# M. Sc in NanoElectronics and NanoEngineering

## First Semester

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Type</th>
<th>Course</th>
<th>LTP</th>
<th>Credits</th>
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<tbody>
<tr>
<td>22NNE501</td>
<td>FC</td>
<td>Statistical Data Analysis</td>
<td>101</td>
<td>2</td>
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<tr>
<td>22NNE502</td>
<td>SC</td>
<td>Quantum Science</td>
<td>300</td>
<td>3</td>
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<tr>
<td>22NNE503</td>
<td>SC</td>
<td>Solid State Phenomena at Nanoscale</td>
<td>300</td>
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<tr>
<td>22NNE504</td>
<td>SC</td>
<td>Chemical Synthesis Nanomaterials</td>
<td>300</td>
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<tr>
<td>22NNE505</td>
<td>SC</td>
<td>Nanophotonics</td>
<td>300</td>
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<tr>
<td>22NNE506</td>
<td>SC</td>
<td>Modern Concepts in Materials Science</td>
<td>300</td>
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<tr>
<td>21HU601</td>
<td>HU</td>
<td>Amrita Values Programme</td>
<td>P/F</td>
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<tr>
<td>21HU602</td>
<td>HU</td>
<td>Career Competency-I</td>
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<td>22NNE581</td>
<td>SC</td>
<td>Lab-I: Optoelectronics Lab</td>
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<tbody>
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<td>Computational Methods for Condensed Matter</td>
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<td>22NNE512</td>
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<td>Nano- Opto- and Bio-electronic Devices</td>
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<tr>
<td>22NNE513</td>
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<td>Characterization of Nanomaterials</td>
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<td>22NNE514</td>
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<td>Emerging Nano-manufacturing technologies</td>
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<td>22NNE515</td>
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<td>NanoEngineering for Energy Conversion and Storage</td>
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<td>FC</td>
<td>Ethics in Research and Research Methodology</td>
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<tr>
<td>22NNE602</td>
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<td>Introduction to Machine Learning</td>
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<td>22NNE603</td>
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<td>Nano Carbon and Nanocomposites</td>
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<td>VLSI Technology and Design</td>
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**Overall Credits**: 76
22NNE501  Statistical Data Analysis  1-0-1 (2 Credits)

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.


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 & Non parametric methods.

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.


TEXT BOOKS/REFERENCES:

22NNE502  Quantum Science  3-0-0 (3 Credits)

Review of mechanics, failures of classical mechanics, Planck’s quantum hypothesis, photo-electric effect, Compton Effect, Bohr’s H-atom model, particle in a box, Bohr’s correspondence principle, wave-particle duality, uncertainty principle, observables and operators, Schrödinger’s equation, free-electron, particle in a box, harmonic oscillator, tunnelling, applications of quantum mechanics in nanotechnology.

TEXT BOOKS/REFERENCES:
22NNE503  Solid State Phenomena at Nanoscale  3-0-0 (3 Credits)

Solid state science: introduction to solids, materials classification by bonding, amorphous and crystalline materials, crystal structure, Miller indices, phonons, heat capacity, specific heat capacity models: Debye and Einstein models, anharmonicity and thermal expansion, heat conduction, dielectrics and ferroelectrics, magnetism and superconductivity, plasmons, polaritons and polarons.

TEXT BOOKS/REFERENCES:

22NNE504  Chemical Synthesis of Nanomaterials  3-0-0 (3 Credits)

Synthesis Methods of Nanomaterials: Top down : Milling; Bottom up approaches – Synthesis of zero dimensional metal, metal oxides, semiconductor nanoparticles by different routes – Colloidal method, Sol-gel, Electrodeposition; Kinetically Confined Synthesis of Nanoparticles - Aerosol synthesis, Micellar growth, Spray pyrolysis, Template-based synthesis; Synthesis of one dimensional nanosystems by different routes – VLS and SLS methods, Electrospinning; Synthesis of two dimensional nanosystems – Fundamentals of Film Growth; Vapor phase deposition methods - Physical and chemical methods; Superlattices; Self Assembly; Langmuir-Blodgett Films; Electrochemical Deposition; Special Nanomaterials – Core/shell structures, Carbon-based Nanomaterials, Micro and Mesoporous Materials, Organic-Inorganic Hybrids

TEXT BOOK/REFERENCES:

22NNE505  Nanophotonics  3-0-0 (3 Credits)

Review of vector analysis, electrostatics, electric fields in matter, magnetostatics, magnetic field in matter, electrodynamics, light-matter interactions, concepts and devices in nanoscale optics and photonics. Nano-scale and near-field optics, near-field optical probes, quantum confined materials, plasmonics, photonic crystals, silicon, graphene and diamond photonics, metamaterials, nanolasers, single-photon sources.

TEXT BOOKS / REFERENCES:
22NNE506  Modern Concepts in Materials Science   3-0-0 (3 Credits)

Crystalline and amorphous materials, defects in solids, properties of materials, structure-size-property correlation, solid solutions and phase equilibrium, phase diagrams, phase transitions, kinetics and thermodynamics of phase transitions, ceramics, polymers, corrosion and wear.

TEXT BOOK/REFERENCES:


21HU601  Amrita Values Programme       P/F

Culture – definition and scope. Values and culture, cultural freedom, Culture and Education
Culture of Research – creativity and responsibility in research
Spirituality and Culture – spirituality as a way of life, spirituality and religion
Culture and women – gender oppression, motherhood
Culture and the Media
Culture and Politics – national values and political harmony
Philosophy and Culture, epistemology

21HU602- Career Competency-I       P/F

22AVP103  Mastery Over Mind (MAOM)  1-0-2 2

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)

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:

REFERENCES:
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

3. Evaluation and Grading

<table>
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<th>External</th>
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<tr>
<td><strong>Components</strong></td>
<td><strong>Weightage</strong></td>
<td><strong>Practical (attendance and class participation) 60%</strong></td>
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<tr>
<td>Quizzes (based on the reading material)</td>
<td>20%</td>
<td>40%</td>
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<tr>
<td>Assignments (Based on webinars and lecture series)</td>
<td>20%</td>
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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

*Programme 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
22NNE581 Lab-I: Optoelectronics 0 0 2 (2 Credits)


TEXTBOOKS/ REFERENCES:

22NNE511 Computational Methods for Condensed Matter 2-0-1 (3 Credits)

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. 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. Couse-graining approaches and mesoscale models. This course offers a project involving simulations for any physical or chemical properties of a material of student’s choice (for 1 credit in addition). Introduction to multi-physics software such as Matlab, Comsol…etc.

TEXTBOOKS/ REFERENCES:
3. www.electronicstructure.org
**22NNE512** Nano- Opto- and Bio-electronic Devices  
3-0-0 (3 Credits)

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, 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. 2D materials (Graphene QDs, TMDs, MXenes... etc.) electronic, photonics and optoelectronics applications. Spintronics: GMR, TMR, spin injection and detection, magnetic tunnel junctions, dilute magnetic semiconductors and spintronic devices. Bioelectronic devices: biosensors, micro-fluidics, biophysical concepts and methods, analytical electrochemistry, biomolecular electronics, BioNano machines. Industrial relevant failure analysis, metrology and device characterizations.

**TEXTBOOKS/ REFERENCES:**


**22NNE513** Characterization of Nanomaterials  
3-0-0 (3 Credits)

X-ray diffraction and Reciprocal lattice, structure factor and form factor, Bragg’s law, Ewald’s sphere construction, XRD of nanolayers, effects of nanosize and shape anisotropy of nanostructures, texture and strain measurements, modes of operation. SEM: scattering of electrons, secondary and backscattered electrons, electron sources, imaging modes in SEM and its use for nanomaterials size and shape analysis, TEM: Interaction of high energy electrons with matter, elastic and inelastic scattering, TEM instrumentation, imaging and diffraction modes of operation, imaging and contrast in TEM, HRTEM, Energy dispersive analysis of x-rays, Nanomaterials size and size distribution analysis, shape and structural analysis, SPM: Principle of operation, contact and non-contact AFM, dynamic force microscopy, and various other modes of SPM including STM. Chemical Characterization – Microwave Spectroscopy, IR spectroscopy: vibrational modes, theory of IR spectroscopy, single and group frequencies, advantages of FTIR. Raman spectroscopy, surface enhanced Raman spectroscopy, X-ray photoelectron spectroscopy. Use of these techniques for nanomaterials and biomaterials analysis.

**TEXT BOOKS/ REFERENCES:**
1. Elements of X-ray Diffraction, B. D. Cullity and S. R. Stock (Pearson)
3. Scanning Probe Microscopy and Spectroscopy, D. A. Bonnell (Wiley)

22NNE514 Emerging Nano-manufacturing technologies  3-0-0 (3 Credits)
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. Micro- and nanofabrication overview, Photolithography, e-beam lithography. Modern fabrication technologies: nano-imprint lithography, soft lithography, microfluidic applications and devices. 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:

22NNE515 NanoEngineering for Energy Conversion and Storage  3-0-0 (3 Credits)
Semiconductor junctions, Shockley–Queisser limit, electrical and optical characteristics of solar cells: I-V, EQE, CV, and VOC decay, wafer and thin film based solar cells, carrier transport and loss mechanisms, recombination models-anti-reflective coating, surface texturing and excitonic solar cells. Energy conversion at nanoscale, charge carrier dynamics at nanoscale in energy conversion devices.
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. Electrochemical methods: potentiostatic and galvanostatic, cyclic voltammetry, chronoamperometry, chronopotentiometry and electrochemical impedance. Thermo-electric and piezo-electric materials and devices, fabrication and characterizations.

TEXT BOOKS/REFERENCES:

**22NNE516 Digital Electronics 3-0-0 (3 Credits)**

Analog and digital number systems (decimal and binary), Deci-Binary, Binary-Deci, Hexa-Deci conversion, rules of binary addition, subtraction, multiplication and division, Logic gates (AND, OR, NOT, NAND, NOR…), introduction to TTL, CMOS, NMOS, PMOS, Boolean algebra, Flip-flops (RS, JK…), counters and converters, microprocessors and microcontrollers, memory devices.

**TEXT BOOKS / REFERENCES:**


**21HU603 Career Competency-II 0 0 2 1**

**22NNE582 Nanoelectronics and Nanofabrication Lab 0-0-2 (2 Credits)**

Hands of experiments involving: Electronic transport in nanoscale materials (quantum dots, nanowires, carbon nanotubes), low temperature and high temperature measurements, lithography process and device fabrication, ensemble and isolated nanostructures electrical and photonic characterizations and finally exposure to cleanroom protocols and usage. PCB design and fabrication (ex: design using EasyEDA or similar platform).

**22NNE583 NanoEnergy Devices Lab 0-0-2 (2 Credits)**

Dye sensitized solar cell fabrication and testing, thin film hetero-junction photovoltaic device fabrication and testing, Quantum dot solar cell fabrication and testing, Li ion battery anode and cathode half-cell fabrication and testing, Li ion battery full-cell fabrication and testing, Supercapacitor/Pseudocapacistor fabrication and testing.

**22NNE601 Ethics in Research and Research Methodology 1-0-1 (2 Credits)**

Plagiarism, regulatory principles, safety in research, ethics in stem cell research, ethics in clinical research, ethics in nanomaterials based research. Principles of data documentation, protocol development, research questions and hypothesis driven research, technical writing fundamentals.

**TEXTBOOKS/REFERENCES:**

22NNE602 Introduction to Machine Learning 3-0-0 (3 Credits)

Artificial Neural Networks, Deep learning, Kernel Regression methods, Descriptors: feature selection, supervised and unsupervised machine learning, Regression; Simple Linear, multilinear and non-linear Regression, Model Evaluation in Regression Models, Evaluation Metrics in Regression Models, Classification and Clustering.

TEXTBOOKS/REFERENCES:
1. Artificial intelligence: A modern approach by Stuart J. Russel and Peter Norvig
2. Deep learning by Ian Goodfellow, Yoshua Bengio and Aaron Courville
4. The Elements of Statistical Learning: Data Minining and prediction by Trevor Hastie, Robert Tibshirani and Jerome Friedman

22NNE603 NanoCarbon and Nanocomposites 3-0-0 (3 credits)

Introduction to carbon and its nanostructures (including: graphite, nanotubes, fullerenes, graphene, graphene oxide, amorphous nanocarbon...etc.). Structure, size, synthesis, property and applications in nanoelectronics and energy. Nanocomposites of carbon with other inorganic materials examples and applications. Organic frameworks of nano-materials (including MOF and COF) design strategies, synthesis, characterization and their application in nanoelectronics and energy.

TEXT BOOKS/REFERENCES:

22NNE604 VLSI Technology and Design 3-0-0 (3 Credits)

Introduction to wafer fabrication, Packaging, MOS process (n-well and p-well), Silicon on insulator process, 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. Alternative CMOS Logic structures, Design of Adders, Parity generators, Detectors, Comparators and Counters, ALU, Multipliers and Shifters, memory elements. Types of ASICS, Standard Cell Array, Gate Arrays,
Programmable Array Logic- PLAs, CPLDs, FPGAs, Design capture and verification tools, preparation and testing. Industrial relevant software packages (ex: Cadence, Ansys, CAD…etc.)

TEXT BOOKS / REFERENCES:


22NNE690 Dissertation – Mini project 0-0-6 (6 Credits)

22NNE699 Dissertation – Project 0-0-15 (15 Credits)

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