SCHOOL OF NANOTECHNOLOGY

COURSE STRUCTURE & SYLLABUS

M.Tech. NANOTECHNOLOGY PROGRAMME

(Applicable for batches admitted from 2025-2026)

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA

I -SEMESTER

S.No	Course Code	Course Title		L	T	P	C
1	NT 101(Core-1)	Introduction to Nano Materials		3	1	0	4
2	NT102 (Core-2)	Synthesis of Nano Materials		3	1	0	4
	NT 103 (Core-3)	Nano Material Characterization Techniques		3	1	0	4
3	Program Elective – I NT 104	NT 1041	Thin Film Science & Technology	3	0	0	3
		NT 1042	Nano Materials for Energy Systems				
		NT 1043	Nano Photonics				
		NT 1044	Societal Impact of Nanotechnology				
4	Program Elective – II NT 105	NT 1051	Nano Fluidics	3	0	0	3
		NT 1052	Nanoscopic Dielectric Materials and Battery Applications				
		NT 1053	Carbon Nanostructures and Application				
		NT 1054	Surface Engineering of Nanomaterials				
5	NT 106	Nanomaterials Synthesis Lab		0	1	2	2
6	NT 107	Nanomaterials Simulation Lab		0	1	2	2
7	NT 108	Seminar I		0	0	2	1
		Total		**15**	**5**	**6**	**23**

II –SEMESTER

S. No	Course Code	Course Title		L	T	P	C
1	NT 201 (Core-1)	Nano Composites and Applications		3	1	0	4
2	NT 202 (Core-2)	Nano Sensors and Applications		3	1	0	4
	NT 203 (Core-3)	Nanoelectronics		3	1	0	4
3	Program Elective– III NT 204	NT 2041	Nanoscale Magnetic Materials and Devices	3	0	0	3
		NT 2042	Colloid and Interface Science				
		NT 2043	Computational Nanotechnology				
		NT 2044	Nano Plasmonics				
4	Program Elective– IV NT 205	NT 2051	Biomedical Nanotechnology	3	0	0	3
		NT 2052	MEMS and NEMS				
		NT 2053	Multifunctional Nanomaterials				
		NT 2054	Nanoscopic Ferroelectric Materials and Applications				
		NT2055	Introduction to Quantum Technologies				
5	NT 206	Nanomaterials Characterization Lab		0	1	2	2
6	NT 207	Advanced Nanotechnology Lab		0	1	2	2
7	NT 208	Seminar II		0	0	2	1
		Total		**15**	**5**	**6**	**23**

Note: Students are informed to complete Summer Internship (duration 8-10 weeks) at the end of the II Semester.

M. Tech (NANO TECHNOLOGY)

III- SEMESTER

S. No	Course Code	Course Title	L	T	P	C
1		Research Methodology and IPR/Swayam 12 Week MOOC Course RM&IPR	3	0	0	3
2		Summer Internship/Industrial Training (8-10 Weeks)	-	-	-	3
3		Comprehensive Viva	-	-	-	2
4		Dissertation Part - A	-	-	20	10
TOTAL			3	-	20	18

IV –SEMESTER

S. No	Course Code	Course Title	L	T	P	C
1		Dissertation Part - B	-	-	32	16
TOTAL			-	-	32	16

I Semester	INTRODUCTION TO NANO MATERIALS	L	T	P	C
		3	1	0	4

Objective:

This course covers basic concepts of crystallography, quantum mechanics, matter and energy relations, deBroglie hypothesis, Schrodinger wave equation, quantum dot, wires and wells etc.

Outcome of the study:

1. Student can assess different types of chemical bonding in materials
2. Student can grasp the importance of crystal structure on physical and mechanical behavior of materials
3. To evaluate nanostructures on quantum mechanical basis.
4. Students would be able to distinguish between classical electromagnetic theory and Quantum Mechanics.

Pre-requisites: Basics of Physics, Chemistry and Quantum Mechanics.

Unit-I: Introduction to Nanomaterials definitions: zero, one, two and three dimensional nanostructures; Basics of Chemistry: Chemical bonding, Hybridization, Reduction potentials. Crystal structure: crystalline and amorphous solids; crystal lattice and crystal structure; transitional symmetry; space lattice, Unit cell and primitive cell, symmetry elements in crystals crystal systems, Miller indices, Miller Bravais indices, indices of a lattice direction and planes; the inter planar spacing of a set of crystal planes.

Unit-II: Reciprocal lattice and crystal imperfections: Concept of a reciprocal lattice, Properties of Reciprocal lattice of SCC, BCC and FCC, Bragg's law in Reciprocal lattice, diffraction conditions, Brillouin zones. Some imperfections in crystals, Importance of lattice imperfections types of imperfections-Point defects and dislocations.

Unit-III: Introduction to quantum mechanics: Matter waves, De-Broglie hypothesis, wave particle duality, Heisenberg's uncertainty principle, Schrodinger wave equation, general postulates of Quantum mechanics, particle in one dimensional box. Particle in 2D and 3D Box, Bloch Theorem, Band theory of solids.

Unit-IV: Electronic, Optical and Magnetic properties**:** Energy bands and gaps in semiconductors, Fermi surfaces, localized particles, donors, acceptors, deep traps, exactions, mobility, size dependent effects, conduction electrons and dimensionality, Fermi gas and density of states, Examples of semiconducting nanoparticles. Optical properties of semiconductors, band edge energy, band gap dependence on nanocrystalline size, luminescence. Introduction of magnetic materials, basics of ferromagnetism, magnetic clusters, dynamics of nanomagnets, nanocarbon ferro magnets, ferro fluids.

Unit-V: Applications: Nanomaterials in environment, nanoparticles in air, water and soil. Nanomaterials in Healthcare and case studies (Nano enabled Covid 19 recognition).

Textbooks:

1. An introduction to solid states electronic devices by Ajay Kumar Saxena Macmillan India Ltd {Unit-I, II}
2. Solid state Physics by Kittle {Unit-I,II}
3. P.M. Mathews and K.Venkatesan “A text book of Quantum Mechanics”, Tata McGrawHill Publishing Company Ltd {Unit-III}
4. Quantum Mechanics–Schiff{Unit-III}
5. Quantum Mechanics by B.K Agarwal and Hariprakash, PHI{Unit-III}
6. Fundamentals of nanoelectronics by George W.Hanson Pearson education {Unit-IV,V}

Reference Books:

1. Quantum Mechanics by Brandsen & Joachem
2. J.J.Sakurari, “Modern Quantum Mechanics Mc.Graw Hill, Addison Wesley Longman Inc., USA, 1999
3. Nanotechnology and nanoelectronics materials devices and measurement techniques by WR Fahrner Springer.

I Semester	SYNTHESIS OF NANO MATERIALS	L	T	P	C
		3	1	0	4

Objective: To make students know about physical, chemical and biological methods of synthesis of nanomaterials and bring out the distinct properties like electronic, magnetic, and optical properties of nanostructures.

Outcome of the study:

1. To develop knowledge about the electronic properties of semiconductor devices.
2. To construct the magnetic properties of bulk nanostructured materials.
3. To visualize the effect of optical properties of various materials
4. Students can acquire knowledge based on the physical, chemical and biological methods of synthesis of nanomaterials.

Pre-requisite:

1. Familiarization on energy band gap.
2. Basic of physics, chemistry and mechanics of solids.

Unit-I: Introduction to synthesis of nanostructure materials, bottom-up approach and top-down approach with examples, stabilization techniques, electrostatic and steric stabilizations. **Physical methods:** Inert gas condensation, arc discharge, RF plasma, plasma arc technique, electric explosion of wires.

Unit-II: **Chemical methods:** chemical kinetics, Gibbs free energy, thermodynamics, thermolysis route spray pyrolysis and solvated metal atom dispersion, sol-gel method, solvo thermal and hydrothermal routes, solution combustion synthesis, chemical vapour synthesis.

Unit-III: Advanced Chemical Techniques: Nanocrystals by chemical reduction, photochemical synthesis, electro chemical synthesis; nanocrystals of semiconductors and other materials by arrested precipitation, emulsion synthesis, and sonochemical routes.

Unit-IV: **Nanosynthesis by Mechanical Methods:** Introduction-Different Severe plastic deformation Techniques-Importance, Equi Channel Angular Extrusion (ECAE)-Die design, effect of die-angle on grain refinement,equi-channel angular rolling(ECARE)-die-design effect of die angle on grain refinements. Advantages of ECAR over ECAE. Advantages and limitations of SPD nanosynthesis over other techniques,Ball milling.

Unit-V: Biological Methods: Use of bacteria, fungi, actinomycetes for nanoparticle synthesis, magneto-tactic bacteria for natural synthesis of magnetic nanoparticles,Green synthesis.

Textbooks:

1. Inorganic Materials Synthesis and Fabrication by J.N. Lalena, D.A. Cleary, E.E. Carpenter, N.F.Dean John Wiely & Sons Inc.
2. Introduction to nano technology by Charles P. Poole Jr. and Frank J. Owens. Wiley India Pvt Ltd.
3. The Chemistry of nanomaterials: Synthesis, Properties and Applications,Vol-IbyC.N.R. Rao, A. Muller and A.K. Cheetham

Reference Books:

1. Encyclopedia of Nanotechnology by M. Balakrishna Rao and K.Krishna Reddy, Vol I to X, Campus books.
2. Encyclopedia of Nanotechnology by H.S.Nalwa
3. Nano:The essentials understanding nanoscinece and nanotechnology by T.Pradeep, Tata Mc.Graw Hill.

I Semester	NANO MATERIAL CHARACTERIZATION TECHNIQUES	L	T	P	C
		3	1	0	4

Objective:
To familiarize the students with compositional, structural, morphological, spectroscopic, electrical, thermal and magnetic characterization techniques of materials at the nanoscale and interpretation of results including standards etc.

Outcome of the study:

1. To evaluate the spectroscopic characterization techniques of nanomaterials.
2. To compare various compositional and structural characterization techniques.
3. To infer the importance of advanced characterization techniques.
4. Student can develop knowledge about various electrical, magnetic and thermal characterization techniques.
5. Gain overall knowledge of various mechanical characterization techniques.

Pre-requisite:

1. Basics of band gap, electrical, thermal and magnetic and mechanical behaviour of materials.
2. Mechanics of solids, metallurgy & materials science and spectroscopic techniques.

Unit-I: Compositional Analysis: X-ray Photo electron spectroscopy (XPS), Energy Dispersive X ray Analysis (EDX), Inductively Coupled Plasma Optical Emission Spectroscopy (ICPOES), Electron Probe Micro Analysis (EPMA).
Structural Analysis: X-ray Diffraction (XRD), Electron Diffraction.

Unit-II: Micro structural characterization techniques:
Surface: Scanning Electron Microscopy (SEM),Atomic Force Microscopy (AFM), Scanning Tunneling microscopy(STM).
Bulk: Transmission Electron Microscopy(TEM), High Resolution Electron Microscopy(HREM).
Surface area measurements: Adsorption principle Freundlich, Langmuir, and BET methods of measurement.

Unit-III: Optical and Molecular Structural Ananlysis: UV-Visible Spectroscopy,Fourier Transform infrared (FTIR) spectroscopy, Raman spectroscopy techniques: micro Raman and laser Raman.

Unit-IV: Electrical characterization techniques: Measurement of resistivity by 4-probe method, Hall measurement, See beck coefficient measurements, electron beam induced current measurement (EBIC),impedance and ferroelectric measurements.

Unit-V: Magnetic,Thermal and Mechanical characterizations: Vibrating Sample Magnetometer (VSM), Thermal analysis – TG/DTA, DSC, and TMA. UTM, Vickers, Rockwell hardness testers, fatigue and Creep testing machines, Nanoindentation techniques.

Text Books:

1. Characterization of Nanostructured Materials by Z LWang
2. Introduction to Nanotechnology by Charles P Poole Jr and Frank J Owns Wiley India Pvt Ltd.
3. Nano:The Essentials Understanding NanoScience and Nanotechnology by T. Pradeep, Tata Mc.Graw Hill
4. Principles of Instrumental Analys is by D A Skoog FJ Hollen and T A Niemann
5. A Practical Approach to X-Ray Diffraction Analysis by C Suryanarayana

Reference Books:

1. Nanotechnology: Principles and Practices Sulabha K Kulkarni Capital Publishing Company
2. Specimen preparation for transmission eelectron microscopy by John & Bravmno etal, published by MRS
3. Photoelectron spectroscopy by JHD Eland, Butterworth &Co.Publishers,2^{nd}edition
4. Encyclopedia of nanoscience and nanotechnology by HS Nalwa
5. Electron Microscopy and Analysis by P J Goodhew and F J Humpreys
6. Scanning Electron Microscopy and X-ray Microanalysis by J I Goldstein
7. Modern Raman Spectroscopy: A Practical approach by E Smith and G Dent.

I Semester	THIN FILM SCIENCE AND TECHNOLOGY	L	T	P	C
		3	0	0	3

Objective:
This course brings out the importance of thin film technology and nanofabrication, vacuum technology, various physical and chemical methods of thin film fabrication and various applications of thin films including sensors.

Outcome of the study:

1. To develop deep understanding on vacuum technology.
2. To compile all the conditions for formation of thin films
3. To know the importance of Physical Vapor Deposition techniques.
4. To prioritize the role of electrical discharges used in thin film deposition
5. To improve the understanding of deposition using CVD.

Pre-requisite:

1. Vacuum pump technology.
2. Basics of vacuum pump technology, Pirani and penning gauge technology.

UNIT-I: Vacuum technology: clean room, clean room technology and its Classes. Principles of vacuum pumps for creating vacuum in the range of 10^{-2} Torr to10^{-11} Torr, principles of different vacuum pumps: roots pump, rotary, oil diffusion pump, turbo molecular pump, cryogenic-pump, ion pump,Ti- sublimation pump, importance of measurement of vacuum, concept of different gauges: Bayet Albert gauge, Pirani,Penning and pressure control.

UNIT–II: Conditions for the formation of thin films: Environment for thin film deposition, deposition parameters and their effects on film growth, formation of thin films (sticking coefficient, formation of thermo-dynamically stable cluster theory of nucleation), capillarity theory, micro-structure in thin films, adhesion, properties of thin films: mechanical, electrical and optical properties of thin films, few applications of thin films in various fields, thermo mechanical behavior of thin film nanostructures.

UNIT-III: Physical vapour deposition techniques: Thermal evaporation, resistive evaporation, electron beam evaporation, laser ablation, flash and cathodic arc deposition.

UNIT –IV: Electrical discharges used in thin film deposition: Sputtering, Glow discharge sputtering, Magnetron sputtering, Ion beam sputtering, R.F sputtering, Triode sputtering, Ion Plating, Difference between thin films and coating.

UNIT-V: Electro deposition, molecular beam epitaxy and laser pyrolysis. Chemical vapour deposition techniques: Advantages and disadvantages of cchemical vapour deposition (CVD) techniques over PVD techniques, reaction types, boundaries and flow, different kinds of CVD techniques: Metal Organic CVD (MOCVD), Thermally activated CVD, CVD Spray pyrolysis, etc.

Text Books

1. Thin film pphenomenon by K.L. Chopra, McGraw-Hill

References

1. Methods of Experimental Physics(Vol14) by G.L. Weissler and R.W. Carlson "Vacuum Physics and Technology"
2. A User's Guide to vacuum technology by J.F.O Hanlon, John Wiley and Sons
3. Vacuum Physics and Techniques by T.A. Delchar Chapman and Hall Evaporation: Nucleation and Growth Kinetics by J. P. Hirth and G.M. Pound, Pergamon Press

I Semester	NANO MATERIALS FOR ENERGY SYSTEMS	L	T	P	C
		3	0	0	3

Objective:
The course covers various energy forms, alternate and renewable energy system using nanotechnology.

Outcome of the study:

1. Study the basic energy need and role of battery materials
2. To up grade the knowledge of super capacitors and it's aapplications.
3. Study the role of nanostructured material to meet energy challenges.
4. Learn about the concept of hydrogen storage technology.
5. Gain knowledge on role of fuel cell technology.
6. Gain knowledge on micro-fluidic Technology.

Pre-requisite:
Different technologies like renewable energy technology, super capacitors and hydrogen storage technology.

Unit-I: Battery materials and batteries: Renewable energy Technology: Energy challenges, nanomaterials and nanostructures in energy harvesting, developments and implementation of nanotechnology based renewable energy technologies, Lithium ion based batteries. solar cell structures: quantum well and quantum dot solar cells, photo thermal cells for solar energy harvesting, Thin film solar cells, CIGS solar cells, Die sensitized solar cells.

Unit-II: Nanomaterials used in energy and environmental applications and their properties: Evaluation of properties and performance of practical power systems that benefit from optimization of materials processing approaches.

Unit-III: Hydrogen storage Technology: Hydrogen production methods, purification, hydrogen storage methods and materials: metal hydrides and metal-organic framework materials, volumetric and gravimetric storage capacities, multiple catalytic degradation of sorption properties, automotive applications. Green Hydrogen-Production, Purification, Storage and Applications.

Unit-IV: Fuel cell Technology: Fuel cell principles, types of fuel cells (Alkaline Electrolyte, Phosphoric acid, Molten Carbonate, solid oxide and direct methanol and Proton exchange fuel cells), Principle and operation of Proton Exchange Membrane (PEM) fuel cell, Materials and fabrication methods for fuel cell technology, micro fuel cell power sources, bio-fuels,Methane Hydrate as a fuel.

Unit-V: Micro fluidic Technology: MEMS & NEMS technology for microfluidic devices: micro and nano engines and driving mechanism, power generation, micro channel battery pump (TCP), piezoelectric membrane and their applications.

Text Book

1. Renewable Energy Resources by J. Twidell and T.Weir, E & F .N. Spon.Ltd.

References

1. Hydrogen from Renewable Energy Source by D. Infield
2. .Fundamentals of Industrial Catalytic Process by C.H. Bartholomew and Robert J. Farraoto, John Wiley & Sons Inc.
3. Fuelstorage on Board Hydrogen storage in Carbon Nanostructures by R.A. Shatwell
4. Fuel cell Technology Handbook by Hoogers CRC Press
5. Hand book of fuel cells: Fuelcell technology and applications by Vielstich Wiley: CRC Press

I Semester	NANO PHOTONICS	L	T	P	C
		3	0	0	3

NT- 1043
Objective:
The course is intended to cover basics of photonics and their applications.

Outcome of the study:
1. To extend the knowledge on Nanophotonics .
2. To study about quantum confined materials, photonic crystals and Nanophotonic devices.

Pre-requisite:
1. Basics of physics and chemistry

Unit-I: Foundations of Nanophotonics: Photons and electrons: similarities and differences, Free space propagation, Confinement of photons and electrons, propagation through a classically forbidden 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: Quantum confinement effects, nanoscale interaction dynamics, nanoscale electronic energy transfer, cooperative emissions.

Unit-II: Quantum Confined Materials: Inorganic semiconductors, quantum wells, quantum wired, quantum dots, quantum rings. Manifestation of quantum confinement: Optical properties nonlinear optical properties. Quantum confined stark effect, dielectric confinement effect, super lattices, core-shell quantum dots and quantum-dot-quantum wells, quantum confined structures as lasing media.

Unit-III: Photonic Crystals: Basics Concepts, Features of Photonic Crystals, wave propagation, photonic band gaps, light guiding, theoretical modeling of photonic crystals, methods of fabrication, photonic crystal optical circuitry, Nonlinear PhotonicCrystals, Photonic Crystals and Optical Communications. Application to high efficiency emitters miniaturized photonic circuits and dispersion engineering; Photonic Crystal Sensors – Microstructure Fiber applications.

Unit-IV: Nanophotonic Devices: Resonant cavity quantum well lasers and light-emitting diodes,, Fundamentals of Cavity QED, strong and weak coupling regime, Purcell factor, Spontaneous emission control, Application of microcavities, including low threshold lasers, resonant cavityLED, Microcavity-based single photon sources.

Unit-V: Plasmonics:Metallic nanoparticles, nanorods and nanoshells, local field enhancement, collective modes in nanoparticle arrays, particle chains and arrays, Classification of different types of surface plasmons, Plasmon Waveguides, Applications of Metallic Nanostructures, meta materials.

Text Books:

1. Nanophotonics Paras N.Prasad John Wiley & Sons(2004)

References:

1. Photonic Crystals:TowardsNanoscale Photonic Devices JeanMichelLourtioz, Springer ; ISBN 354024431X
2. Fundamentals of Photonic CrystalFibers Fredric Zolla Imperial College Press. ISBN 1860945074
3. Photonic Crystals John.D Joannopoulos Princeton University Press ISBN0691037442
4. Photonic Crystals: Modeling Flow of Light John Djoannopoulos R.D.Meadeand J.N.Winn Princeton University Press (1995)
5. The Handbook of Photonics by Mool Chand Gupta, John.Ballato

I Semester	SOCIETAL IMPACT OF NANOTECHNOLOGY	L	T	P	C
		3	0	0	3

Objective: To provide an adequate basic knowledge on social impact of Nanoscience and Nanotechnology

Outcome of the study:

1. To provide awareness to the engineering students about socio economic impact of nanotechnology and to handle the techniques effectively.
2. Understand the various social impacts of nanotechnology trend and research
3. To enhance the nanotechnology research by taking ethics and public opinion into consideration.
4. To understand of professional and ethical responsibility

UNIT I – Protection & Regulation for Nanotechnology: Patentability requirements-riding the patent office pony-infringement issues-nanotech patents outside the united states copyright requirements-nanotech creation as artist works-Delegation of power of agencies-Examples of regulation of nanotechnology-environmental regulations-regulation of exports-political and judicial control over agency action.

UNIT II – Liability Legal Aspects of Nanotechnology: The applications of civil &criminal laws-civil liability, application of negligence to nanotechnology, strict liability for nanotechnology products-warranty-class actions-nanotechnology business organization-criminal liability.

UNIT III – Economic Impacts and Commercialization of Nanotechnology & Social Scenarios Introduction Socio-Economic Impact of Nanoscale Science: Initial Results and Nanobank-Managing the Nanotechnology Revolution: Consider the Malcolm Baldrige National Quality Criteria. The Emerging Nanoeconomy: Key Drivers, Challenges, and Opportunities-Transcending Moore's Law with Molecular Electronics and Nanotechnology- Navigating Nanotechnology Through Society -Nanotechnology, Surveillance, and Society: Methodological Issues and Innovations for Social Research-Nanotechnology: Societal Implications: Individual Perspectives-Nanotechnology and Social Trends-Five Nanotech.

UNIT IV - Ethics, Law & Governance: Ethics and Law-Ethical Issues in Nanoscience and Nanotechnology: Reflections and Suggestions-Ethics and Nano: A Survey Law in a New Frontier: An Exploration of Patent Matters Associated with Nanotechnology. The Ethics of Ethics Negotiations over Quality of Life in the Nanotechnology Initiative. Governance-Problems of Governance of Nanotechnology -Societal Implications of Emerging Science and Technologies: A Research Agenda for Science and Technology Studies (STS)-Institutional Impacts of Government Science Initiatives -Nanotechnology for National Security.

UNIT V – Public Perceptions & Education Public Perceptions-Societal Implications of Nanoscience: An Agenda for Public Interaction Research -Communicating Nanotechnological Risks. A Proposal to Advance Understanding of Nanotechnology's Social Impacts Nanotechnology in the Media: A Preliminary Analysis-Public Engagement with Nanoscale Science and Engineering Nanotechnology: Moving Beyond Risk-Communication Streams and Nanotechnology: The (Re)Interpretation of a New Technology. Nanotechnology: Societal Implications. Individual Perspectives-Historical Comparisons for Anticipating Public Reactions to Nanotechnology.

REFERENCES

1. Mihail. C, Roco and William Sims Bainbridge "Nanotechnology: Societal Implications II-Individual Perspectives", Springer ,2007.
2. Geoffrey Hunt and Michael. D, Mehta "Nanotechnology: Risk, Ethics and Law", Earthscan/James & James publication ,2006.
3. Jurgen Schulte "Nanotechnology: Global Strategies, Industry Trends and Applications", John Wiley & Sons Ltd ,2005.
4. Mark. R, Weisner and Jean-Yves Bottero "Environmental Nanotechnology applications and impact of nanomaterial", The McGraw-Hill Companies ,2007.

I Semester	NANO FLUIDICS	L	T	P	C
		3	0	0	3

Objective:
To familiarize students with nanofluid science and technology.

Outcome of the study:
1. To make students understand the fundamentals of nanofluids and different synthesis methods
2. To make understand conduction heat transfer and convection in nanofluids
3. To familiarize the theoretical modeling of thermal conductivity of nanofluids.
4. To make understand boiling of nanofluids

Pre-requisite:
Basics of physics, chemistry, materials science and fluid mechanics

UNIT I: Introduction: Fundamentals of cooling, Fundamentals of nanofluids, Making nanofluids, Mechanisms & Models for enhanced thermal transport, Future research. Synthesis of nanofluids: General issues of nanofluids, Synthesis methods-common issues, Study of nanoparticles, Variety in nanomaterials, Micro emulsion based methods for nanofluids, Solvo thermal synthesis, Synthesis using supports, Synthesis using biology, Magnetic nanofluids, Inert gas condensation, Anisotropic nanoparticles, Other nanofluids, summary.

UNIT II: Conduction heat transfer in nanofluids: conduction heat transfer, Measurement of thermal conductivity of liquids, Thermal conductivity of oxide nanofluids, Temperature dependence of thermal conductivity enhancement, Metallic nanofluids, nanofluids with CNTs.

UNIT III: Theoretical modeling of thermal conductivity of nanofluids: Simple mixture rules, Maxwell approach, Particle distribution, Particle geometries, Symmetrical equivalent medium theory, Matrix particle interfacial effects, Dynamic models of thermal conductivity of nanofluids.

UNIT IV: Convection in nanofluids: Fundamentals of convective heat transfer, convection in suspensions & slurries, Convection in nanofluids, Analysis of convection in nanofluids, Numerical studies of convection in nanofluids.

UNIT V: Boiling of nano-fluids: Fundamentals of boiling, Pool boiling of nanofluids, Critical heat flux in pool boiling of nanofluids, Other investigations related to boiling of nanofluids.

TEXT BOOK:

1. Nano Fluids Science and Technology by Sarit Kumar Das, John Wiley and sons

I Semester	NANOSCOPIC DIELECTRIC MATERIALS AND BATTERY APPLICATIONS	L	T	P	C
		3	0	0	3

Objective:
To familiarize students with Piezoelectric, Pyroelectric nanomaterials and their applications.

Outcome of the study:
1. To make students understand the fundamentals of piezo electric nanomaterials, their preparation methods, properties and applications
2. Students understand the fundamentals of pyro electric nanomaterials, their preparation methods, properties and applications

Pre-requisite:
Basics of physics, chemistry, and materials science.

Unit I: Introduction to Dielectrics and Concept of Polarization,Types of Polarization Electronic, Ionic, Orientation, and Space Charge Polarizations; Frequency Dependence of Dielectric polarization; Classification of Dielectric materials, Smart materials, Categories of Smart materials, Conducting polymers, Shape memory alloys, Liquid Crystal materials, Piezoelectric materials, Pyroelectric materials, Ferroelectric materials and Poled Polymers; Introduction to Piezoelectricity, Inverse Piezoelectricity, and Pyroelectricity, Mathematical Description of Piezoelectric effects.

Unit II: Properties of Piezoelectric Materials – Quartz, PZT, PVDF, ZnO and Other materials, Applications to Inertial Sensors, Acoustic Sensors, Tactile Sensors, Flow Sensors and Surface Elastic Waves, Piezoelectricity in wood and bone – Applications of Piezoelectricity in Nanomedicine, Piezoelectric Nanogenerators for self-powered Nanodevices.

Unit III: Preparation methods of Piezoelectric nanoparticles – Mixed Oxide Technology, Mechanochemical Synthesis technique, Chemical Coprecipitation, Hydrothermal synthesis, Sol-gel technique, Mechanical and Electrochemical Characterization of One dimensional Piezoelectric nanomaterials – Nanomechanical Characterization – Electromechanical Characterization

Unit IV: Fundamentals of Pyroelectric materials, Pyroelectric IR detectors, Important Pyroelectric materials – Tri-Glycine Sulphate (TGS) crystals and their isomorphs, Modified Lead Titanate, PZT, $LiTaO_3$ and $LiNbO_3$, AlN, GaN, ZnO, Organic Pyroelectrics, Processing of Pyroelectric Thin film Deposition methods – Non-solution methods: Sputtering, Laser Ablation, and CVD methods, and Solution methods: Sol gel Technique, Metal-Organic Deposition Technique.

Unit V: Applications of Pyroelectric and Pyroelectric nanomaterials - IR detectors, Energy Harvesters - Flexible Pyroelectric Nanogenerators and Particle detectors.

Text Books

1. Foundations of MEMS by Chang Liu, Pearson Education Ltd., 2011
2. Piezoelectric Nanomaterials for Biomedical applications by Gianni Ciofani, Arianna Menciassi (eds.), Springer Verlag Berlin 2012,
3. Pyroelectric Materials by A K Batra and M D Agarwal, SPIE, 2013

References

1. Ya Yang, Jong Hoon Jung etal, “Flexible Pyroelectric Nanogenerators using a Composite Structure of Lead-freeKNbO3 Nanowires”, Advanced Materials, 2012.
2. Athanasios Batagiannis, Michael Wübbenhors, Jürg Hulliger , “Piezo and Pyroelectric Microscopy”, Current Opinion in Solid State and Materials Science 14 (2010) 107–115.

I Semester	CARBON NANOSTRUCTURES AND APPLICATIONS	L	T	P	C
		3	0	0	3

Objective: To familiarize students with different carbon nanostructures and their applications.

Outcome of the study:
1. Students can develop understanding of carbon clusters, fullerenes and carbon nanotubes
2. Students understand synthesis methods of carbon nanotubes, and their applications
3. Students can develop knowledge about graphene and graphene like nanostructures.

Pre-requisite: Basics of physics, chemistry, and materials science.

UNIT – I Allotropy of Carbon, Carbon Nano structures - Carbon clusters Fullerenes and types of Carbon Nano tubes, growth mechanisms, 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 –II , Synthesis of CNTs by Flame, CVD, Laser & Arc-discharge process; Lithium & Hydrogen adsorption & storages, Fuel cell applications and energy storage, Chemical Sensors applications of CNTs, Computer applications (Nano chip), Optical and telecommunication applications, CNT Nano composites, Silicon Nanowires.

UNIT-III Graphene - Fundamentals of Graphene, Synthesis – Different routes, Exfoliation method, Industrial applications

UNIT-IV Graphene oxide – Synthesis, Properties and Applications.

UNIT-V Graphene like Structures – Borophene, Pure Metal Single layers – Properties and Applications

Text Books:

1. Introduction to Nanotechnology by Charles P. Poole Jr 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. Prentice Hall Pearson education.
4. Nano:The Essentials – Understanding Nano Science and Nanotechnology by T.Pradeep; Tata Mc.GrawHill

I Semester	SURFACE ENGINEERING OF NANOMATERIALS	L	T	P	C
		3	0	0	3

Objective: To acquaint a student about the surface structure vis-a-vis the bulk structure of a material.

Outcome of the study: To evaluate the surface properties related to catalysts, Fuel cells, Solar cells etc.

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 Bio-fuels, 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 specialty, 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 (micellar rods).

Text Book

1. Basic principles in applied catalysis – Manfredlaerns

Reference Books

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

I Semester	NANOMATERIALS SYNTHESIS LAB	L	T	P	C
		0	1	2	2

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

The outcome of the study:

1. Gain knowledge on the physical, chemical and biological synthesis techniques involved in experiments.
2. To fabricate thin films using spin coating and spray pyrolysis equipments
3. To construct a theoretical knowledge on the experiments.
4. The ability to write and present the laboratory reports.
5. To maximize knowledge regarding synthesis of nanomaterials.

Pre-requisite: Basic chemistry, synthesis techniques, characterization

List of experiments:

1. Two methods for the synthesis of CNTs (CVD method and Flame Synthesis)
2. Nano Catalyst Preparation by Chemical methods.
3. Synthesis of oxide Nanostructures / nano composites by Sol-gel Process
4. Preparation of any two types of Ceramic Powders, $BaTiO_3$ (ball milling) & Al_2O_3 (flame) Composite preparation using Ball Milling
5. Synthesis of NiO nanoparticles using Urea as fuel by Solution Combustion method.
6. Synthesis of Silica gel (SiO_2) using Sol – gel method
7. Synthesis of Silver (Ag) nanoparticles using green synthesis
8. Fabrication of thin film by Spin Coating
9. Fabrication of thin film by Spray Pyrolysis

I Semester	NANOMATERIALS SIMULATION LAB	L	T	P	C
		0	1	2	2

Objective: To gain knowledge regarding simulation of computational nanochemistry methods

Outcome of the study:

1. To understand how to build atom by atom carbon based nanostructures using simulation methods.
2. To obtain a theoretical knowledge on the simulation experiments
3. To gain ability to write and present laboratory reports.

List of experiments:

1. Introduction to Mathematical Modeling and ARGUS Lab Experiments
2. Construction of fullerene & its energy calculations
3. Construction of Bucky balls (C_{20}, C_{40}, C_{60}, C_{80}, C_{100}, C_{120}) and geometry optimization
4. Construction of Carbon nanotubes and geometry optimization
5. Construction of graphene, geometry optimization and molecular orbital visualization

And

The students perform the experiments using either QUANTUM WISE or NANOHUB:

I. QUANTUM WISE (ATK & VNL)

1. Geometry for Transport Calculations (ATK)
2. Setting up a transport calculation with the script generator (ATK)
3. I-V Curve (ATK)
4. Building and optimizing the geometry (ATK)
5. Calculating the band structure of a SiC crystal (VNL)
6. Transmission spectrum of a graphene nanoribbon with a distortion (VNL)
7. Building a graphene nanoribbon device (VNL)

Or

II. NANOHUB

1. BJT Lab (ABACUS)
2. Carrier Statistics Lab (ABACUS)
3. Drift-Diffusion Lab (ABACUS)
4. MOSFET (ABACUS)
5. PN Junction Lab (ABACUS)

I Semester	SEMINAR - 1	L	T	P	C
		0	0	2	1

II Semester	NANO COMPOSITES AND APPLICATIONS	L	T	P	C
		3	1	0	4

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. Student can able to discuss the basic concepts of Nano Composites.
2. Student can able to prioritize the role of Ceramic Metal Composites in Nano Technology.
3. To understand the role of Synthesis Methods for various Nano Composite materials.
4. Learn about the concepts of Indentations and types of Indentations.
5. Correlate the applications of Polymer Nano Composites and Impregnation Techniques.

Pre-requisites: Basics of composites, properties of bulk composites

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 and Natural nanobiocomposites, Biomimetic nanocomposites and Biologically inspired nanocomposites; Applications to Strategic Sector (Aerospace, Defense - CNT based structures - CNT based Nose cones for reentry vehicles), Armour protection (Polymer-Tungsten, Polymer-CNT 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 Nano Indentation, Types of indentation: Oliver & Pharr method, Vickers Indentation process, Berkovich indentation process, Brinell test, Knoop test

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

Text Books:

1. Nanocomposite Science & Technology by P.M. Ajayan, L.S. Schadler and P.V. Braun, Wiley-VCH GmbH Co.2003

2. Thomas E. Twardowski, Introduction to Nanocomposite Materials, Properties, Processing, Characterization, DesTech Publications, April 2007

3. Nanomaterials advances and applications by Dheeraj Kumar Singh , Sajnay Singh and Prabhakar Singh, 2023 , Springer.

Reference Books:

1. Encyclopedia of Nanotechnology by H.S.Nalwa

2. Encyclopedia of Nano Technology by M.Balakrishna rao and K.Krishna Reddy, Vol I to X

3. Introduction to Nano Technology by Charles. P.Poole Jr and Frank J. Owens; Wiley India Pvt Ltd.

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

II Semester	NANOSENSORS AND APPLICATIONS	L	T	P	C
		3	1	0	4

NT- 202

Objective: The course is intended to cover basics and applications of Nanosensors in various fields.

Outcome of the study: Students get exposure on Nano scale based inorganic sensors, thermal sensors, biosensors, and their applications in addition to sensor characteristics and physical effects.

Pre-requisite: Basics of physics, chemistry, biology and electronics

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, Hall 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, IR 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 and their 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 –Biodetectors, Nano array based detector - Nano Particle based detector, Ultra-sensitive detection of pathogenic biomarkers Ultra-sensitive detection of single bacteria, cancer detection sensors.

Text Books and References:

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

2. H.Rosemary Taylor, "Data acquisition for sensor systems", Chapman & Hall,

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).

II Semester	NANOELECTRONICS	L	T	P	C
		3	1	0	4

Objective: This course is intended to cover basics of electronics, transistor, band structure models, nanocapacitors, coulomb blockade, single electron transistor and spintronics.

Outcome of the study:

1. To assess knowledge on Single Electron and few Electron phenomenon.
2. To determine theory behind Scanning Tunneling Microscope by Applications of Tunneling.
3. Study the basics of coulomb blockade in Quantum mechanics.
4. To persuade Single Electron Transistor and Carbon Nano tube Transistor.
5. To extend the knowledge on Spintronics.

Pre-requisite: Basics of electronics and quantum mechanics

Unit - I: Free and confined electrons: Schrodinger's time independent equation, Wave function and physical significance, Free electrons-the free electron gas theory of metals-electrons confined to a bounded region of space and quantum numbers-electrons confined to atom- the periodic table-quantum dots-wires-wells.

UNIT-II: Single-electron and few-electron phenomena and devices: Tunnel junction and applications of tunneling, Tunneling Through a Potential Barrier, Potential Energy Profiles for Material Interfaces, Metal—Insulator, Metal-Semiconductor, and Metal-Insulator-Metal Junctions, Applications of Tunneling; Field Emission, Gate—Oxide Tunneling and Hot Electron Effects in MOSFETs, Theory of Scanning Tunneling Microscope, Double Barrier Tunneling and the Resonant Tunneling Diode.

UNIT-III: Coulomb Blockade: Coulomb Blockade, Coulomb Blockade in a Nanocapacitor, Tunnel Junctions, Tunnel Junction Excited by a Current Source, Coulomb Blockade in a Quantum Dot Circuit.

UNIT-IV: The Single-Electron Transistor: The Single-Electron Transistor Single-Electron Transistor Logic, Other SET and FET Structures, Carbon Nanotube Transistors (FETs and SETs), Semiconductor Nanowire FETs and SETs, Molecular SETs and Molecular Electronics.

UNIT –V Spintronics: Introduction, Overview, History & Background, Generation of Spin Polarization, Spin injection, Spintronic devices and applications - spin filters, spin diodes, spin transistors.

Text Books:

1. Fundamentals of nano electronics by George W Hanson Pearson publications ,India 2008{Unit-I- IV)

2. Introduction to photoelectron Spectroscopy (Chemical Analysis Vol. 67) by P.K. Ghosh; Wiley Interscience

3. Nanophotonics by P.N.Prasad – Springer Education series.
4. Nanotechnology and Nano Electronics – Materials, devices and measurement Techniques by WR Fahrner – Springer
5. Nanomaterials: Synthesis, properties and applications\edited by A S Edelstein and R C Cammarata (Institute of Physics, UK Series in Micro and Nanoscience and Technology)

Reference Books:

1. Encyclopedia of Nano Technology by M.Balakrishna Rao and K.Krishna Reddy (Vol I to X) Campus books.
2. Nano: The Essentials – Understanding Nano Science and Nanotechnology by T.Pradeep; Tata Mc.Graw Hill
3. Spin Electronics by M. Ziese and M.J. Thornton
4. Nanoelectronics and Nanosystems – From Transistor to Molecular and Quantum Devices by Karl Goser, Peter Glosekotter, Jan Dienstuhl
5. Silicon Nanoelectronics by Shunri Odo and David Feny, CRC Press, Taylor & Franicd Group

II Semester	NANOSCALE MAGNETIC MATERIALS AND DEVICES	L	T	P	C
		3	0	0	3

Objective: The course is intended to cover basics of Nanoscale magnetic materials and devices

Outcome of the study:

1. To extend the knowledge on Nanoscale magnetic materials, hard and soft magnetic materials and measurement techniques of magnetization.
2. To study about Biomagnetism, Biomagnetic nanostructures and biomedical applications of magnetic materials.
3. To gain knowledge on ferrofluids, magnetoresistance and MRAM applications

Pre-requisite: Basics physics and chemistry

Unit I: Nanoscale Magnetic materials – Introduction to Magnetic materials – Dia, Para, Ferro, Antiferro and Ferri magnetic materials, Super paramagnetic materials, Stern - Gerlach Experiment of Electron Spin, Magnetic forces and van der Waals forces in Magnetic nanoparticles (MNps), Magnetic clusters, Magnetization and Demagnetization – Experimental methods, Instruments for measuring Magnetization – VSM, AGM, SQUID magnetometers.

Unit II: Hard and Soft Magnetic materials - Magnetic Nanoparticles for Hard magnetic applications – FePt, CoPt, $SmCo_5$ nanocomposites, Magnetic Nanoparticles for Soft magnetic applications – Co, Fe, Ni Binary alloys – Synthesis, Properties and Applications.

Unit III: Biomagnetism and Biomagnetic Nanostructures – Examples – Haemoglobin, Ferritin and Magnetotactic bacteria – Biomedical Applications of Magnetic nanomaterials and nanostructures.

Unit IV: Ferrofluids – Synthesis, Properties and Applications, inkjet printing toners, shock absorbers, dampers.

Unit V: Other Magnetic Applications – Magnetoresistance – AMR, GMR, TMR, CMR – Core Shell Magnetic nanostructures – Thin Layered Films – MRAM applications, Quantum Computation and NMR.

Text Books:

Introduction to Magnetic materials by Cullity B D
Nanocrystalline materials by Glieter
Introduction to Nanotechnology by Poole and Owens

References:

1. Encyclopedia of Nanoscience and Nanotechnology by H S Nalwa (ed.) Vol I to X.
2. Advanced Magnetic Nanostructures by Sellmyer - Springer

II Semester	COLLOID AND INTERFACE SCIENCE	L	T	P	C
		3	0	0	3

Objective: The course is indented to familiarize a student with the behaviour of colloid solutions and the role of interfaces.

Outcome of the study:

1. To gain knowledge about the difference between surface and inter-facial tensions.
2. To acquaint the student with Surfactants types, polarity and capillarity concepts.

Unit-I: Introduction to colloids, surface properties, origin of charge on colloidal particles, preparation & characterization of colloidal particles. Applications of colloids in oil recovery, super hydrophilic surfaces, self cleaning surfaces.

Unit-II: Surfactants type (Anionic, cationic, Zwitter ionic, Amphiphilic and non-ionic). Theory of Surfactants; CMC, Kraft temperature. Phase behavior of cone surfactant systems, surfactant geometry and packing. Emulsions, Micro emulsions & Gels. Intermolecular Forces, Van der Waals forces (Kessorn, Debye, and London Interactions).Potential energy curve, Brownian motion and Brownian Flocculation.

Unit-III: Unit Surface and interfacial Tension, Sessile drop, pendant drop, Surface free energy, Surface tension for curved interfaces, Surface excess and Gibbs equation. Contact angle, Wetting Young Laplace equation, Dynamic properties of interfaces .Surface viscosity, Kelvin equation.

Unit-IV: Electrical phenomena at interfaces (Electronic kinetic phenomena, Electric double layer,short range forces). DLVO theory, capillary hydrostatics, interfacial hydrodynamics, marangonic effect.

Unit-V: Measurements technique: Surface tension, Interfacial Tension, Contact angle, Zeta potential , Particle size & its distribution. Electro osmosis phenomena, Streaming potential electro viscous flows.

Text Books:

1) A.W. Adamson and A.P Gast, Physical Chemistry of surfaces, Wiley Interscience , NY 2004.
2) P.C Hiemen and R.Rajgopalam, Principle of colloid and surface Chemistry NY Marcel Dekker, 1997.
3) D.J.Shaw, Colloid and surface chemistry, Butterworth Heineman, Oxford,1992.
4) M J Rosen, Surfactant and Interfacial phenomena, Wiley Inter Science Publication, NY 2004
5) Jacob Israelachvilli, Intermolecular and Surface Forces, Academic Press, NY 1992.

Reference Books:

1. Colloid and Interface Science by Pallab Ghosh, PHI Learning Pvt Ltd, 2009

II Semester	COMPUTATIONAL NANOTECHNOLOGY	L	T	P	C
		3	0	0	3

Objective: To familiarize students different computational simulation techniques of nanomaterials

Outcome of the study:

1. To make students understand the basics of mechanical and statistical computational techniques

2. To familiarize students with Atomistic, Molecular dynamics, Monte Carlo and Mesoscale simulation techniques to evaluate different properties of nanomaterials.

Pre-requisite: Basics of computation and Mechanics of solids and materials science

UNIT I: Introduction: Computational simulation, need for discrete computation. Classical Mechanics: Mechanics of Particles, D'Alembert's principle and Lagrange's equation, variational principles, Hamilton's principle, conservation theorems and symmetry properties, central force problems, virial theorem.

UNIT II: Statistical Mechanics: Review of probability and statistics, quantum states of a system, equations of state, canonical and microcanonical ensemble, partition function, energy levels for molecules, equipartition theorem, minimizing the free energy, Maxwell distribution of molecular speeds.

UNIT III: Atomistic Simulation Techniques: Molecular Dynamics (MD): Introduction, inter-atomic potential function, Lennard-Jones potential, various types of potential functions, computational aspects.

UNIT IV: Systems, Models, Simulations and the Monte Carlo Methods: Systems, Models, Simulation and the Monte Carlo Methods, Random number generation, Introduction, Congruential Generators, Statistical Tests of Pseudorandom Numbers, Random variate generation, inverse Transform Method, Composition Method, Acceptance-Rejection Method.

UNIT V: Monte Carlo integration and Variance reduction techniques: Introduction, Monte Carlo Integration, The Hit or Miss Monte Carlo Method, The Sample-Mean Monte Carlo Method, Efficiency of Monte Carlo Method, Mesoscopic Simulation Techniques: Lattice Boltzmann Method (LBM), applications of LBM.

Text Books

1. Wolfram Hergert, Computational Materials science, Springer.
2. Multiscaling in molecular and continuum mechanics by G. C. Sih, Springer.
3. A primer for the monte carlo method, llya M. Sobol' CRC Press
4. Simulation and Monte carlo method by Reuven Y. Rubisten

Reference Books

1. Probability and statistics for engineers, miller and john e. freund, prentice hall of india
2. The monte carlo method, popular lectures in mathematics by sobol.i.m

II Semester	NANOPLASMONICS	L	T	P	C
		3	0	0	3

Objective: The course is intended to cover basics of Nano Plasmonics and their applications.
Outcome of the study:

1. To extend the knowledge on Nano Plasmonics.
2. To study about quantum confined materials, photonic crystals, and nanoplasmonics devices.

Pre-requisite: Basics physics and chemistry

Unit- I: Introduction to Plasmonics Plane waves and Gaussian beams; Boundary conditions; Layered media and characteristic matrices; Reflection and transmission through layered media; Dispersion relations; Resonances as the poles of the scattering coefficients; Surface and guided modes; Surface plasmons and coupled surface plasmons; Avoided crossings; Resonant tunneling; Wigner delay, Goos-Hanchen shift; Hartman effect.

Unit-II: Plasmonics:Metallic nanoparticles, nano rods and nanoshells,localfield enhancement; Collective modes in nanoparticle arrays; particle chains and arrays; surface plasmons, Plasmon Waveguides; Applications of Metallic Nanostructures Metamaterials.

Unit-III: Localized Plasmons Resonances of small particles at micro and nano scales; Mie theory; Quasistatic approximation and localized modes in small metal particles; Dipolar and quadru polar modes. Modes of spheroids and ellipsoids; Shape and size dependence; Polarization aspects of scattering.

Unit-IV: Patterned nanostructures and metasurfaces Dolmen structures and Fano resonances; Quasicrystals Nanofabrication techniques. Quasicrystals and super oscillations. Beating the diffraction limit with propagating waves.

Unit-V: Applications: Plasmonics for sensing; Surface and nanoparticle enhanced spectroscopy; Single molecule spectroscopy; Photothermal therapy of cancer; Plasmon mediated chemical reactions and catalysis; Plasmon mediated non-linear signal enhancement; SPASERs and Nanolasers; Nano ber mediated entanglement, single photon emitters.

Text Books:

(1) S Dutta Gupta, N Ghosh and A. Banerjee, Wave Optics: Basic Concepts and Contemporary Trends, (CRC Press, New York, 2015).
(2) H Raether, Surface plasmons on smooth and rough surfaces and on gratings, (Springer, New York, 1988).
(3) (L Novotny and B Hecht, Principles of Nano-Optics, (Cambridge, newyork, 2006).
(4) W Cai and V Shalaev, Optical Metamaterials Fundamentals and Applications, (Springer, newyork, 2010).
(5) S Maier, Plasmonics Fundamentals and Applications (Springer, UK, 2007).

(6) J P Fillard, Near Field Optics and Nanoscopy, (World Scienti c, Singapore, 1998). (7) Venu Gopal Achanta, Plasmonic Quasicrystals, Prog. Quantu. Electronics 39, 1-23 (2015).
(7) Venu Gopal Achanta, Surface waves at metal-dielectric interfaces: Material Science perspective, Reviews in Physics 5, 100041 (2020).

II Semester	BIOMEDICAL NANOTECHNOLOGY	L	T	P	C
		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 and building blocks.
2. To understand the concepts of Biological Nanostructures
3. To familiarize about Biomedical Applications.
4. To prioritize the role of nano structured materials in diagnosis
5. To gain the improvements in drug delivery system using nanotechnology.
6. To study various Nanopharmacology & Drug Targeting and drugs delivery systems

Pre-requisite: Basics of organic chemistry, Biology

Unit-I Imaging of Bionanostructures: Practical and theoretical aspects of imaging biological systems, from the cellular level through whole-body medical imaging, basic physical concepts in imaging; Major techniques using ionizing and non-ionizing radiation including fluorescence and multi-photon microscopy, spectroscopy, OCT, MRI, X-ray CT, PET, Confocal and SPECT imaging.

Unit-II Nano Bioactive Glasses: Nanobiosensors, Nano Bioactive glasses, Biomaterials Preparation, Methods , Nanobioactive glass powders , Properties ,Mechanical-measurement of bioactivity ,In vitro studies - coating on metallic implant, bio-compatibility, bio-active testing starndars and Characterization - Implant applications.

Unit-III Cancer Treatment: Gold and Silver nanoparticles in cancer targeting and treatment Nanoparticles in treatment of breast cancer –Chemotherapy: Active and Passive cancer tissue targeting, micro fluidics, Chemotherapeutic agents, Immunotherapy, Vaccine immunotherapy, Radiotherapy,Thermotherapy,Photo dynamic therapy, Nano particulate targeting.

Unit-IV Delivery Mechanism: Introduction, Antibody conjugated nanoparticles, Conjugated nanoparticle interaction with biological surfaces, Biomedical nanoparticles, Liposomes, Dendrimers, Different types of drug loading, drug release and Biodegradable polymers, Applications.

Unit-V Targeted Drug Delivery: Basic and special pharmacology, strategies for targeted delivery in nature, Bacteria, virus, prion -strategies for targeted delivery, by human, oral delivery, transdermal, transmucosal, invasive, Targeted delivery to brain, macrophage targeting.

Text Books:

1. ‘Biomedical Applications of Nanotechnology’ by Vinod Labhasetwar, Diandra L. Leslie-Pelecky John Wiley & Sons

2. ‘Nanomedicine and Drug delivery’ by Mathew Sebastian Neethu Ninan A. K. Haghi, Apple Academic Press
3. ‘Nanotechnology for Cancer Therapy’ by Mansoor M. Amji, CRC press

References:

1 Challa Kumar, Nanomaterials for medical diagnosis and therapy , Wiley VCH 2005
2 James A. Schwarz, Cristian I. Contescu, Karol Putyera, “Dekker encyclopedia of nanoscience and nanotechnology” CRC Press, 2004.
3 Natalie P. Praetorius and Tarun K. Mandal, Recent Patents on Drug Delivery & Formulation

4. Y. Lu, S.C. Chen, “Micro and nano-fabrication of biodegradable polymers for drug delivery” Advanced Drug Delivery Reviews, 56 (1621-1633) 2004.

II Semester	MEMS & NEMS	L	T	P	C
		3	0	0	3

Objective: The course is intended to cover deep understanding of micro and nano electromechanical systems their design and various applications as well as micro and nano fabrication techniques.

Outcome of the study:

1. To provide understanding of MEMS/NEMS applications specially sensors, and actuators, Micro machining tools etc.,
2. To provide materials for MEMS/NEMS and material structures.
3. To provide information on MEMS/NEMS design, processing and Technologies
4. To bring out scaling and packaging issues of MEMS
5. To understand different lithographic techniques of fabrication

Prerequisite: Mechano- electronic properties, fabrication techniques.

Unit-I Introduction to MEMS and NEMS: MEMS and NEMS – multidisciplinary nature of MEMS/NEMS – working principles: as micro sensors (acoustic wave sensor, biomedical and biosensor, chemical sensor, optical sensor, capacitive sensor, pressure sensor and thermal sensor), micro actuation (thermal actuation, piezoelectric actuation and electrostatic actuation – micro gripers – micro motors – micro valves – micro pumps – accelerometers – micro fluidics and capillary electrophoresis, active and passive micro fluidic devices;

Unit-II Materials for MEMS/NEMS: Silicon – Compatible material systems, Silicon, Silicon oxide and nitride, Thin metal films, Polymers, Other materials and substrates, Glass and fused quartz substrates, Silicon carbide and diamond, Gallium Arsenide and other group III-V compound semi conductors, Shape - memory alloys transduction atomic bonds, Material structures, metal-chalcogenides.

Unit-III MEMS/NEMS design, processing and Technologies: Basic process tools, Epitaxy, Oxidation, Sputter deposition, spin on methods, Lithography, Lift off process, Bulk Micro machining, Etching processes – Wet etching, Plasma etching, Ion milling, Wafer bonding – Silicon fusion bonding, Anodic bonding, Silicon direct bonding, sol gel deposition methods, Self assembled mono layers, EFAB. LIGA electromagnetic micro drive, DRIE.

Unit-IV MEMS/NEMS applications: Applications in automotive industry – health care – aerospace – industrial product consumer products – lab on chip – molecular machines data storage devices – micro reactor – telecommunications, Servo systems.

Unit –V Introduction to lithography and Optical lithography: Introduction to lithography, proximity printing and Projection Printing, Positive and negative photoresists; Basics of Resolution Enhancement techniques, overlay-accuracies, Mask-Error enhancement factor (MEEF), Electron Lithography; X-ray Lithography; Ion Lithography (Focused Ion Beam Lithography, Masked Ion Beam Lithography, Ion Projection Lithography).

Text Books

1. "An introduction to Micro electro mechanical systems Engineering" by Nadim Malut and Kirt Williams – Second edition – Artech House, Inc, Boston
2. "Micro electro mechanical systems Design" by James J Allen- CRC Press – Taylor and Francis Group
3. John N.Helbert, "Handbook of VLSI Microlithography", Noyes Publication, USA, 2001.
4. James R Sheats and Bruce W.Smith, "Microlithography Science and Technology", Marcel Dekker Inc., New York, 1998

Reference Books

1. "Springer Hand Book of Nano Technology" by Bharath Bhushan – Springer
2. " Nano and Micro electro Mechanical systems" by Sergey Edward Lysherski – CRC Press.
3. MEMS & Micrsystems Design and Manufacture-Tai-Ran Hsu, Tata McGraw Hill
4. L.A.Stelmack, C.T.Thurman and G.R. Thompson "Review of Ion-assisted Deposition: Research to Production", Nuclear Instruments and Methods in Physics Research B, 37/38,787 (1989).
5. J.M.Bennett "When is a surface clean?" p.29 in Optics and Photonics News, June, 1990.

II Semester	MULTIFUNCTIONAL NANOMATERIALS	L	T	P	C
		3	0	0	3

Objective: This course is intended to cover multifunctional nanomaterials, smart materials, synthesis strategies, properties and applications.

Outcome of the study:

1. To assess knowledge on specific multifunctional nanomaterials and smart materials, their properties and applications.
2. To understand specific multifunctional nanomaterial like TiO_2 for water purification as photocatalyst.
3. To assess how nanoparticles are used for the treatment of Arsenic
4. To develop synthesis strategies of specific multifunctional nanomaterials.

Pre-requisite: Basics of chemistry

Unit-I : Introduction to Multifunctional Nanomaterials - Smart materials – Examples – Properties and Applications.

Unit-II: Synthesis/Strategies for Development of multifunctional Nanomaterials – TiO_2, Fe_2O_3, ZnO, SnO_2.

Unit-III: Nanostructured Catalysts – TiO_2 Nanoparticles for Water purification - TiO_2 as a semiconductor photocatalyst, Photo catalytic mechanism, general pathways & kinetics, Intrinsic, Photocatalytic activity, Reaction variables, Photocatalytic Degradation of Specific Waterborne pollutants. Nanoparticles for treatment of Arsenic: Introduction, Environmental Chemistry of Arsenic, Treatment of Arsenic using Nanocrystalline TiO_2, Treatment of Arsenic using nanoparticles other than TiO_2.

Unit IV: TiO_2 Fabrication, Superhydrophilicity – Other applications of TiO_2. Surface mechanisms of TiO_2.

Unit V: Other Examples of Multifunctional Nanomaterials – Fe_2O_3, ZnO, SnO_2, Ag and Au nanomaterials – Properties and Applications

Text Books:

1. Nanoscale Multifunctional materials by S Mukhopadhyay – Wiley 2011
2. ’Nanotechnologies For Water Environment Applications’ American Society of Civil Engineers (ASCE) Publications by Tian C.Zhang, Zhiqiang Hu et al

References:

1. ‘Silver Nanoparticles – Universal Multifunctional Nanoparticles for Bio Sensing, Imaging for Diagnostics and Targeted Drug Delivery for Therapeutic Applications’ by Anitha Sironmani and Kiruba Daniel

2. Silver–Polymer Composite Stars: Synthesis and Applications by Tae-Jong Yoon et al Angew. Chem. Int. Ed. 2005, 44, 1068 –1071
3. Encyclopedia of Nanoscience and Nanotechnology by H S Nalwa Vol I to Vol 10
4. Bulk Nanostructured Materials with Multifunctional properties by I Sabirov, NA Enikeev, MYu Murashkin, and RZ Valiev – Springer
5. Multifunctional Transparent Epoxy Nanocomposites As Encapsulating Materials For Led Devices by Shao-Yun Fu - iccm-central.org/Proceedings
6. Multifunctional composite core–shell nanoparticles by Suying Wei,et al - Nanoscale, 2011, 3, 4474

II Semester	NANOSCOPIC FERROELECTRIC MATERIALS & APPLICATIONS	L	T	P	C
		3	0	0	3

Objective: To familiarize students with, Pyroelectric Nanomaterials and their applications.

Outcome of the study:

1. To make students understand the fundamentals of ferroelectric nanomaterials, their preparation methods, properties and applications.
2. Students understand the fundamentals of pyroelectric nanomaterials, their preparation methods, properties and applications.

Pre-requisite: Basics of physics, chemistry, and materials science.

Unit I: Introduction to Ferroelectric/Pyroelectric materials-Polarization-Polarity- Temperature Dependence Important Ferroelectric materials–Tri-Glycine Sulphate (TGS) crystals and their isomorphs, Modified Lead Titanate, PZT, LiTaO3 and LiNbO3, AlN, GaN, ZnO, Organic Pyroelectrics.

Unit II: Preparation methods of Ferroelectric nanoparticles–Mixed Oxide Technology, Mechanochemical Synthesis technique, Chemical Coprecipitation, Hydrothermal synthesis, Sol-gel technique, thin film fabrication for ferroelectric materials.

Unit III: Mechanical and Electrochemical Characterization of One dimensional Ferroelectric nanomaterials Nanomechanical Characterization – Electromechanical Characterization.

Unit IV: Processing of ferroelectric Thin film Deposition methods – Non-solution methods: Sputtering, Laser Ablation, and CVD methods, and Solution methods: Sol gel Technique, Metal-Organic Deposition Technique.

UnitV: Applications of Pyroelectric nanomaterials- IRdetectors, Energy Harvesters Flexible Pyroelectric Nanogenerators and Particle detectors.

Text Books

1. Foundations of MEMS by Chang Liu,PearsonEducationLtd.,2011
2. Piezoelectric Nanomaterials for Biomedical applications by GianniCiofani, AriannaMenciassi (eds.), Springer Verlag Berlin 2012.
3. Pyroelectric Materials by AK Batra and MD Agarwal,SPIE, 2013

References

1. YaYang, JongHoon Jungetal,“Flexible Pyroelectric Nanogenerators using a Composite Structure of Lead-free$KNbO_3$ Nanowires”, Advanced Materials, 2012.
2. Athanasios Batagiannis, Michael Wübbenhors, JürgHulliger,“Piezo and Pyroelectric Microscopy”, Current Opinion in Solid State and Materials Science 14 (2010) 107–115.

II Semester	INTRODUCTION TO QUANTUM TECHNOLOGIES	L	T	P	C
		3	0	0	3

Course Objectives:

1. To introduce fundamental concepts of quantum mechanics and its mathematical formalism.
2. To explore quantum computing and communication principles and technologies.
3. To understand the physical implementation and limitations of quantum systems.
4. To enable students to relate quantum theory to practical applications in computing, cryptography, and sensing.
5. To familiarize students with the emerging trends in quantum technologies.

Course Outcomes:

After completing this course, students will be able to:

CO1. Explain core principles of quantum mechanics and their technological implications.
CO2. Analyze quantum phenomena like superposition and entanglement.
CO3. Apply mathematical tools to model and solve quantum systems.
CO4. Demonstrate understanding of quantum algorithms and quantum circuits.
CO5. Evaluate potential applications and challenges in quantum communication and sensing.

Unit 1: Fundamentals of Quantum Mechanics: Historical background: Blackbody radiation, photoelectric effect, and Compton scattering; Dual nature of light and matter; De Broglie hypothesis; Schrodinger equation; Free particle, infinite potential well, step potential; Operators and observables: position, momentum, Hamiltonian; Commutation relations and uncertainty principle; Quantum postulates and measurement theory; Eigenvalues, eigenfunctions.

Unit 2: Quantum Information Theory: Classical vs. quantum information; Qubit representation using Bloch sphere; Quantum superposition and quantum entanglement; Dirac notation (bra-ket), tensor products, and composite systems; Bell states; Quantum gates: Pauli-X, Y, Z; Hadamard; Phase; T; CNOT; Quantum circuit models and notation; Measurement in computational basis; Quantum teleportation and no-cloning theorem; Quantum state tomography (introductory)

Unit 3: Quantum Computing: Classical computing review and limitations; Quantum parallelism and interference; Deutsch and Deutsch-Jozsa algorithms; Grover's search algorithm, Oracle and amplitude amplification; Shor's factoring algorithm (overview and significance); Quantum Fourier Transform (QFT); Quantum error correction: Bit-flip, phase-flip, Introduction to quantum programming: Qiskit(overview)

Unit 4: Quantum Communication: Introduction to quantum cryptography; Quantum key distribution (QKD): BB84 protocol; Entanglement-based QKD: Ekert protocol (E91); Eavesdropping and security of QKD; Quantum teleportation (circuit and protocol); Quantum dense coding; Quantum networks and entanglement swapping; Role of quantum repeaters; Single-photon sources and detectors; Implementation challenges (loss, decoherence, noise)

Unit 5: Quantum Technologies and Applications: Quantum sensors: magnetometry, gravimetry; Quantum metrology: standard time, atomic clocks; Quantum imaging and lithography; Quantum materials: topological insulators, graphene, quantum dots; NV centers in diamonds for sensing; Hardware platforms: Superconducting qubits, Trapped ions, Photonic quantum processors; Quantum supremacy and NISQ era.

Text Books:

1. "Quantum Computation and Quantum Information" by Michael A. Nielsen and Isaac L. Chuang
2. "Quantum Mechanics: Concepts and Applications" by Nouredine Zettili

I Semester	NANOMATERIALS CHARACTERIZATION LAB	L	T	P	C
		0	1	2	2

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

Outcome of the study:

1. Gain knowledge on the Dynamic Light Scattering, AFM, SEM, Raman Spectroscopy and Differential Scanning Calorimetry
2. To construct a theoretical knowledge on the experiments.
3. To analyze results of X-Ray diffraction, UV-Visible Spectroscopy and TG/DTA apparatus
4. The ability to write and present the laboratory reports.
5. To maximize knowledge regarding Characterization of nanomaterials.

Pre-requisite: Basic chemistry, synthesis techniques of nanomaterials

List of Experiments:

1. Nano Particle Size Analysis by Dynamic light scattering
2. Three experiments on Characterization of Thin films/nano films using AFM, STM, etc
3. Three experiments on Characterization of 1D, 2D and 3D structures using AFM, SEM, etc
4. Raman Spectroscopy of synthesized nanomaterials using BWTEK Raman Spectrophotometer.
5. Determination of average Crystallite size and microstrain by X-Ray diffraction analysis
6. Determination of energy band gap by using UV – Visible spectroscopy
7. Study of thermal properties by using Differential Scanning Calorimetry
8. Study of thermal properties by TG/DTA Analysis.
9. Study and Bonding analysis of Nanomaterials by FTIR.

II Semester	ADVANCED NANOTECHNOLOGY LAB	L	T	P	C
		0	1	2	2

Objective: The course is intended to cover the wide spectrum of applications of nanotechnology.

Outcome of the study:

1. To impart the basic knowhow in connection with the fabrication of solar cells.
2. To provide practical knowledge for performance evaluation of Lithium-ion based materials
3. To perform the anti-microbial tests
4. To detect the various gases using nanosensors.
5. To evaluate the photocatalysis process.

List of Experiments:

1. Fabrication of Dye Sensitized Solar Cell and Evaluation of performance
2. Evaluation and performance of Lithium-ion based materials for battery and using cyclic voltameter.
3. Ant-microbial tests using nanomaterials
4. Evaluation and performance analysis of fuel cells
5. Germination testing using nanomaterials
6. Photocatalysis evaluation
7. Detection of Gases by metal oxide sensors
8. Biosensors using nanomaterials
9. Evaluation and performance of nanomaterials for capacitance applications using cyclic voltameter

II Semester	SEMINAR - II	L	T	P	C
		0	0	2	1

III Semester	RESEARCH METHODOLOGY AND IPR	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

- To understand the knowledge on basics of research and its types.
- To impart the concept of Literature Review, Technical Reading, Attributions and Citations.
- To know the Ethics in Engineering Research.
- To know the concepts of Intellectual Property Rights in Engineering.

COURSE OUTCOMES:
Upon successful completion of this course, the student will be able to:

	Course Outcome	***BTL (K#)***
CO1	Explain the meaning of engineering research and apply to develop an appropriate framework for research studies.	K2& K3
CO2	Identify the procedure of Literature Review, Technical Reading, etc. and apply to develop a research design during their project work.	K2 & K3
CO3	Explain and apply the fundamentals of patent laws and drafting procedure in their research works.	K2& K3
CO4	Demonstrate the copyright laws, subject matters of copyrights, designs etc. to apply in patent filing.	K2 & K3
CO5	Identify the new developments in IPR and employ the applications of computer software in writing/filing patents in future.	K2 & K3

 # Based on suggested Revised Blooms Taxonomy Level (BTL)

K1: ***Remember***	**K2:** ***Understand***	**K3:** ***Apply***
K4: ***Analyse***	**K5:** ***Evaluate***	**K6:** ***Create***

Unit Description *Contact Hrs.*

UNIT – I: **[10]**

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

UNIT – II: **[10]**

Effective literature studies approaches, analysis Plagiarism, Research ethics, Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee.

UNIT – III: **[10]**

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

UNIT – IV: **[10]**

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

UNIT – V: **[09]**

New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR.

TEXTBOOKS:

1. C.R. Kothari , 2nd Edition, "Research Methodology: Methods and Techniques".
2. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step-by-Step Guide for beginners"

REFERENCE BOOKS:

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students.
2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction".
3. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
4. Mayall, "Industrial Design", McGraw Hill, 1992.
5. Niebel, "Product Design", McGraw Hill, 1974.
6. Asimov, "Introduction to Design", Prentice Hall, 1962.
7. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
8. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

WEB REFERENCES:

- Please include hyperlinks related to NPTEL/VLabs etc.,

III Semester	SUMMER INTERNSHIP	L	T	P	C
		0	0	0	3

COURSE OBJECTIVES:

- Internships provide students with an opportunity to put into practice skills they have learned while in college.
- In addition, students should have an opportunity to enhance those skills, obtain the perspective of a work environment and benefit from a mentor or supervisor's experience and advice.

COURSE OUTCOMES:

Upon successful completion of this course, the student will be able to:

	Course Outcome	***BTL (K#)***
CO1	Integrate theory and practice to assess interests and abilities in their field of study.	K3 & K4
CO2	Develop work habits, attitudes necessary to appreciate work and its function in the economy.	K3
CO3	Develop communication, interpersonal and other critical skills to build a record of work experience.	K3

 # Based on suggested Revised Blooms Taxonomy Level (BTL)

K1: ***Remember***	**K2:** ***Understand***	**K3:** ***Apply***
K4: ***Analyse***	**K5:** ***Evaluate***	**K6:** ***Create***

III Semester	COMPREHENSIVE VIVA	L	T	P	C
		0	0	0	2

III Semester	DISSERTATION PART A	L	T	P	C
		0	0	20	10

COURSE OBJECTIVES:

- To impart fundamental and disciplinary concepts and methods in ways appropriate to their principal areas of study.
- To familiarise how to incorporate skill and knowledge of current information and technological tools and techniques specific to the professional field of study.
- Expose to the critical aspects like identifying, analysing and solving problems creatively through sustained critical investigation using effective oral, written and visual communications.
- To inculcate the key aspects like awareness and application of appropriate personal, societal and professional ethical standards to excellence needed to engage in lifelong learning.

COURSE OUTCOMES:
Upon successful completion of this course, the student will be able to:

	Course Outcome	*BTL (K#)*
CO1	Carryout a critical review of literature on a chosen topic of research and identify gaps in the literature to define a problem for research work.	K3 & K4
CO2	Formulate/adapt a clear methodology using multi-disciplinary approach and modern tools.	K3& K6

 # Based on suggested Revised Blooms Taxonomy Level (BTL)

K1: ***Remember***	**K2:** ***Understand***	**K3:** ***Apply***
K4: ***Analyse***	**K5:** ***Evaluate***	**K6:** ***Create***

IV Semester	DISSERTATION PART B (*Main Project*)	L	T	P	C
		0	0	32	16

COURSE OBJECTIVES:

- To impart fundamental and disciplinary concepts and methods in ways appropriate to their principal areas of study.
- To familiarise how to incorporate skill and knowledge of current information and technological tools and techniques specific to the professional field of study.
- Expose to the critical aspects like identifying, analysing and solving problems creatively through sustained critical investigation using effective oral, written and visual communications.
- To inculcate the key aspects like awareness and application of appropriate personal, societal and professional ethical standardsto excellence needed to engage in lifelong learning.

COURSE OUTCOMES:
Upon successful completion of this course, the student will be able to:

	Course Outcome	*BTL (K#)*
CO1	Carryout design/analysis of a product/system or devise experiments to study and develop a system/process/product.	K3 & K4
CO2	Interpret & validate results of analysis/experiments conducted to study behaviour of a product /system/ process considered for the research leading to valid conclusions that add value to the body of knowledge.	K3 & K5
CO3	Write and present a technical report of the project work.	K6

 # Based on suggested Revised Blooms Taxonomy Level (BTL)

K1:	***Remember***	**K2:**	***Understand***	**K3:**	***Apply***
K4:	***Analyse***	**K5:**	***Evaluate***	**K6:**	***Create***