Learning Outcomes Based Curriculum Framework

(W.E.F. 2020-21)

for

M.Tech (Nano Science & Technology)

BASED ON

CHOICE BASED CREDIT SYSTEM

Department of Bio and Nano Technology

Guru Jambheshwar University of Science & Technology

Hisar-125 001, Haryana

SCHEME OF EXAMINATION FOR M. Tech (NANO SCIENCE & TECHNOLOGY)

FIRST SEMESTER

Sr. No.	Course No.	Title	L	P	Credits
1	MNL-701	Introduction to Biotechnology and Nanotechnology	4	0	4
2	MNL -702	Bionanotechnology-An Introduction	4	0	4
3	MNL -703	Physics and Chemistry of Solids	4	0	4
4	MNL-704	Quantum and Statistical Mechanics	4	0	4
5	MNL-705	Critical Analysis of Remarkable Papers	2	0	2
6	MNP-706	(Lab-I Basic Techniques in Bionanotechnology)	0	8	4
7		Audit Course- I	2		NC
		Total	20	8	22

SECOND SEMESTER

Sr. No.	Course No.	Title	L	P	Credits
1	MNL -711	Carbon based Nanostructures and Thin Films	3	0	3
2	MNL -712	Nanomaterials- Synthesis, Properties and Applications	4	0	4
3	MNL -713	Instrumentation Techniques for Nanotechnology	4	0	4
4	MNL -714	Nanoparticles in Microorganisms and Biosystems	3	0	3
5	MNL- 715	Research Methodology and Scientific Communication Skills	2	0	2
6	MNP-716	(Lab-II Nanomaterials/ CNT and Thin Films)	0	8	4
7	MNP-717	(Lab-III Advanced Instrumentation Techniques)	0	8	4
8		Audit Course- II	2		NC
Total			18	16	24

THIRD SEMESTER

Sr. No.	Course No.	Title	L	P	Credits
1	MNL – 721 to 722	*Program Elective-I	3	0	3
2	MNL – 723 to 724	*Program Elective-II	3	0	3
3	MNL -725	MEMS & NEMS – Sensors and Devices	3	0	3
4	MNL-726	Project Proposal Preparation and Presentation	2	0	2
5	MNP-727	(Lab-IV Applied Nanotechnology)	0	8	4
6	OPEN ELECTIVE	Open Elective offered by other department	3	0	3
Total			14	8	18

*For each of the Program Elective courses I and II Student can opt for any two out of the five courses including MOOC

FOURTH SEMESTER

Sr. No.	Course No.	Title	L	P	Credits
1	MND -800	Thesis	0	18	18

Program Elective-I	Program Elective-II
MNL- 721 Bionanostructures-Applications and Perspectives	MNL-723 Nano Composites
MNL-722 Environmental Nanotechnology and IPR	MNL-724 Nanomedicine and Drug Delivery
	MOOC Online Course as per list on SWAYAM / NPTEL

Program core (PC)	Program Elective (PE)	Open Elective (OE)	Total Credits
73	**6**	**3**	**82**

General Instructions:

1. The minimum credit requirement for the M. Tech. degree in Nano Science & Technology is 82 credits inclusive of the 6 credits for Program Elective courses including MOOC and 3 credits for open elective. As per MHRD guidelines student may opt one MOOC course through SWAYAM /NPTEL to earned total credit. List of offered MOOC courses will be notified by the department in the beginning of semester.
2. Among the Program Electives Courses I and II Student can opt for any one out of the two/three courses offered in 3rd Semester.
3. For theory courses, one hour per week per semester is assigned as one credit. For practical courses Eight hours per week accounts for 4 credits.
4. Each theory paper examination will be of 3 hours duration and practical examination will be of 4 hours duration.
5. Thesis (MND-800) will start in fourth semester and will be of 18 credits in all and the grades of thesis will be submitted as marks.
6. In the third semester, each student has to undertake Project Proposal Preparation & Presentation course. Three Teachers of the department including the Supervisor will evaluate the preparation of Synopsis, poster and research proposal of the student and award marks based on oral presentation internally.
7. Audit Courses Non-credit (2+0+0) will be offered in Sem-1 and Sem-2: Student required to undertake one course in each semester out of the given below courses:

   Semester-I
   i) AC01: English for Research Paper Writing
   ii) AC02: Disaster Management
   iii) AC07: Stress management by YOGA
   iv) AC04: Value Education

   Semester-II
   v) AC03: Sanskrit for Technical Knowledge
   vi) AC05: Constitution of India
   vii) AC06: Pedagogy studies
   viii) AC08: Personality Development through Life Enlightening skills

8. A total of 100 marks has been allocated to each theory and practical course. The distribution of marks will be as follows:

S.No.	Type of Test		Marks
1	**Major Test (External)**		**70**
2	**Internal Assessment Marks**		**30**
	A	Minor Test (Internal)	20
	B	Co-curricular Activities (Including assignment)	6
	C	Attendance Weightage	4

9. The candidates who have greater than 65% attendance will be awarded Internal Assessment Marks as follows:
   a) 65% to 70 % = 1 Marks
   b) 71% to 75 % = 2 Marks
   c) 76% to 80 % = 3 Marks
   d) 81 % onwards = 4 Marks

MNL 701: Introduction to Biotechnology and Nanotechnology (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to introduce students to the foundational knowledge of the biotechnology, microbial biotechnology, and nanotechnology along with an understanding of plant biotechnology and medical biotechnology.	**On completion of this course, students should be able to: -** • **Gain fundamental knowledge in biotechnologyand nanotechnology;** • **Know about the societal implications and ethical issues in nanotechnology;** • **Gain overview of scope and importance of different forms of biotechnology involving microbes, immune-technology, and medicine.**

Unit-I [15 Lectures]

Biotechnology: An Overview-definition, scope and importance of Biotechnology, Concept of Recombinant DNA technology and Gene Cloning, Tools of Recombinant DNA Technology-
Restriction enzymes, vectors etc.

Microbial Biotechnology: Brief history, Important group of microorganisms, Bacterial Growth and culturing of microbes, Control of microorganisms by physical & chemical agents, Antibiotics & chemotherapeutic agents, A brief account of microbes in industry and agriculture.

Unit-II [15 Lectures]

Nano Science & Technology: An Overview, Insights and intervention into the Nano world, Historical Developments, Societal implications & Ethical issues in Nanotechnology, Applications of Nanotechnology in different areas of Food, Agriculture, Automobiles, IT, Cosmetics & Consumer products, Textile and Medical Sciences.

Unit-III [15 Lectures]

Plant Biotechnology: Transgenic Plants, Biotechnology & Genomics, Principles of DNA sequencing, Automated DNA sequencing, DNA Chip Technology and Microarray Technology, Methods and applications of Genomics and Proteomics Research.

Unit-IV [15 Lectures]

Animal Biotechnology: Transgenic Animals, Immuno-technology and Immunoglobulins, Antigens and antigenicity, Cells of Immune system, Active and passive Immunity, Adjuvants, Hybridoma technology and Monoclonal antibodies. Techniques in Immunology-ELISA, RIA, Immunodiffusion, Immuno- Electrophoresis.

Medical Biotechnology: Biotechnology in medicine, Nano Medicine & Drug Delivery, Vaccines, Diagnostic, Forensic, Gene therapy, Cell & Tissue Engineering, Stem Cell therapy

Recommended Textbooks and References:

1. Tizard I.R. (2013). Immunology- An introduction, 5th Edition, Philadelphia Saunders College press.
2. Bhushan, Bharat (Ed.) (2012). Encyclopedia of Nanotechnology. Springer.
3. Jain, K. K. (2012). The Handbook of Nanomedicine. Springer
4. Gupta P.K. (2010). Biotechnology & Genomics, 5th Reprint, Rastogi Publications Meerut.
5. Singh B.D. (2010). Biotechnology, 4th edition, Kalyani Publication.
6. Black J.G (2008). Microbiology- Principles and Explorations, 7th edition, John Wiley & Sons.
7. Kuby J. (2006). Immunology, 6th Edition, W.H. Freeman & Co., New York.
8. Wolfson, J.R. (2003). 'Social and Ethical Issues in Nanotechnology: Lessons from Biotechnology and Other High Technologies', *Biotechnology Law Report*, **22**, no 4, 376-96.

MNL 702: Bionanotechnology-An Introduction (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course areto introduce students to the exciting and emerging field of bionanotechnology. It provides an understanding of biophysics, modern biomaterials, bionanomachines, biomolecular design, and functional principles of bionanotechnology.	**On completion of this course, students should be able to: -** • **Gain knowledge and understanding about harnessing biological systems to further nanotechnological endeavor;** • **Gain knowledge of structure and function of biological systems and cellular systems to construct the functional devices within nanotechnology;** • **Learn current applications and state of the art within bionanotechnology.**

Unit-I [15 Lectures]

Bionanotechnology – An Overview: Introduction to Bionanotechnology, Examples of Nanotechnology in nature, What can engineers learn from biology? From biotechnology to Bionanotechnology, Bionanomachines in action.

Biophysics: Bioelectromagnetism, Bioenergetics, Neuro transport, Biological Rhythms.

Unit-II [15 Lectures]

Modern Biomaterials: Proteins, Nucleic acids, Lipids, Polysaccharides, Life processes & Cell, Cell and its properties, Nucleic Acid & Central Dogma, DNA tools and Biotechnology, DNA Nanotechnology.

Unit-III [15 Lectures]

Structural Principles of Bionanotechnology: Natural Bionano-machinery, Hierarchical strategy, raw materials, Protein folding, self-assembly and self- organization, molecular recognition and flexibility.

Unit-IV [15 Lectures]

Functional Principles of Bionanotechnology: Information driven Nano assembly, Energetics, chemical transformation, regulation. Biomolecular motors, Biomolecular sensing, self-replication and machine - phase bionanotechnology.

Bionanotechnology Today and Future: Basic capabilities, Nanomedicine today, DNA computers, artificial life and biosensors.

Recommended Textbooks and References:

1. Jain, K. K. (2012). The Handbook of Nanomedicine. Springer
2. Bhushan, Bharat (Ed.) (2012). Encyclopedia of Nanotechnology. Springer.
3. Sharon, M. & Sharon, M (2012) Bio-Nanotechnology- Concepts and Applications, CRC Press.

4. David E. Reisner (2011) Bionanotechnology II- Global Prospects, CRC Press. Endo, Isao; Nagamune, Teruyuki (Eds.) (2010). Nano/Micro Biotechnology. Springer.
5. David E. Reisner (2008) Bionanotechnology- Global Prospects, CRC Press.
6. Niemeyer C.M. & Mirkin, C.A. (2004). Nanobiotechnology- Concepts, Applications and Perspectives, Wiley-VCH Verlag.
7. Goodsell, David S. (2004). Bionanotechnology- Lessons from Nature. John Wiley & Sons, INC., Publication.
8. Avouris, P., Klitzing, K. Von, Sakaki H. & Wiesendanger, R. (2003). Nano Science and Technology Series. Springer.
9. Pattabhi,V & Gautham, N. (2002). Biophysics. Narosa Publications.
10. Hench L.L, Ethridge, E.C. (2007) Biomaterials- An Interfacial Approach, Academic Press.

MNL 703: Physics and Chemistry of Solids (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to introduce students to thephysical and chemical insights into the properties and potential applications of different materials. The focus is also given to acquaint students aboutgreener strategies along with electrochemical methods and associated diverse applications.	**On completion of this course, students should be able to: -** • **Learn about different aspects related to physical and chemical properties of materials;** • **Gain knowledge about different types of materials, their structures and applications;** • **Know about the basics of greenerprocesses for synthesis of materials and associated advantages.**

Unit-I [15 Lectures]

Chemical Bonding and PN Junctions: Amorphous and crystalline materials, polycrystals, symmetry, Unit Cells, Crystal Structures. Atomic Bonding in solids, Types of bond: Metallic, Ionic, Covalent and Van der Waals bond; Hybridisation; H- bonding, Molecular orbital theory for simple molecules, Physics of Semiconductor materials, Drift velocity, Mobility, Scattering, Diffusion current, Band model, Fabrication of pn junctions, Step junction, linearly graded junction, Use of Junction diode as a rectifier, Zener Diode, Tunnel Diode, Varactor Diode, MOSFETs.

Unit-II [15 Lectures]

Types of Material: Different types of materials: Metals, Semiconductors, Composite materials, Ceramics, Polymers, polymer applications, frontiers of polymer materials (biogradable polymers, biomedical polymers, conducting polymers, magnetic polymers, polymers for space, nonlinear optical polymers), problems of polymer (thermoxidative degradation, fire hazards, toxicity, effluent disposal, feedstock scarcity), Superconductors, meissner effect, origin of superconductivity BCS theory of superconductivity, Type –I and Type II superconductors, Josephson effect, High Temperature Superconductors.

Unit-III [15 Lectures]

Imperfections in solids and Electrochemistry: Imperfections of crystal structure: point defects, Grain boundaries, phase boundaries, Dislocations Screw, Edge and Mixed Dislocations. Electrochemical cell, Electrolysis, Fundamental equations: Nernst equation, Fick's law of diffusion, Faraday's Law, Cyclic Voltammetry, Solid Electrode Materials, Ultramicroelectrodes, Chemically modified electrodes and their applications.

Unit-IV [15 Lectures]

Green Synthesis Strategies: Basic principles of green chemistry, High-yield and zero-waste chemical processes: Microwave synthesis, electro-organic synthesis, the design and development of environmentally friendly chemical pathways: challenges and opportunities.

Materials for green chemistry and technology: Catalysis, environmental friendly catalysts, Bio-catalysis, biodegradable polymers, alternative solvents, ionic liquids. Applications of green chemistry.

Recommended Textbooks and References:

1. Schlaad, H (2013). Bio-synthetic Polymer Conjugates, Springer.
2. Gazit, E, Nussinov, R. (Eds.) (2008). Nanostructure Design Methods and Protocols. Springer.
3. Kalia, S; Kaith, B. S. & Kaur Inderjeet (Eds.) (2011). Cellulose Fibers: Bio- and NanoPolymer Composites, Green Chemistry and Technology, Springer.
4. William D. C. (Jr). (2007). Materials Science & Engineering: An Introduction, 7th edition, Wiley.
5. McKelvey, J.P. (1966). Introduction to Solid State and Semiconductor Physics, Harper and Row and John Weathe Hill.
6. Sze, S.M. 1981. Physics of Semiconductor Devices, 2nd edition, John Wiley.
7. Green Reaction Media in Organic Synthesis by Mikami Koichi Wiley-Blackwell, 2005
8. Koichi Tanaka Solvent-free Organic Synthesis Green chemistry Wiley-VCH; 2003
9. Stanley E. M. (2005) Green Chemistry and the Ten Commandments of Sustainability, ChemChar
10. R. A. Sheldon, Isabel Arends, and Ulf Hanefeld. (2007) Green Chemistry and Catalysis.Wiley VCH.
11. C. P. Pool, Jr., H. A. Farach and R. J. Creswick (1995) Superconductivity, Academic Press.
12. J. Kahovec, I.Meisel, C.S.Kniep (2001) Polymers in Medicine Wiley VCH.
13. K. Holmberg, B. Jonsson, B. Kronberg, B. Lindman,(2004) Surfactants and Polymers in Aqueous Solution, Wiley.
14. C.G. Zoski (2007) Handbook of Electrochemistry, Elsevier.

MNL 704: Quantum and Statistical Mechanics (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objective of this course is to give conceptual exposure of essential contents of quantum mechanics and statistics to the students. The basic phenomenon required to appreciate the importance of quantum theories and statistical processes in nanotechnology are focused	**On completion of this course, students should be able to:** • **Gain broad understanding inquantum mechanics and statistics;** • **Recognize importance and value of quantum phenomenon and statistical thinking, training, and approach to problem solving, on a diverse variety of disciplines.** • **Students should be able to have a firm foundation in fundamentals and application of current scientific theories.**

Unit-I [15 Lectures]

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

Unit-II [15 Lectures]

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

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

Unit-III [15 Lectures]

Scattering Theory: Scattering Cross-section and scattering amplitude, partial wave analysis, born approximation and its application to simple potentials. Introduction to Non-Degenerate and degenerate perturbations theory.

Unit-IV [15 Lectures]

Ensembles Theory and Quantum Statistics: Concept of microstate and macrostate**,** Different types of ensembles**,** The microcanonical ensemble theory and its application to ideal gas of monatomic particles; The canonical ensemble and its thermodynamics; Partition function, energy fluctuations, equipartition; A system of harmonic oscillators as canonical ensemble; The grand canonical ensemble and significance of statistical quantities. Basic concepts and thermodynamic behavior of an ideal Bose gas, Bose-Einstein condensation, Pauli paramagnetism, heat capacity of a free-electron gas at low temperatures.

Recommended Textbooks and References:

1. Khanna, M.P. 1966.Quantum Mechanics. Har Anand, New Delhi.
2. Sakurai, J.J. & Jim Napolitano (2011) Modern Quantum Mechanics, Addison Wesley.
3. Schiff, L.I. (1968) Quantum Mechanics, 3rd Edition, McGraw Hill, NY.
4. Loknathan, S & Ghatak, A. (2004) Quantum Mechanics, Kluwer Academic.
5. Merzbacher, E. (1998) Introduction to Quantum Mechanics, 3rd edition, John Wiley, NY.
6. Pathria, R.K. & P.D. Beale (2011). Statistical Mechanics, Reprint Elseivier.
7. Davidson, N (2003) Statistical Mechanics, Dover Publications, NY.

MNL 705: Critical Analysis of Remarkable Papers (Credits: 2+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Internal Assessment: Students will be divided in groups and each group will be responsible for one classical paper. Each week there will be a one-hour presentation cum discussion for each of the papers. At the end of the semester each student will be asked to write a mini-review (2-3 pages long) on any one classical paper, other than the one he/she presented/discussed.

Course Objectives	Student Learning Outcomes
The objectives of this course are to familiarize students with classic literature to make them appreciate how ground- breaking discoveries were made without, necessarily, use of high-end technologies.	**Students should be able to train in the exercise of hypothesis building and methods of addressing the hypothesis with readily available technology.**

Unit-I [08 Lectures]

Foundation of Nanotechnology

1. Feynman, R. P. (1960). There's plenty of room at the bottom. *California Institute of Technology, Engineering and Science magazine*.
2. Eric Drexler, K. (1986). Engines of creation: the coming era of nanotechnology.
3. Albrecht, T. R., Akamine, S., Carver, T. E., & Zdeblick, M. J. (1993). *U.S. Patent No. 5,221,415*. Washington, DC: U.S. Patent and Trademark Office.
4. Toumey, C. (2009). Plenty of room, plenty of history. *Nature nanotechnology*, *4*(12), 783-784.
5. Lok, C. (2010). Nanotechnology: Small wonders. *Nature*, *467*(7311), 18.
6. Baumann, S., Lutz, C. P., & Eigler, D. M. (2016). Nano on reflection. *Nature Nanotechnology*, *11*, 828-834.
7. Saha, S. K., Wang, D., Nguyen, V. H., Chang, Y., Oakdale, J. S., & Chen, S. C. (2019). Scalable submicrometer additive manufacturing. *Science*, *366*(6461), 105-109.

Unit-II [07 Lectures]

Fascinating Nanomaterials:

1. Kroto, H. W., Heath, J. R., O'Brien, S. C., Curl, R. F., & Smalley, R. E. (1985). C60: Buckminsterfullerene. N*ature*, *318*(6042), 162-163.
2. Iijima, S. (1991). Helical microtubules of graphitic carbon. *nature*, *354*(6348), 56-58.
3. Onushchenko, A. A., & Petrovskii, G. T. (1996). Size effects in phase transitions of semiconductor nanoparticles embedded in glass. *Journal of non-crystalline solids*, *196*, 73-78.

4. Monticone, S., Tufeu, R., & Kanaev, A. V. (1998). Complex nature of the UV and visible fluorescence of colloidal ZnO nanoparticles. *The Journal of Physical Chemistry B*, *102*(16), 2854-2862.
5. Novoselov, K. S., Geim, A. K., Morozov, S. V., Jiang, D., Zhang, Y., Dubonos, S. V., ... & Firsov, A. A. (2004). Electric field effect in atomically thin carbon films. *science*, *306*(5696), 666-669.
6. Thompson, D. (2007). Michael Faraday's recognition of ruby gold: the birth of modern nanotechnology. *Gold Bulletin*, *40*(4), 267-269.
7. Chen, J., & Li, Y. (2016). The Road to MOF-Related Functional Materials and Beyond: Desire, Design, Decoration, and Development. *The Chemical Record*, *16*(3), 1456-1476.
8. Jeevanandam, J., Barhoum, A., Chan, Y. S., Dufresne, A., & Danquah, M. K. (2018). Review on nanoparticles and nanostructured materials: history, sources, toxicity and regulations. *Beilstein journal of nanotechnology*, *9*(1), 1050-1074.

Unit-III [07 Lectures]

High Resolution Imaging:

1. Müller, E. W. (1963). Field Emission Microscopy of Clean Surfaces with Electrons and Positive Ions. *NYASA*, *101*(3), 585-598.
2. Binnig, G., & Rohrer, H. (1983). Scanning tunneling microscopy. *Surface science*, *126*(1-3), 236-244.
3. Binnig, G., Quate, C. F., & Gerber, C. (1986). Atomic force microscope. *Physical review letters*, *56*(9), 930.
4. Haguenau, F., Hawkes, P. W., Hutchison, J. L., Satiat-Jeunemaître, B., Simon, G. T., & Williams, D. B. (2003). Key events in the history of electron microscopy. *Microscopy and Microanalysis*, *9*(2), 96.
5. Pease, D. C. (2013). *Histological techniques for electron microscopy*. Elsevier.
6. Chao, W., Harteneck, B. D., Liddle, J. A., Anderson, E. H., & Attwood, D. T. (2005). Soft X-ray microscopy at a spatial resolution better than 15 nm. *Nature*, *435*(7046), 1210-1213.
7. Ishikawa-Ankerhold, H. C., Ankerhold, R., & Drummen, G. P. (2012). Advanced fluorescence microscopy techniques—Frap, Flip, Flap, Fret and flim. *Molecules*, *17*(4), 4047-4132.
8. Blom, H., & Widengren, J. (2017). Stimulated emission depletion microscopy. *Chemical reviews*, *117*(11), 7377-7427.

Unit-IV [08 Lectures]

Multifaceted Healthcare Applications:

1. Mendel, J. (1999). Dispersions and Coatings. In *Nanostructure Science and Technology* (pp. 35-47). Springer, Dordrecht.
2. Gabbay, J. (2000). *U.S. Patent No. 6,124,221*. Washington, DC: U.S. Patent and Trademark Office.
3. Mazzola, L. (2003). Commercializing nanotechnology. *Nature biotechnology*, *21*(10), 1137-1143.
4. Handy, R. D., Owen, R., & Valsami-Jones, E. (2008). The ecotoxicology of nanoparticles and nanomaterials: current status, knowledge gaps, challenges, and future needs. *Ecotoxicology*, *17*(5), 315-325.

5. Zheng, J., Birktoft, J. J., Chen, Y., Wang, T., Sha, R., Constantinou, P. E., ... & Seeman, N. C. (2009). From molecular to macroscopic via the rational design of a self-assembled 3D DNA crystal. *Nature*, *461*(7260), 74-77.
6. Petros, R. A., & DeSimone, J. M. (2010). Strategies in the design of nanoparticles for therapeutic applications. *Nature reviews Drug discovery*, *9*(8), 615-627.
7. Wang, Y., Zheng, D., Tan, Q., Wang, M. X., & Gu, L. Q. (2011). Nanopore-based detection of circulating microRNAs in lung cancer patients. *Nature nanotechnology*, *6*(10), 668-674.
8. Yang, X., Yang, M., Pang, B., Vara, M., & Xia, Y. (2015). Gold nanomaterials at work in biomedicine. *Chemical reviews*, *115*(19), 10410-10488.
9. Grodzinski, P., Kircher, M., Goldberg, M., & Gabizon, A. (2019). Integrating nanotechnology into cancer care. *ACS Nano*, *13*(7), 7370–7376.

Energy and Environment:

1. Qian, L., & Hinestroza, J. P. (2004). Application of nanotechnology for high performance textiles. *Journal of textile and apparel, technology and management*, *4*(1), 1-7.
2. Shirai, Y., Osgood, A. J., Zhao, Y., Kelly, K. F., & Tour, J. M. (2005). Directional control in thermally driven single molecule nanocars. *Nano Letters*, *5*(11), 2330-2334.
3. Scrosati, B. (2007). Paper powers battery breakthrough. Nature nanotechnology, 2(10), 598-599.
4. Tarascon, J. M. (2009). Viruses electrify battery research. *Nature nanotechnology*, *4*(6), 341-342.
5. DeRosa, M. C., Monreal, C., Schnitzer, M., Walsh, R., & Sultan, Y. (2010). Nanotechnology in fertilizers. *Nature nanotechnology*, *5*(2), 91-91.
6. Liang, Z., & Fan, D. (2018). Visible light–gated reconfigurable rotary actuation of electric nanomotors. *Science advances*, *4*(9), eaau0981.
7. Chen, X., Roemer, M., Yuan, L., Du, W., Thompson, D., Del Barco, E., & Nijhuis, C. A. (2017). Molecular diodes with rectification ratios exceeding 10^5 driven by electrostatic interactions. *Nature nanotechnology*, *12*(8), 797-803.
8. Alvarez, P. J., Chan, C. K., Elimelech, M., Halas, N. J., & Villagrán, D. (2018). Emerging opportunities for nanotechnology to enhance water security. *Nature nanotechnology*, *13*(8), 634.

MNL 711: Carbon based Nanostructures and Thin Films (Credits: 3+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to introduce students to the fascinating world of carbon-based nanostructures and thin films. The emerging trends related to synthesis and functionalization for diverse applications will be covered. The students will be educated about fundamentals and advancements in thin film technology and associated applications.	**On completion of this course, students should be able to: -** • **Gain knowledge about historical development and structures of carbon-based nanomaterials;** • **Get an overview of different synthesis strategies and functionalization approaches** • **Learn about different properties of these nanostructures for diverse applications in energy, environment, healthcare devices.**

Unit-I [12 Lectures]

Introduction: Different Allotropes of carbon, Introduction to CNTs, Historical developments, Structure of CNTs based on chirality, Types of CNTs- SWNTs, MWNTs, Buckyballs, Graphene.

Applications of Carbon Nanotubes and Graphene: Field emission, Fuel Cells, Display devices, CNT-based biosensors, Graphene as sensing material in biosensors, CNTs for energy conversion and storage, CNTs as nanocarrier for healthcare applications,Graphene in solar cells, Graphene electrodes in supercapacitors/lithium ion batteries, etc.

Unit-II [11 Lectures]

Synthesis of Carbon Nano-Tubes and Graphene: Different methods of synthesis of CNTs:laser ablation, carbon arc method, Chemical vapor deposition, Electrodeposition, Flame synthesis etc, Properties of Carbon Nanotubes and Graphene: Physical, Thermal, Electrical, Optical, Mechanical, and Vibrational properties, Synthesis strategies for graphene, Improved Hummer's method.

Unit-III [11 Lectures]

Functionalization and characterization of Carbon Nanotubes and Graphene: Functionalization of Carbon Nanotubes and graphene, Covalent and Non-covalent Functionalization, Purification methods: Oxidation, Acid treatment, Annealing, Ultrasonication, Micro filtration, Ferromagnetic separation, and Chromatography techniques. Characterization/confirmation of functionalization through different techniques.

Unit-IV [11 Lectures]

Thin Films: Introduction to Thin Films, History, Types of Thin Films, Basic Concepts of deposition, Methods of deposition/ Methods of Preparation of Thin Films: CVD, Langmuir

Blodgett Film deposition system, Spin coating, Dip coating, RF plasma, Electron Beam, Sputtering, Vacuum Deposition (Thermal Evaporation) system etc., Magnetic Thin Films, Applications of Thin Films.

Recommended Textbooks and References:

1. Ren, Zhifeng, Lan, Yucheng, Wang, Yang (2013) Aligned Carbon Nanotubes: Physics, Concepts, Fabrication and Devices. Springer.
2. Wonbong Choi, Jo Won Lee (2012) Graphene: Synthesis and Applications, CRC Press.
3. Lüth, Hans (2010) Solid Surfaces, Interfaces and Thin Films. Springer.
4. Gazit, Ehud; Nussinov, Ruth (Eds.) (2008). Nanostructure Design Methods and Protocols. Springer.
5. Anke Krueger (2010) Carbon Materials and Nanotechnology, Wiley – VCH Verlag, GmbH & Co. K GaA.
6. Kannan Balasubramanian and Marko Burghard (2010) Carbon nanotubes-Methods and protocol, Humana Press.
7. Dirk M. Guldi and Nazario Martín (2010) Carbon Nanotubes and Related Structures, Wiley – VCH Verlag, GmbH & Co. K GaA.
8. Kazuyoshi Tanaka, Tokio Yamabe and Kenichi Fukui (1999) The Science and Technology of Carbon Nanotubes, Elsevier Science Ltd.
9. Sie Chin Tjong(2009), Carbon Nanotube Reinforced Composites *Wiley – VCH Verlag, GmbH & Co*
10. Y. Gogotsi(2006) Nanotubes and Nanofibers, Taylor and Francis.
11. S. Carrarra (2011) Nano-Bio-Sensing, Springer.
12. D. Smith (1995) Thin Film Deposition: Principles and Practices, Mcgraw Hill.

MNL 712: Nanomaterials- Synthesis, Properties and Applications (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to introduce students about exotic properties of nanomaterials suitable for plethora of applications. The students will be exposed to numerous routes for controlled synthesis of variety of nanomaterials.	**On completion of this course, students should be able to: -** • **Gain information about different classes of nanomaterials, their associated properties and futuristic applications;** • **Learn about different synthesis approaches in terms of physical methods, chemical methods, biological synthesis and lithographic techniques.**

Unit-I [15 Lectures]

Nanomaterials: Various classes, properties & applications, semiconductor nano particles – metal organic frameworks- types, properties and applications. metal and metal oxide based nanomaterials, composites for applications in environmental remediation, sensing of analytes, catalysis, and energy storage.

Unit-II [15 Lectures]

Physical Methods: Inert gas condensation, Arc discharge, RF-plasma, Plasma arc technique, Ion sputtering, Laser ablation, Laser pyrolysis, Ball Milling, Molecular beam epitaxy, Chemical vapour deposition method and other variants, Electrodeposition, Microwave synthesis method.

Unit-III [15 Lectures]

Chemical Methods: Metal nanocrystals by reduction, Solvothermal synthesis, Photochemical synthesis, Electrochemical synthesis, Thermolysis routes, Sonochemical routes, Sol- gel, Micelles and microemulsions,

Lithographic Techniques: AFM based nanolithography and nanomanipulation, E beam lithography and SEM based nanolithography and nanomanipulation, Ion beam lithography, oxidation and metallization. Mask and its application. Deep UV lithography.

Unit-IV [15 Lectures]

Biological Methods of Synthesis: Use of bacteria, fungi, Actinomycetes for nanoparticle synthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Mechanism of formation; Viruses as components for the formation of nanostructured materials; Synthesis process and application, Role of plants in nanoparticle synthesis.

Recommended Textbooks and References:

1. Hari Singh Nalwa (2011) Encyclopedia of Nano Science &Nanotechnology, American Scientific Publishers.
2. Gazit, Ehud; Nussinov, Ruth (Eds.) 2008. Nanostructure Design Methods and Protocols. Springer.
3. Sakka, S. (Ed.) 2005. Handbook of Sol-Gel Science and Technology: Processing, Characterization and Applications, V. I - Sol-Gel Processing/Hiromitsu Kozuka, Editor, V. II - Characterization of Sol-Gel Materials and Products/Rui M. Almeida, Editor, V. III - Applications of Sol-Gel Technology/Sumio Sakka, Editor. Springer.
4. Lüth, Hans 2010 Solid Surfaces, Interfaces and Thin Films. Springer.
5. Vajtai, R 2013. Springer Handbook of nanomaterials, Springer.

MNL 713: Instrumentation Techniques for Nanotechnology (Credits: 4+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
This course is broad-based in nature encompassing several new technologies that current experimental researchers are employing to probe complex nanosystems. The objectives of this course are to teach basics of the new principles to students so as to appreciate current-day research tool-kit better.	**Students should be to learn history, theoretical basis and basic understanding of latest technologies in area of Nano Science and Technology. Students should also be able to learn about various applications of these technologies. The students may also learn one-two techniques in depth through an assignment and/or seminar.**

Unit-I [15 Lectures]

Introduction to electron microscopy, principle, and operation of SEM and TEM. Different detectors as attachment with electron microscopes. Sample preparation for SEM and TEM. High resolution imaging, safety measures in electron microscopy. Introduction to scanning probe microscopes. Principle and operation of STM, AFM, MFM, EFM, LFM, SCM, SThM. Principle and operation of confocal microscopy.

Unit-II [15 Lectures]

Principle, operation and applications of X ray Diffraction (XRD)-powder and single crystal method. small angle X ray scattering (SAXS), X ray Fluorescence (XRF): WD-XRF and EXRF, X ray photoelectron spectroscopy (XPS), X-ray absorption spectroscopy (XAS).

Unit-III [15 Lectures]

Principle, operation and applications of Fluorescence spectroscopy, UV-Visible spectroscopy,
Ultraviolet photoelectron spectroscopy (UPS),Fourier Transform Infra-red spectroscopy (FTIR), Raman Spectroscopy, Auger electron spectroscopy (AES), Nuclear magnetic resonance (NMR) spectroscopy, Mass spectroscopy, atomic absorption spectroscopy, atomic emission spectroscopy.

Unit-IV [15 Lectures]

Principle, operation and applications of Differential Scanning Calorimetry (DSC), Differential Thermal Analysis (DTA), Thermogravimetric analysis (TGA), Dynamic Light Scattering (DLS) based particle size analyzer, Zeta Potential, Optical Tweezers, High-performance liquid chromatography (HPLC), Circular Dichroism.

Recommended Textbooks and References:

1. Bhushan, Bharat 2004. Handbook of Nanotechnology. Springer.
2. Papkovsky, D., Zhdanov, A.V., Fercher, A., Dmitriev, R.I., Hynes, J. 2012 Phosphorescent Oxygen-Sensitive Probes. Springer.
3. Ye, Bang-Ce, Zhang, Min, Yin, Bin-Cheng 2012 Nano-Bio Probe Design and Its Application for Biochemical Analysis. Springer
4. Carrara, Sandro (Ed.) 2011 Nano-Bio-Sensing. Springer.
5. Bhushan, Bharat (Ed.) 2013 Scanning Probe Microscopy in Nanoscience and Nanotechnology Springer.
6. Schultz, J.; Mrksich, M.; Bhatia, S.N.; Brady, D.J.; Ricco, A.J.; Walt, D.R.; Wilkins, C.L.
7. (Eds.) 2006 Biosensing: International Research and Development. Springer.
8. Avouris, P., Klitzing, K. Von, Sakaki, H. & Wiesendanger,R .2003.
9. NanoScience and Technology Series. Scanning Probe Microscopy- Analytical Methods (R. Wiesendanger eds), Springer.
10. Avouris, P. Klitzing, K. von H. Sakaki & Wiesendanger, R,.2003. NanoScience and Technology Series. Noncontact Atomic Force Microscopy (S.Morita & R. Wiesendanger eds), Springer.

MNL 714: Nanoparticles in Microorganisms and Biosystems (Credits: 3+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are: - • **To introduce nanoparticles in microorganisms and biosystems.** • **To explore the biomaterials with exciting properties for interfacing between biochemical phenomena and electronic devices.** • **To attain fundamental knowledge about tissue engineering in various organs, and advancements in use of nanomaterials in tissue engineering.**	**On completion of this course, students should be able to: -** • **Gain information about different microorganisms for synthesis of nanomaterials along with consideration of their toxicity;** • **Learn information about nanocomposite biomaterial for application in implants and tissue engineering;** • **Acquaint with synthetic nanomaterials mimicking naturally occurring biomaterials.** • **Gain insights of nano-bio systems.**

Unit-I [11 Lectures]

Microorganisms for synthesis of Nano materials and for toxicity detection: Natural and artificial synthesis of Nano particles in microorganisms; Use of microorganisms for nanostructure formation, Testing of environmental toxic effect of Nano particles using microorganisms.

Unit-II [12 Lectures]

Nano composite biomaterials, teeth and bone substitution: Natural nanocomposite systems as spider silk, bones, shells; organic-inorganic nanocomposite formation through self-assembly. Biomimetic synthesis of nanocomposite material; Use of synthetic nano composites for bone, teeth replacement, Nanophase Materials Coatings, Advantages of Nanomaterials Used as Implants, Nanophase Materials in Tissue Engineering Applications.

Unit-III [11 Lectures]

Nano bio Systems: Nano particle-biomaterial hybrid systems for bioelectronic devices, Bioelectronic systems based on nanoparticle-enzyme hybrids; nano particle based bioelectronic biorecognition events. Biomaterial based metallic nanowires, networks and circuitry. DNA as functional template for nano circuitry; Protein based nanocircuitry; Neurons for network formation. DNA nanostructures for mechanics and computing and DNA based computation; DNA based nanomechanical devices.

Unit-IV [11 Lectures]

Tissue Engineering: The status of tissue engineering of specific organs, including bone marrow, skeletal muscle, and cartilage. Cell biological fundamentals of tissue engineering. Nano-regenerative medicine towards clinical outcome of stem cell and tissue engineering in humans.

Recommended Textbooks and References:

1. David S. Goodsell (2004) Bionanotechnology: Lessons from Nature, Wiley-Liss Inc.
2. Rai, Mahendra; Duran, Nelson (Eds.) (2011) Metal Nanoparticles in Microbiology. Springer.
3. Cioffi, Nicola; Rai, Mahendra (Eds.) (2012) Nano-Antimicrobials. Springer
4. R. A. Freitas (2003) Nanomedicine, Vol. IIA: Biocompatibility, Landes Bioscience.
5. Hari Singh Nalwa (2005) Handbook of Nanostructured Biomaterials and Their Applications in Nanobiotechnology, American Scientific Publishers.
6. Nanobiotechnology; ed. C.M.Niemeyer, C.A. Mirkin.
7. Introduction to Nanoscale Science and Technology (Nanostructure Science and Technology)- Massimiliano Di Ventra
8. Seeram Ramakrishna, Ramalingam Murugan, T .S. Sampath Kuma(2010)Biomaterials: a nano approach, CRC Press/Taylor & Francis.

MNL 715: Research Methodology and Scientific Communication Skills (Credits: 2+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to give background on history of science, emphasizing methodologies used to do research, use framework of these methodologies for understanding effective lab practices and scientific communication and appreciate scientific ethics.	**Students should be able to:** **• Understand history and methodologies of scientific research, applying these to recent published papers;** **• Understand and practice scientific reading, writing and presentations; Appreciate scientific ethics through case studies.**

Unit-I [08 Lectures]

History of science and science methodologies: Empirical science; scientific method; manipulative experiments and controls; deductive and inductive reasoning; descriptive science; reductionist vs holistic biology.

Preparation of Research: Choosing a mentor, lab and research question; maintaining a lab notebook.

Unit-II [08 Lectures]

Process of Communication: Concept of effective communication- setting clear goals for communication; determining outcomes and results; initiating communication; avoiding breakdowns while communicating; creating value in conversation; barriers to effective communication; non-verbal communication-interpreting non-verbal cues; importance of body language, power of effective listening; recognizing cultural differences; Presentation skills - formal presentation skills; preparing and presenting using over-head projector, PowerPoint; defending interrogation; scientific poster preparation & presentation; participating in group discussions; Computing skills for scientific research - web browsing for information search; search engines and their mechanism of searching; hidden Web and its importance in scientific research; internet as a medium of interaction between scientists; effective email strategy using the right tone and conciseness.

Unit-III [08 Lectures]

Scientific Communication: Technical writing skills - types of reports; layout of a formal report; scientific writing skills - importance of communicating science; problems while writing a scientific document; plagiarism, software for plagiarism; scientific publication writing: elements of a scientific paper including abstract, introduction, materials & methods, results, discussion, references; drafting titles and framing abstracts; publishing scientific papers - peer review process and problems, recent developments such as open access and nonblind review; plagiarism; characteristics of effective technical communication; scientific presentations; ethical issues; scientific misconduct.

Unit-IV **[07 Lectures]**

Biostatistics: Probability: counting, conditional probability, discrete and continuous random variables; Error propagation; Populations and samples, expectation, parametric tests of statistical significance, nonparametric hypothesis tests, linear regression, correlation & causality, analysis of variance, factorial experiment design. Introduction and applications of SPSS and R softwares.

Recommended Textbooks and References:

1. Valiela, I. (2001). Doing Science: Design, Analysis, and Communication of Scientific Research. Oxford: Oxford University Press.
2. On Being a Scientist: a Guide to Responsible Conduct in Research. (2009). Washington, D.C.: National Academies Press.
3. Gopen, G. D., & Smith, J. A. The Science of Scientific Writing. American Scientist, 78 (Nov-Dec 1990), 550-558.
4. Mohan, K., & Singh, N. P. (2010). Speaking English Effectively. Delhi: Macmillan India. 5. Movie: Naturally Obsessed, The Making of a Scientist.
6. Rosner, B. (2000). Fundamentals of Biostatistics. Boston, MA: Duxbury Press.
7. Daniel, W. W. (1987). Biostatistics, a Foundation for Analysis in the Health Sciences. New York: Wiley.

MNL 721: Bionanostructures -Applications and Perspectives (Credits: 3+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to introduce students with different kinds of bio nanostructures and their further applications and perspectives.	**Students should be able to:** • **Gain information about different kinds of bionanostructures including protein-based and DNA-based nanostructures;** • **Understand the biodegradable polymers in terms of their possible renewable resources and further applications;** • **Gain insights of nano structured fluids and nanoformulations for applicability in healthcare, cosmetics, foods, and nutraceuticals.**

Unit-I [12 Lectures]

Protein Based Nanostructures: S- layers- structures, self-assembly and applications; Engineered Nanopores; Magnetosomes- Nanoscale magnetic iron minerals in bacteria; Bacteriorhodopsin and its potential in technical applications & preparation of Bacteriorhodopsin films.

Unit-II [10 Lectures]

DNA based Nanostructures: DNA-Protein Nanostructures- overview, conjugation, supra-molecular Assembly, DNA directed immobilization, Microarray Technologies; DNA-template electronics, DNA Gold Nanoparticles conjugates- Chip Based DNA detection assays; DNA Nanostructures for mechanics and Computing; Nanoparticles as Non-Viral Transfection Agents, Real Time PCR based methods in Diagnosis of Infectious Diseases.

Unit-III [11 Lectures]

Biodegradable Polymers: Polymers derived from Renewable resources, Petroleum resources, Bacterial polymers, Applications of Biodegradable polymers, Biodegradable polymers in controlled drug delivery.

Analysis of Biomolecular Structures: Luminescent quantum dots for Biological Labeling, Nanoparticle molecular labels, Role of AFM and Force spectroscopy in Nanoanalytics and molecular pulling, Biocojugated Silica Nanoparticles for Bioanalytical Applications.

Unit-IV [12 Lectures]

Nano Structured Fluids and Nanoformulations: Properties, Characterization, design & formulation, Novel approaches for enhancing of Drug bioavailability, Nanotechnology as emerging tool for enhancing solubility for poorly water-soluble drugs; nano-emulsions for foods and nutraceuticals, smart materials.

Recommended Textbooks and References:

1. Fan, Chunhai (Ed.) (2013) DNA Nano Technology: From structure to function. Springer.
2. Schlaad, Helmut (Ed.) 2013 Bio-synthetic Polymer Conjugates Springer
3. Rahman, M., Laurent, S., Tawil, N., Yahia, L., Mahmoudi, M. 2013 Protein-Nanoparticle Interactions - The Bio-Nano Interface. Springer.
4. Gracheva, Maria E. (Ed.) 2012 Nanopore-Based Technology. Springer
5. Kalia, Susheel; Kaith, B. S.; Kaur, Inderjeet (Eds.) 2011 Cellulose Fibers: Bio- and Nano-Polymer Composites. Green Chemistry and Technology. Springer
6. Zvelindovsky, A.V. (Ed.) 2007 Nanostructured Soft Matter. Experiment, Theory, Simulation and Perspectives. Springer.
7. Niemeyer C.M. & Mirkin, C.A., 2004. Nanobiotechnology- Concepts, Applications and Prespectives. Wiley-VCH Verlag.
8. Bauerlein, E. 2000. Biomineralization- From Biology to Biotechnology and Medical Applications. Wiley-VCH Verlag.

MNL 722: Environmental Nanotechnology (Credits: 3+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are: - • **To familiarize students with environmental nanotechnology, safety, and toxicology.** • **To educate about use of nanotechnology for waste remediation** • **The students will also be exposed to intellectual property rights and protection.**	**Students should be able to:** • **Gain information about nanomaterials for environmental protection in terms of sensing of pollutants and their remediation.** • **Understand the concept of nano pollution and its impact on health.** • **Gain insights of need and legal issues related to patent filing.**

Unit-I [11 Lectures]

Environmental Nanotechnology: An introduction, Concept of Nano pollution, Nanotechnology for Reduced waste and improved energy efficiency, Nanotechnology based water treatment strategies, Nanomaterials for sensing of pollutants, Nanomaterials for cleaner energy. Case studies based on recent research reported in these areas.

Unit-II [11 Lectures]

Waste remediation: Nanoporous polymers and their applications in water purification, Photocatalytic fluid purification. Energy conversion; Hierarchical self-assembled nanostructures for adsorption of heavy metals, Nano-pesticide formulations, Role of nanotechnology in pesticide residue management, Nanoparticles for dye removal and water filtration.

Unit-III [11 Lectures]

Pollution by Nano-particles: Health impact, Safety and Toxicological effects.
Societal impact & Ethical issues: Societal impact & Ethical issues in Nanoscience and Nanotechnology, Problems and possible solutions, Regulation, Green Nanotechnology, 12 principles of Green chemistry, Green methodologies for synthesis of metal-organic frameworks.

Unit-IV [12 Lectures]

Guidelines and Best Practices for Safe Handling of Nanomaterials in Research Laboratories and Industries: Best practices to be followed while handling nanoparticles, Best practices and adequate approaches regarding making and handling of nanopowders and use of products relating to food and healthcare, Safety practices.

Recommended Textbooks and References:

1. Schlaad, Helmut (Ed.) (2013) Bio-synthetic Polymer Conjugates, Springer
2. Hambleton, P.; Salusbury, T. (Eds.) (1994) Biosafety in Industrial Biotechnology. Springer.
3. Sweeney, A. E., Seal, S. & Vaidyanathan, P. (2003), 'The promises and perils of nanoscience and nanotechnology: Exploring emerging social and ethical issues', *Bulletin of Science, Technology & Society*, **23**(4), 236-245.
4. Wolfson, J.R.: 2003, 'Social and Ethical Issues in Nanotechnology: Lessons from Biotechnology and Other High Technologies', *Biotechnology Law Report*, **22**, no 4, 376-96.
5. Roco, M.C.; Bainbridge, W.S. (eds.): (2001) *Societal implications of nanoscience and nanotechnology*, (Proceedings of a workshop organized by the National Science Foundation, September 28-29, 2000), Kluwer, Dordrecht.
6. Mark Wiesner, Jean-Yves Bottero (2007)Environmental Nanotechnology : Applications and Impacts of Nanomaterials: Applications and Impacts of Nanomaterials, McGraw Hill Professional.

MNL 723: Nano Composites (Credits: 3+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to introduce students with different kinds of nanocomposites and their applications in biomedical, material science and engineering field.	**Students should be able to:** • **Gain information about different types of nanocomposites and their diverse applications;** • **Gain insights of preparation techniques and associated properties of different nanocomposites.**

Unit-I [12 Lectures]

Metal based Nano composites: Metal-Oxide or Metal-Ceramic composites, Different aspects of their preparation techniques and their final properties and functionality. Applications in various fields.

Unit-II [11 Lectures]

Metal-metal nanocomposites: Some simple preparation techniques and their new electrical and magnetic properties.

Design of Super hard materials: Super hard Nano composites, its designing and improvements of mechanical properties.

Unit-III [11 Lectures]

New kind of Nano composites: Fractal based glass-metal Nano composites, its designing and fractal dimension analysis. Electrical property of fractal based Nano composites. Core-Shell structured Nano composites.

Unit-IV [11 Lectures]

Polymer based Nano composites: Classification of polymer-based nanocomposites, Synthesis routes, Surface modifications, Applications of polymer-based nanocomposites in food packaging, healthcare applications and biomedical field, Industrial possibilities for polymer-based nanocomposites.

Recommended Textbooks and References:

1. P. M. Ajayan, L.S. Schadler, P. V. Braun.(2003) Nano composites Science and Technology, Wiley-VCH.
2. V. Mittal (2011) Nanocomposites with Biodegradable Polymers: Synthesis, Properties, and Future perspectives., Oxford University Press.
3. Schlaad, Helmut (Ed.) 2013 Bio-synthetic Polymer Conjugates Springer

4. Kalia, Susheel; Kaith, B. S.; Kaur, Inderjeet (Eds.) 2011 Cellulose Fibers: Bio- and NanoPolymer Composites. Green Chemistry and Technology. Springer
5. Christian Brosseau, Jamal Ben, Youssef, Philippe Talbot, Anne-Marie Konn (2003) Nanometer versus micrometer-sized particles, (Review Article)J. Appl. Phys, Vol 93, 2003.
6. R. K. Gupta, E. Kennel, Kwang-Jea Kim(2010) Polymer Nanocomposites Handbook, CRC Press.
7. S C Tjong, Y.-W. Mai (2010) Physical Properties and Applications of Polymer Nanocomposites, Woodhead Publishing Limited, UK.

MNL 724: Nanomedicine and Drug Delivery (Credits: 3+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are: - • **To familiarize students with use of nanotechnology in nanomedicine, medical imaging, and drug delivery.** • **To cover in detail, role of nanotechnological advances in cancer therapy**	**Students should be able to:** • **Gain insights of concept and applications of nanomedicine.** • **Gain information about therapeutic action of nanoparticles and their applicability in imaging, detection and drug delivery.** • **Understand the role of nanotechnology in cancer research.**

Unit-I [11 Lectures]

Nanomedicine: Concept and applications

Gene Therapy and Nanotechnology: An Introduction, gene therapy using nanoparticles; stem cell therapy, Medical applications of molecular nanotechnology, Nanobiopharmaceutics.

Unit-II [11 Lectures]

Nanotechnology for Imaging - Detection and Therapy: Fluorophores and Quantum dots, Labeling and functionalization, Image analysis, Imaging facilitating surgical approaches.Diagnostics using nanomaterial, Nanoparticles for bioanalytical applications**,** Nanodevices for sensing and therapy. Use of nanoparticles for MRI, X Ray, Ultrasonography, Gamma ray imaging. Nanoparticles as molecular labels, nanotechnology in surgery,Photodynamic therapy (PDT).

Unit-III [11 Lectures]

Drug Delivery, Therapeutic action of nano particles and nano devices

Nanotechnology for Drug Targeting, Targeted, non-targeted delivery, Controlled drug release,exploiting novel delivery routes using nanoparticles, Nanostructures for use as antibiotics, Diseased tissue destruction using nanoparticles, Biosafety aspects of nanoparticles.

Unit-IV [12 Lectures]

Nanotechnology for Cancer Therapy: Cancer biology – Fundamentals, Physiology of Tumourgenesis, Clinical aspects & current approaches, Challenges in cancer therapy, Role of nanotechnology in cancer therapy, Nanotechnology platforms, Properties of nanoplatforms, Passive versus active targeting, Nanotechnology in brain cancer therapeutics, Multifunctional

nanotherapeutics, Radiosensitization and tumor ablation with nanoparticles, Biosafety aspects of nanotherapies.

Nanotechnology in Cancer Research: Genome and proteome perturbations: overview, Protein and nucleic acid markers: handle for early detection, Current methodology and instrumentation, Cantilevers, Limitations.

Recommended Textbooks and References:

1. Jenkins, Gareth; Mansfield, Colin D. (Eds.) (2013). Microfluidic Diagnostics: Methods and Protocols. Springer.
2. Pavlovic, Mirjana, Balint, Bela. (2013) Stem Cells and Tissue Engineering. Springer
3. Taxman, Debra J. (Ed.) (2013) siRNA Design Methods and Protocols. Springer
4. Baharvand, Hossein; Aghdami, Nasser (Eds.) (2013) Regenerative Medicine and Cell Therapy. Springer.
5. Jain, Kewal K. (2012) The Handbook of Nanomedicine. Springer.
6. Kunugi, Shigeru; Yamaoka, Tetsuji (Eds.) (2012) Polymers in Nanomedicine. Springer.
7. Zahavy, E.; Ordentlich, A.; Yitzhaki, S.; Shafferman, A. (Eds.) (2012) Nano-Biotechnology for Biomedical and Diagnostic Research. Springer.
8. Baharvand, Hossein; Aghdami, Nasser (Eds.) (2012) Advances in Stem Cell Research. Springer.

MNL 725: MEMS & NEMS – Sensors and Devices (Credits: 3+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are: - • **To introduce students with concept of micro and nano sensors for therapeutic and non-therapeutic applications.** • **To impart insights into their fabrication techniques, packaging, and further characterization for device fabrication.**	**Students should be able to:** • **Gain information about micro/nano sensors for applications in biomedical, food, civil, veterinary technology.** • **Gain insights of micro/nano fabrication techniques.** • **Learn concept of biosensors, quantum structures and devices.**

Unit-I [11 Lectures]

Micro and Nano-sensors: Fundamentals of sensors, biosensor, MEMS and NEMS, Overview of MEMS & NEMS devices.

Sensors: Therapeutic Nanodevices and Non-therapeutic Nanodevices: Sensors for aerospace and defense: Accelerometer, Pressure Sensor, Sensor for bio-medical and food applications:

Cardiology, Cancer and as diagnostic tool in food and medical sciences, for other civil applications: metrology, bridges etc. Nanoscale devices for veterinary technology

Unit-II [11 Lectures]

Micro/Nanofabrication Techniques: Stamping/Fabrication techniques for Micro and Nanofabrication**,** Material aspects of MEMS and NEMS, Bulk & Surface micromachining, Dry & wet Etching, fabrication techniques for Silicon, polymers and Glass.

Packaging and characterization of sensors: Packaging & Reliability. Method of packaging.

Micro fluidics and their Applications: Materials for Micro fluidic devices, active and smart passive Micro fluidics devices, Lab-on-a-chip for Biochemical analysis.

Unit-III [11 Lectures]

Biosensors: History, Clinical Diagnostics, generation of biosensors, Biological elements, Performance factors of Biosensors, immobilization of Biological components, Screen Printing Electrode, applications of Biosensors, Types of transducer technology, conducting Polymer based sensor, DNA Biosensors, Biochips and biosensors for detection of pathogens and allergens, Electronic Nose & Tongue, Nanobiosensors.

Unit-IV **[12 Lectures]**

Quantum Structures and Devices: Quantum dots and wires, Nanowires- Synthesis Methods, physical properties, characterization methods and applications. Engineered multifunctional nanowires as novel biosensing tools.

Recommended Textbooks and References:

1. Jenkins, Gareth; Mansfield, Colin D. (Eds.) (2013). Microfluidic Diagnostics: Methods and Protocols. Springer.
2. Ye, Bang-Ce, Zhang, Min, Yin, Bin-Cheng (2012) Nano-Bio Probe Design and Its Application for Biochemical Analysis. Springer.
3. Carrara, Sandro (Ed.) (2011) Nano-Bio-Sensing. Springer.
4. H. Meixner (1995) Sensors: Micro & Nanosensors, Sensor Market trends (Part 1&2**),** Vch Verlagsgesellschaft Mbh.
5. Michael Rieth (2003) Nano Engineering in Science & Technology: An Introduction to the world of Nano Design. World Scientific.
6. Baltes, H. Brand, O. Fedder, G.K. Hierold, C. Korvink, J.C. Tabata, O (2004) Enabling Technology for MEMS and Nanodevices, Wiley-VCH.
7. Ananthasuresh, G.K. (2003) Optimal Synthesis Methods for MEMS, Kluwer International Series.
8. Choudhury, P. Rai (2000) MEMS & MOEMS Technology and Applications, SPIE publications.
9. Tay, F.E.H (2003) Microfluidics & Bio MEMS applications. Kluwer International Series.

MNL 726: Project Proposal Preparation and Presentation (Credits: 2+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The purpose of this course is to help students organize ideas, material and objectives for their dissertation and to begin development of communication skills and to prepare the students to present their topic of research and explain its importance to their fellow classmates and teachers.	**After successful completion of this course, students should be able to:** • **Formulate a scientific question;** • **Present scientific approach to solve the problem;** • **Interpret, discuss and communicate scientific results in written form;** • **Gain experience in writing a scientific proposal;** • **Learn how to present and explain their research findings to the audience effectively.**

Unit-I [08 Lectures]

Selection of research lab and research topic: Students should first select a lab wherein they would like to pursue their dissertation. The supervisor or senior researchers should be able to help the students to read papers in the areas of interest of the lab and help them select a topic for their project. The topic of the research should be hypothesis driven. Review of literature: Students should engage in systematic and critical review of appropriate and relevant information sources and appropriately apply qualitative and/or quantitative evaluation processes to original data; keeping in mind ethical standards of conduct in the collection and evaluation of data and other resources.

Unit-II [08 Lectures]

Writing Research Proposal: With the help of the senior researchers, students should be able to discuss the research questions, goals, approach, methodology, data collection, etc. Students should be able to construct a logical outline for the project including analysis steps and expected outcomes and prepare a complete proposal in scientific proposal format for dissertation.

Unit-III [08 Lectures]

Poster Presentation: Students will have to present the topic of their project proposal after few months of their selection of the topic. They should be able to explain the novelty and importance of their research topic

Unit-IV [07 Lectures]

Oral Presentation: At the end of their project, presentation will have to be given by the students to explain work done by them in detail. Along with summarizing their findings they should also be able to discuss the future expected outcome of their work.

Open Elective Course for M. Tech students of other Departments

MNL 751: Basic Nanotechnology (Credits: 3+0)

Maximum Marks	**70**
Internal Marks	**30**
Total Marks	**100**
Time	**3 H**

Note: Examiner will set nine questions in all, selecting two questions from each unit and one question of short answer/objective type covering the entire syllabus, which will be compulsory. Students will have to attempt five questions in all selecting one from each unit and the compulsory question. All questions will carry equal marks.

Course Objectives	Student Learning Outcomes
The objectives of this course are to introduce students with the basics of nanotechnology. The focus is also given to different nanomaterials, micro/nanofabrication techniques and associated methods for revealing their morphological, topological and elemental features for numerous applications.	**Students should be able to:** • **Gain information about historical background and recent advances in nanotechnology.** • **Gain insights of characterization techniques for understanding detailed features associated with nanomaterials;** • **Learn about different micro/nanofabrication techniques for nanostructured materials.**

Unit-I [11 Lectures]

Introduction & Background: Introduction to Nanotechnology, Insights and intervention into the Nanoworld, Historical Background, recent advances and future aspects, Applications of Nanotechnology in different fields- Agriculture, medical applications, Environmental applications, Space, Defence, Food processing, consumer durables, textiles, cosmetics etc, Safety, Health & environmental issues, Societal implications of Nanotechnology.

Unit-II [11 Lectures]

Instrumentation Techniques for Nanotechnology: FTIR, DSC, Scanning Probe Microscopy (SPM), AFM, Scanning Tunneling Microscopy (STM), SEM, TEM, XRD (Powder/Single crystal), Particle size analyzer and Zeta Sizer.

Unit-III [11 Lectures]

Nanomaterials: Types, Properties and applications; Synthesis methods- Physical, Chemical and Biological methods of synthesis; Carbon Nanotubes – Synthesis methods, characterization and applications; Nanowires- synthesis methods, physical properties, applications; Smart materials.

Unit-IV [12 Lectures]

Micro and Nanofabrication Techniques: Concept of MEMS and NEMS, Fabrication techniques- A brief account, applications of Micro and Nanodevices, Micro fluidic devices and their Applications; Material aspects for Micro fluidic devices, active and smart passive Micro fluidics devices, Lab-on-a-chip.

Recommended Textbooks and References:

1. Kulkarni, S, K. 2014. Nanotechnology- Principles and Practices. 3rd Edition, Capital Publishing Company.
2. Vajtai, R 2013. Handbook of Nanomaterials, Springer.
3. Hari Singh Nalwa 2011. Encyclopedia of Nano Science & Nanotechnology. American Scientific Publishers.
4. Balzani, V., Credi, A. & Verturi, M. 2003. Molecular Devices and Machines- A Journey into Nanoworld. Wiley-VCH Verlag.
5. Albert Folch (2013) “Introduction to BioMEMS”, CRC Press.
6. Wolfson, J.R.: 2003, 'Social and Ethical Issues in Nanotechnology: Lessons from Biotechnology and Other High Technologies', *Biotechnology Law Report*, **22**, no 4, 376-96. 7.Bhushan, Bharat. 2004. Handbook of Nanotechnology. Springer.