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: **INTRODUCTION TO ENGINEERING MATERIALS AND SURFACE COATINGS** Adhesives: Introduction, basic terminologies, history of adhesives, functions of adhesives, advantages and disadvantages; Criteria for selection of adhesives; Requirements of a good bond; Factors affecting adhesion strength; Fundamental aspects of adhesion: Forces available (primary chemical bonds, Van der Waals bonds, hydrogen bonds), surfaces, and change of phase; Mechanism of adhesive action: Specific adhesion, Mechanical adhesion, Diffusion adhesion, Electrostatic adhesion; Development of adhesive strength; Factors affecting adhesive	08	L1, L2, L3

action: Physical (interfacial tension, porosity, physical characteristics of adhesive films, effect of temperature, pressure, and time), and Chemical (degree of polymerization of polymeric resins, pH of the medium, polar characteristics, side chains) factors.		
Module 2: TYPES AND APPLICATIONS OF ENGINEERING ADHESIVES Types of glues: types (animal based, plant based, solvent type, and synthetic glues) and examples; Introduction and applications of Non-reactive adhesives (drying adhesives, pressure-sensitive adhesives, contact adhesives, hot-melt adhesives, RTV silicone adhesives) Reactive adhesives (multi-part adhesives, one-part adhesives); Types by origin: natural and synthetic; Structural adhesives: structure properties and applications of epoxies, urethanes adhesives, acrylic adhesives, and phenolic adhesives; Water-based adhesives.	08	L1, L2, L3
Module 3: ADDITIVES FOR ENGINEERING APPLICATIONS Introduction; Introduction, examples and importance of: plasticizers, impact modifiers, PVC stabilizers, antioxidants, UV absorbers, optical brightening agents, flame retardants, antistatic agents, smoke suppressants; Processing aids introduction to: viscosity depressants, mould release agents, slip agents, antiblocking agents; Colourants: Introduction, visual and processing requirements; Examples, advantages and limitations of inorganic, and organic pigments.	08	L1, L2
Module 4: PAINTS AND LUBRICANTS Paints: Introduction; Components: Vehicle (Binder, thinner), Pigment and filler, Additives; Introduction to colour-changing paint; Varieties of paints: primer and its needs, emulsion paints, varnish resins, properties of shellac, anti-graffiti coatings (sacrificial coating, non-bonding coating), anti-climb paint, anti-fouling paint, luminous paints; paint and environment. Lubricants: Introduction; Properties (Formulation, Additives); Types of lubricants (Base oil groups, Bio-lubricants, Synthetic oils, Solid lubricants, Aqueous lubrication); Applications by fluid types; Glaze (Compacted oxide layer glaze).	08	L1, L2, L3
Module 5: APPLICATIONS OF NANOTECHNOLOGY IN ADHESIVES, PAINTS, AND LUBRICANT INDUSTRIES Importance of nano solder particles; nano-conductive Adhesives for nano-electronics, Interconnection: Introduction; nano isotropic conductive adhesives (nano-ICAs): with Ag nanowires, effect of Ag nanoparticles, Ni nano particles, with CNTs; Introduction to inkjet printable nano-ICAs and inks; Introduction to CNT-Based conductive nanocomposites for transparent, conductive, and flexible electronics. Importance of	08	L1, L2, L3, L4

nanotechnology paints; nanomaterials in coatings and their functions (function, examples, and advantages); Potential environmental benefits of nanomaterials in coating; The nanolubricant approach: Examples and applications.		

Course Outcome:
On completion of this course, students will have comprehension:

- Materials for adhesive applications
- Paints and Lubricants
- Recent developments in nano technology assisted adhesive, paints, and lubricant industries

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1.Adhesive Technology Handbook, 2nd Edition, ISBN: 978-0-8155-1533-3, William Andrew Inc., 2008
2. Adhesion and Adhesives: Science and Technology, Anthony Kinloch, Springer; 1987

REFERENCE BOOKS:

1.A text book of engineering chemistry by Shashi Chawla, DhanpathRai and Co. (PVT) LTD, New Delhi, 2011
2. Electrical Conductive Adhesiveswithnanotechnologies, Yi Li, Daniel Lu, and C.P. Wong, e-ISBN 978-0-387-88783-8, DOI 10.1007/978-0-387-88783-8, Springer Science+Business Media, LLC 2010

Facilitation, Validation, QC, and QA
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VII

Subject Code	15NT744	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture	40	Exam	03

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B.E. Nano Technology

Hours		Hours	
CREDIT – 03			

Course Objective:
As a graduate of this program you will have learned how to do the following:

- To Perform a variety of Quality Control activities including developing QC policies and Standard Operation Procedures
- To Identify and analyze unexpected results during routine analyses and help to provide solutions based on scientific and regulatory considerations by implementing preventive action and corrective actions programs.
- To understand the concept of quality systems and compliance in the regulated industry and the role of quality assurance.
- To understand the use of controlled documentation.
- To know about ISO series of Standards

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: **INTRODUCTION** Validation, Quality control and Quality Assurance: Introduction, history, definition, Validation and Regulatory Affairs: The Fundamentals of Regulatory Compliance with respect to Good Clinical Practice (GCP), Good Manufacturing Practice (GMP) & Good Laboratory Practice (GLP). An Introduction to the Basic Concepts of Process Validation & how it Differs from Qualification (IQ, OQ & PQ) Procedures, A Review of Prospective, Concurrent, Retrospective Validation & Revalidation including the use of Statistical Process Control (SPC) Techniques	08	L1, L2
Module 2: **UTILITIES VALIDATION AND ANALYTICAL METHOD VALIDATION** Validation of water system- for production of DM water, distilled water, Validation of Air handling Units- classification of environment (class 100, 10,000, 1,00,000), Performance qualification & parameter of cleanliness such as number of airborne particles, microbes filter integrity test of HEPA filter, air velocity, air flow pattern, no. of air changes, pressure differentials etc. Analytical Method Validation: Recommendation of ICH guideline- Definition of accuracy, precision, linearity, Limit of Detection, Limit of Quantification, range, robustness, ruggedness, specificity, system suitability test. USP requirement of analytical validation- different category of assays.	08	L1, L2, L3
Module 3: **PLANNING AND VALIDATION** ISO 9000 Series & International Harmonization & their effect upon GMP's, Planning & Managing a Validation Program including Change Control, Scale-Up and Post-Approval Changes (SUPAC), Validation of Water & Thermal Systems, including HVAC Facilities & Cleaning	08	L1, L2, L3, L4

Validation. Validation of Active Pharmaceutical Ingredients (APIs) & Aseptic Processes. Validation of Non-Sterile Processes (used in the manufacture of Solids, Liquids, & Semisolid Dosage Forms). Overview of methods of evolution, FDA and ICH guidelines, Development and validation, sample preparation, separations, Minimum detectable amount		
Module 4: QUALITY STANDARDS ISO 9000 Series of Standards, Quality System, Contract Review, Design Control, Document and Data Control, Preservation and Delivery, Control of Quality Records, Internal Quality Audits, Training, Servicing, Statistical Techniques, ISO-9001-2000, Scope, Normative Reference, Terms and Definitions, Quality Management, System, Documents Requirements, Management's Responsibility, Resource Management, Infrastructure, Product Realization, Measurement, Analysis and Improvement, ISO-14000 - Environmental Management Systems.	08	L1, L2, L3, L4
Module 5: QUALITY CONTROL, QUALITY ASSURANCE AND MANAGEMENT Objectives of QC, Customer Satisfaction, Capability; Terms Relating to Management, Management System, Quality Management System, Quality Policy, Quality Planning, Quality Control, Quality Assurance, Quality Improvement, Continual Improvement, Effectiveness, Efficiency; Relating to Process and Product, Process, Product, Procedure; Terms relating to Characteristics, Quality Characteristics; Terms Relating to Conformity, Non-Conformity, Defect, Preventive Action, Corrective Action, Correction, Rework, Repair, Scrap, Concession, Deviation Permit, Release; Terms Relating to Documentation, Information, Document, Specification, Quality Manual, Quality Plan, Record; Terms Relating of Examination, Objective Evidence, Inspection, Test, Metrological Confirmation. The development of regulatory requirements for validation, Impact Assessment; Failure Mode and Effects Analysis (FMEA), Contamination Control	08	L1, L2, L3
Course Outcome: • Describe the validation, Quality control, Quality Assurance • Understand the importance of GAMP and ISO standards • Explain the implementation of control measures taken in process and product development • Identify the objectives of Quality control, Quality Assurance and management		
Graduate Attributes (as per NBA): • Engineering Knowledge. • Problem Analysis. • Design / development of solutions (partly). • Interpretation of data.		
Question paper pattern: • The question paper will have ten questions. • Each full Question consisting of 16 marks		

- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. Total Quality Management- Guiding Principle for Application, J. P. Peker, ASTM manual series, Philadelphia.
2. Total Quality Management – The Key to Business Improvement, Champman and Hall, Londan.
3. Quality Assurance Guide by Organisation of Pharmaceutical products of India.
4. ISO 9000 and Total Quality Management – Sadhank. G. Ghosh
5. ISO 9000 Quality Systems Handbook - updated for the ISO 9001:2008 standard, Sixth Edition: Using the standards as a framework for business improvement by David Hoyle, 2009.

REFERENCE BOOKS:

1. R. Nash and Wachter, "Pharmaceutical Process Validation". Volume 129, Latest Edition. Marcel Dekker Inc., New York.
2. Guidance for Industry, Sterile Drug Products Produced by Aseptic Processing — Current Good Manufacturing Practice-USFDA.
3. www.fda.org
4. US-FDA guideline for bio analytical studies. Dekker Inc., New York
5.Juran's Quality Handbook, 5th Ed, by J M Juran, A B Godfrey, McGrawHill International Edition
6. Total quality management: strategies and techniques proven at today's most successful companies (Portable Mba Series) by Stephen George and Arnold Weimerskirch, 1998.

Signal and Image Processing

[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VII

Subject Code	15NT751	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03

CREDIT – 03

Course Objective:

- To understand the basics of biomedical signal and image processing techniques and data acquisition methods
- Todesign and develop mathematical models for biomedical signal and image processing techniques
- Toevaluate and analyse biomedical imaging techniques in nanomedicine

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level

Module 1: INTRODUCTION TO DIGITAL SIGNAL AND IMAGE PROCESSING Signals and Biomedical Signal Processing, Fourier Transform, Filter Design, Image Filtering, Enhancement, and Restoration, Edge Detection and Segmentation of Images, Wavelet Transform	08	L1, L2
Module 2: PROCESSING OF BIOMEDICAL SIGNALS Electrical Activities of Cell, Introduction and Overview, Ion Transport in Biological Cells, Electrical Characteristics of Cell Membranes, Hodgkin-Huxley Model, Electrical Data Acquisition, Some Practical Considerations for Biomedical Electrodes, Electrocardiogram: Introduction and Overview, Electroencephalogram: Introduction and Overview, Electromyogram: Introduction and Overview, Other Biomedical Signals: Introduction and Overview	08	L1, L2, L3
Module 3: PROCESSING OF BIOMEDICAL IMAGES Principles of Computed Tomography:Introduction and Overview, X-Ray Imaging and Computed Tomography: Introduction and Overview, Magnetic Resonance Imaging: Introduction and Overview, Ultrasound Imaging: Introduction and Overview, Positron Emission Tomography: Introduction and Overview, Other Biomedical Imaging Techniques: Introduction and Overview	08	L1, L2, L3, L4
Module 4: NANOTECHNOLOGY IMAGING IN CARDIOLOGY nanotechnology and cardiovascular science, nanotechnology matrices employed for cardiovascular constructs, nanotechnology-based imaging in cardiology, nanotechnology materials for enhanced MRI and ultrasonography-based imaging, specific matrices for nanoparticles used in cardiovascular imaging, nanotechnology for scaffolding platforms and tissue reconstruction, materials and techniques used for nano-scaffold construction, future research directions and conclusion.	08	L1, L2, L3, L4
Module 5: NANOIMAGING FOR NANOMEDICINE Applications of Nanoparticles in Medical Imaging, Nanoparticles for Multi-Modality Diagnostic Imaging and Drug Delivery, Atomic Force Microscopy for Nanomedicine, Image-Based High-Content Analysis, Stem Cells and Nanomedicines: A Novel Strategy for Drug Discovery	08	L1, L2, L3
Course Outcome: After successfully completing this course, students will be able to: • Understand the fundamentalsofbiomedical signal and imaging techniques • Develop mathematical models image processing algorithms and evaluate their performances • Apply appropriate image processing techniques in cardiology and Nanomedicine		
Graduate Attributes (as per NBA): • Engineering Knowledge.		

- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. KayvanNajarian, Robert Splinter, Biomedical Signal and Image Processing, Second Edition, CRC Press, 2012
2. Information Resources Management Association, Medical Imaging: Concepts, Methodologies, Tools, and Applications, IGI Global, 2016 (Chapter 34) (https://www.safaribooksonline.com/library/view/medical-imaging-concepts/9781522505716/)
3. Raj Bawa, Gerald F. Audette, Israel Rubinstein, Handbook of Clinical Nanomedicine: Nanoparticles, Imaging, Therapy, and Clinical Applications, Pan Stanford, 2016

REFERENCE BOOKS:

1. John L. Semmlow, Benjamin Griffel, Biosignal and Medical Image Processing, Third Edition, CRC Press, 2014
2. Ayman El-Baz, Jasjit S. Suri, Lung Imaging and Computer Aided Diagnosis, CRC Press, 2011

Nanotechnology for Energy and Environment

[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VII

Subject Code	15NT752	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03

CREDIT – 03

Course Objective:

- To understand the scope of nanotechnology and its materials for the development of energy and environmental issues
- To study about nanomaterials and their devices for the improvement of already existing devices and machineries in energy and environmental issues
- To understand nano-remediation technologies, and sustainable nanotechnology.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level

Module 1: NANOTECHNOLOGY FOR SUSTAINABLE ENERGY Nanotechnology for sustainable energy- Energy conversion process, indirect and direct energy conversion-Materials for light emitting diodes-batteries-advanced turbines-catalytic reactors-capacitors-fuel cells. Material structure, Energy carriers, Energy states, Doping. Transport: heat, charge, mass, Thermo-electrics: applications, fundamentals, metrics, materials. Solar thermal: thermoelectric conversion. Photovoltaics: solar resource, p-n junctions, Solar photovoltaics.	08	L1, L2
Module 2: NANOMATERIALS FOR ALTERNATIVE ENERGY Nanomaterials for Fuel Cells and Hydrogen Generation and storage, Nano-structures for efficient solar hydrogen production, Metal Nanoclusters in Hydrogen Storage Applications, Metal Nanoparticles as Electro-catalysts in Fuel Cells, Nanowires as Hydrogen Sensors, Ceramic nanocomposites for alternate energy and environment protection, Applications for Cobalt Nanoparticles and Graphite Carbon-Shells, Nanomaterials for Solar Thermal Energy and Photovoltaic. Semiconductor Nanocrystals and Quantum Dots for Solar Energy Applications.	08	L1, L2, L3
Module 3: NANO-ELECTROMECHANICAL SYSTEMS AND NOVEL MICROFLUIDIC DEVICES Nano engines – driving mechanisms - power generation - microchannel battery - micro heat engine (MHE) fabrication - thermocapillary forces -Thermocapillary pumping (TCP) - piezoelectric membrane. Nanomaterials in Energy Storage Devices: MWNT for Li Ion Batteries, Nanomaterials in Electrodes, Hybrid Nanotubes: Anode Material, Supercapacitor, Battery Electrodes.	08	L1, L2, L3, L4
Module 4: NANO REMEDIATION TECHNOLOGIES Nanomaterials-Remediation: Nano Membranes, Nano Meshes, Nano Fibres, NanoClays and Adsorbents, Zeolites, Nano Catalysts, Carbon Nano Tubes, Bio Polymers,Single Enzyme Nano particles, Bio Metallic Iron Nano Particles, Nano Semi-Conductors,Photo catalysis, Nano-sensors. Nano Remediation Technologies: Environmental Nano Remediation Technology -Thermal, Physico-Chemical and Biological Methods, Nano Filtration for treatment ofwaste – removal of organics & inorganics and pathogens, Nanotechnology for water remediation and purification. Treatment of hi-tech industrial waste waters using nanoparticles/ modified structures/devices. Environmental Benefits of nanomaterials.	08	L1, L2, L3, L4
Module 5: SUSTAINABLE NANOTECHNOLOGY Application of industrial ecology to nanotechnology, Fate	08	L1, L2, L3

ofnanomaterials in environment, environmental life cycle of nano materials, environmentaland health impacts of nano materials, toxicological threats, eco-toxicology, exposure tonano particles – biological damage, threat posed by nano materials to humans, Environmental reconnaissance and surveillance. Corporate social responsibility fornanotechnology, Nano materials in future - implications.		

Course Outcome:
Students can

- understand the scope of nanotechnology and its materials for the development of energy and environmental issues
- study about nanomaterials and their devices for the improvement of already existing devices and machineries in energy and environmental issues
- Understand nano-remediation technologies, and sustainable nanotechnology.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, (1986).
2. Martin A Green, Solar cells: Operating principles, technology and system applications, Prentice Hall Inc, Englewood Cliffs, NJ, USA, (1981).
3. Hoogers, Fuel cell technology handbook. CRC Press, (2003).
4.Nanotechnlogy: Health and Environmental risk by Jo Anne Shatkin. CRC press,2008.

REFERENCE BOOKS:

1. Vielstich, Handbook of fuel cells: Fuel cell technology and applications, Wiley, CRC Press, (2003).
2. Junhui He, Nanomaterials in Energy and Environmental Applications, (2016), CRC Press
3. Nanotechnologies, Hazards and Resource efficiency by M. Steinfeldt, AvonGleich, U. Petschow, R. Haum. Springer, 2007.

3D Printing Technology
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VII

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM
CHOICE BASED CREDIT SYSTEM (CBCS)
B.E. Nano Technology

Subject Code	15NT753	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03

CREDIT – 03

Course Objective:
The students should be made to:
- Understand the basic concepts and nuances of 3D Printing Technology

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: INTRODUCTION Introduction; Design considerations – Material, Size, Resolution, Process; Modelling and viewing - 3D; Scanning; Model preparation – Digital; Slicing; Software; File formats	08	L1, L2
Module 2: PRINCIPLE Processes – Extrusion, Wire, Granular, Lamination, Photo-polymerisation; Materials - Paper, Plastics, Metals, Ceramics, Glass, Wood, Fibre, Sand, Biological Tissues, Hydrogels, Graphene; Material Selection - Processes, applications, limitations.	08	L1, L2, L3
Module 3: INKJET TECHNOLOGY Printer - Working Principle, Positioning System, Print-head, Print-bed, Frames, Motion control; Print-head Considerations – Continuous Inkjet, Thermal Inkjet, Piezoelectric Drop-On-Demand; Material Formulation for jetting; Liquid based fabrication – Continousjet, Mulitjet; Powder based fabrication – Colour-jet.	08	L1, L2, L3, L4
Module 4: LASER TECHNOLOGY Light Sources – Types, Characteristics; Optics – Deflection, Modulation; Material feeding and flow – Liquid, powder; Printing machines – Types, Working Principle, Build Platform, Print-bed Movement, Support structures.	08	L1, L2, L3, L4
Module 5: INDUSTRIAL APPLICATIONS Product Models, manufacturing – Printed electronics, Biopolymers, Packaging, Healthcare, Food, Medical, Biotechnology, Displays; Opensource; Future trends.	08	L1, L2, L3

Course Outcome:
Upon completion of the course, the student should be able to:
- Learn 3D printing workflow
- Understand the basic types of 3D Printing, materials used and their applications
- Select appropriate method for designing and modelling applications

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CHOICE BASED CREDIT SYSTEM (CBCS)
B.E. Nano Technology

Graduate Attributes (as per NBA):
- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:
- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. Ian M. Hutchings, Graham D. Martin, "Inkjet Technology for Digital Fabrication", John Wiley & Sons, 2013.
2. Christopher Barnatt, "3D Printing: The Next Industrial Revolution", CreateSpace Independent Publishing Platform, 2013.

REFERENCE BOOKS:

1. Ibrahim Zeid, "Mastering CAD CAM" Tata McGraw-Hill Publishing Co.2007
2. Joan Horvath, "Mastering 3D Printing", APress, 2014
3. Chua, C.K., Leong K.F. and Lim C.S., "Rapid prototyping: Principles and applications", second edition, World Scientific Publishers, 2010.

Nano Toxicology

[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VII

Subject Code	15NT754	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03

CREDIT – 03

Course Objective:
- To learn the basic importance and regulations of nanotoxicology in biological fields.
- To understand toxicity produced by nanostructures and methods to reduce their toxicity.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: INTRODUCTION Concept of Nanotoxicology - Inhalation of nanomaterials–	08	L1, L2

overview. Introduction Inhalation – deposition and pulmonary clearance of insoluble solids- bio– persistence of Inhaled solid material. Systemic translocation of inhaled particles.Nano particle exposure and systematic cardiovascular effects – experimental data–respiratory particulate matter exposure and cardiovascular toxicity, nanoparticles–hypothesis and research approaches - Ecotoxicologic studies – Methodology - for Nanotoxicology - toxicity testing.		
Module 2: NANOMATERIAL POLLUTION, PUBLIC PERCEPTIONS, AND EDUCATION Nanomaterials pollution: Nanomaterials in Environment - Toxicology of Airborne – Effect of Nanomaterials in the environment. Safety and pollution Control techniques-handling, storage, packaging, transportation and disposal. Public perceptions & education: Communicating Nanotechnological Risks - Understanding of Nanotechnology's Social Impacts - Nanotechnology in the Media. Educating Undergraduate Nanoengineers, Education Opportunities - Human Resources for Nanotechnology	08	L1, L2, L3
Module 3: HUMAN EXPOSURE TO NANOSIZED MATERIALS Biological Activities of Nanomaterials and Nanoparticles - Respiratory Tract – Efficient deposition of inhaled NSPs. - Disposition of NSPs in the respiratory - Disposition of NSPs in the respiratory -Epithelial translocation - Translocation to the circulatory system - Neuronal uptake and translocation - Translocation of NSPs in the blood circulation to bone marrow in mice - Studies of neuronal translocation of UFPs from respiratory tract -Exposure via GI Tract and Skin.	08	L1, L2, L3, L4
Module 4: ECONOMIC IMPACTS OF NANOTECHNOLOGY Socio-Economic Impact of Nanoscale Science - Managing the Nanotechnology Revolution: Consider the Malcolm - Transcending Moore's Law with Molecular Electronics and Nanotechnology - Semiconductor Scaling as a Model for Nanotechnology Commercialization - Nanotechnology and Zettabits - Sustaining the Impact of Nanotechnology - Non-Nano Effects of Nanotechnology on the Economy.	08	L1, L2, L3, L4
Module 5: ETHICS LAWS AND REGULATIONS Ethical Issues in Nanoscience and Nanotechnology - Ethics & Law in a New Frontier– An Exploration of Patent Matters Associated with Nanotechnology - The Ethics of Ethics- Negotiations over Quality of Life in the Nanotechnology Initiative. Patenting nanotechnology, nanomedicine and nanopharmaceuticals.	08	L1, L2, L3
Course Outcome: • To learn the basic concepts of nanobiotoxicology.		

- To understand nanomaterial pollution, public perceptions & education
- To study the human exposure to nanosized materials
- To do risk economic impacts of nanotechnology
- To study ethics laws and regulations of nanomaterials and their toxicity

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. Yuliang Zhao and Hari Singh Nalwa, 'Nanotoxicology: Interactions of Nanomaterials with Biological Systems, American Scientific Publishers, 2007
2. "Nanotoxicology - Interactions of Nanomaterials with Biological Systems", Ed Yuliang Zhao
and Hari Singh Nalwa, June 2006
3. Mihail C. Roco and William Sims Bainbridge, "Nanotechnology: Societal Implications II – Individual Perspectives", Springer Publishers, Sponsored by National Science Foundation, ISBN-10 1-4020-4658-8.
4. "Nanotechnology in health care" edited by P.D. gupta and N. Udupa.

REFERENCE BOOKS:

1. E P. Widmaier, H. Raff, K.T. Strang, Vander, Sherman and Luciano, 'Human Physiology: The Mechanisms of Body. Functions', 9th edition, McGraw Hill, New York, 2004
2. Gunter Oberdörster, Eva Oberdorster and Jan Oberdorster, Environmental Health Perspectives, Volume 113 Number 7, July 2005
3. D. Drobne, 'Nanotoxicology for safe and Sustainable Nanotechnology', Nanotoxicology for safe and sustainable Nanotechnology , 58, pp. 471-478, December 2007
4. Monteiro-Riv, 'Nanotoxicology: Characterization, Dosing and Health Effects', Informa Healthcare publishers, 2007
5. A Reference handbook of nanotoxicology by M. Zafar Nyamadzi

Nano - Composites, Device Fabrication, and Characterization Lab
[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VII

Laboratory Code	15NTL76	IA Marks	20
Number of Lecture	01Hr Tutorial + 02 Hrs	Exam	80

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B.E. Nano Technology

Hours/Week	Laboratory	Marks	
		Exam Hours	03
CREDIT - 02			

Course Objective:
- To study about the nanomaterials, and their composite preparation
- To learn about the device fabrication and designing by using nanomaterials and nanocomposites.
- To characterize the nanomaterials

List of Experiments	Revised Bloom's Taxonomy (RBT) Level
1. Dye Sensitised Solar cell fabrication	L5,L6
2. Gas sensor fabrication	L5,L6
3. Bio-chemical sensor fabrication	L5,L6
4. Fabrication of nanomaterial based super capacitor	L5,L6
5. Preparation of ceramic based nanocomposites	L5,L6
6. Preparation of metal-biopolymer nanocomposites	L2,L3,L4
7. Preparation of metal-polymer nanocomposites	L2,L3,L4
8. Calculate the wear rate from wear track depth 2D images.	L2,L3,L4
9. Calculation of the Area under the curve for a specified element/compound for a Raman data by filling the area under curve using origin Pro.	L2,L3,L4
10. Analyse of the amount of elastic and plastic deformation from a Nanohardness test (NHT) data using origin pro.	L5,L6
11. Analyse the average particle size and shape of the particles for a given image using image J software. (Average Diameter of Spherical shape particles, Average length and width of a rod/wire shaped).	L5,L6
12. Get the tafel plot for a given Electrochemical potential studies sample data and find out • β_a and β_c • E_{corr} and I_{corr} • Corrosion resistance (CR) in mmpy.	L2,L3,L4
13. Get the Raman plot from the given data and find out the FWHM and Sp^3/Sp^2 ratio for DLC (Diamond like carbon) coated sample.	L2,L3,L4
14. Get the COF vs Sliding Distance & wear loss vs sliding distance for a given two different samples data for wear studies and analyse, calculate the sliding distance manually.	L2,L3,L4
15. Get the XRD peaks from the given ASCII file and find the FWHM and calculate interplanar distance "d" using Bragg's equation.	L2,L3,L4

Course Outcome:
Students can
- Prepare nanomaterials, and their composites.
- Prepare nanotechnology based devices
- Characterize the nanomaterials

Graduate Attributes (as per NBA):
- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:
- The question paper will have ten questions.

• Each full Question consisting of 16 marks • There will be 2 full questions (with a maximum of four sub questions) from each module. • Each full question will have sub questions covering all the topics under a module. • The students will have to answer 5 full questions, selecting one full question from each module.
REFERENCE BOOKS: 1. Lab manual

MEMS Simulations Lab [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2015 -2016) Course: B.E. / Nano Technology Semester: VII			
Laboratory Code	15NTL77	IA Marks	20
Number of Lecture Hours/Week	01Hr Tutorial + 02 Hrs Laboratory	Exam Marks	80
		Exam Hours	03
CREDIT - 02			
Course Objective: • To understand the simulation programmes for the MEMS characteristics • To study about MEMS devices and calculations by using MEMSolver software			
List of Experiments			Revised Bloom's Taxonomy (RBT) Level
1. Calculation & Simulation of burst pressure, non-linearity & plot graph for sensitivity for Piezoresitive pressure sensor with a square diaphragm.			L2,L4,L5
2. Calculation & Simulation of burst pressure, non-linearity & plot graph for sensitivity for Piezoresitive pressure sensor with a round diaphragm.			L2,L3,L4
3. Calculation & Simulation ofburst pressure, non-linearity & plot graph for sensitivity for Piezoresitive pressure sensor with a rectangular diaphragm.			L2,L3,L4
4. Calculation & Simulation of maximum acceleration, maximum sensitivity, non-linearity & plot graph for acceleration V/S displacement of capacitive accelerometer for static signal.			L5,L6

5. Calculation & Simulation of maximum acceleration, maximum displacement & plot graph for acceleration V/S displacement of capacitive accelerometer for step signal.	L5,L6
6. Calculation & Simulation of time duration of pulse & plot graph for acceleration V/S time of capacitive accelerometer for pulse signal.	L2,L3,L4
7. Calculation & Simulation of output current, output voltage, piezoelectric capacitance & plot graph for output V/S frequency of piezoelectric accelerometer under longitudinal load.	L5,L6
8. Calculation & Simulation of output current, output voltage, piezoelectric capacitance & plot graph for output V/S frequency of thin film based piezoelectric accelerometer.	L2,L3,L4
9. Calculation & Simulation of pull in voltage, actuation force, balanced displacement & plot graph for force V/S displacement of parallel plate actuator for normal motion.	L2,L3,L4
10. Calculation & Simulation of pull in voltage, angular displacement, actuation torque & plot graph for voltage V/S tilt angle of torsion bar actuator for torsion motion.	L5,L6
11. Calculation & Simulation of balanced displacement, actuation force, normal spring constant & plot graph for voltage V/S displacement of comb drive actuator for lateral motion.	L5,L6
12. Calculation & Simulation of tip deflection, tip force & plot graph for deflection V/S film thickness of cantilever based bimetallic thermal actuator.	L2,L3,L4
13. Calculation & Simulation of deflection, tip force & plot graph for deflection V/S beam length of thermal bimorph actuator	L2,L3,L4
14. Calculation & Simulation of maximum deflection, response time, maximum temperature change & plot graph for transient response of thermal bent beam actuator.	L2,L3,L4
15. Calculation & Simulation of actuator displacement, actuator force, electric field strength & plot graph for actuator force of longitudinal piezoelectric actuator.	L2,L3,L4
16. Calculation & Simulation of actuator displacement, actuator force, electric field strength & plot graph for actuator displacement of transverse piezoelectric actuator.	

Course Outcome:
Students can

- understand the simulation programmes for the MEMS characteristics
- study about MEMS devices and calculations by using MEMSolver software

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:
1. Lab manual

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM
CHOICE BASED CREDIT SYSTEM (CBCS)
B.E. Nano Technology

Semester: VIII

Core Subjects

Nano-Electronics [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2015 -2016) Course: B.E. / Nano Technology Semester: VIII			
Subject Code	15NT81	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03
CREDIT – 04			
Course Objective: • To understand the basic concepts of nano-electronics • To learn the techniques which are used for develop devices which are developed by nanotechnology.			
Modules		Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: QUANTUM ELECTRONICS AND SINGLE ELECTRON TRANSISTOR		10	L1, L2

Introduction, Quantum Electronic Devices, Examples of quantum Electronics Device – Short Channel MOS transistor, Split Gate Transistor, Electronic spin Transistor, Quantum Cellular Automata and Quantum dot array. Single electron transistor: principles of SET, SET circuit design and Applications, molecular SETs, and molecular electronics		
Module 2: CNT AND NANOELECTRONIC DEVICES Carbon Nanotube: Introduction, properties, characterization and application of carbon nano tube. Introduction to Nano devices: Graphene transistors, Nanowire FET, quantum Dot devices,Quantum Dot FET, Organic transistors, CNTFET, FinFETs.	10	L1, L2, L3
Module 3: CARBON NANOTUBE FETS Introduction, Single Wall Nano Tube (SWNT), Double Wall Nano Tube (DWCNT), IV characteristics of P-CNTFET, N-CNTFET, small signal model for CNTFET, electrical equivalent of CNTFET, design of inverter using CNTFET, CNTFET based digital and analog circuits, memory cell using CNTFET.	10	L1, L2, L3, L4
Module 4: NANO ELECTRONICS WITH TUNNELING DEVICES Tunnelling Diode, Resonant Tunnelling Diode (RTD), Three Terminal Resonant Tunnelling devices, Technology of RTD, Digital Circuit Based On RTDs – Memory Application, Basic Logic Circuits, Dynamic Logic Circuits and Digital circuits Based on the RTBT.	10	L1, L2, L3, L4
Module 5: TUNNEL JUNCTIONS Tunnel junctions and applications of tunnelling, tunnelling through potential barrier, potential energy profiles, applications of tunnelling, field emission, gate oxide tunnelling, hot electron effects in MOSFETs, coulomb blockade, blockade in nano capacitor, tunnel junctions, blockade in quantum dot circuits	10	L1, L2, L3
Course Outcome: • Students will understand how to design the electronics circuits to work at nanoscale level • Students can learn how I-V characteristics and other electronic properties may change at nanoscale level.		
Graduate Attributes (as per NBA): • Engineering Knowledge. • Problem Analysis. • Design / development of solutions (partly). • Interpretation of data.		
Question paper pattern: • The question paper will have ten questions. • Each full Question consisting of 16 marks • There will be 2 full questions (with a maximum of four sub questions) from each module.		

- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. Niraj K. Jha. (2010) Deming Chen, Nanoelectronic Circuit Design, Springer.
2. Goser Karl and Peter Glosekotter. (2004) Nanoelectronics and Nanosystems: From Transistors to Molecular and Quantum Devices, Springer.
3. Lundstrom, Mark, Guo, Jing, Nanoscale Transistors:Device Physics, Modelling and Simulation, Springer, 2006.

REFERENCE BOOKS:

1. Gregory Timp. (2008) Nanotechnology, AIP Press.
2. Colm Durkan. (2007) Current at the Nanoscale, Imperial College Press.
3. S. Dutta. (2005) Quantum Transport: Atom to Transistor, Cambridge University Press

Bio-Nanotechnology

[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VIII

Subject Code	15NT82	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03

CREDIT – 04

Course Objective:

- To learn the basics of Nanobiotechnology, the devices of Nanobiotechnology and their applications to the different fields.
- To understand and fabricate the nanostructures and nanocontainers for several applications

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: **FUNCTIONAL PRINCIPLES OF BIO-NANOTECHNOLOGY** Basic terms; Features and functions of DNA, RNA, and Artificial nucleic acids; Bio-nanotechnology and nano-biotechnology; Information driven nano-assembly: genetic information transfer, construction of proteins, storage of information; Energetics:	10	L1, L2

approaches for powering chemical reactions, light dependent and independent reactions, electron carriers, storage of energy; Chemical transformations: reduction of entropy, chemical stabilization, specialized chemical tools; Biomaterials: introduction, biomineralization, biocompatibility and biopolymers, use of biomaterials; Self-replication; Machine-phase bio-nanotechnology.		
Module 2: STRUCTURAL PRINCIPLES OF BIO-NANOTECHNOLOGY Introduction; Natural bio-nanomachinery and specific environment; Strategies of construction of nanomachines: sequential covalent synthesis, covalent polymerization, self-organizing synthesis, and self-assembly; Biomolecular structure and stability: covalent bonds, dispersion and repulsion forces, hydrogen bonds, electrostatic interactions, and hydrophobic effects; Protein folding: Introduction, globular proteins, chaperons, stability, rigidity and disorder; Self-assembly: design principles, point group symmetries (cyclic, dihedral, and cubic), translational symmetry (line symmetry, plane symmetry, and space group symmetry), quasi-symmetry, crowded conditions; Self organization: introduction, self-organization of lipids; Molecular recognition: introduction, Crane principles. Flexibility and design of bio-nanomachines.	10	L1, L2, L3
Module 3: BIO-NANOMACHINES Introduction; Nanoscale effect on gravity, inertia, atomic granularity, thermal motion; Bionanomachies and water environment; Modern biomaterials and molecular plans: proteins (glycine and proline; carbon rich amino acids; phenylalanine, tyrosine, tryptophan; serine, threonine, histidine, aspargine, glutamine; cysteine, methionine), nucleic acids, polysaccharides, and lipids; Evolution of bio-nanomachines; Bio-nanomachines: Thymidylate synthase, DNA, Ribosome, ATP synthase, Actin and Myosin, Opsin, Triskelion molecules, and Collagen.	10	L1, L2, L3, L4
Module 4: BIOMEDICAL APPLICATIONS Medical diagnostics: targeted and sustained drug delivery; Transdermal drug release; Nanoscale device for drug delivery; Nano-medicine and nano-surgery: Respirocytes and Microbivores, Surgical nanorobotics, nanorobotics advantages and disadvantages; Nanobased therapy of cancer; nanopathology; nanosurgery; Applications of DNA based bionanotechnology; Biosensors: antibodies, detection of glucose level, detection of specific DNA sequences; Medical imaging techniques: MRI, Ultrasound imaging.	10	L1, L2, L3, L4
Module 5: BIO-NANOTECHNOLOGY: TODAY AND THE FUTURE Basic capabilities: simplification of natural proteins, design of proteins, construction of protein with non-natural amino acids, peptide nucleic acids; Nanomedicine: computer aided drug design, immunotoxins, Liposomes as vesicles, Artificial blood, Gene therapy,	10	L1, L2, L3

personalized medicine; Biomolecular sensing: smell and taste, light, motion, chemical gradients; A Timetable for bionanotechnology; Lessons for Molecular Nanotechnology; Case Studies: Nanotube synthesis, A general nanoscale assembler, Nanosurveillance		

Course Outcome:
Students can

- To learn the basics of Nanobiotechnology, the devices of Nanobiotechnology and their applications to the different fields.
- To understand and fabricate the nanostructures and nanocontainers for several applications

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. David S. Goodsell, Bionanoechnology-lessons from nature, Wiley India Pvt. Ltd., 2013, ISBN: 978-81-265-3836-2
2. Niemeyer and Mirkin ed. Nanobiotechnology: concepts, applications & perspectives,
3. Jain, KK. Nanobiotechnology in molecular diagnostics: current techniques and Applications
4.

REFERENCE BOOKS:

1. Bionanotechnology - Global Prospects by David E. Reisner, Taylor & Francis Group, LLC, 2009
2. Bio-Applications of Nanoparticles BY Warren C.W. Chan, Springer Science, Business Media, 2007
3. Applications of nanoparticles in biology and medicine by Salata O.V., Journal of Nanobiotechnology, 2:3, 2004.

Professional Elective Subjects

Nano-Photonics

[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VIII

Subject Code	15NT831	IA Marks	20
Number of Lecture Hours	03	Exam	80

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CHOICE BASED CREDIT SYSTEM (CBCS)
B.E. Nano Technology

Per Week		Marks	
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT – 03			
Course Objective: • To understand the basic principles of Photonics and its importance • To study the nano-photonics its fabrication and applications			
Modules		Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: **INTRODUCTION TO OPTICS, PHOTONICS AND NANO-PHOTONICS** Different quantities associated with light; Properties of Light; Reflection; Refraction; Interference & Diffraction; Absorption &Scattering, Properties of materials with respect to reflection, refraction, absorption and transmission of light. Photonics: Introduction, history; Classical optics, and modern optics; Applications of photonics; Emerging fields of photonics: light sources, transmission media, amplifiers, modulation, photonic systems, Photonic integrated circuits; Organic photonics; Optoelectronics: Introduction, classification with examples. Nanophotonics: Introduction, Principles: Plasmons and metal optics, Near-field optics, and Metamaterials.		08	L1, L2
Module 2: **FOUNDATIONS OF NANO-PHOTONICS** Photons and electrons: similarities and differences, Free space propagation. Confinement of photons and electrons. Propagation through a classically forbidden zone: tunnelling. Localization under a periodic potential: Band gap. Cooperative effects for photons and electrons, Nanoscale optical interactions, axial and lateral nanoscopic localization.Nanoscale confinement of electronic interactions: Quantun confinement effects, nanoscale interaction dynamics, nanoscale electronic energy transfer. Cooperative emissions.		08	L1, L2, L3
Module 3: **FABRICATION AND APPLICATIONS OF PHOTONIC CRYSTALS AND DEVICES** Thermal, mechanical and chemical properties of optical materials; Optical coatings and methods; Optical Filters; Surface quality of optical components.Choices of materials in photonic crystals: semiconductors, amorphous, and polymers, fabrication of photonic crystals structures (1-D, 2-D); Couplers; Waveguides; Photonic crystals fibres; Tunable Photonic crystal filter; High-Q cavites.		08	L1, L2, L3, L4
Module 4: **FUNDAMENTALS OF NANO-PHOTONIC FABRICATION** Adiabatic nanofabrication – Non-adiabaticnano-fabrication: near		08	L1, L2, L3, L4

field optical CVD and near field photolithography – Self assembling method via optical near field interactions – Regulating the size and position of nanoparticles using size dependent resonance – Size controlled, position controlled and separation controlled alignment of nanoparticles.		
Module 5: FUNDAMENTALS OF NANO-PHOTONIC SYSTEMS Introduction – Optical excitation transfer and system fundamentals – Parallel architecture using optical excitation transfer: memory based architecture, Global Summation Using Near-Field Interactions; Interconnections for nano-photonics – Signal transfer and environment – tamper resistance – Hierarchy in nano-photonics and its system fundamentals, Hierarchical Memory Retrieval, Analysis and Synthesis of Hierarchy in Nano-photonics, Hierarchy Plus Localized Energy Dissipation: Traceable Memory.	08	L1, L2, L3

Course Outcome:
Students can

- understand the basic principles of Photonics and its importance
- Study the nano-photonics its fabrication and applications

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. Principals of Nanophotonics (Optics and Optoelectronics),M.Ohtsu,K.Kobayashi,T.Kawazoe and T.Yatsui, University of Tokyo,Japan,2003
2. Nanophotonics, P N Prasad, John Wiley & Sons (2004)
3. Photonic Crystals: Towards Nanoscale Photonic Devices; Jean Michel Lourtioz, Springer; ISBN 354024431X3.

REFERENCE BOOKS:

1. NanoBiophotoics, H.Masuhara,SKawata and F TokungaElsevier Science 2007
2. Fundamentals of Photonics, BEA Saleh and AC Teich, John Wiley and Sons,NewYork,1993
3. Introduction to Biophotonics, P.N.Prasad, John Wiley and Sons,2003.
4. Fundamentals of Photonic Crystal Fibres; Fredric Zolla- Imperial College Press. ISBN 1860945074.

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CHOICE BASED CREDIT SYSTEM (CBCS)
B.E. Nano Technology

Nanomedicine and Biomedical Imaging [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2015 -2016) Course: B.E. / Nano Technology Semester: VIII			
Subject Code	15NT832	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT – 03			

Course Objective:

- To learn the new opportunities of nanotechnology in biomedical industries, for bio-imaging with several Nanomaterials.
- To understand and design the nanostructures nanospheres and nanoparticles for biomedical industries, pharmaceutical and cosmetic industries.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: **TECHNIQUES IN BIOMEDICAL IMAGING AND NANOSTRUCTURING** Immuno Fluorescent Biomarker Imaging- Immuno gold labelling- NanoprobesBioPhotonics- Diagnostic Biosensors- Catalyst- Functionalized Metallic Nanoparticles and their Applications in Colorimetric Sensing- Dip stick Tests- Nanoparticles as Catalysts for Signal Generation and Amplification- Iron Oxide Nanoparticles in Magnetic Resonance Imaging- Optical nanoparticles sensors for quantitative intracellular imaging. Cancer imaging- Nanophotonics. Design aspects of Nanostructures-Lithographic techniques- Nanoimprinting- Near Field Optical Methods of fabrication- Nano-polishing with diamond and Etching of nanostructures- Nanoindendation-Focused Ion beam.	08	L1, L2
Module 2: **NANOPARTICLES IN THERAPEUTICS** Nanorobotics, gold and silver nanoparticles for cancer therapy, chemotherapy, Immunotherapy, Vaccine immunotherapy, Radiotherapy, thermotherapy, photo dynamic therapy, textiles and wound care products, Implantable materials for vascular interventions, active implantable devices and bionics, Implantable materials for orthopaedic and dentistry. **NANOSURGERY**	08	L1, L2, L3

Introduction to Surgery, Impact of nanotechnology on surgery: Surgical blades and suture needles. Femto-second lasers, Nanoshell particles, minimally invasive surgery using catheters, optical tweezers, Bio-molecular motors, Biocompatibilities, molecular robots (utility fog).		
Module 3: NANOBIOMECHANICS Nano-materials in bone substitutes & Dentistry, Biosensors-Natural nanocomposite systems as spider silk, bones, shells; organic-inorganic nanocomposite formation through self-assembly. Polymeric nanofibres – Implications in Neuro science, tissue engineering and cancer therapy. Polyelectrolyte multilayers-coated colloids- smart capsules. Colloids and colloids assembly of bio nanotechnology. Micro emulsions in nanotechnology.	08	L1, L2, L3, L4
Module 4: NANOPARTICLES IN DIAGNOSIS Nanochips (Gene chip and protein chip), ultrasensitive biobarcode, Nanochip for HIV detection. Transport and toxicity properties of semiconductor nano crystals, Imaging applications. Nano Bioactive glasses-preparation methods, nanobioactive glass powders and properties, biomed applications.Gene therapy and Nanotechnology:Gene therapy using nanoparticles; stem cell therapy. Nanostructured materials for biological sensing. Nanoporous membranes.	08	L1, L2, L3, L4
Module 5: NANOPARTICLES IN DRUG DELIVERY DEVICES Sustained and targeted drug delivery, delivery mechanism – Introduction, antibody conjugated nanoparticles and their interactions with biological surfaces,Biomedical nanoparticles – Liposomes, dendrimers, different types of drug loading, Nanoscale drug delivery devices, Nano vectors for gene therapy, mechanism of drug targeting, drug delivery carriers, Biodegradable polymers, Nanoparticulate delivery systems, solid polymer nanoparticles, nano-particle mediated drug delivery to solid tumors, colloidal nanosilver particles as an effective nano antibiotic.	08	L1, L2, L3
Course Outcome: Students can • learn the new opportunities of nanotechnology in biomedical industries, for bio-imaging with several Nanomaterials. • understand and design the nanostructures nanospheres and nanoparticles for biomedical industries, pharmaceutical and cosmetic industries.		
Graduate Attributes (as per NBA): • Engineering Knowledge. • Problem Analysis. • Design / development of solutions (partly). • Interpretation of data.		
Question paper pattern: • The question paper will have ten questions.		

- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. M. Reza Mozafari (2007) Nanomaterials and Nanosystems for Biomedical Applications, Springer.
2. VinodLabhasetwar and Diandra L. Leslie, "Biomedical Applications of nanotechnology", A John Willy& son Inc,NJ, USA, 2007 .
3. J. B Park, "Biomaterials Science and Engineering", Plenum Press, New York, 1984.
4. T. Pradeep, "Nano: The essentials", McGrew – Hill, 2007
5. J.J. Davis, Dekker, "Encyclopedia of Nanoscience and nanotechnology"

REFERENCE BOOKS:

1. Natalie P. Praetories and Tarun K. Mandal, Recent Patents on Drug Delivery& Formulation Y. Lu, S.C. Chen, Advanced Drug Delivery Reviews.
2. P.P. Simeonova, N. Opopol and M.I. Luster, "Nanotechnology - Toxicological Issues and EnvironmentalSafety", Springer 2006.
3. G.L Hornyak, J Dutta, H.Tibbals and A.K.Rao, Introduction to NanoScience, Taylor & Francis Group, CRC press, 2008.
4. Miyawaki, J.; et.al Toxicity of Single-Walled Carbon Nanohorns. ACS Nano 2 (213–226) 200
5. Hutchison, J. E. Green Nanoscience: A Proactive Approach to Advancing Applications and Reducing Implications of Nanotechnology. ACS Nano 2, (395–402) 2008.
6. Mo-Tao Zhu et.al Comparative study of pulmonary responses to nano- and submicron-size ferricoxide in rats Toxicology, 21 (102-111) 2008.
7. Dracy J. Gentleman, Nano and Environment: Boon or Bane? Environmental Science and technology, 43 (5), P1239, 2009.

Mechanical Operations

[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VIII

Subject Code	15NT833	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03

CREDIT – 03

Course Objective:

- Students can learn different techniques and methods to reduce the size, to analyse the size of the particles.
- Students can understand the different methods used in the filtration, agitation,

mixing and sampling of the minute or micron particles.		
Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: PARTICLE TECHNOLOGY, EQUIPMENTS AND ANALYSIS Particle shape, particle size, different ways of expression of particle size, standard screen, screens – ideal and actual screens, differential and cumulative size analysis, specific surface of mixture of particles, Number of particles in a mixture, effectiveness of screen. Industrial screening equipment, Motion of screen, Gyratory screen, Vibrating screen, Trommels, Sub sieve analysis – Air permeability method, Sedimentation and elutriation methods.	08	L1, L2
Module 2: SIZE REDUCTION Types of forces used for comminution, Criteria for comminution, characteristics of comminuted products, Laws of size reduction, Work Index, Energy utilization, Methods of operating crushers – Free crushing, Choke feeding, Open circuit grinding, Closed circuit grinding, Wet and dry grinding, Equipment for size reduction – Blake jaw crusher, Gyratory crusher, Smooth roll crusher, Toothed roll crusher, Impactor, Ball mill, Ultrafine grinders, Cutters – Knife cutter.	08	L1, L2, L3
Module 3: FILTRATION Introduction, Classification of filtration, Cake filtration, Clarification, Batch and continuous filtration, pressure and vacuum filtration, Constant rate filtration, characteristics of filter media, industrial filters, sand filter, Filter press, leaf filter, Rotary drum filter, Horizontal belt filter, Bag filter, Centrifugal filtration – Suspended batch centrifuge, Filter aids, Application of filter aids.	08	L1, L2, L3, L4
Module 4: AGITATION AND MIXING Application of agitation, Agitation equipment, Types of impellers – Propellers, Paddles and Turbines, Flow patterns in agitated vessels, Prevention of swirling, Standard turbine design, Power correlation and power calculation, Mixing of solids, Types of mixers – Change can mixers, Muller mixers, Mixing index, Ribbon blender, Internal screw mixer, Tumbling mixer.	08	L1, L2, L3, L4
Module 5: SAMPLING, STORING AND CONVEYING OF SOLIDS Sampling of solids, storage of solids, Open and closed storage, Bulk and bin storage, Conveyors – Belt conveyor, Chain conveyor, Apron conveyor, Bucket conveyor, Bucket elevator, Screw conveyor, Slurry transport, Applications of fluidization, Pneumatic conveying.	08	L1, L2, L3
Course Outcome: Students can understand:		

- The particle size analysis by different models and methods
- Different size reduction methods and techniques.
- The filtration, agitation and mixing aspects and applications.
- The sampling, storing of solid samples.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. Unit Operations of Chemical Engineering, McCabe W.L., et.al., V Edn., McGraw Hill International, New york, 2000.
2. Introduction to Chemical Engineering, Badger, W.L. and Banchero J.T., 3rd Edition, McGrawHill International Edition, Singapore, 1999.
3. Coulson and Richardson's Chemical Engineering Vol. 2 Particle Technology and Separation Processes, Coulson J.M. and Richardson J.F., 4th Edition, Asian Books Pvt. Ltd, New Delhi, 1998.

REFERENCE BOOKS:

1. Unit Operations, Brown. G.G., 1st Edition, CBS Publishers, New Delhi, 1995.
2. Perry's Chemical Engineers' Handbook, Perry R and Green W.D., 1st Edition, McGraw Hill, International, New York, 2000.
3. Principles of Unit Operations, Foust A. S. et.al., 3rd Edition, John Wiley and Sons, New York,1977.

Green Nanotechnology

[As per Choice Based Credit System (CBCS) scheme]
(Effective from the academic year 2015 -2016)
Course: B.E. / Nano Technology
Semester: VIII

Subject Code	15NT834	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03

CREDIT – 03

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CHOICE BASED CREDIT SYSTEM (CBCS)
B.E. Nano Technology

Course Objective:

- To understand the eco-friendly nature of nanotechnology and the Nanomaterials
- To study nanotechnology and nanodevices which are environmental friendly

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: GREEN MANUFACTURING TRENDS Green Manufacturing - Fundamentals and Applications - basic definitions and issues surrounding green manufacturing at the process, machine and system - government motivations for green manufacturing - traditional manufacturing to green manufacturing - economic issues surrounding green manufacturing – the areas of automotive - semiconductor and medical areas and also supply chain and packaging areas.	08	L1, L2
Module 2: SUSTAINABLE GREEN MANUFACTURING Green manufacturing sustainability - processes - requirements, and risk – The sustainable lean and green audit process - International green manufacturing standards and compliance - Green rapid prototyping and rapid manufacturing - Green flexible automation - Green collaboration processes - Alternative energy resources - Sustainable green manufacturing system design.	08	L1, L2, L3
Module 3: WASTE MANAGEMENT Sustainability and global conditions - Material and solid waste management - Energy management -chemical waste management and green chemistry – Climate change and air emissions management - Supply water and waste water management - Environmental business management.	08	L1, L2, L3, L4
Module 4: INDUSTRIAL ECOLOGY Introduction - Material flows in chemical manufacturing - Industrial parks - Assessing opportunities for waste exchanges and by product synergies – Life cycle concepts - Product stewardship and green engineering - Regulatory, social and business environment for green manufacturing - Metrics and analytical tools - Green supply chains - Present state of green manufacturing.	08	L1, L2, L3, L4
Module 5: GREEN PLASTICS MANUFACTURING Introduction to commercial plastics and elastomers - Natural Rubber (NR), modified NR and blends - Polyesters from microbial and plant biofactories (polylactic acid and poly hyroxyalkanoates) -Plastics from vegetable oils – Cellulose and starch based materials - Natural fillers, fibres, reinforcements and clay nanocomposites - Biodegradability, life cycle assessment and economics of using	08	L1, L2, L3

natural materials.		

Course Outcome:
Students can

- understand the eco-friendly nature of nanotechnology and the Nanomaterials
- study nanotechnology and nanodevices which are environmental friendly

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

- The question paper will have ten questions.
- Each full Question consisting of 16 marks
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

TEXT BOOKS:

1. David Allen T. and David R. Shonnard, “Green engineering”, Prentice Hall NJ, 2002.
2. David Dornfeld,” Green manufacturing fundamental and applications” Prentice hall, 2002.

REFERENCE BOOKS:

1. Sammy Shinga G., “Green electronics design and manufacturing”, Prince Publications,2008.
2. James Clark, “Green chemistry”, Blackwell publishing, 2008.
3. Paulo Davim,” Sustainable manufacturing”, Wiley publications 2010.
4. Frank Kreith, George Tchobanoglous, “Solid waste management”, McGraw Hill, 2002.
5. Stevens S., “Green plastics”, Princeton University press, 2002.
6. Robert Ayres U., “A Handbook of Industrial Ecology”, Edward Elgar publishing, 2002.