

## **M.Tech. Nano Electronics and Nano Engineering 2024**

This is a two-year course in *Nano Electronics and Nano Engineering* with a focus on applications in nanoelectronics, optoelectronics, materials sciences and energy sciences. Considerable research over the past decade has shown that nanomaterials can play a significant role in the above applications through use of nanoparticles, thin films and composites and materials with nano and mesoporous architectures. In the first year, this course provides a strong fundamental understanding of the processing and properties of such materials and the physics and chemistry behind use of such materials in device applications, and the physics of the devices themselves. Apart from those basic courses, core courses dealing with design of nanosystems, nanomaterials and their processing, properties and characterization, as well as on the applications of nanomaterials will be taught. Each student will have a thesis requirement involving one year of hands-on independent research experience in the advanced labs.

## M. Tech in NanoElectronics and NanoEngineering

### First Semester

Course Code	Type	Course Title	LTP	Credits
24NE601	SC	Nanomaterials: Synthesis and Characterization	3 0 0	3
24NE602	SC	Nano-electronic & Opto-electronic Devices	3 0 0	3
	HU	Amrita Values Programme	1 0 0	1
23HU601	HU	Career Competency-I	0 0 3	P/F
22AVP103		Mastery Over Mind	1 0 2	2
24NE681	SC	Micro-Electronics Lab	0 0 4	2
24NE682	SC	Nanomaterials Lab	0 0 4	2
		<b>Electives Select (2 courses out of 3)</b>		
		24NE631   Solid State Phenomena at Nanoscale	3 0 0	6
		24NE632   Introduction to Quantum Science		
		24NE633   Nanomaterials: Science & Properties		
<b>Total Credits</b>				<b>19</b>

### Second Semester

Course Code	Type	Course	LTP	Credits
24NE611	SC	NanoEngineering Applications	2 0 1	3
24NE612	SC	VLSI Design and Technology	3 0 0	3
24NE683	SC	Nanoelectronics and Nanofabrication Lab	0 0 4	2
24NE684	SC	NanoEnergy Devices Lab	0 0 4	2
		<b>Electives Select (3 courses out of 4)</b>		
		24NE641   Emerging Nano-manufacturing Technologies	3 0 0	9
		24NE642   Nanocarbon and Nanocomposites		
		24NE643   Hydrogen Energy: Production, Storage and Applications		
		24NE644   Flexible and Wearable Electronics		
<b>Total Credits</b>				<b>19</b>

### Third Semester

Course Code	Type	Course	LTP	Credits
24NE798	P	Dissertation-I	0 0 28	14
		<b>Electives Select (1 courses out of 2)</b>		
	E	24NE731   Computational Methods for Material Science	2 0 0	2
		24NE732   Nanophotonics		
24NE701	FC	Statistical Data Analysis	1 0 1	2
24NE702	FC	Ethics in Research and Research Methodology	1 0 1	2
<b>Total Credits</b>				<b>20</b>

### Fourth Semester

Course Code	Type	Course	LTP	Credits
24NE799	P	Dissertation-II	0 0 32	17
23HU611	HU	Career Competency-II	0 0 3	1
<b>Total Credits</b>				<b>18</b>
<b>Total Credits</b>				<b>76</b>

Table 2 New names for Amrita Value Programmes for PG programmes			
Course Code	Title	L-T-P	Credits
22ADM502	Vedanta in day-to-day life	1-0-0	1
22AVP506	Message of Swami Vivekananda	1-0-0	1
22AVP508	Indian Arts and Literature	1-0-0	1
22AVP510	Appreciation of Kerala Mural Arts Forms	1-0-0	1
22AVP501	Message of Śrī Mātā Amritanandamayi Devi	1-0-0	1
22AVP502	Insights from the Ramayana	1-0-0	1
22AVP503	Insights from the Mahabharata	1-0-0	1
22AVP504	Insights from the Upanishads	1-0-0	1
22AVP505	Insights from Bhagavad Gita	1-0-0	1
22AVP512	Ancient Indian Science and Technology	1-0-0	1
22AVP507	Great Spiritual Teachers of India	1-0-0	1
22AVP509	Yoga and Meditation	1-0-0	1

### 1<sup>st</sup> Semester

**24NE601**

**Nanomaterial Synthesis & Characterization**

**3 0 0-3**

**Pre-requisites:** Basic physics, chemistry and biology

**Total number of classes: 45**

**Course Outcomes:**

- *To understand various chemical synthesis (Bottom-up) of diverse types of nanomaterials (0D, 1D and 2D)*
- *To understand various physical methods (Top-down) of fabricating nanomaterials and nanostructures*
- *Decipher information on the various class of nanomaterials based on composition, shape and size (1D, 2D, 3/0D nanostructures)*
- *To understand the application potential of nanomaterials based on their unique properties and importance of selecting appropriate synthesis methods that will suit the specific application.*
- *To learn the fundamental principles of characterizing nanomaterials for their morphology, structure, chemistry and functionality through diverse methods of microscopy, spectroscopy, scattering and diffraction.*

**Course content:**

**Nanomaterial Synthesis:**

### **Unit 1 (5 lectures)**

Synthesis of nanomaterials: Basic chemistry concepts, Inorganic, organic synthesis and analytical chemistry methods, concepts of precipitation reaction, mechanisms of nanocrystal growth, LaMer theory, Oswald ripening, coalescence

### **Unit 2 (5 lectures)**

Bottom-up synthesis approaches – Nanoprecipitation reaction, synthesis of zero-dimensional metal, metal oxides, semiconductor nanoparticles by nanoprecipitation routes, high-pressure homogenization

### **Unit 3 (5 lectures)**

Bottom-up synthesis approaches- Micro-emulsion route of synthesis, basic concepts of surfactant, emulsion, micelles, reverse micelles, critical micellar concentration, micro-emulsions: water-in-oil and oil-in-water emulsions, double emulsion and applications

### **Unit 4 (4 lectures)**

Bottom-up synthesis approaches: Sol-gel method, hydrolysis and condensation, Self-assembly, Kinetically Confined Synthesis of Nanoparticles

### **Unit 5 (4 lectures)**

Template-based synthesis; Synthesis of one dimensional nanosystems by different routes – VLS and SLS methods, Synthesis of two dimensional nanosystems

### **Unit 6 (5 lectures)**

Top-down approaches: Fundamentals of nano–thin film Growth; Vapor phase deposition methods - Physical and chemical vapor phase methods; Langmuir-Blodgett Films; Electrochemical Deposition; laws of electrolysis and deposition

### **Characterization:**

#### ***Unit 7: Structure, Morphology and Surface (10 lectures)***

Crystal structure, Lattice parameters, nanoparticle size by Debye-Scherrer's formula. Working principles of the Scanning electron microscope and Transmission electron Microscope, particle size Dynamic Light scattering, Elemental analysis using energy dispersive X-ray analysis, Atomic absorption and inductively coupled Plasma. Fundamental working principles of scanning probe microscopy (STM) Atomic Force Microscopy, confocal fluorescence microscopy

#### ***Unit 8: Spectroscopy (7 lectures)***

Fundamentals of spectroscopy, vibrational and rotational spectroscopy, Nanomaterials analysis using UV-VIS, Infrared & Raman spectroscopy, Surface enhanced Raman spectroscopy using nanotechnology. FTIR and NMR spectroscopy, Basic principles and applications of Mass spectrometry, chromatography and High-pressure Liquid chromatography in nanomaterial or nanomedicine characterization.

### ***References***

1. *Nanomaterials – An introduction to synthesis, properties and applications*, D. Vollath, Wiley-VCH, Second Edition 2013.
2. *G. Cao, Nanostructures and Nanomaterials – Synthesis, Properties and Applications*, Imperial College Press 2006.
3. *Elements of X-ray Diffraction*, B. D. Cullity and S. R. Stock (Pearson)
4. *Physical Principles of Electron Microscopy*, R.F. Egerton (Springer)
5. *Scanning Probe Microscopy and Spectroscopy*, D. A. Bonnell (Wiley)
6. *Fundamentals of Molecular Spectroscopy*, C. N. Banwell (McGraw Hill)
7. *Nanostructured materials: Processing, Properties and Potential Applications*, Edited by Carl. C. Koch, Noyes Publications, 2002.
8. *Materials Science and Engineering – An Introduction*, William D Callister, 12<sup>th</sup> Edition, John Wiley (Available in Amazon India, Rs. 287)

**24NE602**

**Nano- electronic & Opto-electronic Devices**

**3 0 0-3**

**Pre-requisites:** Basic maths, physics and chemistry

**Total number of classes: 45**

**Course Outcomes:**

- *Familiarity with fundamental concepts related to material science of semiconductors.*
- *Get introduced crystal structures relation with fundamental aspects of atomic bonds and energy bands.*
- *Bulk semiconductors and their significance along with size effects and applications.*
- *Understand the influence of size effects on charge transport characteristics under various circumstances.*
- *Will be able to identify and choose suitable semiconductor nanostructures for different applications as required.*
- *Estimate the various physical parameters that are related to semiconductor nanostructures for example charge carrier mobility, conductivity and sheet resistance.*
- *Get introduced to emerging atomically thin nano-semiconductors such as 2D layered functional materials from current research literature.*
- *Understand the basics of spintronics and spintronic devices*

**Course content:**

**Unit-1: Introduction to semiconductors and properties (12 lectures)**

Review of semiconductors, low dimensional semiconductors and materials, transport in nanostructures, Electron flow in solids, diffusive and ballistic electron transport, Coulomb blockade, hall-effect and quantum hall-effect, optical and electro-optic processes in heterostructures.

**Unit-2: Semiconductor devices (15 lectures)**

Nanoelectronic devices: heterojunction bipolar transistor, hot electron transistors, single electron transistors, resonant tunnelling transistors, low dimensional semiconductor lasers: quantum-well lasers, quantum dot lasers, vertical cavity surface emitting lasers, low dimensional photodetectors and modulators.

**Unit-3: Advanced materials for nanoelectronics and optoelectronics (5 lectures)**

2D materials (Graphene QDs, TMDs, MXenes... etc.) electronic, photonics and optoelectronics applications.

#### **Unit-4: Spintronics and devices (8 lectures)**

Spintronics: GMR, TMR, spin injection and detection, magnetic tunnel junctions, dilute magnetic semiconductors and spintronic devices.

#### **Unit-5: Industry relevance analysis (5 lectures)**

Industrial relevant failure analysis, metrology and device characterizations.

#### **TEXTBOOKS/ REFERENCES:**

1. *Nanotechnology for Microelectronics and Optoelectronics* by Raúl José Martín-Palma, José Martínez-Duart, Fernando Agullo-Rueda, Elsevier (2006).
2. *Spintronics: Fundamentals and Applications* by Igor Zutic, J. Fabian, and S. Das Sarma, *Rev. Mod. Phys.* 76, 323 (2004).

### **Amrita Values Program**

**1 0 0 1**

Amrita University's Amrita Values Program (AVP) is a new initiative to give exposure to students to the richness and beauty of the Indian way of life. India is a country where history, culture, art, aesthetics, cuisine, and nature exhibit more diversity than anywhere else in the world. Amrita Values Programs emphasize making students familiar with the rich tapestry of Indian life, culture, arts, science, and heritage which has historically drawn people from all over the world. Post-graduate students shall have to register for any one of the following courses, in the second semester, which may be offered by the respective school.

Courses offered under the framework of the Amrita Values Program:

#### **22AVP501 Message of Śrī Mātā Amritanandamayi Devi**

Amma's messages can be put into action in our life through pragmatism and attuning of our thought process in a positive and creative manner. Every single word Amma speaks, and the guidance received in matters which we consider trivial are rich in content and touches the very inner being of our personality. Life gets enriched by Amma's guidance, and She teaches us the art of exemplary life skills where we become witness to all the happenings around us keeping the balance of the mind.

#### **22AVP502 Insights from the Ramayana**

The historical significance of Ramayana, the first Epic in the world, influence of Ramayana on Indian values and culture, storyline of Ramayana, study of leading characters in Ramayana, influence of Ramayana outside India, misinterpretation of Ramayana by colonial powers and its impact on Indian life, relevance of Ramayana for modern times.

#### **22AVP503 Insights from the Mahabharata**

The historical significance of Mahabharata, the largest Epic in the world, influence of Mahabharata on Indian values and culture, storyline of Mahabharata, study of leading

characters in Mahabharata, Kurukshetra War and its significance, importance of Dharma in society, message of the Bhagavad Gita, relevance of Mahabharata for modern times.

#### **22AVP504                      Insights from the Upanishads**

Introduction: Sruti versus Smrti, overview of the four Vedas and the ten Principal Upanishads, the central problems of the Upanishads, ultimate reality, the nature of Atman, the different modes of consciousness, Sanatana Dharma and its uniqueness, The Upanishads and Indian Culture, relevance of Upanishads for modern times, a few Upanishad Personalities: Nachiketas, Satyakama Jabala, Aruni, Shvetaketu.

#### **22AVP505                      Insights from Bhagavad Gita**

Introduction to Bhagavad Gita, brief storyline of Mahabharata, context of Kurukshetra War, the anguish of Arjuna, counsel by Sri. Krishna, key teachings of the Bhagavad Gita, Karma Yoga, Jnana Yoga, and Bhakti Yoga, theory of Karma and Reincarnation, concept of Dharma, idea of the self and realization of the self, qualities of a realized person, concept of Avatar, relevance of Mahabharata for modern times.

#### **22AVP506                      Message of Swami Vivekananda**

Brief sketch of Swami Vivekananda's life, meeting with Guru, disciplining of Narendra, travel across India, inspiring life incidents, address at the parliament of religions, travel in the United States and Europe, return and reception in India, message to Indians about our duties to the nation.

#### **22AVP507                      Great Spiritual Teachers of India**

Sri Rama, Sri Krishna, Sri Buddha, Adi Shankaracharya, Sri Ramanujacharya, Sri Madhvacharya, Sri Ramakrishna Paramahansa, Swami Vivekananda, Sri Ramana Maharshi, Mata Amritanandamayi Devi

#### **22AVP508                      Indian Arts and Literature:**

The aim of this course is to present the rich literature, culture of ancient India, and help students appreciate their deep influence on Indian life, Vedic culture, the primary source of Indian culture, brief introduction, and appreciation of a few of the art forms of India, arts, music, dance, theatre, paintings, sculpture and architecture, the wonder language, Sanskrit, and ancient Indian Literature.

#### **22AVP509                      Yoga and Meditation**

The objective of the course is to provide practical training in YOGA ASANAS with a sound theoretical base and theory classes on selected verses of Patanjali's Yoga Sutra and Ashtanga Yoga. The coverage also includes the effect of yoga on integrated personality development.

#### **22AVP510                      Appreciation of Kerala's Mural Art Forms:**

A mural is any piece of artwork painted or applied directly on a wall, ceiling, or another large permanent surface. In the contemporary scenario, Mural painting is not restricted to permanent structures and is being done even on canvas. A distinguishing characteristic of mural painting is that the architectural elements of the given space are harmoniously incorporated into the picture. Kerala mural paintings are frescos depicting mythology and legends, which are drawn on the walls of temples and churches in South India, principally in Kerala. Ancient temples, churches, and places in Kerala, South India, display an abounding tradition of mural paintings mostly dating back to the 9th to 12th centuries CE

when this form of art enjoyed Royal patronage. Learning Mural painting through the theory and practice workshop is the objective of this course.

#### 22AVP512 Ancient Indian Science and Technology

Science and technology in ancient and medieval India covered all the major branches of human knowledge and activities, including mathematics, astronomy, physics, chemistry, medical science and surgery, fine arts, mechanical, civil engineering, architecture, shipbuilding, and navigation. Ancient India was a land of sages, saints, and seers as well as a land of scholars and scientists. The course gives awareness of India's contribution to science and technology.

23HU601

Career Competency I

L-T-P-C: 0-0-3-P/F

**Pre-requisite:** An open mind and the urge for self-development, basic English language skills and knowledge of high school level arithmetic.

#### **Course Objectives:**

- Help students transit from campus to corporate and enhance their soft skills
- Enable students to understand the importance of goal setting and time management skills
- Support them in developing their problem solving and reasoning skills
- Inspire students to enhance their diction, grammar and verbal reasoning skills

#### **Course Outcomes:**

**CO1: Soft Skills** - To develop positive mindset, communicate professionally, manage time effectively and set personal goals and achieve them.

**CO2: Soft Skills** - To make formal and informal presentations with self-confidence.

**CO3: Aptitude** - To analyze, understand and employ the most suitable methods to solve questions on arithmetic and algebra.

**CO4: Aptitude** - To analyze, understand and apply suitable techniques to solve questions on logical reasoning and data analysis.

**CO5: Verbal** - To infer the meaning of words and use them in the right context. To have a better understanding of the nuances of English grammar and become capable of applying them effectively.

**CO6: Verbal** - To identify the relationship between words using reasoning skills. To understand and analyze arguments and use inductive/deductive reasoning to arrive at conclusions and communicate ideas/perspectives convincingly.

#### **CO-PO Mapping**



PO	PO1	PO2	PO3
CO			
CO1	2	1	-
CO2	2	1	-
CO3	2	1	-
CO4	2	1	-
CO5	1	2	-
CO6	2	2	-

## Syllabus

### Soft Skills

Introduction to 'campus to corporate transition':

Communication and listening skills: communication process, barriers to communication, verbal and non-verbal communications, elements of effective communication, listening skills, empathetic listening, role of perception in communication.

Assertiveness skills: the concept, assertiveness and self-esteem, advantages of being assertive, assertiveness and organizational effectiveness.

Self-perception and self-confidence: locus of control (internal v/s external), person perception, social perception, attribution theories-self presentation and impression management, the concept of self and self-confidence, how to develop self-confidence.

Goal setting: the concept, personal values and personal goals, goal setting theory, six areas of goal setting, process of goal setting: SMART goals, how to set personal goals

Time management: the value of time, setting goals/ planning and prioritizing, check the time killing habits, procrastination, tools for time management, rules for time management, strategies for effective time management

Presentation skills: the process of presentation, adult learning principles, preparation and planning, practice, delivery, effective use of voice and body language, effective use of audio visual aids, dos and don'ts of effective presentation

Public speaking-an art, language fluency, the domain expertise (Business GK, Current affairs), self-confidence, the audience, learning principles, body language, energy level and conviction, student presentations in teams of five with debriefing

### Verbal

**Vocabulary:** Familiarize students with the etymology of words, help them realize the relevance of word analysis and enable them to answer synonym and antonym questions. Create an awareness about the frequently misspelt words, commonly confused words and wrong form of words in English.

**Grammar:** Train students to understand the nuances of English Grammar and thereby enable them to spot grammatical errors and punctuation errors in sentences.

**Reasoning:** Stress the importance of understanding the relationship between words through analogy questions and learn logical reasoning through syllogism questions. **Emphasize the importance of avoiding the gap (assumption) in arguments/ statements/ communication.**

**Oral Communication Skills:** Aid students in using the gift of the gab to improve their debating skills.

**Writing Skills:** Introduce formal written communication and keep the students informed about the etiquettes of email writing. **Make students practise writing emails especially composing job application emails.**

### Aptitude

**Numbers:** Types, Power Cycles, Divisibility, Prime, Factors & Multiples, HCF & LCM, Surds, Indices, Square roots, Cube Roots and Simplification.

**Percentage:** Basics, Profit, Loss & Discount, and Simple & Compound Interest.

**Ratio, Proportion & Variation:** Basics, Alligations, Mixtures, and Partnership.

**Averages:** Basics, and Weighted Average.

**Time and Work:** Basics, Pipes & Cistern, and Work Equivalence.

**Time, Speed and Distance:** Basics, Average Speed, Relative Speed, Boats & Streams, Races and Circular tracks.

**Statistics:** Mean, Median, Mode, Range, Variance, Quartile Deviation and Standard Deviation.

**Data Interpretation:** Tables, Bar Diagrams, Line Graphs, Pie Charts, Caselets, Mixed Varieties, and other forms of data representation.

**Equations:** Basics, Linear, Quadratic, Equations of Higher Degree and Problems on ages.

**Logarithms, Inequalities and Modulus:** Basics

### References

#### Soft Skills

Communication and listening skills:

- Andrew J DuRbin , “Applied Psychology: Individual and organizational effectiveness”, Pearson-Merril Prentice Hall, 2004
- Michael G Aamodt, “An Applied Approach, 6<sup>th</sup> edition”, Wadsworth Cengage Learning, 2010

Assertiveness skills:

- Robert Bolton, Dorothy Grover Bolton, “People Style at Work..and Beyond: Making Bad Relationships Good and Good”, Ridge Associates Inc., 2009
- John Hayes “Interpersonal skills at work”, Routledge, 2003
- Nord, W. R., Brief, A. P., Atieh, J. M., & Doherty, E. M., “Meanings of occupational work: A collection of essays (pp. 21- 64)”, Lexington, MA: Lexington Books, 1990

Self-perception and self-confidence:

- Mark J Martinko, “Attribution theory: an organizational perspective”, St. Lucie, 1995
- Miles Hewstone, “Attribution Theory: Social and Functional Extensions”, Blackwell, 1983

Time management:

- Stephen Covey, "The habits of highly effective people", Free press Revised edition, 2004
- Kenneth H Blanchard , "The 25 Best Time Management Tools & Techniques: How to Get More Done Without Driving Yourself Crazy" , Peak Performance Press, 1<sup>st</sup> edition 2005
- Kenneth H. Blanchard and Spencer Johnson, "The One Minute Manager" , William Morrow, 1984

### **Verbal**

- Erica Meltzer, "The Ultimate Guide to SAT Grammar"
- Green, Sharon, and Ira K. Wolf, "Barron's New GRE", Barron's Educational Series, 2011
- Jeff Kolby, Scott Thornburg & Kathleen Pierce, "Nova's GRE Prep Course"
- Kaplan, "Kaplan New GRE Premier", 2011-2012
- Kaplan's GRE Comprehensive Programme
- Lewis Norman, "Word Power Made Easy", Goyal Publishers, Reprint edition, 1 June 2011
- Manhattan Prep, "GRE Verbal Strategies Effective Strategies Practice from 99th Percentile Instructors"
- Pearson- "A Complete Manual for CAT", 2013
- R.S. Aggarwal, "A Modern Approach to Verbal Reasoning"
- S. Upendran, "Know Your English", Universities Press (India) Limited, 2015
- Sharon Weiner Green, Ira K. Wolf, "Barron's New GRE, 19th edition (Barron's GRE)", 2019
- Wren & Martin, "English Grammar & Composition"
- [www.bbc.co.uk/learningenglish](http://www.bbc.co.uk/learningenglish)
- [www.cambridgeenglish.org](http://www.cambridgeenglish.org)
- [www.englishforeveryone.org](http://www.englishforeveryone.org)
- [www.merriam-webster.com](http://www.merriam-webster.com)

### **Aptitude**

- Arun Sharma, "How to Prepare for Quantitative Aptitude for the CAT Common Admission Test", Tata Mc Graw Hills, 5th Edition , 2012
- Arun Sharma, "How to Prepare for Logical Reasoning for the CAT Common Admission Test", Tata Mc Graw Hills, 2nd Edition, 2014
- Arun Sharma, "How to Prepare for Data Interpretation for the CAT Common Admission Test", Tata Mc Graw Hills, 3rd Edition, 2015
- R.S. Aggarwal, "Quantitative Aptitude For Competitive Examinations", S. Chand Publishing, 2015
- R.S. Aggarwal, "A Modern Approach To Verbal & Non-Verbal Reasoning", S. Chand Publishing, Revised -2015
- Sarvesh Verma, "Quantitative Aptitude-Quantum CAT" , Arihant Publications, 2016
- [www.mbatious.com](http://www.mbatious.com)
- [www.campusgate.co.in](http://www.campusgate.co.in)
- [www.careerbless.com](http://www.careerbless.com)

### **Evaluation Pattern**

Assessment	Internal	External
Continuous Assessment (CA)* – Soft Skills	30	-
Continuous Assessment (CA)* – Aptitude	10	25
Continuous Assessment (CA)* – Verbal	10	25
Total	50	50
<b>Pass / Fail</b>		

\*CA - Can be presentations, speaking activities and tests.

## 1. Course Overview

Master Over the Mind (MAOM) is an Amrita initiative to implement schemes and organise university-wide programs to enhance health and wellbeing of all faculty, staff, and students (UN SDG -3). This program as part of our efforts for sustainable stress reduction gives an introduction to immediate and long-term benefits and equips every attendee to manage stressful emotions and anxiety facilitating inner peace and harmony.

With a meditation technique offered by Amrita Chancellor and world-renowned humanitarian and spiritual leader, Sri Mata Amritanandamayi Devi (Amma), this course has been planned to be offered to all students of all campuses of AMRITA, starting off with all first years, wherein one hour per week is completely dedicated for guided practical meditation session and one hour on the theory aspects of MAOM. The theory section comprises lecture hours within a structured syllabus and will include invited guest lecture series from eminent personalities from diverse fields of excellence. This course will enhance the understanding of experiential learning based on university's mission: "Education for Life along with Education for Living", and is aimed to allow learners to realize and rediscover the infinite potential of one's true Being and the fulfilment of life's goals.

## 2. Course Syllabus

### Unit 1

(4 hours)

Causes of Stress: The problem of not being relaxed. Need for meditation -basics of stress management at home and workplace. Traditions and Culture. Principles of

meditation– promote a sense of control and autonomy in the Universal Human Value System. Different stages of Meditation. Various Meditation Models. Various practices of Meditation techniques in different schools of philosophy and Indian Knowledge System.

### Unit 2

(4 hours)

Improving work and study performance. Meditation in daily life. Cultivating compassion and good mental health with an attitude of openness and acceptance. Research and Science of Meditation: Significance of practising meditation and perspectives from diverse fields like science, medicine, technology. philosophy, culture, arts, management, sports, economics, healthcare, environment etc. The role of meditation for stress and anxiety reduction in one's life with insights based on recent cutting-edge technology. The effect of practicing meditation for the wholesome wellbeing of an individual.

### Unit 3

(4 hours)

Communications: principles of conscious communication. Relationships and empathy: meditative approach in managing and maintaining better relationships in life during the interactions in the world, role of MAOM in developing compassion, empathy and responsibility, instilling interest, and orientation to humanitarian projects as a key to harness intelligence and compassion in youth. Methodologies to evaluate effective awareness and relaxation gained from meditation. Evaluating the global transformation through meditation by instilling human values which leads to service learning and compassion driven research.

## TEXT BOOKS:

- 1.Mata Amritanandamayi Devi, "Cultivating Strength and vitality," published by Mata Amritanandamayi Math, Dec 2019
- 2.Swami Amritaswarupananda Puri , "The Color of Rainbow " published by MAM, Amritapuri.

## REFERENCES:

- 1.Craig Groeschel, "Winning the War in Your Mind: Change Your Thinking, Change Your Life" Zondervan Publishers, February 2019
- 2.R Nagarathna et al, "New Perspectives in Stress Management "Swami Vivekananda Yoga Prakashana publications, Jan 1986
3. Swami Amritaswarupananda Puri "Awaken Children Vol 1, 5 and 7 - Dialogues with Amma on Meditation", August 2019
4. Swami Amritaswarupananda Puri "From Amma's Heart - Amma's answer to questions raised during world tours" March 2018
5. Secret of Inner Peace- Swami Ramakrishnananda Puri, Amrita Books, Jan 2018.
6. Mata Amritanandamayi Devi "Compassion :The only way to Peace:Paris Speech", MA Center, April 2016.
7. Mata Amritanandamayi Devi "Understanding and collaboration between Religions", MA Center, April 2016.
8. Mata Amritanandamayi Devi "Awakening of Universal Motherhood: Geneva Speech" M A center, April 2016.

## 3. Evaluation and Grading

Internal		External		Total
Components	Weightage		Practical ( attendance and class participation) 60%	100%
Quizzes( based on the reading material)	20%	40%		
Assignments (Based on webinars and lecture series)	20%			

## 4. Course Outcomes (CO)

**CO1: Relate to the causes of stress in one's life.**

**CO2: Experiment with a range of relaxation techniques**

**CO3: Model a meditative approach to work, study, and life.**

**CO4: Develop appropriate practice of MA-OM technique that is effective in one's life**

**CO5: Inculcate a higher level of awareness and focus.**

**CO6: Evaluate the impact of a meditation technique**

**\*Program Outcomes (PO)** (As given by NBA and ABET)

**PO1:** Engineering Knowledge

**PO2:** Problem Analysis

**PO3:** Design/Development of Solutions

**PO4:** Conduct Investigations of complex problems

**PO5:** Modern tools usage

**PO6:** Engineer and Society

**PO7:** Environment and Sustainability

**PO8:** Ethics

**PO9:** Individual & Team work

**PO10:** Communication

**PO11:** Project management & Finance

**PO12:** Lifelong learning

**CO – PO Affinity Map**

PO	P0	P0	P0	P0	P0	P0	P0	P0	P0	P0	P0	P0	P0	P0	P0
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
<b>CO 1</b>	3	3	3	2		-	2	3	-	3	-	3	-	-	-
<b>CO 2</b>	3	3	3	2	2	-	2	3	3	3	-	3	-	-	-
<b>CO 3</b>	3	3	2	2	2	2	2	3	3	3	-	3	-	-	-
<b>CO 4</b>	3	3	3	2	-	2	3	3	3	3	-	3	-	-	-
<b>CO 5</b>	3	2	2	2	-	2	-	3	2	2	-	2	-	-	-
<b>CO 6</b>	3	2	2	2	3	2	-	3	2	2	-	2	-	-	-

24NE681

Microelectronics Lab

004-2

**Pre-requisites:** Basic understanding of experimental research

**Total number of lab sessions:** 15

**Course Outcomes:**

- *Students will be able to gain hands on experience in preparation and characterization of semiconductor nanomaterials.*
- *Practically correlate process parameters and property (electrical, optical...etc.)*
- *Fabricate devices and investigate their characteristics.*
- *Be able to learn operation of characterization tools and independently handle the instruments.*
- *A comprehensive experimental understanding of electrical and optical properties of semiconductors.*

**Course Content:**

**Unit-1: Preparation and characterization of microelectronic devices (6 sessions)**

Study of Zener diode, diode based half/full-wave rectifier, Metal-semiconductor Schottky diode fabrication, thin film field effect transistor, BJT transistor (BC 547) as amplifier and switch. Characterization of nanomaterials.

**Unit-2: Optical properties of materials and devices (4 sessions)**

UV-VIS Spectroscopy, Optical reflectance/transmittance and luminescence. Opto-electronic properties of bulk and thin films, electrical and optical characterization of LEDs.

**Unit-3: Advanced semiconductors (3 sessions)**

Nanomaterials size-structure-property correlation, 2D materials semiconductor processing and properties. Delayering commercial IC-chip to understand microstructure and reverse engineering.

**Mini-project: based on the experiments executed**

**Unit-4: Standards in nanomaterials assessment and device testing (2 sessions)**

Introduction to quality assessments, ISO, IEC standard testing.

**TEXTBOOKS/ REFERENCES:**

1. S. M. Sze, "*Physics of Semiconductor Devices*", Wiley-Interscience, 1969.
2. D. K. Schroder, "*Semiconductor Material and Device Characterization*", 3<sup>rd</sup> Edition, Wiley Publishers, 2006.

**Pre-requisites:** Basic understanding of experimental research

**Total number of lab sessions:** 15

**Course Outcomes:**

- *Understand the preparation of standard solutions in different concentration units: Molarity, Molality and Normality*
- *Understand the synthesis of metal nanoparticles.*
- *Learn synthesis of plasmonic silver nanoparticles and observe its color change with varying size & shape of nanoparticles.*
- *Understand the principle and working of UV -Vis absorption spectroscopy technique and relation of absorption peak of silver nanoparticles with size and shape changes.*
- *Understand the synthesis of nanoparticles in non-aqueous route and observe its luminescence under UV lamp to understand quantum confinement effect.*
- *Understand the synthesis of nanoparticles in aqueous route and study the fluorescence properties of nanoparticles using spectrofluorometer*
- *Understand the UV-VIS absorption properties of nanoparticles and estimation of particle size using Brus equation*
- *Understand the principles of Atomic Force Microscope (AFM) and hands on experience in use of AFM in nanoparticle size characterization*
- *Understand the principles of Scanning Electron Microscope (SEM) and its use in characterizing nanoparticles*

**Course Content:**

**Unit 1 (4 sessions)**

Introduction to Nanolab and standard solution preparation, Synthesis of plasmonic silver nanoparticles *study its color change with varying size & shape of nanoparticles using UV -Vis absorption spectroscopy*

**Unit 2 (5 sessions)**

*Preparation of metal oxide ZnO nanoparticles (Non-Aqueous route) and observe its luminescence under UV lamp, UV-VIS absorption properties of ZnO nanoparticles and estimation of particle size using Brus equation*

**Unit 3 (2 sessions)**

*Synthesis of Mn doped ZnS nanoparticles in aqueous route and study the fluorescence properties of nanoparticles using spectrofluorometer*

**Unit 4 (4 sessions)**

Nanoparticle imaging for size and shape analysis using *Atomic Force Microscope (AFM) and Scanning Electron Microscope (SEM) characterizing nanoparticles*

**References:**

- *A Handbook of Laboratory Solutions, M H Gabb, Scientific Publishers, 2013*
- *Nanostructures & Nanomaterials: Synthesis, Properties & Applications; Guozhong Cao, Imperial College Press*



## ELECTIVES (For Semester-1)

24NE631

Solid-State Phenomena at Nanoscale

3 0 0-3

**Pre-requisites:** Basic math, physics and chemistry

**Total number of classes:** 45

### Course Outcomes:

- *Understand the basics of crystal structure, lattice vibrations, Phonons*
- *Familiarize with the Harmonic oscillator model and Debye & Einstein models*
- *A thorough understanding of Dielectric, Ferroelectric and Piezoelectric concepts*
- *Gain in-depth knowledge in Magnetism & Superconductivity and understand its fundamental theories.*

### Course content:

#### **Unit 1. Chemical bonding and Crystal structures (10 lectures)**

Solid state science: introduction to solids, materials classification by bonding, amorphous and crystalline materials, basics of crystal structure, lattice points and space lattice, Bravais lattice, Lattice planes and Miller indices, the reciprocal lattice, bulk to Nano effects – examples, fundamental excitations on solids – brief (plasmons, polaritons and polarons).

#### **Unit 2. Vibrations (8 lectures)**

Lattice vibrations, a simple Harmonic oscillator, an infinite chain of atoms, the Brillouin zone, a finite chain of atoms, Modes of vibrations and density of states, Classical and quantum oscillator comparisons, Quantized vibrations-Phonons, Confinement of phonons (Nanoscale effects).

#### **Unit 3. Thermal Properties (8 lectures)**

Three-dimensional solids, Vibrational frequency estimation, Specific heat capacity, Classical theory and experimental results, Debye and Einstein models, Thermal conductivity, Anharmonic effects and thermal expansion, Heat Conduction.

#### **Unit 4. Dielectrics, Ferroelectrics and Piezoelectrics (10 lectures)**

Dielectric materials and phenomena, Microscopic Polarization, Frequency dependence of the Dielectric constant, Bulk, nano, thin-film dielectrics, High-K dielectrics and applications, Ferroelectrics and Piezoelectrics, Dielectric breakdown.

#### **Unit 5. Magnetism and Superconductivity (10 lectures)**

Magnetic effects in atoms, Diamagnetism, Magnons, paramagnetism, Curie and Pauli Paramagnetism, Ferromagnetic domains, Hysteresis, Nanoscale effects, Magnetic tunnel junctions, Magneto-resistance, Zero resistivity, The Meissner effect, BCS theory.

### Textbooks:

1. *Solid-state Physics - An Introduction by P Hofmann, 2nd Edition, Wiley VCH (2015)*
2. *Introduction to Solid-State Physics by C. Kittel, 8th Edition, John Wiley and Sons (2005).*

**Pre-requisites:** Basic math, physics and chemistry

**Total number of classes: 45**

**Course Outcomes:**

- *Understand the failure of classical mechanics*
- *Realize the importance of particle-like behavior of waves and wave-like behavior of particles.*
- *Understand initial success of quantization from blackbody radiation to Compton effect*
- *Know the importance of dual nature*
- *Distinguish the difference between classical models and Bohr's atom model and its success.*
- *Comprehensive understanding of Schrodinger's equation and its application to quantum systems.*

**Course content:**

**Unit-1: Review of mechanics and failure of classical mechanics (10 lectures)**

Review of mechanics, failures of classical mechanics,

**Unit-2: Particle properties of waves (7 lectures)**

Electromagnetic waves; blackbody radiation; Planck's quantum hypothesis, photo-electric effect, Compton Effect,

**Unit-3: Wave properties of particles (7 lectures)**

De Broglie waves; probability and phase and group velocities; particle in a box, wave-particle duality, uncertainty principle.

**Unit-4: Atomic structure and models (6 lectures)**

Atomic structure; atomic spectra; planetary model (classical); Bohr's H-atom model, Bohr's correspondence principle,

**Unit-5: Schrodinger's equation and applications (15 lectures)**

Wave equation; Schrodinger's equation (time dependent and independent), Linearity and superposition; expectation values; observables and operators; SE of particle in a box, finite potential well; harmonic oscillator; tunnelling.

**TEXT BOOKS/REFERENCES:**

1. Concepts of Modern Physics, A. Beiser, S. Mahajan and S. R. Choudhury 7<sup>th</sup> Edition, McGraw Hill, 2015
2. *Introductory Quantum Mechanics for Applied Nanotechnology* by D. M. Kim, Wiley-VCH; 2015.

**Pre-requisites:** Basic level Physics & Chemistry

**Total number of classes:** 45

### **COURSE OUTCOMES:**

Students who complete the course will have demonstrated the following:

- *Relate electronic bonding to material properties and materials classification*
- *Map crystal directions and planes in crystalline structure*
- *Relate crystalline structure to density and ease of deformation*
- *Quantify imperfections in crystalline structure and its role on properties*
- *Quantify diffusion within solids using Fick's First and Second Laws*
- *Quantify Mechanical properties of solids in terms of stress and strain and their relationship to each other*
- *Be able to predict failure from deformation behavior and geometry*
- *Relate composite properties to the individual materials combined and their architecture*
- *Define and quantify unique polymer properties and their relationship to polymer structure*
- *Predict phase composition from composition and temperature*
- *Quantify surface area and volume in nanosystems in comparison with microsystems*
- *To be able to develop and utilize equations for the thermodynamics of nanosystems*
- *Be able to quantitatively derive and relate particle size to physical properties, including, melting point and internal pressure*
- *Predict mechanical properties of nanoparticles and nanocomposites*
- *Quantify structural and mechanical parameters of classical nanomaterials classes.*

### **COURSE CONTENT:**

#### **Unit 1**

##### **Basic Materials Science: (15 lectures)**

Materials classification by bonding, amorphous and crystalline materials, crystal lattices, Miller indices, defects in crystal structure, principles of dislocations, theory of diffusion, mechanical properties, phase diagrams, polymeric materials, composite materials, electrical and optical properties

#### **Unit 2**

##### **Nanomaterials science: (15 lectures)**

Types of Nanomaterials, definition of nanoscale, surfaces and particle size, surface energy and surface tension and relation to size, phase transformation in nanomaterials, specific heat and heat capacity of nanomaterials, mechanical properties of nanomaterials, optical properties of nanomaterials, electrical and magnetic properties of nanomaterials.

### **Unit 3 (10 lectures)**

Inclusion and importance of surface energy, equations of thermodynamics with surface energy  
Equilibrium Particle size, internal pressure and stability, nucleation processes

### **Unit 4 (5 lectures)**

Kinetics of reactions at nanoscale, Diffusion at nanoscale, ripening among nanoprecipitates.

### **TEXTBOOKS:**

1. *Materials Science and Engineering – An Introduction, William D Callister, 12<sup>th</sup> Edition, John Wiley (Available in Amazon India, Rs. 287)*
2. *Nanomaterials – An introduction to synthesis, properties and applications, D. Vollath, Wiley-VCH, Second Edition 2013.*

## **2<sup>nd</sup> Semester**

**24NE611**

**Nano Engineering Applications**

**2 0 1-3**

**Pre-requisites:** Basic math, physics and chemistry

**Total number of classes: 45**

### **Course Outcomes:**

- *To understand the basics of energy conversion and storage at nanoscale (phenomena to devices)*
- *Introduce the fabrication and characterization technologies of Solar cells, batteries, thermo-electric and piezo-electric devices.*
- *Applications of electrochemical analysis techniques in characterizing energy storage devices*

### **Course Content:**

#### **Unit 1: Concepts in Energy conversion (8 lectures)**

Semiconductor junctions, Shockley–Queisser limit, electrical and optical characteristics; Energy conversion at nanoscale, charge carrier dynamics at nanoscale in energy conversion devices

#### **Unit 2: Energy conversion devices (12 lectures)**

Solar cells: I-V, EQE, CV, and VOC decay, wafer, thin films and excitonic solar cells; carrier transport and loss mechanisms, recombination models; anti-reflective coating, surface texturing; photodetectors and LEDs.

#### **Unit 3: Basics of Energy storage (8 Lectures)**

Introduction to electrochemistry, potentials and thermodynamics of cells, galvanic and electrolytic cells, kinetics of electrochemical reactions, mass transfer by migration and diffusion, non-Faradaic and Faradaic reactions.

#### **Unit 4: Energy storage devices (10 Lectures)**

Positive and negative electrodes of batteries and electrochemical capacitors, advanced batteries with nanoscale materials, Reaction mechanisms and fundamental understanding, cycle-life, capacity, energy and power density assessments, safety concerns and solutions.

#### **Unit 5: Electrochemical analysis techniques (8 Lectures)**

Electrochemical methods: potentiostatic and galvanostatic, cyclic voltammetry, chronoamperometry, chronopotentiometry and electrochemical impedance spectroscopy.

#### **TEXT BOOKS/REFERENCES:**

1. Jenny Nelson, "The Physics of Solar Cells", First Edition, Imperial College Press, 2003.
2. Stephen Fonash, Solar Cell Device Physics - 2nd Edition, Academic Press, 2010
3. L. R. Martinez and N. Omar, Emerging Nanotechnologies in Rechargeable Energy Storage Systems, 1st Edition, Elsevier (2017).
4. G. A. Nazri and G. Pistoia, Lithium Batteries, Springer, 2009.
5. Allen Bard and Larry R. Faulkner, Electrochemical Methods, John Wiley & Sons Inc, 2001.

**24NE612**

**VLSI Design and Technology**

**3 0 0-3**

**Pre-requisites:** Basic math, physics and chemistry

**Total number of classes: 45**

#### **Course Outcomes:**

- Understand the concepts and laws of combinational and sequential logic circuits
- Introduced to wafer level fabrication and packaging.
- To be able to understand the design of logical circuits, operation and testing.
- Know the role of circuit elements including comparators and counters, multipliers and shifters.
- Introduce to circuit design software and packages utilized in the industry.

#### **Course Content:**

##### **Unit 1: Digital Logic Families (8 lectures)**

Logic Gates(all-types), Boolean algebra, variables, literals and terms in Boolean expressions, Postulates and theorems of Boolean Algebra, Diode-logic, Introduction to transistor-transistor logic (TTL), CMOS logic family, NMOS and PMOS Logic.

##### **Unit-2: Combinational and Sequential Logic Circuits (7 lecture)**

Combinational vs Sequential logic circuits, adders, subtractors, multiplier, comparator, encoder and decoder, latches vs flip-flops, multivibrator, R-S Flip-flops, J-K Flip-flop, T Flip-flop.

##### **Unit-3: VLSI Fabrication and processes (10 lectures)**

Introduction to wafer fabrication, Packaging, MOS process (n-well and p-well), Silicon on insulator process.

#### **Unit-4: VLSI design and testing (10 lectures)**

Introduction to VLSI Design, Basic MOS transistors, Enhancement mode transistor operation, Drain current Vs voltage derivation, NMOS and CMOS inverters, Sheet Resistance and capacitance, Delay, Driving large Capacitive Loads, Propagation delay, Fan- in and fan-out characteristics, introduction to scaling.

#### **Unit-5: Design and testing of circuit elements (10 lectures)**

Design of Adders, Parity generators, Detectors, Comparators and Counters, Registers and Shifters, memory elements. Case-studies of digital circuits using circuit analysis software-packages

Exposure to VFabLab.org to do virtual experiments on semiconductor manufacturing.

#### **Text Books**

1. Kamran Eshraghian, Eshraghian Douglas and A. Pucknell, "Essentials of VLSI circuits and systems", PHI, 2005 Edition.

2. CMOS VLSI Design: A Circuits and Systems Perspective by Neil Weste and David Harris (2010) Pearson; 4th edition

3. Digital Electronics: Principles and Integrated Circuits by AK. Maini, Wiley (2007).

#### **References:**

1. S.M. Sze and M. K. Lee. "Semiconductor Devices: Physics and Technology", 3<sup>rd</sup> Edition, 2012

2. R. C. Jaeger, "Introduction to Microelectronic Fabrication", 2<sup>nd</sup> Edition, 2002.

**24NE683**

**Nanoelectronics and Nanofabrication Lab**

**0 0 4-2**

**Pre-requisites:** Basic understanding of experimental research

**Total number of lab sessions: 15**

#### **Course Outcomes:**

- *Electronic transport characterization of nanomaterials with hands on experience.*
- *Will be trained to use cryogenic systems and materials characterization at low and high temperatures.*
- *Will be able to handle Laser based lithography systems to design nanoscale devices in the clean room environment.*
- *PCB design and fabrication will be explored.*

#### **Course Content:**

**Unit-1: Electronics, transport in nanoscale and cryogenics (5 sessions)**

Digital electronics demonstrating logical gates using commercial ICs (ex: 7404 & 7408). Hands of experiments involving electronic transport in nanoscale materials (quantum dots, nanowires, carbon nanotubes), low temperature and high temperature measurements.

**Unit-2: Nanofabrication and characterization (5 sessions)**

Lithography process and device fabrication, ensemble and isolated nanostructures electrical and photonic characterizations.

**Unit-3: PCB design and cleanroom usage training (5 sessions)**

PCB design and fabrication (ex: design using EsayEDA or similar platform). Exposure to cleanroom protocols and usage.

**24NE684**

**NanoEnergy Devices Lab**

**0 0 4-2**

**Pre-requisites:** Basic understanding of experimental research

**Total number of lab sessions:** 15

**Course Outcomes:**

- *Hands on experience in energy conversion devices: fabrication and testing.*
- *In depth exposure to energy storage materials and devices: fabrication and testing.*

**Course Content:**

**Unit-1: Energy conversion devices (7 sessions)**

Dye sensitized solar cell fabrication and testing, thin film hetero-junction photovoltaic device fabrication and testing, Quantum dot solar cell fabrication and testing,

**Unit-2: Energy storage devices (7 sessions)**

Li ion battery anode and cathode half-cell fabrication and testing, Li ion battery full-cell fabrication and testing, Supercapacitor/Pseudocapacitor fabrication and testing.

**ELECTIVES (For Semester-2)**

**24NE641**

**Emerging Nano-manufacturing technologies**

**3 0 0-3**

**Pre-requisites:** Basic math, physics and chemistry

**Total number of classes:** 45

**Course Outcomes:**

- *Introduced to vacuum techniques (how to create and measure vacuum).*

- *Deeper understanding of physical vapour deposition techniques.*
- *Fundamental exposure of chemical vapour deposition.*
- *Theoretical understanding of advances in nanofabrication techniques*
- *Explore nanomaterials based device fabrication techniques and advanced manufacturing processes.*

### **Course Content:**

#### **Unit-1: Thin-films deposition by vacuum and non-vacuum processes (18 lectures)**

Vacuum science and technology, physical vapour deposition: process and systems, thermal evaporation, electron beam evaporation, sputtering (DC, RF magnetron) chemical vapour deposition, film formation and nanostructure, characterization of thin films.

#### **Unit-2: Advanced micro and nanofabrication techniques (12 lectures)**

Micro- and nanofabrication overview, Photolithography, e-beam lithography. Modern fabrication technologies: nano-imprint lithography, soft lithography, microfluidic applications and devices.

#### **Unit-3: Device fabrication and advanced processing methods (15 lectures)**

Fabrication of 0 to 2-D nanostructures, Transistors and electronic building blocks, MEMS/NEMS, Applications of nanofabrication. Additive manufacturing and variants of 3D printing (electrochemical, laser sintering, jet fusion...).

### **TEXT BOOKS/REFERENCES:**

1. *Z. Cui, Nanofabrications: Principles, capabilities and limits, Springer (2017).*
2. *T. Li and Z. Liu, Outlook and challenges in Nanodevices, Sensors and MEMS, Springer (2017).*
3. *Handbook of Thin Film Technology, H. Frey and H. R. Khan, Springer Science and Business Media (2015)*
4. *The Materials Science of Thin Films, Milton Ohring, Academic Press (2002).*
5. *Additive Manufacturing by C.P. Paul, A.N. Jinoop, McGraw Hill (2021).*

**24NE642**

**Nanocarbon and Nanocomposites**

**3 0 0-3**

**Pre-requisites:** Basic math, physics and chemistry

**Total number of classes: 45**

### **Course Outcomes:**

- *Understand how to synthesize and characterize the carbon based nanostructures*
- *Gain knowledge on nanocomposites and its applications*
- *Be familiar with structural, electrical and electrochemical properties of Carbon nanocomposites*
- *Learn the synthesis and design strategies of metal organic frameworks*

### **Course Content:**

#### **Unit 1: Carbon Nanostructures (10 Lectures)**

Introduction to carbon and its nanostructures, graphite, single walled and multi-walled carbon nanotubes, fullerenes, graphene, graphene oxide, amorphous nanocarbon.



## **Unit 2: Properties of Carbon Nanomaterials (12 Lectures)**

Structure, size, synthesis, optical and mechanical properties; applications in nanoelectronics, energy conversion and energy storage.

## **Unit 3: Carbon nanocomposites (12 Lectures)**

Metal/Carbon nanocomposites, Nanocomposites of carbon with other inorganic materials and its applications.

## **Unit 4: Organic frameworks (10 Lectures)**

Organic frameworks of nano-materials (including MOF and COF) design strategies, synthesis, characterization and their application in nanoelectronics and energy.

### **TEXT BOOKS/REFERENCES:**

1. *Carbon Nanotechnology: Recent developments in chemistry, physics, materials science and device applications* edited by Liming Dai, Elsevier-2006.
2. *Carbon Nanomaterials: Synthesis, Structure, Properties and Applications* by Rakesh B. Mathur, B.P.Singh and S. Pande, CRC Press-2017
3. *Introduction to Reticular Chemistry: Metal-Organic Frameworks and Covalent Organic Frameworks* by O.M. Yaghi, M.J. Kalmutzki and C.S. Diercks, Wiley-2019

**24NE643          Hydrogen Energy: Production, Storage and Applications          3 0 0-3**

**Pre-requisites:** Basic math, physics and chemistry

**Total number of classes: 45**

### **Course Outcomes:**

- *To understand the Hydrogen economy and properties of Hydrogen as fuel.*
- *Introduce the hydrogen production and storage technologies.*
- *Applications of hydrogen as fuel in combustion engines and fuel cells.*

### **Course Content:**

#### **Unit 1: Hydrogen Production (15 Lectures)**

Hydrogen economy, Properties of Hydrogen, Methods of hydrogen production: Thermochemical, Photochemical, Electrochemical and Photoelectrochemical (PEC) methods. Steam reforming, Catalyst activation, hydrolysis of NaBH<sub>4</sub>, water electrolysis – electrolyzers, Photo-Catalytic Water Splitting, Homogeneous and Heterogeneous Photo-Catalysis, Principles of Photoelectrochemical Cells, Nanostructured  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub> Photoanodes, Mixed Metal Oxide Photoelectrodes and Photocatalysts, Multijunction Approaches to Photoelectrochemical Water Splitting.

#### **Unit 2: Hydrogen Storage (18 Lectures)**

Hydrogen storage methods – Compressed gas, Liquid state and Solid-state methods.

Solid-state hydrogen storage: Metal hydrides, Intermetallic hydrides, complex hydrides, Physisorption of hydrogen on porous materials. thermodynamics and kinetics of metal hydrides, tailoring reaction enthalpy of hydrides, nanoparticles for hydrogen storage. nanoparticles in 3D support. Various methods of nanomaterial synthesis, Carbon based materials for hydrogen storage.

### **Unit 3: Applications (12 Lectures)**

Fuel cells, Electrochemistry and thermodynamics of fuel cells, Types of fuel cells, Proton exchange membrane cells- Current collectors and gas delivery system, Gas diffusion layers, Catalyst action, Overall performance and reversible operation, Degradation and lifetime. Combustion engines with Hydrogen fuel and Hydrogen sensing.

### **TEXT BOOKS / REFERENCES:**

1. *Handbook of Hydrogen Energy* edited by S. A. Sherif, D. Yogi Goswami, CRC Press
2. *Handbook of Hydrogen Storage: New Materials for Future Energy Storage* edited by Michael Hirscher, Wiley-2010.
3. *Nanomaterials for solid state hydrogen storage*-Robert A. Varin, springer 2007.
4. *Hydrogen and Fuel Cells: Emerging Technologies and Applications (Sustainable World)* Bent Sorensen, Elsevier Academic Press 2005.

**24NE644**

**Flexible and Wearable Electronics**

**3 0 0-3**

**Pre-requisites:** Basic math, physics and chemistry

**Total number of classes: 45**

### **Course Outcomes**

- Knowledge on fundamentals of flexible & wearable electronics.
- Understand the design and fabrication challenges for engineering applications
- Understand basic principles, design, fabrication and working of wearable electronics
- Foundation on smart sensors, fabrics, watches...etc (IoT applications).

### **Introduction (10 lectures)**

Introduction to flexible electronics, materials (organic, inorganic, polymers, composites, flexible substrates), processes, electrodes & electronics design, functionality, packaging and device characterizations.

### **Flexible electronics & engineering applications (10 lectures)**

Introduction to flexible systems, displays, consumer electronics, batteries & solar cells, automotive circuits, electronic skin, defence, space, smart fabrics, actuators & sensors.

### **Wearables for healthcare (10 lectures)**

Introduction to wearable systems, Diagnostics, Monitoring Patients, Multi parameter monitoring, Neural recording, Sports Medicine, wearable devices: Inertia sensors, Respiration sensor, motion sensors, pressure sensors, strain gauges, electrochemical biosensors, CMOS –Based Biosensors, E-Textiles, Bio compatibility.

### **IoT for wearable electronics (10 lectures)**

Introduction: Definition and Characteristics of IoT, design, protocols, communication. Technologies: Wireless Sensor Networks, Embedded Systems, Smart watches, glasses, clothing and fitness trackers.

### **Text Books/References**

1. *Flexible Electronics: Materials and Applications*, Editors: Alberto Salleo, William S. Wong  
Springer © 2009.
2. Raj Kamal, “Internet of Things – Architecture and Design Principles”, Mc Graw Hill Education Pvt.Ltd., 2017.
3. Annalisa Bonfiglio, Danilo De Rossi, "Wearable Monitoring Systems", Springer, 2011.
4. *Flexible Electronics: Status, Challenges and Opportunities*, D. Corzo, G. T. Blázquez, D. Baran, *Front.Electron.*, 1 (2020) 594003, <https://doi.org/10.3389/felec.2020.594003>
5. *A Review of Manufacturing Methods for Flexible Devices and Energy Storage Devices*, Y. Han, Y. Cui, X. Liu and Y. Wang, *Biosensors* 13 (2023) 896, <https://doi.org/10.3390/bios13090896>.

## **3<sup>rd</sup> Semester**

**24NE798**

**Dissertation-I –**

**0-0-28 (14 Credits)**

### **ELECTIVES (For Semester-3)**

**24NE731**

**Computational Methods for Material Science**

**2 0 0-2**

**Pre-requisites:** Basic math, physics and chemistry

**Total number of classes: 30 + 7 Lab sessions**

### **Course Outcomes:**

- *Introduced to fundamentals of computation relevant for condensed matter physics.*
- *Understanding first principles calculations of materials.*
- *Introduced to simulations using Monte Carlo and molecular dynamics.*
- *Practical hands on training in computational tools for physical and chemical property calculation of materials.*

### **Course Content:**

**Unit-1: Fundamentals of condensed matter computation (15 lectures)**

Interatomic potentials or force fields, structure chemistry and properties relations, first-principle based density functional atomic simulations methods, pseudopotentials, total energy functional and its derivatives, boundary conditions for molecules, clusters and extended systems, Ewald simulation using classical potentials.

### **Unit-2: Properties and simulations (15 lectures)**

Vibrational principles, methods of optimization for linear problem and nonlinear problems. Errors and accuracy of quantitative predictions: thermodynamics ensembles, Monte Carlo sampling, molecular dynamics simulation. Free energy and phase transitions. Fluctuations, Susceptibilities and transport properties. Coarse-graining approaches and mesoscale models.

### **Unit-3: Hands on Computational training (7 sessions)**

This course offers a project involving simulations for physical or chemical properties of a material of student's choice (for 1 credit). Introduction to multi-physics software such as Matlab, Comsol...etc.

### **TEXTBOOKS/ REFERENCES:**

1. *Electronic structure: Basic Theory and Practical Methods*, by Richard Martin Cambridge University Press (2004).
2. *Computer Simulations of Liquids* by M.P. Allen and D. J. Tildesley, Oxford Scholarship (2017).
3. [www.electronicstructure.org](http://www.electronicstructure.org)
4. *Understanding Molecular Simulations* by D. Frenkel and B. Smit, Academic Press (2002)

**24NE732**

**Nanophotonics**

**2 0 0-2**

**Pre-requisites:** Basic math, physics and chemistry

**Total number of classes: 30**

### **Course Outcomes:**

- *Understand how the light-matter interactions are depends on particle size (bulk to nanoscale)*
- *Be familiar with Near-field optics and localized surface plasmons*
- *Understand the use of photonic crystals as a waveguides*
- *Learn optical metamaterials and its application in imaging the objects.*
- *Comprehend the working of nanolasers and Quantum cascade lasers.*

### **Course Content:**

#### **Unit 1: Basics of nanophotonics (8 Lectures)**

Review of Electrodynamics, light-matter interactions, Photons and electrons: similarities and differences, free-space propagation, Confinement of photons and electrons. Localization under a periodic potential: Bandgap, Cooperative effects. Nanoscale optical interactions, Nanoscale confinement of electronic interactions.

#### **Unit 2: Near-field optics and microscopy (5 Lectures)**

Concepts and devices in nanoscale optics and photonics. Nano-scale and near-field optics, near-field optical probes, near-field scanning optical microscopy, transmission through nanoscale apertures.

### **Unit 3: Lasers and quantum lasers (6 Lectures)**

Solid-state lasers and gas lasers, Quantum materials, Quantum confined structures as lasing media, nanolasers, Quantum Cascade Lasers.

### **Unit 4: Plasmonics (6 Lectures)**

Metallic Nanoparticles and Nanorods, Local field enhancement, Subwavelength aperture plasmonics, Plasmonic wave guiding, Applications of metallic nanostructures.

### **Unit 5: Photonic crystals (5 Lectures)**

Basic concepts, Features of Photonic crystals, Photonic crystals (0D, 1D, 2D & 3D), silicon, graphene and diamond photonics.

### **TEXT BOOKS / REFERENCES:**

1. *J. W. Haus, "Fundamentals and Applications of Nanophotonics", Woodhead Publishing, 2016.*
2. *S. V. Gaponenko, "Introduction to Nanophotonics", Cambridge University Press, 2010.*
3. *Introduction to Electrodynamics, David J Griffiths, 3rd edition, 1999.*

**24NNE701**

**Statistical Data Analysis**

**1 0 1-2**

**Pre-requisites:** Undergraduate level basic maths, physics, chemistry and biology

**Total number of classes:** 30

### **Course Outcomes:**

- *The basic concepts of statistics and the need for statistical methods in research*
- *Data Analysis Methods*
- *The fundamental theory of probability and standard distributions*
- *Tests of Significance used in Statistical analysis*
- *The different types of multivariate analysis used in research*
- *Practical analysis of data using standard softwares like SPSS, SAS*
- *Practical understanding of Descriptive Data Analysis, Sampling Theory, Biostatistical Inference, Testing of Hypotheses, Nonparametric Methods and Multivariate Regression Analysis*

### **Course Contents:**

#### **Unit-1 (6 Lectures)**

Introduction to Statistics-Need for Statistical Methods –Their uses and Misuses, Types of Variables, Data collection Methods, Population and Sample.

Descriptive Data Analysis Methods- Statistical Tables, Diagrams & Graphs, Measures of Averages, Measures of Dispersion, Correlation Analysis Methods, Regression Analysis Methods.

#### **Unit-2 (6 Lectures)**

Theory of probability and Standard Distributions - Binomial, poisson & Negative Binomial, Standard univariate continuous distributions – Normal, Log normal & Exponential. Sampling distributions – Chi-square distribution and F & 't' distributions.

### **Unit-3 (6 Lectures)**

Tests of Significance of Statistical Hypotheses- Concept of Statistical Hypotheses –Null and Alternative hypotheses, Type I and Type II errors, Significance level, Critical region and Power of a test, P-value and its interpretation; Large and Small Sample Test – Normal test, Student's 't' test, Chi-square tests, Analysis of variance.

### **Unit-4 (6 Lectures)**

Nonparametric methods-Non-parametric methods for estimation, Methods for tests of significance for the independent and correlated samples, Nonparametric Methods for more than two populations.

Multivariate analysis Methods- Principles of Multivariate analysis, Multivariate regression analysis, Multivariate logistic regression analysis.

### **Unit-5 (6 Lectures)**

Practicals- (Statistical Software to be used: SPSS & SAS): (i) Practical in Descriptive Data Analysis Methods, (ii) Practical in Sampling Theory, (iii) Practical in Biostatistical Inference, (iv) Practical in Testing of Hypotheses, (v) Practical in Nonparametric Methods, (vi) Practical in Multivariate Regression Analysis.

### **TEXT BOOKS/REFERENCES:**

1. *Statistical Techniques for data Analysis: J.K. Taylor & Cheryl C, 2004 Chapman & Hall (CRC).*
2. *Performing Data Analysis Using IBM SPSS: Lawrence S Meyers, 2015, John Wiley.*

**24NE702**

**Ethics in Research and Research Methodology**

**1 0 1- 2**

**Pre-requisites:** Any undergraduate degree

**Total number of classes:** 30

### **Course Outcomes:**

- *Understand the basic concepts of ethics in proper conduct of research*
- *Understand about plagiarism in research and how it should be avoided*
- *Gain a clear idea about the importance of proper data documentation*
- *Students will have a clear idea about the research methodologies that need to be adopted during their research*

### **Course Content:**

**Unit-1 (15 Lectures)**

Plagiarism, regulatory principles, safety in research, ethics in nanomaterials based research.

## Unit-2 (15 Lectures)

Principles of data documentation, protocol development, research questions and hypothesis driven research.

### TEXTBOOKS:

1. *Research Ethics for Scientists*, C. Neal Stewart Jr., Wiley-Backwell Publishers, 2011
2. *Ethics in Science, Ethical Misconduct in Scientific Research*, John D'Angelo, CRC Press, 2012

## 4<sup>th</sup> Semester

24NE799

Dissertation-II

0-0-34 (17 Credits)

23HU611

Career Competency II

L-T-P-C: 0-0-3-1

**Pre-requisite:** Willingness to learn, team spirit, basic English language and communication skills and knowledge of high school level arithmetic.

### Course Objectives:

- Help students to understand the importance of interpersonal skills and team work
- Prepare the students for effective group discussions and interviews participation.
- Help students to sharpen their problem solving and reasoning skills
- Empower students to communicate effectively by using the correct diction, grammar and verbal reasoning skills

### Course Outcomes:

**CO1: Soft Skills** - To demonstrate good interpersonal skills, solve problems and effectively participate in group discussions.

**CO2: Soft Skills** - To write technical resume and perform effectively in interviews.

**CO3: Aptitude** - To identify, investigate and arrive at appropriate strategies to solve questions on arithmetic by managing time effectively.

**CO4: Aptitude** - To investigate, understand and use appropriate techniques to solve questions on logical reasoning and data analysis by managing time effectively.

**CO5: Verbal** - To be able to use diction that is more refined and appropriate and to be competent in knowledge of grammar to correct/improve sentences

**CO6: Verbal** - To be able to examine, interpret and investigate passages and to be able to generate ideas, structure them logically and express them in a style that is comprehensible to the audience/recipient.

### CO-PO Mapping

PO	PO1	PO2	PO3
CO			
CO1	2	1	-
CO2	2	1	-
CO3	2	1	-
CO4	2	1	-
CO5	1	2	-
CO6	2	2	-

### Syllabus

#### Soft Skills

Interpersonal skill: ability to manage conflict, flexibility, empathetic listening, assertiveness, stress management, problem solving, understanding one's own interpersonal needs, role of effective team work in organizations

Group problem solving: the process, the challenges, the skills and knowledge required for the same.

Conflict management: the concept, its impact and importance in personal and professional lives, (activity to identify personal style of conflict management, developing insights that helps in future conflict management situations.)

Team building and working effectively in teams: the concept of groups (teams), different stages of group formation, process of team building, group dynamics, characteristics of effective team, role of leadership in team effectiveness. (Exercise to demonstrate the process of emergence of leadership in a group, debrief and reflection), group discussions.

Interview skills: what is the purpose of a job interview, types of job interviews, how to prepare for an interview, dos and don'ts of interview, One on one mock interview sessions with each student

#### Verbal

**Vocabulary:** Help students understand the usage of words in different contexts. Stress the importance of using refined language through idioms and phrasal verbs.



**Grammar:** Enable students to identify poorly constructed sentences or incorrect sentences and improvise or correct them.

**Reasoning:** Facilitate the student to tap her/his reasoning skills through critical reasoning questions and logical ordering of sentences.

**Reading Comprehension:** Enlighten students on the different strategies involved in tackling reading comprehension questions.

**Public Speaking Skills:** Empower students to overcome glossophobia and speak effectively and confidently before an audience.

**Writing Skills:** Practice closet tests that assess basic knowledge and skills in usage and mechanics of writing such as punctuation, basic grammar and usage, sentence structure and rhetorical skills such as writing strategy, organization, and style.

## Aptitude

**Sequence and Series:** Basics, AP, GP, HP, and Special Series.

**Geometry:** 2D, 3D, Coordinate Geometry, and Heights & Distance.

**Permutations & Combinations:** Basics, Fundamental Counting Principle, Circular Arrangements, and Derangements.

**Probability:** Basics, Addition & Multiplication Theorems, Conditional Probability and Bayes' Theorem.

**Logical Reasoning I:** Arrangements, Sequencing, Scheduling, Venn Diagram, Network Diagrams, Binary Logic, and Logical Connectives, Clocks, Calendars, Cubes, Non-Verbal reasoning and Symbol based reasoning.

**Logical Reasoning II:** Blood Relations, Direction Test, Syllogisms, Series, Odd man out, Coding & Decoding, Cryptarithmic Problems and Input - Output Reasoning.

**Data Sufficiency:** Introduction, 5 Options Data Sufficiency and 4 Options Data Sufficiency.

**Campus recruitment papers:** Discussion of previous year question papers of all major recruiters of Amrita Vishwa Vidyapeetham.

**Miscellaneous:** Interview Puzzles, Calculation Techniques and Time Management Strategies.

## References

### Soft Skills

### **Team Building**

- Thomas L.Quick, "Successful team building", AMACOM Div American Mgmt Assn, 1992

- Brian Cole Miller, “Quick Team-Building Activities for Busy Managers: 50 Exercises That Get Results in Just 15 Minutes”, AMACOM; 1 edition, 2003.
- Patrick Lencioni, “The Five Dysfunctions of a Team: A Leadership Fable”, Jossey-Bass, 1<sup>st</sup> Edition, 2002

### Verbal

- “GMAT Official Guide” by the Graduate Management Admission Council, 2019
- Arun Sharma, “How to Prepare for Verbal Ability And Reading Comprehension For CAT”
- Joern Meissner, “Turbocharge Your GMAT Sentence Correction Study Guide”, 2012
- Kaplan, “Kaplan GMAT 2012 & 13”
- Kaplan, “New GMAT Premier”, Kaplan Publishing, U.K., 2013
- Manhattan Prep, “Critical Reasoning 6th Edition GMAT”
- Manhattan Prep, “Sentence Correction 6th Edition GMAT”
- Mike Barrett “SAT Prep Black Book The Most Effective SAT Strategies Ever Published”
- Mike Bryon, “Verbal Reasoning Test Workbook Unbeatable Practice for Verbal Ability, English Usage and Interpretation and Judgement Tests”
- [www.bristol.ac.uk/arts/skills/grammar/grammar\\_tutorial/page\\_55.htm](http://www.bristol.ac.uk/arts/skills/grammar/grammar_tutorial/page_55.htm)
- [www.campusgate.co.in](http://www.campusgate.co.in)

### Aptitude

- Arun Sharma, “How to Prepare for Quantitative Aptitude for the CAT Common Admission Test”, Tata Mc Graw Hills, 5th Edition, 2012
- Arun Sharma, “How to Prepare for Logical Reasoning for the CAT Common Admission Test”, Tata Mc Graw Hills, 2nd Edition , 2014
- Arun Sharma, “How to Prepare for Data Interpretation for the CAT Common Admission Test”, Tata Mc Graw Hills, 3rd Edition , 2015
- R.S. Aggarwal, “Quantitative Aptitude For Competitive Examinations”, S. Chand Publishing , 2015
- R.S. Aggarwal, “A Modern Approach To Verbal & Non-Verbal Reasoning”, S. Chand Publishing , Revised -2015
- Sarvesh Verma, “Quantitative Aptitude-Quantum CAT” , Arihant Publications , 2016
- [www.mbatious.com](http://www.mbatious.com)
- [www.campusgate.co.in](http://www.campusgate.co.in)
- [www.careerbless.com](http://www.careerbless.com)

### Evaluation Pattern

Assessment	Internal	External
Continuous Assessment (CA)* – Soft Skills	30	-
Continuous Assessment (CA)* – Aptitude	10	25
Continuous Assessment (CA)* – Verbal	10	25
Total	50	50

\*CA - Can be **presentations, speaking activities and tests.**