JNTUA College of Engineering (Autonomous), Ananthapuramu
Department of Chemical Engineering
M. Tech NANOTECHNOLOGY (2015-16 Admitted Batch)
Course Structure & Syllabus

SEMESTER-I

Course	Name of the course	Periods per week			Credits
		Lec	Lab	Total	
Theory	Bottom Up Synthesis of Nanostructures	4	-	4	4
Theory	Physics and Chemistry of Materials	4	-	4	4
Theory	Synthesis and Applications of Nanomaterials	4	-	4	4
Theory	Nanobiotechnology, materials and devices	4	-	4	4
Theory	Mathematical Modeling and Simulation	4	-	4	4
Theory	Elective - I	4	-	4	4
Lab	Lab-I: Syntheses and Processing Lab	-	4	4	2
	Total	**24**	**4**	**28**	**26**

Elective – I
1. Nanotechnology for energy systems
2. Surface sciences and advanced catalysis
3. Quantum Mechanics

SEMESTER-II

Course	Name of the course	Periods per week			Credits
		Lec	Lab	Total	
Theory	Nanosensors, Detectors and Their Applications	4	-	4	4
Theory	MEMS and NEMS	4	-	4	4
Theory	Physicochemical methods for characterization of Nanomaterials	4	-	4	4
Theory	Imaging techniques for Nanotechnology	4	-	4	4
Theory	Lithography and Nanofabrication	4	-	4	4
Theory	Elective-II	4	-	4	4
Audit	Research Methodology	4	-	4	0
Lab	Lab-II: Nanometrology and Microscopy		4	4	2
	Total	**28**	**4**	**40**	**26**

Elective – II
1. Nanocomposites-Design and Synthesis
2. Advanced Drug Delivery Systems
3. Carbon nanotubes and applications

SEMESTER-III & IV

Course	Name of the course	Periods per week			Credits
		Lec	Lab	Total	
	III Semester Seminar-I (15D61301)	-	-	-	2
	IV Semester Seminar-II (15D61401)	-	-	-	2
	III & IV Semester Project Work (15D61302)	-	-	-	44
	Total	**-**	**-**	**-**	**48**

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BOTTOM UP SYNTHESIS OF NANOSTRUCTURES (15D61101)

UNIT-1: THIN FILM TECHNOLOGIES – I:

CVD Chemical vapor deposition –Atmospheric pressure CVD(APCVD) – Low pressure CVD (LPCVD) - Plasma enhanced chemical vapor deposition (PECVD) or - The HiPCO method - Photo-enhanced chemical vapor deposition (PHCVD)- LCVD Laser–Induced CVD.

UNIT-2: THIN FILM TECHNOLOGIES – II:

Physical vapor deposition- Sputter technologies- Diode sputtering - Magnetron sputtering. Ion beam (sputter) deposition, ion implantation and ion assisted deposition - Cathodic arc deposition- pulsed laser deposition.

UNIT-3: EPITAXIAL FILM DEPOSITION METHODS:

Epitaxy, Different kinds of epitaxy- Influence of substrate and substrate orientation, mismatch, MOCVD Metal Organic Chemical Vapor Deposition. CCVD Combustion Chemical Vapor Deposition - ALD Atomic Layer Deposition -LPE Liquid phase epitaxy -MBE Molecular Beam Epitaxy.

UNIT-4: CHEMICAL METHODS:

Sol-gel synthesis-different types of coatings –spin coating –self assembly-(periodic) starting points for self assembly –Directed self –assembly using conventional lithography –template self-assembly –Vapor liquid solid growth- Langmuir –Blodgett films –DNA self assembly.

UNIT-5: PRINTING TECHNOLOGIES:

Screen printing- Inkjet printing- Gravure printing and Flexographic printing- Flex graphic printing- Gravure printing- Roll-to-Roll techniques.

Text Books & References:

1. G. Cao, “Nanostructures & Nanomaterials: Synthesis, Properties &Applications” Imperial College Press, 2004.
2. W.T.S. Huck, “Nanoscale Assembly: Chemical Techniques (Nanostructure Science and Technology)”,
3. “Handbook of Nanoscience, Engineering and Technology”, Kluwer publishers, 2002.

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PHYSICS AND CHEMISTRY OF MATERIALS (15D61102)

UNIT-1: INTRODUCTION TO NANOMATERIALS:

Bulk materials vs. nanomaterials, classification, unique properties of nanomaterials, applications, microstructure and defects in nanocrystalline materials: dislocations, twins, stacking faults and voids, grain boundaries, triple and disclinations.

UNIT-2: EFFECT OF NANO-DIMENSIONS ON MATERIALS BEHAVIOR:

Elastic properties, melting point, diffusivity, grain growth characteristics, enhanced solid solubility, magnetic properties: soft magnetic nanocrystalline alloy, permanent magnetic nanocrystalline materials, giant magnetic resonance, electrical properties, optical properties, thermal properties and mechanical Properties.

UNIT-3: PHYSICAL PROPERTIES:

Melting point and phase transition processes- quantum-size-effect (QSE). Size-induced metal-insulator-transition (SIMIT)- nano-scale magnets, transparent magnetic materials, and ultrahigh-density magnetic recording materials-chemical physics of atomic and molecular clusters.

UNIT-4: PHYSICAL CHEMISTRY OF SOLID SURFACES:

Surface energy – chemical potential as a function of surface curvature-Electrostatic stabilization-surface charge density-electric potential at the proximity of solid surface-Van der Waals attraction potential.

UNIT-5: CHEMISTRY ASPECTS:

Photochemistry; Photoconductivity; Electrochemistry of Nanomaterials-Diffusion in Nanomaterials; Nanoscale Heat Transfer; Catalysis by Gold Nanoparticles; Transport in Semiconductor Nanostructures; Transition Metal Atoms on Nanocarbon Surfaces; Nanodeposition of Soft Materials; Nanocatalysis.

References:

1. Text book of Nanoscience and Nanotechnology by B. S. Murthy, P. Shankar, Baldev Raj, B B Rath, James Murday, Springer series, Universities Press,
2. K.W. Kolasinski, “Surface Science: Foundations of Catalysis and Nanoscience”, Wiley, 2002.
3. Joel I. Gersten, “The Physics and Chemistry of Materials”, Wiley, 2001.
4. A. S. Edelstein and R. C. Cammarata, “Nanomaterials: Synthesis, Properties and Applications”, Institute of Physics Pub., 1998.
5. S.Yang and P.Shen: “Physics and Chemistry of Nanostructured Materials”, Taylor & Francis, 2000.
6. G.A. Ozin and A.C. Arsenault, “Nanochemistry : A chemical approach to nanomaterials”, Royal Society of Chemistry, 2005.

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SYNTHESIS AND APPLICATIONS OF NANOMATERIALS (15D61103)

UNIT-1: BULK SYNTHESIS

Synthesis of bulk nano-structured materials –sol gel processing –Mechanical alloying and mechanical milling- Inert gas condensation technique – Nanopolymers – Bulk and nano composite materials.

UNIT-2: CHEMICAL APPROACHES

Self-assembly, self-assembled monolayers (SAMs). Langmuir-Blodgett (LB) films, clusters, colloids, zeolites, organic block copolymers, emulsion polymerization, templated synthesis, and confined nucleation and/or growth. Biomimetic Approaches: polymer matrix isolation, and surface-templated nucleation and/or crystallization. Electrochemical Approaches: anodic oxidation of alumina films, porous silicon, and pulsed electrochemical deposition.

UNIT-3: PHYSICAL APPROACHES

Vapor deposition and different types of epitaxial growth techniques- pulsed laser deposition, Magnetron sputtering - Micro lithography (photolithography, soft lithography, micromachining, e-beam writing, and scanning probe patterning).

UNIT-4: NANOPOROUS MATERIALS:

Nanoporous Materials – Silicon - Zeolites, mesoporous materials - nanomembranes and carbon nanotubes - AgX photography, smart sunglasses, and transparent conducting oxides –molecular sieves – nanosponges.

UNIT-5: APPLICATION OF NANOMATERIALS

Molecular Electronics and Nanoelectronics – Nanobots- Biological Applications – Quantum Devices – Nanomechanics - Carbon Nanotube – Photonics- Nano structures as single electron transistor –principle and design.

References:

1. S.P. Gaponenko, Optical Properties of semiconductor nanocrystals, Cambridge University Press, 1980.
2. W.Gaddand, D.Brenner, S.Lysherski and G.J.Infrate(Eds.), Handbook of NanoScience, Engg. and Technology, CRC Press, 2002.
3. K. Barriham, D.D. Vvedensky, Low dimensional semiconductor structures: fundamental and device applications, Cambridge University Press, 2001.
4. G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties ications , Imperial College Press, 2004.
5. J.George, Preparation of Thin Films, Marcel Dekker, Inc., New York. 2005.

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NANO BIO-TECHNOLOGY-MATERIALS AND DEVICES (15D61104)

UNIT-1: FUNDAMENTALS TERMS IN BIOTECHNOLOGY

Biological building blocks: Sizes of building blocks Nanostructures, Polypeptide nanowire and protein nanoparticles.

UNIT-2: NUCLEIC ACIDS

– DNA Double Nano wire, Genetic code and protein synthesis.

UNIT-3: BIOLOGICAL NANOSTRUCTURES:

Bio-mimitics with examples, Bio compatible Bio sensors, Examples of proteins, vesicles, bilayers. Multilayer films, application of bio- nanotechnology: bio nano machines, molecular modeling.

UNIT-4: APPLICATIONS TO NEMS AND NANO DEVICES:

Nano bio-sensors and biomedical applications nano materials in drug del very, organic semiconductors, biological neurons and their functions**.** Bio-chemical and quantum mechanical computers: DNA computers, parallel processing, Bit and 'Q' bit, Quantum parallelism.

UNIT-5: NANOSCALE PROCESSES IN THE ENVIRONMENT

Nano technology for Immune system, clinical imaging, nano robots, Nano Fibres for Tissue Engineering.

Text books:

1. Bio Nano Technology by Good Sell, Wiley Liss
2. Introduction to Nanotechnology by Charles. P.Poole Jr and Frank J. Owens, Wiley India Pvt Ltd.
3.Nano Technology, A gentle introduction to the next big idea by Mark Ranter and Daniel Ranter, Pearson education
4 Nanotechnology – science, innovation and opportunity by Lynn E Foster, Prentice Hall – Pearson education.

Reference books:

1. Encyclopedia of Nanotechnology by H.S.Nalwa
2. Encyclopaedia of Nanotechnology by M.Balakrishna Rao

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MATHEMATICAL MODELING AND SIMULATION (15D61105)

UNIT-1:Fundamentals of modeling:
Principles & uses of modeling, classification of mathematical models-steady state Vs dynamic models, lumped Vs distributed parameter models, deterministic Vs stochastic models.
Examples of mathematical models-Two heated tanks, constant volume CSTRs, Gravity flow tank, Dynamics of first order & second order systems (Mercury in glass thermometer, Damped vibrator)
UNIT-2:Empirical model building- method of least squares, linear, polynomial and multiple regression, non-linear regression.**Solution of simultaneous algebraic equations***:* Direct methods: Gauss-elimination method, Gauss–Jordan method, Iterative methods: Jacobi's method, Gauss-Siedal method.
UNIT-3:Solution of ODEs:Euler method, Runge-Kutta method, Milne's Predictor-Corrector method **Solution of PDEs**: Elliptic equations-one dimensional, parabolic equation-hyperbolic equation- partial differential equations-separation of variables-wave equation.

UNIT-4:Finite Difference: Difference operator (?), operator E, Interpolation, Formulation of linear and non-linear finite difference equations**Advanced methods for Differential Equations**: method of lines, Orthogonal Collocation, Finite Volume Method.

UNIT-5:
Fourier series and Fourier integral: Periodic function, Trigonometric series, Fourier series, Functions of any period, Even andodd functions, Half-range Expansion, Forced oscillations, Fourier integral. **Laplace Transforms and Applications**: Laplace transform, Inverse Laplace transform, Linearity, Shiftingtheorem, Transforms of derivatives and integrals, Differential equations, Unit step function, Second shifting theorem, Dirac's delta function.

References:

1. S.C. Chapra and R.P.Canale, "Numerical methods for Engineers", Tata McGraw Hill, New Delhi, 2002.
2. Erwin Kreyzig, "Advanced Engineering Mathematics", John Wiley & Sons, 2004.
3. Jenson and Jeffery, Mathematical Methods in Chemical Engineering,
4. Mickley, Reid and Sherwood, Applied Mathematics in Chemical Engineering, Tata-McGraw-Hill, New Delhi
5. Zill, Dennis and Cullen, Michael Advanced Engineering 3rd Edition, 2006, Jones and Bartlett, Publisher

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NANOTECHNOLOGY FOR ENERGY SYSTEMS (15D61106)
(Elective-I)

UNIT-1: INTRODUCTION

Nanotechnology for sustainable energy-Materials for light emitting diodes-batteries-advanced turbines-catalytic reactors-capacitors-fuel cells.

UNIT-2: RENEWABLE ENERGY TECHNOLOGY:

Energy challenges, development and implementation of renewable energy technologies - nanotechnology enabled renewable energy technologies - Energy transport, conversion and storage, Nano, micro and meso scale phenomena and devices.

UNIT-3: MICRO FUEL CELL TECHNOLOGY:

Micro-fuel cell technologies, integration and performance for micro-fuel cell systems - thin film and microfabrication methods - design methodologies - micro-fuel cell power sources,

UNIT-4: MICROFLUIDIC SYSTEMS:

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.

UNIT-5: HYDROGEN STORAGE METHODS:

hydrogen storage methods - metal hydrides - size effects - hydrogen storage capacity - hydrogen reaction kinetics - carbon-free cycle- gravimetric and volumetric storage capacities - hydriding/dehydriding kinetics - high enthalpy of formation - and thermal management during the hydriding reaction - distinctive chemical and physical properties - multiple catalytic effects - degradation of the sorption properties - hydride storage materials for automotive applications.

References:

1. J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, 1986.
2. Hydrogen from Renewable Energy Sources by D. Infield,
3. Fuel Storage on Board Hydrogen Storage in Carbon Nanostructures by R.A. Shatwell,
4. Fuel cell technology handbook. Hoogers. CRC Press, 2003.

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SURFACE SCIENCES AND ADVANCED CATALYSIS (15D61107)

(Elective-I)

UNIT-1: Adsorption phenomenon: Chemisorption & Physisorption, orption isotherms and methods of determination of pore size and surface area of materials using the adsorption isotherms.Catalysis – Definition, types of catalysis with suitable examples, characteristics of a catalyst, selectivity or specificity of the catalyst, activation and deactivation of catalysts, catalytic poisoning

UNIT-2: Necessity for the alternate energy sources and the role of catalytic technology in the energy sector – Fuel cells, Solar cells, Biomass and Biofuels, New trends in heterogenous catalysis – catalytic sensors, membrane and monolithic reactors

UNIT-3: Catalysis in environmental protection & green process- Industrial catalytic wet air oxidation processes, water purification, synthesis of ity, commodity and fine chemicals, catalysis in automobiles : catalytic converter applications

UNIT-4: Important catalytic materials – Nanostructured metals like Pt, Pd and Fe. Nanostructured ceramics like silica, silicate and alumina, pillared clays, colloids and porous materials (viz. mesoporous materials)

UNIT-5: Mesoporous materials – Introduction, synthesis & characterization, properties and applications (with suitable examples), unipore size, b pore size, graphs., supramolecular chemistry, synthesis (micelar rods).

References

1. Basic principles in applied catalysis – Manfredlaerns
2. Nanotechnology in Catalysis – Pinzhan
3. Introduction to Nanotechnology – Charles P Poole Jr & Frank J Owens
4. Nanoscale Materials –LM Liz Marzan & Prashant V. Kamat
5. Nanostructured catalysts – SL Scott, CM Crudden & CW Jones
6. Concepts of Modern Catalysis & kinetics - I. Chorkendorff, J.W. Niemantsverdriet
7. Chemistry of Nanomaterials: Synthesis, properties & applications, Volume-I – CNR Rao, A Muller & AK Cheetham

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QUANTUM MECHANICS (15D61108)
(Elective-I)

UNIT-1: Introduction

Wave-particle duality, Schrödinger equation and expectation values, Uncertainty principle

UNIT-2: Basics of Quantum mechanics

Solutions of the one-dimensional Schrödinger equation for free particle, particle in a box, particle in a finite well, linear harmonic oscillator.

3.Reflection and transmission by a potential step and by a rectangular barrier.

UNIT-3: Solution of Time independent Schrödinger equation

Particle in a three dimensional box, linear harmonic oscillator and its solution, density of states, free electron theory of metals. The angular meomentum problem. The spin half problem and properties of Pauli spin matrices.

UNIT-4: Approximate methods

Time independent and time dependent perturbation theor for non-degenerate and degenerate energy levels. The variational method, WKB approximation, adiabatic approximation, sudden approximations.

UNIT-5: Quantum computation

Concept of quantum computation, Quntum Qbits etc.

Books and References:

1. Modern Physics - Beiser
2. Quantum Mechanics - Bransden and Joachen
3. Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles, 2nd Edition by Eisberg, Robert; Resnick, Robert
4. Quantum Physics – A. Ghatak
5. Principles of Quantum Mechanics 2nd ed. - R. Shankar
6. Quantum Mechanics - Vol 1&2 - Cohen-Tannoudji

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SYNTHESES AND PROCESSING LAB (15D61109)

- Nano – Catalyst Preparation by Chemical methods
- Two methods for the synthesis of CNT's (CVD method and Flame Synthesis)
- Synthesis of oxide Nanostructures / nanocomposites by Sol - Gel Process
- Synthesis of nanocomposites by Sol - Gel Process

Reference books

1. Advanced catalysis and Nano structured material by WR Moser.
2. Introduction to Nano Technology by Charles. P.Poole Jr and Frank J. Owens Wiley India Pvt Ltd.
3. Encyclopedia of Nanotechnology by H.S. Nalwa
4. Nano: The Essentials – Understanding Nano Scinece and Nanotechnology – by T.Pradeep; Tata Mc.Graw Hill

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NANOSENSORS, DETECTORS AND THEIR APPLICATIONS (15D61201)

Unit-I SENSOR CHARACTERISTICS AND PHYSICAL EFFECTS: Active and Passive sensors – Static and dynamic characteristics - Accuracy, offset and linearity - First and second order sensors – Physical effects involved in signal transduction- Photoelectric and Photo dielectric effect – Photoluminescence–Electroluminescence – chemiluminescence effect – Doppler effect – Barkhausen effect – Hal effect – Ettinshausen effect – Thermoelectric effect – Peizoresistive effect – Piezoelectric effect – Pyroelectric effect –Magneto-mechanical effect (magnetostriction) – Magneto resistive effect.

Unit-II NANO BASED INORGANIC SENSORS: Density of states (DOS) – DOS of 3D, 2D, 1D and 0D materials – one dimensional gas sensors:- gas sensing with nanostructured thin films – absorption on surfaces – metal oxide modifications by additives – surface modifications – nano optical sensors – nano mechanical sensors – plasmon resonance sensors with nano particles – AMR, Giant and colossal magneto resistors – magnetic tunneling junctions.

Unit-III THERMAL SENSORS: Thermal energy sensors -temperature sensors, heat sensors- Electromagnetic sensors- electrical resistance sensors, electrical current sensors, electrical voltage sensors, electrical power sensors, magnetism sensors - Mechanical sensors -pressure sensors, gas and liquid flow sensors, position sensors - Chemical sensors - Optical and radiation sensors.

Unit-IV ORGANIC / BIOSENSORS: Structure of Protein – role of protein in nanotechnology – using protein in nanodevices – antibodies in sensing – antibody in nano particle conjugates – enzymes in sensing – enzyme nanoparticle hybrid sensors – Motor proteins in sensing – transmembrane sensors. Nanosensors based on Nucleotides and DNA – Structure of DNA – DNA decoders and microarrays – DNA protein conjugate based sensors – Bioelectronic sensors – DNA sequencing with nanopores – sensors based on molecules with dendritic architectures – biomagnetic sensors.

Unit-V SENSOR DETECTORS AND APPLICATIONS: Cantilever array sensors - for diagnosis of diabetes mellitus and cancer diagnosis - Nanotube based sensors - for DNA detection and capnography - Nanowire based sensors - Nanowire based electrical detection of single viruses - Nanowire based electrical detection of biomolecules. Bio receptors –Bio detectors - Nano array based detector - Nano Particle based detector - Ultra-sensitive detection of pathogenic biomarkers - Ultra-sensitive detection of single bacteria.

Text Books & References:

1.Kourosh Kalantar – Zadeh, Benjamin Fry, “Nanotechnology- Enabled Sensors”, Springer , 2008

2.H.Rosemary Taylor, “Data acquisition for sensor systems”, Chapman & Hall, 97.

3.Jerome Schultz, Milan Mrksich, Sangeeta N. Bhatia, Dav J. Brady, Antonio J. Ricco, David R. Walt, Charles L. Wilkins, “Biosensing: International Research and Development”, Springer, 2006

4.Ramon Pallas-Areny, John G. Webster, “Sensors and signal conditioning” John Wiley & Sons, 2001.

5.Vijay.K.Varadan, Linfeng Chen, Sivathanupillai, “Nanotechnology Engineering in Nano and Biomedicine”, John Wiley & Sons, 2010.W. Ranier, “Nano Electronics and Information Technology”, Wiley, (2003).

5. K.E. Drexler, “Nano systems”, Wiley, (1992).

6. M.C. Pettey, “Introduction to Molecular Electronics”.

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MEMS AND NEMS (15D61202)

Unit-I Development of micro electronics - Region of Nanostructures - methods and limits on microminiaturization in semiconductors- micro electro mechanical systems.

Unit-II Silicon micromachining- semiconductors and insulators - Microsystems fabrication techniques - Silicon MEMS fabrication technology - Single crystal reactive etching and metallization process.

Unit-III Non-silicon MEMS and fabrication techniques - SIC MEMS - Biomedical-MEMS techniques - Integration of microsystems with electronics – RF MEMS – Applications.

Unit-IV Polymers in Microsystems - Packaging of MEMS devices by anodic/fusion bonding - Pressure sensors and packaging - MEMS performance and evaluation.

Unit-V Nano electro mechanical systems - fabrication and process techniques - lntegration of nanosystems and devices - applications and future challenges.

Text Books & References:

1.W.R.Fahrner, “Nanotechnology and Nanoelectronics: Materials, Devices, Measurement Techniques”, Springer, 2005.

2.K.Goser, P.Glosekotter & J.Dienstuhl, “Nanoelectronic Nanosystems – From Transistors to Molecular Quantum Devices” Springer, 2004.

3.S. E. Lyshevski, “MEMS and NEMS: Systems, Devices and Structures”, CRC Press, 2002.

4.Gregory Timp, “Nanotechnology”, Springer, 1999.

5.Vijay K Varadan, K J Vinoy, S Gopalakrishnan, “Smart Material Systems and MEMS: Design and Development”, John Wiley &Sons, 2006

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PHYSICOCHEMICAL METHODS FOR CHARACTERIZATION OF NANOMATERIALS (15D61203)

Unit-I:

X-RAY DIFFRACTION-I:

X-rays, electromagnetic radiation, characteristic spectrum, mosley law,scattering, Diffraction, condition for diffraction, X rays as source to see diffraction, Braggs Law, Diffraction directions, diffraction methods

Unit-II:

X-RAY DIFFRACTION-II:

single crystal diffraction techniques - Determination of accurate lattice parameters - structure analysis - -relaxation of Braggs law, powder diffractometer, determination of crystal structures,interpretation of diffraction pattern, particle size analysis using Scherer formula.

Unit-III:

THERMAL ANALYSIS METHODS:

Principle and Instrumentation of Thermogravimetry; Differential Thermal Analysis and Differential scanning calorimetry-Importance of thermal analysis for nanostructures.

Unit-IV:

QUALITATIVE AND QUANTITATIVE ANALYSIS:

Electron Energy Loss Spectroscopy; High Resolution Imaging Techniques- HREM, Atom probe field ion microscopy-X-Ray Photoelectron Spectroscopy, X-Ray Characterization of Nanomaterials – EDAX and WDA analysis – EPMA – ZAP corrections.

Unit-V:

SPECTROSCOPIC TECHNIQUES:

Introduction to Molecular Spectroscopy and Differences-With Atomic Spectroscopy-Infrared (IR) Spectroscopy and Applications- Microwave Spectroscopy- Raman Spectroscopy and CARS Applications-Electron Spin Resonance Spectroscopy; New Applications of NMR Spectroscopy.

References:

1. B. D.Cullity, “Elements of X-ray Diffraction”, 4th Edition, Addison Wiley, 1978.
2. M. H.Loretto, “Electron Beam Analysis of Materials”, Chapman and Hall, 1984.
3. R.M.Rose, L.A.Shepard and J.Wulff, “The Structure and Properties of Materials”, Wiley Eastern Ltd,
4. B.W.Mott, “Micro-Indentation Hardness Testing”, Butterworths, London, 1956.

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IMAGING TECHNIQUES FOR NANOTECHNOLOGY (15D61204)

Unit-I OPTICAL MICROSCOPY:

Optical microscopy- Use of polarized light microscopy – Phase contrast microcopy – Interference Microscopy – hot stage microscopy - surface morphology – Etch pit density and hardness measurements.

Unit-II SCANNING ELECTRON MICROSCOPY

Basic design of the scanning electron microscopy – Modes of operation– Backscattered electrons – secondary electrons- X-rays – typical forms of contrast– Resolution and contrast – enhancement – Specimen Preparation, Replicas Various-application of SEM.

Unit-III TRANSMISSION ELECTRON MICROSCOPY:

Basic principles - Modes of operation – Specimen preparation – Diffraction in imperfect crystals – Dislocations – precipitates – Structure of Grain boundaries and interfaces- HRTEM use in nanostructures.

Unit-IV ATOMIC FORCE MICROSCOPY:

Basic concepts-Interaction force-AFM and the optical lever- Scale drawing- AFM tip on nanometer scale structures- force curves, measurements and manipulations-feed back control-different modes of operation –contact, non contact and tapping mode-Imaging and manipulation of samples in air or liquid environments-Imaging soft samples. Scanning Force Microscopy-Shear force Microscopy-Lateral Force Microscopy-Magnetic Force microscopy.

Unit-V SCANNING TUNNELING MICROSCOPY:

Principle- Instrumentation- importance of STM for nanostructures – surface and molecular manipulation using STM -3D map of electronic structure.

References:

1. J.Goldstein, D. E. Newbury, D.C. Joy, and C.E. Lym, “Scanning Electron Microscopy and X-ray Microanalysis”, 2003.
2. S.L. Flegler, J.W. Heckman and K.L. Klomparens, “Scanning and Transmission Electron Microscopy: A Introduction”, WH Freeman & Co, 1993.
3. P.J.Goodhew, J.Humphreys, R.Beanland, “Electron Microscopy and Analysis”,
4. R.Haynes, D.P.Woodruff and T.A.Talchar, “Optical Microscopy of Materials”, Cambridge University press, 1986.

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LITHOGRAPHY AND NANOFABRICATION (15D61205)

Unit-I PATTERNING OF THIN FILMS:

Introduction - Necessity for a clean room- different types of clean rooms-construction and maintenance of a clean room- Lithography -Optical lithography- Optical projection lithography- Multistage scanners resolution- Photomask- Binary mask- Phase shift mask - Attenuated phase shift masks - alternating phase shift masks - Off axis illumination- Optical proximity correction - Sub resolution assist feature enhancement-Optical immersion lithography- Optical interferometric lithography- Holographic lithography.

Unit-II MASKLESS OPTICAL LITHOGRAPHY:

Maskless optical projection lithography - Zone plate array lithography-Extreme ultraviolet lithography.

Unit-III ELECTRON BEAM LITHOGRAPHY:

Scanning electron-beam lithography- maskless EBL- parallel direct-write e-beam systems- electron beam projection lithography - Scattering with angular limitation projection e-beam lithography- Projection reduction exposure with variable axis immersion lenses.

Unit-IV X-RAY LITHOGRAPHY:

Ion beam lithography- Focusing ion beam lithography - Ion projection lithography - Projection focused ion multi-beam - Masked ion beam lithography- Masked ion beam direct structuring- atom lithography.

Unit-V NANOIMPRINT LITHOGRAPHY AND SOFT LITHOGRAPHY:

Nanoimprint lithography (NIL)- NIL- hot embossing- UV-NIL- Soft Lithography- Moulding/Replica moulding: Printing with soft stamps- Edge lithography -Dip-Pen Lithography- set up and working principle. Etching techniques- Reactive Ion etching- RIE reactive ion etching- Magnetically enhanced RIE- IBE Ion beam etching- Other etching techniques.

References:

1. D. S. Dhaliwal et al., PREVAIL –"Electron projection technology approach for next generation lithography", IBM Journal Res. & Dev. 45, 615 (2001).
2. M. Baker et al., "Lithographic pattern formation via metastable state rare gas atomic beams", Nanotechnology 15, 1356 (2004).
3. H. Schift et al., "Fabrication of polymer photonic crystals using nanoimprint lithography", Nanotechnology 16, 261, (2005).
4. R.D. Piner, "Dip-Pen" Nanolithography, Science 283, 661 (1999).

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NANOCOMPOSITES - DESIGN AND SYNTHESIS (15D61206)
(ELECTIVE – II)

Unit-1: Introduction to Nanocomposites, Composite material, Mechanical properties of Nano composite material: stress - strain relationship, toughness, strength, plasticity. ic-Metal Nanocomposites, Ceramic based nanoporous composite, Metal matrix nanocomposites, Polymer-based nanocomposites

Unit-2: Carbon nanotube based nanocomposites and Natural nanobiocomposites, Biomimetic nanocomposites and Biologically inspired nanocomposites.

Unit-3: Synthesis methods for various nanocomposite materials: mechanical alloying, thermal spray synthesis etc. properties of nanocomposites.

Unit-4: Nano composites for hard coatings; DLC coatings; Thin lm nanocomposites; Modeling of nanocomposites. Nano Indentation, Types of indentation: Oliver & Pharr, Joslin-Oliver, Vickers Indentation process.

Unit-5: Processing of polymer nanocomposites, Salt infiltration, Powder mixing, Intrusion method, Exfoliation & interaction, Gel-casting impregnation techniques: Hot melt impregnation, solution impregnation.

Text Books & References:

1. Nanocomposite Science & Technology by P.M. Ajayan, L.S. Schadler and P.V. Braun, Wiley-VCH GmbH Co.
2. Introduction to Nano Technology by Charles. P.Poole Jr and Frank J. Owens; Wiley India Pvt Ltd.

3. Nanotechnology, A gentle introduction to the next big idea by Mark Ratner, Daniel Ratner Pearson education.

Reference books:

1. Encyclopedia of Nanotechnology by H.S.Nalwa
2. Encyclopaedia of Nano Technology by M.Balakrishna rao K.Krishna Reddy, Vol I to X Campus books.

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M.Tech. Nanotechnology II-Sem

L	T	P	C
4	0	0	4

ADVANCED DRUG DELIVERY SYSTEMS (15D61207)
(ELECTIVE-II)

Unit-1: Dendrimers- Synthesis -Nanoscale containers- Gene transfection. Nanoscafold systems-Biocompatibility of Dendromers

Unit-2: Microfabricated drug delivery systems – Microneedles- Micropumps-Microvalves-Implantable microchips – sustained chronic disease.

Unit-3: Properties of drug targeting delivery systems-ADME hypothesis-site specific drugs. Synthetic carrier for drugs-liposomes-Antidodies.

Unit-4: Targeted Nano particles for drug delivery-Polymers nanotubes-Issues for specific disease will be addressed.

Unit-5: Virus Based Nanoparticles - Modification by bioconjugation. Tumour targetting invivo – use in biomedical Imaging.

Text Books & References:

1. Drug Delivery: Engineering Principles for Drug Therapy, M. Salzman,

   Oxford University Press, 2001.

2. Drug Delivery and Targeting, A.M. Hillery, CRC Press, 2002.
3. Drug Delivery: Principles and Applications, B. Wang, Wiley Intersceince, 2005.

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M.Tech. Nanotechnology II-Sem

L	T	P	C
4	0	0	4

CARBON NANO TUBES AND APPLICATIONS (15D61208)
(ELECTIVE-II)

Unit-I: Carbon Nano structures and types of Carbon Nano tubes, growth mechanisms. Synthesis of CNTs by Flame, CVD, Laser & Arc-discharge process.

Unit-II: Mechanical reinforcements, Solid Disordered carbon Nanostructures, Nano structured crystals. Graphene,Carbon nanofibers. Electrical, Vibrational, Mechanical Properties of CNTs, optical properties & Raman spectroscopy of CNTs

Unit-III: Carbon clusters and Fullerenes.

Unit-IV: Lithium & Hydrogen adsorption & storages. Fuel cell applications and energy storage, Chemical Sensors applications of CNTs.

Unit-V: Computer applications (Nano chip), optical and telecommunication applications, Nano composites, silicon Nanowires.

Text books:

1. Introduction to Nanotechnology by Charles P. Poole and Frank J.Owens Wiley India Pvt Ltd.
2. Nanotechnology and Nano Electronics – Materials, devices and measurement techniques by WR Fahrner, Springer publications

Reference books:

1. Encyclopaedia of Nanotechnology by M.Balakrishna rao and K.Krishna Reddy, Vol I to X Campus books.
2. Encyclopedia of Nanotechnology by HS Nalwa
3. Nanotechnology – science, innovation and opportunity by Lynn E.Foster. Hall Pearson education.
4.Nano:The Essentials – Understanding Nano Scinece and Nanotechnology by T.Pradeep; Tata Mc.Graw Hill

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M.Tech. Nanotechnology II-Sem

L	T	P	C
3	0	0	0

RESEARCH METHODOLOGY (15D54201)

(Audit Course For M.Tech. –II Semester Program from 2015 admitted batches onwards)

UNIT I

Meaning of Research – Objectives of Research – Types of Research – Research Approaches – Guidelines for Selecting and Defining a Research Problem – research Design – Concepts related to Research Design – Basic Principles of Experimental Design.

UNIT II

Sampling Design – steps in Sampling Design –Characteristics of a Good Sample Design – Random Sampling Design.

Measurement and Scaling Techniques-Errors in Measurement – Tests of Sound Measurement – Scaling and Scale Construction Techniques – Time Series Analysis – Interpolation and Extrapolation.

Data Collection Methods – Primary Data – Secondary data – Questionnaire Survey and Interviews.

UNIT III

Correlation and Regression Analysis – Method of Least Squares – Regression vs Correlation – Correlation vs Determination – Types of Correlations and Their Applications

UNIT IV

Statistical Inference: Tests of Hypothesis – Parametric vs Non-parametric Tests – Hypothesis Testing Procedure – Sampling Theory – Sampling Distribution – Chi-square Test – Analysis of variance and Co-variance – Multi-variate Analysis.

UNIT V

Report Writing and Professional Ethics: Interpretation of Data – Report Writing – Layout of a Research Paper – Techniques of Interpretation- Making Scientific Presentations in Conferences and Seminars – Professional Ethics in Research.

Text books:

1. Research Methodology:Methods and Techniques – C.R.Kothari, 2nd Edition,New Age International Publishers.
2. Research Methodology: A Step by Step Guide for Beginners- Ranjit Kumar, Sage Publications (Available as pdf on internet)
3. Research Methodology and Statistical Tools – P.Narayana Reddy and G.V.R.K.Acharyulu, 1st Edition,Excel Books,New Delhi.

REFERENCES:

1. Scientists must Write - Robert Barrass (Available as pdf on internet)
2. Crafting Your Research Future –Charles X. Ling and Quiang Yang (Available as pdf on internet)

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M.Tech. Nanotechnology II-Sem	**L**	**T**	**P**	**C**
	0	**0**	**4**	**2**

NANOMETROLOGY AND MICROSCOPY LAB (15D61209)

- Preparation of any two types of Ceramic Powders, $BaTiO_3$ (ball milling) & Al2O3 (flame)
- Composite preparation (Ball Milling)
- X-ray Diffraction measurements of Nano Crystallites
- Nano Particle Size Analysis

Reference books:

1. Advanced catalysis and Nano structured material by WR Moser.
2. Introduction to Nano Technology by Charles. P.Poole Jr and Frank J. Owens Wiley India Pvt Ltd.
3. Encyclopedia of Nanotechnology by H.S. Nalwa
4. Nano: The Essentials – Understanding Nano Scinece and Nanotechnology – by T.Pradeep; Tata Mc.Graw Hill

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JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY ANANTAPUR
JNTUA COLLEGE OF ENGINEERING (AUTONOMOUS) :: ANANTHAPURAMU
Ananthapuramu – 515 002, Andhra Pradesh, India

Course Structure of R21 Academic Regulations for M.Tech (Regular) Programs with effect from AY 2021-2022

DEPARTMENT OF CHEMICAL ENGINEERING

NANO TECHNOLOGY

I SEMESTER

S.No.	Course Code	Subject Name	Cate Gory	Hours Per Week			Credits
				L	T	P	
1	21D81101	Physics and Chemistry of Nano-materials	PC	3	0	0	3
2	21D81102	Synthesis of Nanostructures	PC	3	0	0	3
3	**Professional Elective – I**						
	21D81103	Machine Learning & Data Analytics for Technologist	PE	3	0	0	3
	21D81104	Numerical Methods for Researchers					
	21D81105	Mathematical Modeling and Simulation					
4	**Professional Elective – II**						
	21D81106	Nanostructured Materials for Clean Energy Systems	PE	3	0	0	3
	21D81107	Nanotechnology in Energy Conversion and Storage					
	21D81108	Solar Energy and Harvesting Techniques					
5	21D11109	Research Methodology and IPR	MC	2	0	0	2
6	21D11110	English for Research Paper Writing	AC	2	0	0	0
	21D11111	Value Education					
	21D11112	Pedagogy Studies					
7	21D81109	Synthesis and Processing Lab	PC	0	0	4	2
8	21D81110	Design and Simulation Lab	PC	0	0	4	2
Total				**16**	**00**	**08**	**18**

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Ananthapuramu – 515 002, Andhra Pradesh, India

Course Structure of R21 Academic Regulations for M.Tech (Regular) Programs with effect from AY 2021-2022

DEPARTMENT OF CHEMICAL ENGINEERING

NANO TECHNOLOGY

II SEMESTER

S.No.	Course Code	Subject Name	Cate Gory	Hours Per Week			Credits
				L	T	P	
1	21D81201	Characterization of Nanomaterials	PC	3	0	0	3
2	21D81202	Nanomaterials for Meta-materials and Nanophotonics	PC	3	0	0	3
3	**Professional Elective – III**						
	21D81203	Nanocomposites Design and Synthesis	PE	3	0	0	3
	21D81204	Nanocatalysis					
	21D81205	Nanobiotechnology: Materials and Devices					
4	**Professional Elective – IV**						
	21D81206	Nanofabrication Technologies	PE	3	0	0	3
	21D81207	Industrial Trends & Applications of Nanotechnology					
	21D81208	Self-Assembly of Nanostructures					
5	21D11209	Technical Seminar	PR	0	0	4	2
6	21D11210	Disaster Management	AC	2	0	0	0
	21D11211	Constitution of India					
	21D11212	Stress Management by Yoga					
7	21D81209	Fabrication and Characterization Laboratory	PC	0	0	4	2
8	21D81210	Nanomaterials Application Laboratory	PC	0	0	4	2
Total				**14**	**00**	**12**	**18**

NANO TECHNOLOGY

III SEMESTER

S.No.	Course Code	Subject Name	Cate Gory	Hours Per Week			Credits
				L	T	P	
1	**Professional Elective – V**						
	21D81301	MEMS and NEMS	PE	3	0	0	3
	21D81302	Nanosensors, Detection and their applications					
	21D81303	Carbon nanotubes and Applications					
2	**Open Elective**						
	21D80301	Introduction to Nanoscience and Nanotechnology	OE	3	0	0	3
3	21D81304	Dissertation Phase – I	PR	0	0	20	10
4	21D00301	Co-Curricular Activities	PR				2
Total				**06**	**00**	**20**	**18**

IV SEMESTER

S.No.	Course Code	Subject Name	Cate Gory	Hours Per Week			Credits
				L	T	P	
1	21D81401	Dissertation Phase – II	PR	0	0	32	16
Total				**00**	**00**	**32**	**16**

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81101	PHYSICS AND CHEMISTRY OF MATERIALS (21D81101)	L	T	P	C
Semester	I		3	0	0	3

UNIT-1:
INTR ODUCTION TO NANOMATERIALS:
Bulk materials vs. nanomaterials, classification, unique properties of nanomaterials, applications, microstructure and defects in nanocrystalline materials: dislocations, twins, stacking faults and voids, grain boundaries, triple and disclinations.

UNIT-2:
EFFECT OF NANO-DIMENSIONS ON MATERIALS BE HAVIOR:
Elastic properties, melting point, diffusivity, grain growth characteristics, enhanced solid solubility, magnetic properties: soft magnetic nanocrystallinealloy, permanent magnetic nanocrystallinematerials, giant magnetic resonance, electrical properties, optical properties, thermal properties and mechanicalProperties.

UNIT-3:
P HYSICAL PROPERTIES:
Melting point and phase transition processes- quantum-size-effect (QSE). Size-induced metal-insulator-transition (SIMIT)-nano-scale magnets, transparent magnetic materials, and ultrahigh-density magnetic recording materials-chemical physics of atomic and molecular clusters.

UNIT-4:
PHYSICAL CHEMISTRY OF SOLID SURFACES:
Surface energy – chemical potential as a function of surface curvature-Electrostatic stabilization- surface charge density-electric potential at the proximity of solid surface-VanderWaalsattractionpotential.

UNIT-5:
CHEMISTRY ASPECTS:
Photochemistry; Photoconductivity; Electrochemistry of Nanomaterials-Diffusion in Nanomaterials; Nanoscale Heat Transfer; Catalysis by Gold Nanoparticles; Transport inSemiconductorNanostructures; Transition Metal Atoms on NanocarbonSurfaces; NanodepositionofSoft Materials;Nanocatalysis.

References:
1. Text book of Nanoscience and Nanotechnology by B. S. Murthy, P. Shankar, Baldev Raj, B BRath, James Murday, Springer series, UniversitiesPress,
2. K.W. Kolasinski, “Surface Science: Foundations of Catalysis andNanoscience”,Wiley, 2002.
3. Joel I. Gersten, “ ThePhysicsand Chemistry of Materials”, Wiley,2001.
4. A. S. Edelstein and R. C. Cammarata, “Nanomaterials: Synthesis, Properties and Applications”, Institute of Physics Pub.,1998.
5. S.YangandP.Shen:“Physicsand ChemistryofNano-structuredMaterials”,Taylor &Francis,2000.
6. G.A. OzinandA.C. Arsenault, “Nanochemistry: A chemical approachtonanomaterials”, Royal Society of Chemistry, 2005.

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81102	SYNTHESIS OF NANOSTRUCTURES (21D81102)	L	T	P	C
Semester	I		3	0	0	3

UNIT-1: BULK SYNTHESIS
Synthesis of bulk nano-structured materials –sol gel processing –Mechanical alloying and mechanical milling- Inert gas condensation technique – Nanopolymers– Bulk and nano composite materials.

UNIT-2: CHEMICAL APPROACHES
Self-assembly, self-assembled monolayers (SAMs). Langmuir-Blodgett (LB) films, clusters, colloids, zeolites, organic block copolymers, emulsion polymerization, templated synthesis, and confined nucleation and/or growth. Biomimetic Approaches: polymer matrix isolation, and surface-templated nucleation and/or crystallization. Electrochemical Approaches: anodic oxidation of alumina films, porous silicon, and pulsed electrochemical deposition.

UNIT-3: PHYSICAL APPROACHES
Vapor deposition and different types of epitaxial growth techniques- pulsed laser deposition, Magnetron sputtering - Micro lithography (photolithography, soft lithography, micromachining, e-beam writing, and scanning probe patterning).

UNIT-4: NANOPOROUS MATERIALS:
Nanoporous Materials – Silicon - Zeolites, mesoporous materials - nanomembranes and carbon nanotubes - AgX photography, smart sunglasses, and transparent conducting oxides –molecular sieves – nanosponges.

UNIT-5: APPLICATION OF NANOMATERIALS
Molecular Electronics and Nanoelectronics – Nanobots- Biological Applications – Quantum Devices – Nanomechanics- Carbon Nanotube – Photonics- Nano structures as single electron transistor –principle and design.

References:
1. S.P. Gaponenko, Optical Properties of semiconductor nanocrystals, CambridgeUniversity Press, 1980.
2. W.Gaddand, D.Brenner, S.Lysherski and G.J.Infrate(Eds.), Handbook of NanoScience,Engg. and Technology, CRC Press, 2002.
3. K. Barriham, D.D. Vvedensky, Low dimensional semiconductor structures: fundamentaland device applications, Cambridge University Press, 2001.
4. G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties Applications, ImperialCollege Press, 2004.
5. J.George, Preparation of Thin Films, Marcel Dekker, Inc., New York. 2005

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81103	MACHINE LEARNING & DATA ANALYTICS FOR TECHNOLOGISTS (21D81103)	L	T	P	C
Semester	I		3	0	0	3

Unit I:
Introduction- overview of machine learning- Different forms of learning- Generative learning- Gaussian parameter estimation- maximum likelihood estimation- MAP estimation- Bayesian estimation- bias and variance of estimators- missing and noisy features- nonparametric density estimation- applications- software tools. Classification Methods-Nearest neighbour- Decision trees- Linear Discriminant Analysis - Logistic regression-Perceptrons- large margin classification- Kernel methods- Support Vector Machines.

UNIT II:
Classification Methods-Nearest neighbour- Decision trees- Linear Discriminant Analysis - Logistic regression-Perceptrons- large margin classification- Kernel methods- Support Vector Machines. Classification and Regression Trees.Graphical and sequential models- Bayesian networks- conditional independenceMarkov random fields- inference in graphical models- Belief propagation- Markov models- Hidden Markov models- decoding states from observations- learning HMM parameters.

UNIT III
Clustering Methods-Partitioned based Clustering - K-means- K-medoids; Hierarchical Clustering - Agglomerative- Divisive- Distance measures; Density based Clustering - DBScan; Spectral clustering.Neural networks- the perceptron algorithm- multilayer perceptron's- back propagationnonlinear regression- multiclass discrimination- training procedures- localized network structure- dimensionality reduction interpretation.

UNIT -IV:
Learning, Regression and Classification techniques: Supervised and Unsupervised Learning concepts, Regression and Classification techniques, Neural Networks, Clustering, Association Rule Mining, Deep learning Concepts, Challenges for Big data |Analytics

UNIT -V:
Prescriptive analytics: Creating data for analytics through Active learning, Creating data for analytics through Reinforcement learning, Python Machine Learning & Data Analysis Tutorial/Lab.
Review of Statistical methods: Descriptive Statistics, Probability Distributions, (Binomial, Poisson, Normal), Sampling Distributions (Chi-squared, t, F).
Inferential Statistics: Estimation, Test of Hypothesis.
Regression &Analysis of Variance (ANOVA): Regression, ANOVA

TEXT BOOK:
1. Montgomery, Douglas C., and George C. Runger. Applied Statistics and Probability for Engineers. John Wiley & Sons, 2010
2. Artificial Intelligence: A Modern Approach, Stuart Russel& Peter Norvig, Pearson, 2009
3. Machine Learning: A probabilistic perspective ,kevin P. Murphy
4. Pattern Recognition and Machine Learning, Chris Bishop
5. The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Trevor

Hastie, Robert Tibshirani, Jerome Friedman

REFERENCE:

1. Business Intelligence: A Managerial Perspective on Analytics, Ramesh Sharda, DursunDelon, EfraimTurbal, David King, Prentice Hall
2. ModellindTechniuqes in Predictive Analytics, Thomas W Miller, Pearson
3. Introduction to Machine Learning with Python, A. C. Muller & S. Guido, O'Reilly.
4. T. Hastie, R. Tibshirani and J. Friedman, "Elements of Statistical Learning", Springer, 2009.
5. E. Alpaydin, "Machine Learning", MIT Press, 2010.
6. K. Murphy, "Machine Learning: A Probabilistic Perspective", MIT Press, 2012.
7. C. Bishop, "Pattern Recognition and Machine Learning, Springer", 2006.
8. ShaiShalev-Shwartz, Shai Ben-David, "Understanding Machine Learning: From Theory to Algorithms", Cambridge University Press, 2014.
9. John Mueller and Luca Massaron, "Machine Learning For Dummies", John Wiley & Sons, 2016.

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81104	NUMERICAL METHODS FOR RESEARCHERS (21D81104)	L	T	P	C
Semester	I		3	0	0	3

UNIT-I
Errors in approximation, Absolute, Relative and percentage errors. Solution of algebraic and transcendental equations: Bisection method, RegulaFalsi method, Newton Raphson method. Systems of simultaneous Equations: Gauss elimination method, Gauss Jordon method, LU decomposition method, Iterative methods: Jacobi method and Gauss-Seidel method. Curve fitting: Straight line fitting, parabolic curve fitting, fitting of exponential curve, fitting of other curves.

UNIT-II
Finite Differences, Interpolation techniques: Interpolation with equal intervals-Newton Forward, Newton Backward, Gauss forward, Gauss Backward, Stirling, Bessel formulae.

UNIT-III
Interpolation with unequal intervals-Newton's divided difference, Lagrange interpolation technique.Numerical Differentiation using Newton Forward, Newton Backward formulae.

UNIT-IV
Numerical Integration: Newton-Cotes Formulas, Trapezoidal rule, Simpson rule, Romberg's integration, Gauss-Legendre, Gauss-Chebychev formulas. Solution of Ordinary differential equations: Single step methods: Taylor series method, Picard's method, Euler method, Euler modified method, Runge – Kutta methods, Multistep methods: Milne's and Adam's predictor and corrector methods

UNIT-V
Classification of PDEs.Solution of partial differential equations by finite difference method. Solution of Laplace equation: standard and diagonal five point formula for solving Laplace and Poisson equations, Solution of One dimensional Heat equation: Schmidt method, Crank-Nicolson method, Solution of wave equation.

REFERENCES:
1. Mathews, J. H. Numerical Methods for Mathematics, Science and Engineering. PrenticeHall International Editions, 1992.
2. Jain, M. K., Iyengar, S. R. K. and Jain, R. K. Numerical Methods for Scientific &Engg. Computation. New Age International, 2012.
3. Thangaraj, P. Computer Oriented Numerical Methods. PHI Learning Pvt. Ltd, 2013.
4. Chapra, S. C. and Canale, R. P. Numerical Methods for Engineers. McGraw Hill International Edition, 1998.
5. Bartels, R. H. Bealty, J. C. and Beatty, J. C. An Introduction to Spline for use in Computer Graphics and Geometric Modeling. Morgan Kaufmann Publisher, 2006.
6. Boor, C. D. A Practical Guide to Splines. Springer Verlag, 2001.

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81105	MATHEMATICAL MODELING AND SIMULATION (21D81105)	L	T	P	C
Semester	I		3	0	0	3

UNIT-1:
Fundamentals of modeling: Principles & uses of modeling, classification of mathematical models-steady state Vs dynamic models, lumped Vs distributed parameter models, deterministic Vs stochastic models.
Examples of mathematical models-Two heated tanks, constant volume CSTRs, Gravity flow tank, Dynamics of first order & second order systems (Mercury in glass thermometer, Damped vibrator)

UNIT-2:
Empirical model building- method ofleast squares, linear, polynomial andmultipleregression, non-linear regression.Solutionof simultaneous algebraicequations*:* Direct methods: Gauss-elimination method, Gauss–Jordan method, Iterative methods: Jacobi'smethod, Gauss-Siedal method.

UNIT-3:
Solution ofODEs:Eulermethod, Runge-Kuttamethod, Milne's Predictor-Correctormethod Solution of PDEs: Elliptic equations-one dimensional, parabolicequation-hyperbolic equation-partial differential equations-separation of variables-wave equation.

UNIT-4: Finite Difference: Difference operator (?), operator E, Interpolation, Formulationof linear and non-linear finite difference equationsAdvanced methods for Differential Equations: method of lines, Orthogonal Collocation, Finite Volume Method.

UNIT-5:
Fourier series and Fourier integral: Periodic function, Trigonometric series, Fourier series, Functions of any period, Even and odd functions, Half-range Expansion, Forced oscillations, Fourier integral. Laplace Transforms and Applications: Laplace transform, Inverse Laplace transform, Linearity, Shifting theorem, Transforms of derivatives and integrals, Differential equations, Unit step function, Second shifting theorem, Dirac's delta function.

REFERENCES:
1. S.C. ChapraandR.P.Canale, "Numerical methods for Engineers", Tata McGraw Hill, New Delhi,2002.
2. Erwin Kreyzig, "Advanced Engineering Mathematics", John Wiley &Sons,2004.
3. Jenson and Jeffery, Mathematical Methods in ChemicalEngineering,
4. Mickley, Reid and Sherwood, Applied Mathematics in Chemical Engineering, Tata-McGraw-Hill, NewDelhi
5. Zill, DennisandCullen,Michael AdvancedEngineering,3rdEdition, 2006, Jones and Bartlett,Publisher

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81106	NANOSTRUCTURED MATERIALS FOR CLEAN ENERGY SYSTEMS (21D81106)	L	T	P	C
Semester	I		3	0	0	3

Outcome/Knowledge/Skill:
Fundamental understanding of the structure-composition-performance relationships of materials energy materials. Fabrication and evaluation of prototype clean energy conversion & storage devices (DSSC and Perovskite based solar cells, lithium batteries, supercapacitors, and fuel cells).
Fabrication and evaluation of prototype clean energy conversion & storage devices (DSSC and Perovskite based solar cells, lithium batteries, supercapacitors, and fuel cells)

UNIT-I:
Fundamental Concepts in Energy Systems Electrochemical Cell, Faraday's laws, Electrode Potentials, Thermodynamics of electrochemical cells, Polarization losses in electrochemical cells, Electrode process and kinetics, Electrical double layer, Photoelectro-chemical cell, thermoelectric effect.

UNIT-II:
Nanomaterials for Energy Conversion Systems Issues and Challenges of functional Nanostructured Materials for electrochemical Energy, Conversion Systems, Fuel Cells, Principles and nanomaterials design for; Proton exchange membrane fuel cells (PEMFC); Direct methanol fuel cells (DMFC); Solid-oxide fuel cells (SOFC), Current status and future trends.

UNIT-III:
Nanomaterials for Photovoltaic Solar Energy Conversion Systems Principles of photovoltaic energy conversion (PV), Types of photovoltics Cells, Physics of photovoltaic cells, Organic photovoltaic cell cells, thin film Dye Sensitized Solar Cells, Quntum dot (QD) Sensitized Solar Cells (QD-SSC), Organic-Inorganic Hybrid Bulk Hetero Junction (BHJ-SC) Solar cells, Current status and future trends.

UNIT-IV:
Nanomaterials for Energy Storage (Batteries) Systems Issues and Challenges of functional Nanostructured Materials for electrochemical Energy Storage Systems, Primary and Secondary Batteries (Lithium-ion Batteries), Cathode and anode materials, Nanostructured Carbon-based materials, Nano-Oxides, Novel hybrid electrode materials, Current status and future trends.

UNIT-V:
Nanomaterials for Energy Storage (Batteries) Systems Issues and Challenges of functional Nanostructured Materials for electrochemical Energy Storage Systems, Primary and Secondary Batteries (Lithium-ion Batteries), Cathode and anode materials, Nanostructured Carbon-based materials, Nano-Oxides, Novel hybrid electrode materials, Current status and future trends.

REFERENCE BOOK

1. Electrochemical methods: Fundamentals and Applications, Allen J.Bard and Larry R. Faulkner, 2nd Edition John Wiley & Sons. Inc (2004)
2. D. Linden Ed., Handbook of Batteries, 2nd edition, McGraw-Hill, New York (1995)
3. G.A. Nazri and G. Pistoia, Lithium Batteries: Science and Technology, KulwerAcdemic 28 Publishers, Dordrecht, Netherlands (2004).

4. J. Larmine and A. Dicks, Fuel Cell System Explained, John Wiley, New York (2000).
5. Science and Technology of Lithium Batteries-Materials Aspects: An Overview, A. Manthiram, Kulwer Academic Publisher (2000).
6. M. S. Whittingham, A. J. Jacobson, Intercalation Chemistry, Academic Press, New York (1982).
7. M. Wakihara, O. Yamamoto, (Eds.) Lithium Ion Batteries: Fundamentals and Performance, Wiley –VCH ,Weinheim (1998).
8. Nanocomposites Science and Technology - P. M. Ajayan, L.S. Schadler, P. V. Braun

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81107	NANOTECHNOLOGY IN ENERGY CONVERSION AND STORAGE (21D81107)	L	T	P	C
Semester	I		3	0	0	3

UNIT I- INTRODUCTION
Nanotechnology for sustainable energy- Energy conversion process, indirect and direct energy conversion-Materials for light emitting diodes-batteriesadvanced turbines-catalytic reactors-capacitorsfuel cells.

UNIT II- RENEWABLE ENERGY TECHNOLOGY
Energy challenges, development and implementation of renewable energy technologies-nanotechnology enabled renewable energy technologies - Energy transport, conversion and storage- Nano, micro, and poly crystalline and amorphous Si for solar cells, Nano-micro Si-composite structure, various techniques of Si deposition.

UNIT III-MICRO FUEL CELL TECHNOLOGY
Micro-fuel cell technologies, integration and performance for micro-fuel cell systems -thin film and microfabrication methods - design methodologies - micro-fuel cell power sources.

UNIT IV- MICROFLUIDIC SYSTEMS
Nano-electromechanical systems and novel microfluidic devices – nano engines – drivingmechanisms - power generation - microchannel battery - micro heat engine (MHE) fabrication - thermocapillary forces - Thermocapillary pumping (TCP) - piezoelectric membrane.

UNIT V- HYDROGEN STORAGE METHODS
Hydrogen storage methods - metal hydrides - size effects - hydrogen storage capacity -hydrogen reaction kinetics - carbon-free cycle- gravimetric and volumetric storage capacities-hydriding/dehydriding kinetics -high enthalpy of formation - and thermal management during the hydriding reaction.

TextBooks"

1. J. Twidell and T. Weir, "Renewable Energy Resources", E & F N Spon Ltd, 1986.
2. Martin A Green, "Solar cells: Operating principles, technology and system applications", Prentice Hall Inc, Englewood Cliffs, 1981

References:

1. H J Moller, "Semiconductor for solar cells", Artech House Inc, 1993..
2. Ben G Streetman, "Solid state electronic device", Prentice Hall of India Pvt Ltd.,1995.
3. M.A. Kettani , "Direct energy conversion", Addision Wesley Reading, 1970..
4. Linden , "Hand book of Batteries and fuel cells", McGraw Hill, 1984. 5. Vielstich, "Handbook of fuel cells: Fuel cell technology and applications", Wiley, CRC Press, 2003.

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81108	SOLAR ENERGY AND HARVESTING TECHNIQUES (21D81108)	L	T	P	C
Semester	I		3	0	0	3

COURSE OUTCOMES: Selection of nanomaterials for energy harvesting and storage applications is an interdisciplinary course which deals with selection of nanomaterials and key challenges to improve performance of the energy harvesting and storage devices/techniques. In this course we will be covering different energy harvesting and storage techniques and the parameters that are to be considered in selecting the nanomaterials for the same.

UNIT – 1: INTRODUCTION
Energy harvesting Solar Energy Harvesting (SHE), Hydrogen energy harvesting, Nanogenerators, Other energy harvesting methods, Perovskite solar cells, Classification of synthesis procedures of the perovskite solar cel Applications, solar Thermal energy, Working principle, Classification of solar collectors, Selection of nanomaterials for solar absorber collectors, Heat Transfer Fluids, Types of HTF, Synthesis of Nanofluids, Physical properties of nanofluids

UNIT – 2:
Hydrogen Energy: Introduction & Hydrogen Production from Fossil Fuels and Biomass- Introduction, Salient features of hydrogen energy, Hydrogen production from fossil fuel, Hydrogen production from biomass: Introduction, Classification of biomass conversion process into hydrogen, Hydrogen Production from Thermochemical Process- Thermochemical water splitting. Different nanomaterials used in hydrogen production, Hydrogen Production from Electrolysis, Photo-electrochemical Production of Hydrogen Using Solar Energy, Hydrogen Production from Biological Process

UNIT – 3:
Nanogenerators: Introduction & Piezoelectric NanogeneratorsNanogenerators, Piezoelectric effect PyroelectricNanogenerators, Materials used in piezoelectric nanogenerators, Applications, TriboelectricNanogenerators, Triboelectric effect, Hybrid nanogenerators, Difference between piezoelectric &triboelector) nanogenerators, Applications of TENG, Pyroelectricnanogenerators, Thermoelectric Nanogenerators& Electromagnetic generators.

UNIT – 4:
Conventional source of energy, Non-conventional source of energy, Energy Storage, Characteristics of energy storage systems, Different types of energy storage systems- Batteries, Flow batteries, Electrochemical/ Super/ Ultracapacitors, Hydrogen storage, Thermal energy storage (TES), Flywheels, surface modification of nanomaterials, Nanomaterials for energy storage, Electrochemical Energy Storage: (Batteries), Components in batteries system, Classification of batteries, Differences between primary and secondary battery cells. Different types of accumulators, Aging of electrochemical batteries, Nanomaterials used in batteries, Supercapacitors: working and types of super capacitors, Criteria for choosing nanomaterials for supercapacitors,

UNIT – 5:

Hydrogen Storage Characterization techniques of hydrogen storage, Selection of nanomaterials for hydrogen storage, Applications, Thermal Energy Storage Types of thermal energy storage, Criteria to choose materials for PCM materials.

TEXTBOOKS:

1. Energy Harvesting Systems, Principles, Modeling and Applications, ISBN: 978-1-4419-7566-9, Tom J. Kaźmierski,SteveBeeby.
2. Energy Harvesting Technologies, ISBN: 978-0-387-76464-1:Shashank Priya, Daniel J. Inman
3. Waste Energy Harvesting: Mechanical and Thermal Energies, By Ling Bing Kong, Tao Li, Huey HoonHng, Freddy Boey, Tianshu Zhang, Sean Li
4. Energy Harvesting: Solar, Wind, and Ocean Energy Conversion Systems, By AlirezaKhaligh, Omer C Onar.
5. Piezoelectric Energy Harvesting, By AlperErturk, Daniel J. Inman, Wiley publications.

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81109	SYNTHESIS AND PROCESSING LABORATORY (21D81109)	L	T	P	C
Semester	I		3	0	0	3

Outcome/Knowledge/Skill:

Received training in research skills and methodology for novel chemical, physical and biological synthesis and processing approaches of nanomaterials.

Synthesis of semiconducting and ceramic nano-materials by solution combustion, sol-gel, micro-emulsion, chemical co-precipitation, hydrothermal, sono-chemical and microwave assisted methods.

- Synthesis of multi-ferrite nano-particles.
- Synthesis of silver nanoparticles, and its spectral analysis.
- Preparation of nano-composites, nanoporous material, colloidal solid and core –shell nanoparticles.
- Preparation of quantum dots such as cadmium selenides and its optical studies.
- Preparation of cadmium sulphidenanoclusters and its spectral studies

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81110	DESIGN AND SIMULATION LABORATORY (21D81110)	L	T	P	C
Semester	I		3	0	0	3

Objective: The course is intended to cover understanding of nanomaterial fabrication technique and modelling.

Outcome of the study:

1. To gain knowledge on design and construction of carbon molecules.
2. Student can develop math work and gain knowledge on Mat-Lab.
3. To construct a theoretical knowledge on the experiment.
4. The ability to write and present the laboratory reports.
5. To maximize knowledge regarding simulation components.

PART-B: SIMULATION

I. ARGUS LAB

1. Construction of fullerene & its energy calculations
2. Construction of Bucky balls (C20, C40, C60, C80, C100, C120)
3. Construction of Carbon nanotubes
4. Energy minimization of lysozyme and its mutant
5. Energy minimization of chymotrypsin and its mutant
6. Energy minimization of enzymes involved in Neurological science

II.MATLAB

1. Introduction to MATLAB Programming
2. Program assembly, Execution, Data processing and graphic analysis
3. Study of Fermi – Dirac distribution function
4. Introduction to symbolic math computations
5. MATLAB program to plot the one-dimensional rectangular potential well with infinite potential barrier 6. Introduction to Simulink and Sim-electronics

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

DISASTER MANAGEMENT
(Audit Course-II)

CourseObjectives: -Students will be able to:

1. learntodemonstrateacriticalunderstandingofkeyconceptsindisasterriskreductionand humanitarian response.
2. critically evaluatedisasterriskreductionandhumanitarianresponsepolicyandpracticefrom multiple perspectives.
3. developanunderstandingofstandardsofhumanitarianresponseandpracticalrelevanceinspecific types ofdisastersandconflict situations.
4. criticallyunderstandthestrengthsandweaknessesofdisastermanagementapproaches,planning and programming in different countries, particularly their home country orthecountries they work in

Syllabus		
Units	**CONTENTS**	**Hours**
1	**Introduction** Disaster: Definition, FactorsandSignificance; DifferencebetweenHazard andDisaster;Natural and ManmadeDisasters: Difference, Nature, Types And Magnitude.	4
2	**Repercussions Of Disasters andHazards**: EconomicDamage, Loss Of Human And Animal Life, Destruction ofEcosystem. Natural Disasters: Earthquakes, Volcanisms, Cyclones, Tsunamis, Floods, Droughts and Famines,Landslides and Avalanches, Man-madedisaster: Nuclear Reactor Meltdown,Industrial Accidents, Oil Slicks And Spills, Outbreaks of Diseaseand Epidemics, War And Conflicts.	4
3	**DisasterProneAreasInIndia** Study Of Seismic Zones; Areas PronetoFloodsAndDroughts, Landslides And Avalanches; AreasProneto Cyclonic andCoastal Hazards WithSpecial ReferenceTo Tsunami; Post-DisasterDiseases And Epidemics	4
4	**DisasterPreparednessandManagement** Preparedness:MonitoringofPhenomenaTriggering A DisasterOrHazard; Evaluation OfRisk:ApplicationofRemoteSensing, Data From Meteorological And Other Agencies, Media Reports: Governmental And Community Preparedness.	4
5	**RiskAssessment** DisasterRisk: Concept and Elements, Disaster Risk Reduction, Global And National DisasterRiskSituation. Techniques OfRisk Assessment, Global Co-OperationIn Risk Assessment and Warning, People's Participation In Risk Assessment. Strategies forSurvival.	4
6	**Disaster Mitigation** Meaning, Concept and Strategies OfDisasterMitigation, Emerging Trends in Mitigation -Structural Mitigationand Non-StructuralMitigation, Programs of Disaster Mitigation InIndia.	4

SuggestedReadings:

1.R.Nishith,SinghAK,"DisasterManagementinIndia:Perspectives,issuesandstrategies "'New Royal book Company.
2.Sahni,PardeepEt.Al.(Eds.),"DisasterMitigationExperiencesAndReflections",PrenticeHall OfIndia, New Delhi.
3.GoelS.L.,DisasterAdministrationAndManagementTextAndCaseStudies",Deep&Deep Publication Pvt. Ltd., New Delhi.

SANSKRITFOR TECHNICAL KNOWLEDGE
(Audit Course-II)

CourseObjectives

1. To get a working knowledgeinillustrious Sanskrit, thescientificlanguageintheworld
2. Learning ofSanskrit to improvebrain functioning
3. LearningofSanskrittodevelopthelogicinmathematics,science&othersubjects enhancing thememorypower
4. Theengineeringscholarsequippedwith Sanskrit will beabletoexplorethehuge knowledgefromancientliterature

Syllabus

Unit	Content	Hours
1	Alphabets in Sanskrit, Past/Present/FutureTense, Simple Sentences	4
2	Order Introduction ofroots Technical information about Sanskrit Literature	4
3	TechnicalconceptsofEngineering-Electrical,	4
4	TechnicalconceptsofEngineering- Mechanical.	4
5	TechnicalconceptsofEngineering- Architecture.	4
6	TechnicalconceptsofEngineering– Mathematics.	4

Suggestedreading

1.“Abhyaspustakam” –Dr.Vishwas, Sanskrit-Bharti Publication, New Delhi
2.“Teach YourselfSanskrit” PrathamaDeeksha-VempatiKutumbshastri, RashtriyaSanskrit
Sansthanam, New Delhi Publication
3.“India’s Glorious ScientificTradition” Suresh Soni, Ocean books (P) Ltd.,NewDelhi.

CourseOutcomes:

Students will be able to

1. Understanding basic Sanskrit language
2. Ancient Sanskrit literature about science&technology can beunderstood
3. Being a logical languagewillhelpto develop logic in students

PEDAGOGY STUDIES
(Audit Course-II)

CourseObjectives:
Students will be able to:
4. Reviewexistingevidenceonthereviewtopictoinformprogrammedesignandpolicy making undertaken by theDfID, other agenciesand researchers.

Syllabus		
Units	**Content**	**Hours**
1	**Introduction andMethodology:** Aims and rationale, Policy background, Conceptual framework and terminology Theories of learning, Curriculum, Teacher education. Conceptual framework,Research questions**.** Overview of methodology andSearching.	4
2	Thematicoverview:Pedagogicalpracticesarebeingusedbyteachersinformaland informal classroomsin developing countries. Curriculum, Teacher education.	4
3	Evidenceontheeffectiveness of pedagogical practices Methodology for thein depth stage: quality assessment ofincluded studies. Howcanteachereducation(curriculumandpracticum)andtheschoolcurriculumand guidancematerialsbest support effectivepedagogy?	4
4	Theory of change. Strength and natureofthebody ofevidenceforeffectivepedagogical practices. Pedagogic theory and pedagogical approaches. Teachers'attitudesand beliefs and Pedagogicstrategies.	4
5	Professional development: alignment with classroom practices and follow-up support Peer support Support from theheadteacherand the community. Curriculum and assessment Barriers to learning: limited resources and large class sizes	4
6	**Researchgapsandfuturedirections** Research design Contexts Pedagogy Teacher education Curriculum and assessment Dissemination and research impact.	4

5. Identify criticalevidencegaps to guide thedevelopment.

1. AckersJ,HardmanF(2001)ClassroominteractioninKenyanprimaryschools,Compare, 31 (2): 245-261.
2. AgrawalM(2004)Curricularreforminschools:Theimportanceofevaluation,Journalof Curriculum Studies, 36 (3): 361-379.
3. AkyeampongK(2003) Teacher training in Ghana - does it count? Multi-site

teachereducation research project (MUSTER) country report 1. London: DFID.
4. Akyeampong K, LussierK, PryorJ, Westbrook J (2013)Improving teaching and learning of basic maths and reading in Africa: Does teacherpreparationcount?International Journal Educational Development, 33 (3): 272–282.
5. Alexander RJ(2001) Culture and pedagogy: International comparisons in primary education. Oxford and Boston: Blackwell.
6. Chavan M (2003)ReadIndia: A mass scale, rapid, 'learning to read'campaign.
7. www.pratham.org/images/resource%20working%20paper%202.pdf.

CourseOutcomes:

Students will be able to understand:

1. Whatpedagogicalpracticesarebeingusedbyteachersinformalandinformalclassrooms in developing countries?
2. What istheevidence on the effectiveness of these pedagogical practices, in what conditions, and with what population oflearners?
3. Howcanteachereducation(curriculumandpracticum)andtheschoolcurriculumand guidancematerials best support effectivepedagogy?

STRESSMANAGEMENT BY YOGA
(AUDIT COURSE-II)

CourseObjectives

1.Toachieveoverallhealth of body and mind
2.To overcome stress

Syllabus

Unit	Content	Hours
1	Definitions of Eightpartsofyog. (Ashtanga)	5
2	Yam and Niyam. Do`s and Don't's in life. Ahinsa, satya, astheya, bramhacharyaandaparigraha	5
3	Yam and Niyam. Do`s and Don't's in life. Shaucha, santosh, tapa, swadhyay, ishwarpranidhan	5
4	Asanand Pranayam Various yog poses and their benefits formind& body	5
5	Regularization ofbreathingtechniquesand its effects-Types of pranayam	4

Suggestedreading

1.'YogicAsanasforGroupTarining-Part-I": JanardanSwamiYogabhyasiMandal, Nagpur
2."Rajayogaor conquering the Internal Nature" by Swami Vivekananda, Advaita Ashrama(Publication Department), Kolkata

CourseOutcomes:

Students will be able to:
1. Develop healthy mind in a healthy body thus improving social health also

2. Improve efficiency

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

PERSONALITY DEVELOPMENT THROUGHLIFE ENLIGHTENMENTSKILLS (AUDIT COURSE-II)

CourseObjectives

1.To learn to achievethe highest goal happily
2.To become apersonwithstablemind, pleasing personality and determination
3.Toawakenwisdom in students

Syllabus

Unit	Content	Hours
1	Neetisatakam-Holisticdevelopment of personality Verses-19,20,21,22(wisdom) Verses-29,31,32(pride& heroism) Verses-26,28,63,65(virtue)	4
2	Neetisatakam-Holisticdevelopmentofpersonality Verses-52,53,59(dont's) Verses-71,73,75,78(do's)	4
3	Approach to day-to-dayworkand duties. ShrimadBhagwad Geeta:Chapter2-Verses 41, 47,48,	4
4	Chapter3-Verses 13, 21,27, 35, Chapter6-Verses5,13,17, 23, 35, Chapter 18-Verses 45, 46, 48.	4
5	Statements of basic knowledge. ShrimadBhagwadGeeta: Chapter2-Verses 56, 62, 68 Chapter12-Verses 13, 14, 15, 16,17, 18	4
6	PersonalityofRolemodel.ShrimadBhagwadGeeta:Chapter2-Verses 17, Chapter3-Verses 36,37,42, Chapter4-Verses 18, 38,39 Chapter18– Verses 37,38,63	4

Suggestedreading

1."SrimadBhagavadGita"bySwamiSwarupanandaAdvaitaAshram(PublicationDepartment), Kolkata
2.Bhartrihari'sThreeSatakam(Niti-sringar-vairagya) by P.Gopinath, RashtriyaSanskrit Sansthanam, New Delhi.

CourseOutcomes

Students will be able to
1.StudyofShrimad-Bhagwad-Geetawillhelpthestudentindevelopinghispersonalityand achievethehighest goal in life
2.Thepersonwho has studied Geetawilllead the nation and mankind to peace and prosperity
3.Study of Neetishatakamwillhelpin developing versatile personality of students

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R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81201	CHARACTERIZATION OF NANOMATERIALS (21D81201)	L	T	P	C
Semester	II		3	0	0	3

Objective: To familiarize students with Spectroscopic, Electrical, Thermal and Magnetic Characterization techniques and interpretation of results including standards etc.

Outcome of the study:

1. To evaluate the spectroscopic characterization techniques of nano materials.
2. To compare various compositional and structural characterization techniques.
3. To infer the importance of advanced characterization techniques.
4. Student can able to develop knowledge about various electrical and magnetic characterization technique.
5. Gain overall knowledge of various thermal and magnetic characterization techniques.

Unit-I:
Interaction of electromagnetic spectrum with matter, Spectroscopic Techniques: UV- Visible Spectroscopy, Photo-luminescence Spectroscopy, Mossbauer spectroscopy, Fourier Transform infrared (FTIR) spectroscopy, Raman spectroscopy techniques: micro Raman and laser Raman, SERS (surface enhanced raman spectroscopy).

Unit-II: Compositional and structural Characterization techniques: X-ray Photoelectron Spectroscopy (XPS), Energy Dispersive X-ray analysis (EDAX), Principles and applications of X-ray diffraction; electron diffraction, Electron probe microanalysis (EPMA), Ion beam techniques: SIMS & RBS, BET, PSA and Zeta sizer.

Unit-III: Advanced Microscopy Techniques: High resolution microscopy; Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Atomic force microscopy (AFM), scanning tunneling microscopy (STM).

Unit-IV: Electrical and Magnetic characterization techniques: Measurement of resistivity by 4-prob method, Hall measurement, Electron beam induced current measurement (EBIC), Vibrating Sample Magnetometer, SQUID magnetometer, Impedance analyser.

Unit-V: Thermal and Mechanical characterizationtechniques:Thermal-analysis:TGA,DTA,DSC,DMA; Nanoindentation technique, Micro tensile testing, Micro UTM

Text books:

1. Nano: The Essentials -Understanding Nano Science and Nanotechnology by T.Pradeep, TataMc.Graw Hill
2. Introduction to Nano Technology by Charles. P. Poole Jr and Frank J. Owens, Wiley India Pvt Ltd.

3. A practical approach to X-Ray diffraction analysis by C.Suryanarayana
4. Electron Microscopy and analysis by P.J. Goodhew and F.J. Humpreys
5. Characterization of nanostructured materials by Z.L. Wang
6. Modern Raman Spectroscopy: A practical approach by E. Smith and G.Dent
7. Principles of Instrumental analysis by D.A. Skoog, F.J. Hollen and T.A. Niemann 8. Atomic and Molecular Spectroscopy: Basic Aspects and Applications by S.Svanberg.

Reference Books:

1. Nanotechnology: Principles and Practices – Sulabha K. Kulkarni – Capital Publishing Company
2. Specimen preparation for Transmission Electron microscopy by John &Bravmno et al, published by MRS
3. Photoelectron spectroscopy by JHD Eland, Butterworth & Co. publishers, 2nd education.
4. Encyclopedia of Nanotechnology by H.S. Nalwa

Course Code	21D81202	NANOMATERIALS FOR META-MATERIALS AND NANOPHOTONICS (21D81202)	L	T	P	C
Semester	II		3	0	0	3

Course Outcomes:

1. To make the students acquainted with the concepts of Metamaterials and Nanophotonics.
2. To describe the effects of quantization on the optical properties of semiconductors and metals.
3. To determine the areas of opportunity in nanophotonic research.

UNIT I - FOUNDATIONS FOR NANOPHOTONICS

Photons and electrons: similarities and differences,freespace propagation. Confinementof photons and electrons. Propagation through a classicallyforbidden zone: tunneling. 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.

UNIT II - QUANTUM CONFINED MATERIALS

Inorganic semiconductors, quantum wells, quantum wires, quantum dots, quantum rings. Manifestation of quantum confinement: Optical properties nonlinear optical properties. Quantum confined stark effect. Dielectric confinement effect, superlattices.Core-shell quantum dots and quantum-dot-quantum wells.Quantum confinedstructures as Lasing media.Organic Quantum-confined structures.

UNIT III - PLASMONICS AND METAMATERIALS

Introduction to Plasmonics and Metamaterials-Optical properties of metals - Surface plasmon polariton at metal/dielectric interface- Localized surface PlasmonExtraordinary optical transmission mediated by surface Plasmon-Optical properties ofmetal-dielectric composites-Electric and Magnetic Metamaterials- Negative index metamaterials- Applications of Metamaterials: Super-imaging; Transformation Optics and Invisibility Cloaks.

UNIT IV - PHOTONIC CRYSTALS

Important features of photonic crystals-Presence of photonic bandgap-anomalous group velocity dispersion-Microcavity-effects in Photonic Crystals-fabrication of photonic Crystals-Dielectric mirrors and interference filters-photonic crystal laser-PBC based LEDs-Photonic crystal fibers (PCFs)-Photonic crystal sensing.

UNIT V - NEW APPROACHES IN NANOPHOTONICS

Near Field Optics-Apertureless near field optics-near field scanning optical microscopy (NSOM or SNOM)-SNOM based detection of plasmonic energy transport-SNOM based visualization of waveguide structures-SNOM in nanolithography-SNOM based optical data storage and

recovery-generation of optical forces-optical trapping and manipulation of single molecules and cells in optical confinement-laser trapping and dissection for biological systems.

REFERENCES:

1. Lucas Novotny and Bert Hecht, "Principles of Nano-Optics" ,Cambridge University Press, 2012.
2. Masuhara. H. Kawata. S and Tokunga. F “NanoBiophotoics”, Elsevier Science, 2007.
3. Saleh. B. E. A and Teich. A. C “Fundamentals of Photonics”, John Wiley and Sons, NewYork,1993.
4. Prasad. P. N“Introduction to Biophotonics”, John Wiley and Sons, 2003.
5. Ohtsu. M. Kobayashi. K. Kawazoe. T and Yatsui. T. “Principals of Nanophotonics (Optics and Optoelectronics)” University of Tokyo, Japan, 2003

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R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81203	NANOCOMPOSITES DESIGN AND SYNTHESIS (21D81203) PE – III	L	T	P	C
Semester	II		3	0	0	3

Objective:
This course intended to cover nanocomposites, reinforcing nanostructures dispersed in various matrix materials like polymers, ceramics, metals, etc, The subject covers mainly the synthesis methods, modeling and evaluation of nanocomposites.

Outcome of the study:
1. To synthesize and evaluate nanostructure reinforce matrix material
2. To understand the importance of various nanomaterial matrix
3. To discuss various application including aerospace applications

UNIT – I:
Introduction to Nanocomposites, Composite material, Mechanical properties of Nano composite material: stress – strain relationship, toughness, strength, plasticity.

UNIT – II:
Ceramic-Metal Nanocomposites, Ceramic based nanoporous composite, Metal matrix nanocomposites, Polymer-based nanocomposites Carbon nanotube based nanocomposites an Natural nanobiocomposites, Biomimetic nanocomposites and Biologically inspired nanocomposites.

UNIT – III:
Synthesis methods for various nanocomposite materials: mechanical alloying, thermal spray synthesis etc. Nano composites for hard coatings; DLC coatings; thin film nanocomposites; Modeling of nanocomposites.

UNIT – IV:
Types of indentation: Oliver & Pharr, Vickers indentation process, Nano Indentation by AFM

UNIT – V:
Processing of polymer nanocomposites, properties of nanocomposites, Infiltration techniques, Stir mixing, Extrusion method, Exfoliation & intercalation, Solution casting method, impregnation techniques: Hot melt impregnation, solution impregnation.

REFERENCE BOOKS:
1. Nanocomposite Science & Technology by P.M. Ajayan, L. S. Schadler and P. V. Braun, Wiley-VCH GmbH Co.

2. Introduction to Nano Technology by Charles. P. Poole Jr and Frank J. Owens; Wiley India Pvt. Ltd.
3. Nanotechnology, A gentle introduction to the next big idea by Mark Ratner, Daniel Ratner Pearson education.
4. Polyoxometalate Chemistry for Nano- Composite Design
5. Encyclopedia of Nanotechnology by H. S. Nalwa
6. Encyclopedia of Nano Technology by M. Balakrishnarao and K. Krishna Reddy, Vol I to X Campus books.

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R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81204	NANOCATALYSIS (21D81204)	L	T	P	C
Semester	II	PE – III	3	0	0	3

Objective: The course covers the importance of adsorption principles, various catalyst methods and alternate energy sources.

Outcome of the study:

1. Adsorption isotherms and principle of Catalyst types and ranges will be covered.
2. Various alternate energy sources for environmental protection

Unit–I :

Adsorption phenomenon: Chemisorption &Physisorption, adsorption isotherms and methods of determination of pore size and surface area of materials using the adsorption isotherms, Catalysis – Definition, types of catalysis with suitable examples, characteristics of a catalyst, selectivity or specificity of the catalyst, activation and deactivation of catalysts, catalytic poisoning.

Unit–II :

Necessity for the alternate energy sources and the role of catalytic technology in the energy sector – Fuel cells, Solar cells, Biomass and Biofuels,New trends in heterogeneous catalysis – catalytic sensors, membrane and monolithic reactors.

Unit–III:

Catalysis in environmental protection & green process- Industrial catalytic wet air oxidation processes, water purification, synthesis of speciality, commodity and fine chemicals, catalysis in automobiles : catalytic converter applications.

Unit–IV:

Important catalytic materials – Nanostructured metals like Pt, Pd and Fe, nanostructured ceramics like silica, silicate and alumina, pillared clays, colloids and porous materials (viz. mesoporous materials).

Unit–V:

Mesoporous materials – Introduction, synthesis & characterization, properties and applications (with suitable examples), unipore size, bimodal pore size, graphs., supramolecular chemistry, synthesis (micelar rods).

Text Books & References:

Muller & AK Cheetham

1. Basic principles in applied catalysis – Manfredlaerns
2. Nanotechnology in Catalysis – Pinzhan
3. Introduction to Nanotechnology – Charles P Poole Jr & Frank J Owens

4. Nanoscale Materials –LM Liz Marzan&Prashant V. Kamat
5. Nanostructured catalysts – SL Scott, CM Crudden& CW Jones
6. Concepts of Modern Catalysis & kinetics - I. Chorkendorff, J.W. Niemantsverdriet
7. Chemistry of Nanomaterials: Synthesis, properties & applications, Volume-I – CNR Rao, A

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81205	NANO BIO-TECHNOLOGY-MATERIALS AND DEVICES (21D81205) PE – III	L	T	P	C
Semester	II		3	0	0	3

Objective: The course is intended to cover fundamental terms and basics of biotechnology and building blocks; biological nanostructures, biosensors and biomedical applications of nanotechnology, nanodrugs and drug delivery systems.

Outcome of the study:

1. To familiarize students with biological systems, materials, sensors and building blocks.
2. To familiarize about biomedical applications, nanodrugs, molecular modeling of drugs and drugs delivery systems

Unit–I:
Fundamentals terms in biotechnology, Biological building blocks: Sizes of building blocks and Nanostructures, nucleic acids, genetic code and protein synthesis, Enzymes, DNA double nano wires, protein nanoparticles and polypeptide nanowires .

Unit-II:
Biological Nanostructures: Bio-mimitics with examples, Bio mineralization, Bio compatible Bio sensors, Examples of proteins, micelles, vesicles, bilayers, and Multilayer films, application of bio- nanotechnology: bio nano machines, molecular modeling.

Unit-III:
Nano bio-sensors and biomedical applications, organic semiconductors, biological neurons and their functions, bio-chemical and quantum mechanical computers: DNA computers, parallel processing, Bit and _Q' bit, Quantum parallelism.

Unit-IV:
Biomolecular sensing for cancer diagnostics using carbon nanotubes, nano devices in biomedical applications, nanoscale polymer fabrication for biomedical application, nanotechnology in cancer drug therapy: A bio-computational approach.

Unit-V:
Introduction to drugs, Classification of drugs, Encapsulation of drugs, Nano drug delivery: Conventional drug delivery, targeted drug delivery, chemistry of drug delivery, role of nanotechnology in drug delivery, bio-nanoimaging, magnetic nanoparticles for MR imaging, Magnetic hyperthermia in cancer treatment.

Text books:

1. Bio Nano Technology by Good Sell, Wiley Liss
2. Nanotechnology by John F. Mongillo
3. Introduction to Nanotechnology by Charles. P.PooleJr and Frank J. Owens, Wiley India Pvt Ltd.
4. Nano Technology, A gentle introduction to the next big idea by Mark Ranter and Daniel Ranter,Pearson education
5. Nanotechnology – science, innovation and opportunity by Lynn E Foster, Prentice Hall – Pearson education.
6. Biological and Biomedical nanotechnology by Abraham P.Lee and L.James Lee
7. Biomedical Applications of Nanotechnology by VinodLabhasetwar and Diandra L. Leslie - Pelecky
8. Biomedical Nanostructures by Kenneth E.Gonsalves, Craig R. Halberstadt, Cato T. Laurencin, Lakshmi S.Nair
9. Sensors, Nanoscience, Biomedical, Engineering and Instruments by RichordC.Dorf.

Reference books:

1. Encyclopedia of Nanotechnology by H.S.Nalwa
2. Encyclopaedia of Nanotechnology by M.BalakrishnaRao and K.Krishna Reddy (Vol I to X),

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81205	NANO BIO-TECHNOLOGY-MATERIALS AND DEVICES (21D81205) PE – III	L	T	P	C
Semester	II		3	0	0	3

Objective:
The course is intended to cover Biomedical Application and Drug Delivery, Cell BehaviorToward Nano topographic.

Outcome of the study:
1. Students can able to develop deep understanding of Biomedical Application.
2. Student can able to compile all the Drug Delivery Systems.
3. To know the importance of Cell Behavior Toward Nanostructured Surfaces.
4. To prioritize the role of Orthopedic Interface.
5. To gain the improvements in Tissue Engineering/Regenerative Medicine.
6. To Understand the Nanostructures for Cancer Diagnostics

Unit–I:
Micro/Nanomachining and Fabrication of Materials for Biomedical Applications: Introduction, Overview of Ion Implantation Process, Micro/Nanomachining of Soft Polymeric Biomaterials, Micro/Nanomachining of Hard Metallic Biomaterials, Novel Biocompatible Photoresists, Three-Dimensional Lithography.

Unit–II:
Nanotechnology and Drug Delivery:Introduction, Advantages of Nanostructured Delivery Systems, Activation and Targeting of Nanotechnology-Based Drug Delivery Systems (Externally and Internally), Drug Targeting through Targeting Molecules, Multifunctional Nanoparticle Systems, Exploiting Inherent Material Properties.

Unit–III:
Cell Behaviour Toward Nanostructured Surfaces: Introduction, Nano topographic Surfaces: Fabrication Techniques, Cell Behaviour Toward Nano topographic Surfaces Created by: Electron Beam Lithography, Photolithography,Composed of Aligned Nanofibers by Electrospinning, Nanoimprinting, Self-Assembly,Phase Separation, Colloidal Lithography, Composed of Random Nanofibers, Electrospinning, Chemical Etching, Incorporating Carbon Nanotubes/Nanofibers, Polymer Demixing.

Unit–IV:
MultiscaleCoculture Models for Orthopedic Interface Tissue Engineering: Introduction,Cellular Interactions and the Soft Tissue-to-Bone Interface, Types of Coculture Models, Coculture Models for Orthopedic Interface Tissue Engineering, Macro- and MicroscaleCoculture, Two-

Dimensional (2D) and Three-Dimensional (3D) Cocultures, Mechanism of Cellular Interactions During Coculture

Unit–V:

Nanostructures for Tissue Engineering/Regenerative Medicine: Introduction, Nanofibrous Scaffolds, Surface Patterned Scaffolds, Relevance of Nanostructured Scaffolds in Regenerative Medicine, Role of Nanostructured Scaffolds in Tissue Engineering

Text books:

1. Bio-Medical nanostructures edited by Kenneth Gonsalves, Craig R Halberstadt, Wiley-Interscience A John Wiley & Sons, Inc., Publication
2. Introduction to Nanotechnology by Charles. P.PooleJr and Frank J. Owens, Wiley India Pvt Ltd.
3. Nano Technology, A gentle introduction to the next big idea by Mark Ranter and Daniel Ranter,Pearson education

Reference books:

1. Encyclopedia of Nanotechnology by H.S.Nalwa
2. Encyclopaedia of Nanotechnology by M.BalakrishnaRao and K.Krishna Reddy (Vol I to X).

Course Code	21D81206	NANOFABRICATION TECHNOLOGIES (21D81206)	L	T	P	C
Semester	II	PE – IV	3	0	0	3

COURSE OUTCOMES:

The course provides an in-depth understanding of top-down device fabrication. Focus is the unit processes typically used in micro & nanofabrication of devices. Both concepts and practical aspects are covered. Topics include crystal growth, doping, chemical vapor deposition, physical vapor deposition, photolithography, wet etching, dry etching, and packaging. The course is accessible to students from diverse backgrounds, such as materials, physics, chemistry, mechanical engineering, and electrical engineering.

UNIT – I: Substrate and Cleaning

Introduction to micro-fabrication; Substrate;Introduction to cleanroom; **Additive processing-** Contamination and surface cleaning, Advanced cleaning techniques, Defects, Diffusion, Diffusion -- Advanced Concepts, Ion Implantation.

UNIT – II: Advanced Processing-: Native films

Ion Implantation Contd, Native Films, Native Films: Advanced Concepts, Native Films: Defects at Si/SiO2 interface; **Additive Processing**- Chemical VaporDeposition: Basics, Chemical VaporDeposition: Precursor Transport, Chemical VapourDeposition: Types of CVD Equipment, Chemical VaporDepostion: Nucleation and Growth, Chemical VaporDepostion: Other Details.

UNIT – III:: Material Deposition

Atomic Layer Deposition, Physical Vapor Deposition: Basics, Physical Vapor Deposition: Evaporation, Physical Vapor Deposition: Sputtering, Metallization: Contact resistance, Metallization: Electro-migration and Epilogue, Pattern Transfer Basics, Optical lithography- Contact and Proximity printing, Stepper and Scanner, Projection Lithography: Image formation basics, Image formation in photoresist, Surface Reflection, Mask Technology.Optical Lithography: Resolution enhancement, Electron beam lithography: Basics, Resist process, Emerging lithography techniques

UNIT – IV: Chemical Mechanical Polish Design for Manufacturability

Etching Figures of Merit, Wet etching basics, Wet Ething Recipes, Dry etch: Plasma Basics, Plasma etching basics, Plasma tool configuration, Etch mechanism, Etch chemistry,Chemical Mechanical Polishing (CMP): Basics, Tool and process, Design for Manufacturability, Design for Manufacturability: Case study.

UNIT – V: Nanofabrication Techniques

PV integration,CMOS integration,Lab demo: Silicon Nitride cantilever fabrication-1,Lab demo: Silicon Nitride cantilever fabrication-2, CMOS process for photonics application,E-Beam

Nanofabrication, Epitaxy and Strain Engineering, Scanning Probe Techniques ,Self-Assembly and Template Manufacturing

TEXTBOOKS:

1. **1.**Fundamentals of Microfabrication and Nanotechnology **,By Marc J. Madou**

References:

1. S.A. Campbell: The Science and Engineering of Microelectronic Fabrication (Oxford Univ. Press, New York 2001).
2. C.J. Jaeger: Introduction to Microelectronic Fabrication (Prentice Hall, New Jersey 2002) .
3. J.D. Plummer, M.D. Deal, P.B. Griffin: Silicon VLSI Technology (Prentice-Hall, New Jersey 2000).
4. J.E. Bjorkholm: EUV lithography: the successor to

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81207	INDUSTRIAL TRENDS AND APPLICATIONS OF NANOTECHNOLOGY (21D81207) PE – IV	L	T	P	C
Semester	II		3	0	0	3

Objective:

To provide knowledge of various industrial applications of nanotechnology.

Outcome of the study:

1. To elucidate on advantages of nanotechnology based applications in industries.
2. To provide instances of contemporary industrial applications of nanotechnology.
3. To provide an overview of future technological advancements and increasing role of nanotechnology in Industries.

Unit–I: NANOTECHNOLOGY IN ELECTRONICS AND ENERGY

Miniaturization- Nano electronic devices and circuits – Semiconductor Memories - Dynamic Radom Access Memory- Nonvolatile Semiconductor Memories- Quantum Dot based Memory CellSensors; physical and chemical- Electronic noses- Actuators- Micro and Nano-Electromechanical systems– Lighting and Displays –Quantum optical devices- Lasers – Batteries – Super capacitors- Fuel cells–role of nanomaterials in fuel cell applications- Photovoltaic cells – Application of nanotechnology in solar cellsApplication of power in transportation including space Carbon Nano structures and types of Carbon Nano tubes, growth mechanisms, Mechanical reinforcements, Graphene, Carbon Nano fibers, Carbon clusters, Diamond

Unit–II: NANOTECHNOLOGY IN BIOMEDICAL INDUSTRY

Nanoparticles and Micro–organism- Biosensors- Bioreceptors and their properties – BiochipsIntegratednano-sensor networks for detection and response- DNA based biosensors and diagnosticsNatural nano-composite systems; spider silk, bones, shells - Nanomaterials in bone substitutes and dentistry – Implants and Prosthesis –Tissue Engineering – Neuroscience -Neuro-electronic Interfaces -Nanorobotics– Photodynamic Therapy - Protein Engineering – Nano-sensors in Diagnosis–Drug delivery – Cancer therapy and other therapeutic applications.

Unit–III: NANOTECHNOLOGY IN AGRICULTURE AND FOOD SECTOR

Nanotechnology in Agriculture -Precision farming, Smart delivery systems – Insecticides using nanotechnology – Potential of nano-fertilizers – Potential benefits in Nanotechnology in Food industry – Global Challenges- Product innovation and Process improvement- Consumer benefits-Food processing - Packaging- - Packing materials; physical properties- Improvements of mechanical and barrier propertiesAntimicrobial functionality- Active packaging materials- - Information and communication technologySensors- RF identification- Food safety-Nanomaterial based Food diagnostics – Contaminant detection – Intelligent packaging-Nanoengineered Food ingredients- Potential risks to Nanofood to consumers.

UNIT IV - NANOTECHNOLOGY IN TEXTILES AND COSMETICS

Nanofibre production – Electrospinning and charge injectionmethod – morphological control-yarns and polymidenanofibers- Carbon Nanotube and Nanofibre Reinforced Polymer Fibres-multifunctional polymer nanocomposites- Improvement of polymer functionality- Nylon-6 nanocomposites from polymerization- Dyeable Polypropylene - nanocoatings and surface modifications - Nano-filled polypropylene fibers - UV resistant, antibacterial, self-cleaning, flame retardant textiles – Lightweight bulletproof vests and shirts, Colour changing property, Waterproof and Germ proof, Cleaner kids clothes, Wired and Ready to Wear textiles- Cosmetics; Formulation of Gels, Shampoos, Hair-conditioners– Nanomaterials in Sun-screen UV protection – Color cosmetics

UNIT V - NANOTECHNOLOGY IN DEFENCE AND AEROSPACE

Pathways to Physical protection- Detection and diagnostics of chemical and biological agents, methods- Chemical and Biological counter measures- Decontamination- Post exposure and pre exposure protection and decontamination- Nanotechnology enabled bio chemical weapons- Influence operationsEvasion of medical countermeasures- Nanotechnology based satellite communication system- Guidance, Navigation and control- Spacecraft thermal control- mini, micro, nanosatellite concepts- Fiber optic and Chemical microsensors for space craft and launch support- Micro/Nano pressure and temperature sensors for space missions

Text books and References:

1. Mark. A, Ratner and Daniel Ratner, “Nanotechnology: A Gentle Introduction to the Next Big Idea”, Pearson, 2003.
2. Bharat Bhushan, “Springer Handbook of Nanotechnology”, Barnes & Noble 2004.
3. Neelina. H, Malsch (Ed.), “Biomedical Nanotechnology”, CRC Press 2005.
4. Udo. H, Brinker, Jean-Luc Mieusset (Eds.), “Molecular Encapsulation: Organic Reactions in Constrained Systems”, Wiley Publishers 2010.
5. Jennifer Kuzma and Peter VerHage, “Nanotechnology in agriculture and food production”, Woodrow Wilson International Center, 2006.
6. Lynn. J, Frewer, WillehmNorde. R. H, Fischer and Kampers. W. H “Nanotechnology in the Agri- food sector”, Wiley-VCH Verlag, 2011.
7. Brown. P. J and Stevens. K “Nanofibers and Nanotechnology in Textiles”, Woodhead Publishing Limited, Cambridge, 2007.
8. Mai. Y-W “Polymer Nano composites”, Woodhead publishing, 2006.
9. Chang. W.N “Nanofibres fabrication, performance and applications”, Nova Science Publishers Inc, 2009.
10. Helvajian. H and. Robinson. E.Y “micro and nanotechnology for space systems” the aerospace corporation, Micrograph , 1997.
11. Margaret. E, Kosal, “Nanotechnology for Chemical and Biological defence, Springer 2009.

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81208	SELF-ASSEMBLY OF NANOSTRUCTURES (21D81208)	L	T	P	C
Semester	II	PE – IV	3	0	0	3

Course outcomes:
Extend their knowledge of design of innovative nanostructured materials based on basic chemistry, physics, biology and self-assembly concepts applied to Nano electronics, nanophotovoltaic and energy materials Self-assembly of nanomaterials and their nanohybrids for technological applications

UNIT-I:
Self-organization of nanostructured materials, Growth Mechanism, Self-assembly of Nanostructures: Chemical, physical and biological self-assembly, Assembling and patterning of particles, Self organization of different Nano-morphologies (Quntum Dots, Nanorods, Nanowires and Nanotubes).

UNIT-II:
Self-Assembled Monolayers (SAM), Guided Self Assembly - Nanolithography - Surface Topography - Surface Wetting - Electrostatic force; Nanomanipulators - Grippers – design - gripper arm geometry.

UNIT-III:
Bottom-up manufacturing: bottom-up approach, Self-assembly of single electron transistors, Photovoltaic related devices, Langmuir Bladgett films (LB): principle of formation of monolayer formation – from molecules to nanoparticles, compression of monolayer-fabrication of LB filmsapplications.

UNIT-IV:
Self-Assembly by micro contact printing- creating the stamp, substrate- creating self assembled monolayers -applications, Macroscopic expressions of Natural Nanomaterials- Hierarchical Ordering in Natural Nanoscale Materials.

UNIT-V:
Bio-Inspired Approach for Complex Superstructures and Biological World, Self Assembly in biological systems: Superhydrophobicity, Self cleaning property, Multi scale ordering and function in Biological Nanoscale Materials: Proteins, Lipids, DNA and RNA and Shell as a Composite Materials.

REFERENCE BOOKS:
1. Self OrganizedNanoscale Materials: Nanostructure Science and Technology by Motonari Adachi and David J. Lockwood, 2006 Springer Science, Business Media, Inc. NY, USA

2. Self-Assembled Nanostructures: Jin Z. Zhang, Zhong-lin Wang, Jun Liu, Shaowei Chen, and Gang-yu Liu, 2003 Kluwer Academic/Plenum Publishers, NY, USA
3. Nanoparticles: Theory to Applications by Günter Schmid, 2010 WILEY-VCH Verlag GmbH & Co. KGaA, Boschstr. 12, 69469 Weinheim.
4. Hand Book of Nanotechnology, by Bharat Bhushan, 2007, Springer Science+Business Media, Inc, NY, USA.
5. Prospects in Nanotechnology: Toward Molecular Manufacturing, Markus Krummenacker and James Lewis (Editors), Wiley 1995.

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81209	FABRICATION AND CHARACTERIZATION LABORATORY (21D81209)	L	T	P	C
Semester	II		0	0	3	2

Objective: The course is intended to cover basic preparation methods of nanomaterials

The outcome of the study is:

1. Gain knowledge on the synthesis techniques involved in experiments.
2. Students can acquire knowledge on equipment handling like XRD, PSA, UV etc.
3. To construct a theoretical knowledge on the experiment.
4. The ability to write and present the laboratory reports.
5. To maximize knowledge regarding synthesis and characterization of nanomaterials.

PART-A: fabrication

1. 1.Fabrication of thin film by Dip coating
2. Fabrication of thin film by Spin coating
3. Fabrication of thin film by Spray Pyrolysis

Part B- CHARACTERIZATION

1. Verification of BEER-LAMBERT‘s law using Colorimeter
2. Conductometry
3. Preparation of Cobalt nanoparticles by wet chemical reduction method
4. Synthesis of CuO nanoparticles using Glycine as fuel by Solution combustion method
5. Synthesis of ZnO nanoparticles using Ascorbic acid as fuel by Solution combustion Method
6. Synthesis of MgO nanoparticles using Glycine as fuel by Solution combustion method
7. Synthesis of Fe2O3 nanoparticles using Glycine as fuel by Solution combustion method
8. Synthesis of silica gel (SiO2) using Sol-Gel method
9. Synthesis of PVP capped Cadmium Sulfide (CdS) nanoparticles by chemicalCoprecipitation Method
10. Synthesis of oxide nanoparticles by using Multifuel solution combustion method
11. Synthesis of oxide nanoparticles by using Multioxidizer solution combustion method
12. Synthesis of colloidal copper nanoparticles by chemical reduction method

13. Synthesis of the silver nanoparticles by using green synthesis from ociumsantum
14. Synthesis of the copper oxide nanoparticles by using green synthesis from Aloe vera
15. Determination of average crystalline size and microstarin by using X-Ray diffraction Analysis.
16. Determination of average particle size and zeta potential by using Dynamic light scattering.
17. Synthesis of Graphene oxide by using hummers method
18. In-house Chemical sensor testing unit for detection of poisonous and flammable gases
19. Antibacterial applications
20. Seed germination using nanomaterials.

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DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81210	NANOMATERIALS APPLICATION LABORATORY (21D81210)	L	T	P	C
Semester	II		0	0	3	2

1. Synthesis and characterization of graphene oxide (GO) and reduced graphene oxide (RGO) for electrochemical hydrogen storage fuel cell, sensors or solar cell applications.
2. Wide-band-gap semiconductor nano-materials for application in environmental cleaning, optoelectronic devices, nano-phosphors and nano-ferrites.
3. Synthesize pure and doped semiconductor wide-band-gap nano-materials, viz. ZnS, ZnO, CdS, TiO2 and metallic nano-particles, using chemical co-precipitation technique, solgel and chemical reduction method.
4. Synthesized nano-materials are characterized for their photocatalytic activities, as drug carriers, and for their antibacterial activities.

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81301	MEMS AND NEMS (PE – V)	L	T	P	C
Semester	III		3	0	0	3

SEMESTER-3
NT- 301a.:

NT-301b.:NANOSENSORS, DETECTORS AND THEIR APPLICATIONS

Unit-I: SENSORCHARACTERISTICS AND PHYSI CAL EFFECTS:

Active andPassivesensors– Static and dynamic characteristics - Accuracy, offset and linearity - First and second order sensors – Physical effects involved insignaltransduction- Photoelectric and Photo dielectric effect – Photoluminescence–Electroluminescence – chemiluminescenceeffect– Doppler effect – Barkhauseneffect – Hal effect – Ettinshauseneffect – Thermoelectric effect – Peizoresistiveeffect– Piezoelectric effect – Pyroelectric effect – Magneto-mechanical effect (magnetostriction) – Magneto resistiveeffect.

Unit-II:**NANO BASEDINORGANIC SENSORS:**

Density ofstates (DOS) – DOS of 3D, 2D, 1D and 0D materials – one dimensional gas sensors:- gas sensing with nanostructured thin films – absorption on surfaces – metal oxide modifications by additives – surface modifications – nanooptical sensors – nano mechanical sensors – plasmonresonance sensors with nanoparticlesAMR, Giant and colossal magneto resistors – magnetic tunnelingjunctions.

Unit-III: **THERMALSENSORS:**

Thermal energy sensors -temperature sensors, heat sensors- Electromagnetic sensors- electrical resistance sensors, electrical currentsensors, electricalvoltagesensors, electrical power sensors, magnetism sensors - Mechanical sensors -pressure sensors, gas and liquid flow sensors, position sensors - Chemical sensors - Optical and radiation sensors.

Unit-IV:**ORGANIC /BIOSENSORS**:

Structure of Protein –role of protein innanotechnologyusingproteinin nanodevices– antibodies in sensing – antibody in nanoparticle conjugates – enzymes insensing– enzyme nanoparticle hybrid sensors – Motor proteins in sensing – transmembrane sensors. Nanosensors based on Nucleotides and DNA – Structure of DNA – DNA decoders and microarrays – DNA protein conjugate based sensors – BioelectronicsensorsDNAsequencing with nanopores– sensors based on molecules with dendritic architectures–biomagnetic sensors.

Unit-V :SENSORDE TE CTORS AND APPLICATIONS:

Cantilever array sensors –fordiagnosisof diabetes mellitus and cancer diagnosis - Nanotube based sensors - for DNA detectionandcapnography- Nanowire based sensors - Nanowire based electrical detection of single viruses - Nanowire based electrical detection of biomolecules. Bio receptors–Bio detectors - Nano array based detector - Nano Particle based detector - Ultra-sensitive detection of pathogenic biomarkers - Ultra-sensitive detection of singlebacteria.

Text Books & References:

1. KouroshKalantar– Zadeh, Benjamin Fry, "Nanotechnology- Enabled Sensors", Springer,2008
2. H.RosemaryTaylor, "Data acquisition for sensor systems", Chapman & Hall,97.
3. Jerome Schultz, Milan Mrksich, Sangeeta N. Bhatia, Dav J. Brady, Antonio J. Ricco, David R. Walt, Charles L. Wilkins, "Biosensing: International Research and Development", Springer, 2006
4. Ramon Pallas-Areny, John G. Webster, "Sensors and signal conditioning" John Wiley & Sons, 2001.
5. Vijay.K.Varadan, Linfeng Chen, Sivathanupillai, "Nanotechnology Engineering in Nano and Biomedicine", John Wiley & Sons, 2010.
6. W. Ranier, "Nano Electronics and Information Technology", Wiley, (2003).
7. K.E. Drexler, "Nano systems", Wiley, (1992). 6. M.C. Pettey, "Introduction to Molecular Electronics".

NT-301c.: Carbon nanotubes and applications

Unit-I: Carbon Nano structures and types of Carbon Nano tubes, growth mechanisms. Synthesis of CNTs by Flame, CVD, Laser & Arc-discharge process.

Unit-II: Mechanical reinforcements, Solid Disordered carbon Nanostructures, Nano structured crystals. Graphene,Carbonnanofibers. Electrical, Vibrational, Mechanical Properties of CNTs, optical properties & Raman spectroscopy of CNTs

Unit-III: Carbon clusters and Fullerenes.

Unit-IV: Lithium & Hydrogen adsorption & storages. Fuel cell applications and energy storage, Chemical Sensors applications of CNTs.

Unit-V: Computer applications (Nano chip), optical and telecommunication applications, Nano composites, silicon Nanowires.

TEXT BOOKS:

1. Introduction to Nanotechnologyby Charles P.Poole and Frank J.OwensWiley IndiaPvtLtd.
2. Nanotechnology and Nano Electronics – Materials, devices and measurement techniques by WR Fahrner, Springerpublications

REFERENCE BOOKS:

1. Encyclopediaof Nanotechnology by M.Balakrishnaraoand K.KrishnaReddy, VolI to X Campusbooks.
2. Encyclopedia of Nanotechnology by HSNalwa
3. Nanotechnology –science, innovation and opportunity by Lynn E.Foster.Hall Pearsoneducation.
4. Nano:TheEssentials – Understanding Nano Scineceand Nanotechnology by T.Pradeep; Tata Mc.GrawHill

1. Jerome Schultz, Milan Mrksich, Sangeeta N. Bhatia, Dav J. Brady, Antonio J. Ricco,David R. Walt, Charles L. Wilkins, “Biosensing: International Research and Development”, Springer, 2006

2. Ramon Pallas-Areny, John G. Webster, “Sensors and signal conditioning” John Wiley &Sons, 2001.

3. Vijay.K.Varadan, LinfengChen, Sivathanupillai, “Nanotechnology Engineering in Nano and Biomedicine”, John Wiley &Sons, 2010.W. Ranier, “Nano Electronics and Information Technology”, Wiley,(2003).

5. K.E. Drexler, “Nano systems”, Wiley,(1992).
6. M.C. Pettey, “Introduction to MolecularElectronics”.

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D81301	MEMS AND NEMS (PE – V)	L	T	P	C
Semester	III		3	0	0	3

UNIT-I
Development of microelectronics - Region of Nanostructures - methods and limits on microminiaturization in semiconductors- micro electro mechanical systems.

UNIT-I I
Silicon micromachining- semiconductors and insulators - Microsystems fabrication techniques - Silicon MEMS fabrication technology - Single crystal reactive etching and metallization process.

UNIT-III
Non-silicon MEMS and fabrication techniques - SIC MEMS - Biomedical-MEMS techniques - Integration of microsystems with electronics – RF MEMS – Applications.

UNIT-IV
Polymers in Microsystems - Packaging of MEMS devices by anodic/fusion bonding - Pressure sensors and packaging - MEMS performance and evaluation.

UNIT-V
Nano electro mechanical systems - fabrication and process techniques - integration of nanosystems and devices - applications and future challenges.

TEXT BOOKS & REFERENCES:

1. W.R.Fahrner, “Nanotechnology and Nanoelectronics: Materials, Devices, Measurement Techniques”, Springer, 2005.
2. K.Goser, P.Glosekotter&J.Dienstuhl, “NanoelectronicNanosystems – From Transistors to Molecular Quantum Devices” Springer, 2004.
3. S. E. Lyshevski, “MEMS and NEMS: Systems, Devices and Structures”, CRC Press, 2002.
4. Gregory Timp, “Nanotechnology”, Springer, 1999.
5. Vijay K Varadan, K J Vinoy, S Gopalakrishnan, “Smart Material Systems and MEMS: Design and Development”, John Wiley &Sons, 2006

R21 COURSE STRUCTURE &SYLLABUS FOR M.TECH COURSES
DEPARTMENT OF CHEMICAL ENGINEERING
(NANO TECHNOLOGY)

Course Code	21D80301	INTRODUCTION TO NANOSCIENCE AND NANOTECHNOLOGY (OPEN ELECTIVE)	L	T	P	C
Semester	III		3	0	0	3

UNIT – I:
Introduction to Quantum Mechanics; Schrodinger equation and expectation values, Solutions of the Schrodinger equation for free particle, particle in a box, particle in a finite well, Reflection and transmission by a potential step and by a rectangular barrier.

UNIT – II:
Angular momentum and its operators, Eigen values and Eigen functions of the angular momentum operators, spin, Pauli spin operators and their properties, hydrogen atom, density of states, free electron theory of metals.

UNIT – III:
Confinement and Transport in nanostructure, Current, Reservoirs and Electron channels, Conductance formula for nanostructures, Quantized conductance. Local density of states. Ballistic transport, Coulomb blockade, Diffusive transport, Fock space.

UNIT – IV:
Statistical Mechanics, Microstates and entropy and its statistical definition, Entropy of mixing, Gibb's free energy, Gibb's paradox, phase space density, ergodic hypothesis, Liouville's theorem, The microcanonical-, canonical- and grand canonical- ensemble and their connections, Fluctuations, Classical Statistical systems, Boltzman statistics, and quantum statistical systems, Fermi-Dirac and Bose-Einstein Statistics and their applications.

UNIT – V:
Electronic Properties: Free electron theory of metals, Band theory of solids, Bloch theorem, Kroning-Penne model, Metals and Insulators, Semiconductors: Classification, Transport properties, Size and Dimensionality effects, Band structures, Brillouin zones, Mobility, Resistivity, Relaxation time, Recombination centers, Hall effects. Optical Properties, Photoconductivity, Optical absorption & transmission, Photoluminescence, Fluorescence, Phosphorescence, Electroluminescence.Magnetic Materials: Basic Magnetic Phenomena; Diamagnetism, Paramagnetism, Ferromagnetism, Ferrimagnetism, Anti-ferromagnetism, Some examples of these materials and their applications, RKKY Interactions, Ferrofluids, Introduction to superconductivity; London Equation and Josephson effect.

TEXT BOOKS:
1. Quantum Physics – A. Ghatak
2. Quantum Mechanics - Bransden and Joachen
3. Statistical Physics by K. Huang
4. Statistical Mechanics-Landau &Lifshitz

5. Quantum wells, Wires &Dots,: Theoretical & Computational Physics of Semiconductors Nanostuructures, Paul Harrison
6. Principles of Quantum Mechanics 2nd ed. - R. Shankar
7. Thermodynamics and Statistical Mechanics - A N Tikhonov, Peter T Landberg, Peter Theodore Landsberg
8. Thermodynamics and Statistical Mechanics by John M. Seddon , J. D. Gale
9. Statistical Mechanics – Sonntag.
10. Statistical Mechanics – Mc Le Leland