Syllabus for M.Sc.
in
Electrical and Electronic Engineering

Session 2022-2023 and onwards

Department of Electrical and Electronic Engineering
University of Dhaka
Bangladesh

Syllabus

M.Sc. in Electrical and Electronic Engineering

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Department of Electrical and Electronic Engineering (EEE)
University of Dhaka

About the Department

The Department of Electrical and Electronic Engineering (EEE) is a leading department within the Faculty of Engineering and Technology at the University of Dhaka, Bangladesh. Initially established in September 1965 as the Department of Applied Physics, it commenced by offering an M.Sc. degree under the leadership of Professor Shah Md. Fazlur Rahman, the founding chairman. Over the years, the department underwent transformative changes to align with the evolving needs of the electronics industry. In 1974, the department underwent a name change to Applied Physics and Electronics, accompanied by an updated M.Sc. curriculum tailored to meet the demands of the electronics job market. A significant milestone was reached in 1975 with the introduction of the B.Sc. program in Applied Physics and Electronics. Recognizing the growing importance of the telecommunications sector, the department underwent another name change in October 2005, becoming the Department of Applied Physics, Electronics, and Communication Engineering. In June 2008, the department became an integral part of the Faculty of Engineering and Technology, solidifying its position within the academic structure. The final evolution occurred in January 2015 when the department transitioned into its present state as the Department of Electrical and Electronic Engineering. Through these progressive changes, the department has continued to adapt and thrive in the dynamic field of electrical and electronic engineering.

Degrees Offered:

B.Sc. Engg. : **4** years (8 Semesters) undergraduate program.

M.Sc. Engg. : **1.5** year (3 Semesters) postgraduate program.

PhD : **4** years.

Research Areas:

The research areas are divided into four streams:

1) **Electronics and Materials Science:** This includes but not limited to, Analog and Digital Electronics, VLSI Circuit Design, Electronic and Optoelectronic Devices, Photonics, Nanoscience and Technology, Materials Science, Biomedical Engineering.
2) **Instrumentations and Control:** This includes but not limited to, Algorithm Design, Artificial Intelligence, Robotics, Computer Architecture, IoT, Microcontroller-Based Systems, Microprocessor, Big Data Analytic.
3) **Communications and Signal Processing:** This includes but not limited to, Telecommunication Engineering, Mobile Cellular Technology, 3G, 4G, 5G Wireless Networks, Satellite and Radar Communication, Signal Processing,

Optical Fiber Communication.

4) **Power Systems:** This includes but not limited to, Power Electronics, Power Generation, Transmission, Distribution, Fault Detection, Protection, Photovoltaic Systems, and Renewable Energy.

The Framework of the Semester System:

Program: M.Sc. in EEE

1. **Admission:** Students will be admitted to the department as per university rules.
2. **Duration of the Program:** 1.5 years
3. **Total Number of Semesters:** 3 (2 Semesters per year)

Class:	14 weeks
Preparatory Leave (PL):	02 weeks
Final Examination:	03 weeks
Results:	03 weeks
Total:	22 weeks per semester

4. **Total Credits in 3 Semesters (1.5 years): 36**

Course Identification:

Every course has a unique course code. The letter prefix in any course code indicates the field or the discipline of the course, e.g., **EEE** stands for **Electrical and Electronic Engineering**.

The digits in the course code have the following meaning:

- The **first digit** corresponds to the **year** in which the course is offered by the Department.
- The **second digit** defines Thesis/ Project/ Stream/ Optional Courses as follows:
  - **Digit** 0 is for Thesis/Project
  - 1 for Electronics and Materials Science Stream
  - 2 for Instrumentations and Control Stream
  - 3 for Communications and Signal Processing Stream
  - 4 for Power Systems Stream
  - 5 for Optional Courses
- The **third** and **fourth** digits are used to specify the **course/ Thesis/ Project.**

Total credits to be completed for obtaining the degree of M.Sc. in Electrical and Electronic Engineering is 36.

Classes/Contact Hours for the Courses:

a. For each theory course, there will be two (2) classes per week, each of 1.5 hour duration.

b. Total number of classes in a semester for theory course will be 28 (14×2).

c. Total contact hours in a semester for each 1 credit theory course will be 14×1 = 14 hours.

Evaluation of the Courses: As per university rules.

Grading System:

The current University Grants Commission (UGC) approved grading system applies as per university rules.

Marks	Letter Grade	Grade Point
80% and above	A+	4.00
75% to <80%	A	3.75
70% to < 75%	A-	3.50
65% to < 70%	B+	3.25
60% to < 65%	B	3.00
55% to < 60%	B-	2.75
50% to < 55%	C+	2.50
45% to < 50%	C	2.25
40% to < 45%	D	2.00
Less than 40%	F	0.00

Marks Distribution:

For a Theory Course:

i. Attendance	05%
ii. Assignment/Presentation	05%
iii. Mid-term Examination (Incourse)	30%
iv. Final Examination	60%
Total	**100%**

For the Thesis: Total Marks is 400.

i. Thesis	60%
ii. Viva Voce	40%
Total	**100%**

For the Project: Total Marks is 200.

i.	Report	60%
ii.	Viva Voce	40%
	Total	**100%**

Attendance:

Students with **75% attendance and above** in each course will be eligible to sit for the semester final examinations. Students having attendance **>=60% and <75%** will be considered to sit for the examination after paying the fines as per university rules. **Students having attendance below 60% will not be eligible to appear in the examination**. The marks distribution for attendance is given below:

Attendance	Marks
90% and above	5.0%
85% to < 90%	4.5%
80% to < 85%	4.0%
75% to < 80%	3.5%
70% to < 75%	3.0%
65% to < 70%	2.5%
60% to < 65%	2.0%
Less than 60%	0.0%

Rules for the Course Undertaking:

Thesis Group: Every student of the Thesis Group will take five (5) courses from his/her stream and three (3) courses from other streams/ optional courses. The Thesis submission and evaluation will be done at the end of 3rd semester.

Project Group: Every student of the Project Group will take five (5) courses from his/her stream and five (5) courses from other streams/ optional courses. The Project submission and evaluation will be done at the end of 3rd semester.

Requirements for the Award of the M.Sc. in EEE Degree:

To achieve the M.Sc. Engg. degree, the students must obtain CGPA of at least 2.50 out of 4.00 without F grade in any course.

Readmission and Dropout:

A student may be permitted for re-admission for a maximum of two times within two consecutive academic years. A student may seek permission for re-admission provided he/she had at least 30% of attendance in the previous semester or year.

Semester-Wise Course and Credit Distribution of Different Semesters:

M.Sc. in EEE	**Semester I:**	**Semester II:**	**Semester III:**
Thesis Group	Four (4) Courses **Total: 4×3 = 12 Credits**	Four (4) Courses **Total:** **4×3 = 12 Credits**	**Thesis:** **12 Credits** **Total Marks:400**
Project Group	Five (5) Courses **Total: 5×3 = 15 Credits**	Five (5) Courses **Total:** **5×3 = 15 Credits**	**Project:** **6 Credits** **Total Marks:200**
			Grand Total: 36 Credits

The stream wise distribution of credits of different courses is listed below:

There will be four streams as follows:

Stream 1: Electronics and Materials Science

Stream 2: Instrumentations and Control

Stream 3: Communications and Signal Processing

Stream 4: Power Systems

Syllabus for M.Sc. in Electrical and Electronic Engineering

Electronics and Materials Science Stream:

Course Code	Course Title	Credits
EEE-5101	Nanomaterials and Nanoengineering	3
EEE-5102	Characterization of Materials and Semiconductor Devices	3
EEE-5103	Optical Integrated Circuit	3
EEE-5104	Biosensors and Bioelectronics	3
EEE-5105	Energy Materials	3
EEE-5106	Analog CMOS Integrated Circuit Design	3
EEE-5107	RF and Millimeter Wave Circuit Design	3
EEE-5108	Biophysics	3
EEE-5109	Advanced Solid State Physics	3
EEE-5110	Computational Materials Science	3
EEE-5111	Quantum Computation and Information	3
EEE-5112	Applied Quantum Mechanics	3
EEE-5113	Quantum Electronics	3

Instrumentations and Control Stream:

Course Code	Course Title	Credits
EEE-5201	Autonomous and Intelligent Systems	3
EEE-5202	Biomedical Instrumentation	3
EEE-5203	Industrial Process Instrumentation and PLC	3

EEE-5204	Fuzzy Logic, Neural Networks and Deep Learning	3
EEE-5205	Introduction to Artificial Intelligence with Python	3
EEE-5206	Industrial Quality Control	3
EEE-5207	Multivariate and Adaptive Control System	3
EEE-5208	Robotics and Embedded System	3
EEE-5209	Optimal Control Theory	3
EEE-5210	Unmanned and Autonomous Systems Engineering	3
EEE-5211	Radar System Engineering	3

Communications and Signal Processing Stream:

Course Code	Course Title	Credits
EEE-5301	Advanced Digital Signal Processing	3
EEE-5302	Digital Image Processing	3
EEE-5303	Advanced Digital Image Processing	3
EEE-5304	Computer Vision	3
EEE-5305	Biomedical Signal and Image Processing	3
EEE-5306	Video Processing and Coding Technology	3
EEE-5307	Random Signals and Processes	3
EEE-5308	Information Theory and Coding	3
EEE-5309	Traffic Theory and Queuing Systems	3
EEE-5310	Network and Information Security	3
EEE-5311	Digital Speech and Audio Signal Processing	3
EEE-5312	High Speed Computer Networking	3
EEE-5313	Advanced Data and Mobile Communications	3

EEE-5314	Advanced Communications Theory	3
EEE-5315	MIMO Wireless Communications	3
EEE-5316	Human Computer Interaction	3

Power Systems Stream:

Course Code	Course Title	Credits
EEE-5401	Smart Grid Design and Analysis	3
EEE-5402	Power System Stability	3
EEE-5403	Electrical Power Quality	3
EEE-5404	Power System Planning and Reliability	3
EEE-5405	Economics and Planning of Energy Systems	3
EEE-5406	Advanced Power System Analysis	3
EEE-5407	Electrical Distribution System	3
EEE-5408	Energy Harvesting and Storage	3
EEE-5409	Power System Instrumentation	3
EEE-5410	High Voltage Engineering	3
EEE-5411	Advanced Power Electronics	3
EEE-5412	Power System Regulation and Policy	3

Optional Courses:

Course Code	Course Title	Credits
EEE-5501	Electronics for Smart Cities	3
EEE-5502	Research Methodology in Engineering	3
EEE 5503	Project Management	3
EEE 5504	Industrial Ecology and Sustainable Engineering	3
EEE 5505	Technology History and Industrial Archeology	3
EEE 5506	Public Policy and Development	3
EEE 5XXX	Fuzzy Logic, Neural Networks and Deep Learning	3

M.Sc. Thesis and Project:

Course Code	Course Title	Credits
EEE-5000	Thesis	12
EEE-5001	Project	6

Detail Course Contents for M.Sc. in EEE Program

Electronics and Materials Science Stream

EEE 5101	**Nanomaterials**	**3 Credits,** **3 Hours/Week**

Introduction to Nanotechnology: Definitions and an Overview of Nanotechnology, Historical Development of Nanomaterials, Unique Properties of Nanomaterials, and Classification of Nanomaterials into 0-D, 1-D, 2-D, and 3-D Categories.
Nanomaterial Synthesis: Exploration of Chemical Routes, Electrochemical Methods, Vapor Growth, Thin Film Methods: Chemical Vapor Deposition, Physical Vapor Deposition, Sputtering and Laser Ablation, Langmuir-Blodgett Growth, Mechanical Methods: Ball Milling and Mechanical Attrition, Sol-Gel Methods, Specialized Nanomaterials: Carbon Nanotubes, Fullerenes, Nanowires, Porous Silicon. Furthermore, Bio-Inspired Synthesis, Nanocomposite Fabrication and Nanolithography.
Nanomaterial Characterization Techniques: Microscopy: Scanning and Transmission Electron Microscopy, Scanning Probe Microscopy: Atomic Force and Scanning Tunneling Microscopy, Diffraction and Scattering Techniques, Vibrational Spectroscopy and Various Surface Techniques.
Applications: Nano-Sensors for Chemical and Bio-Sensing, Biological/Bio-Medical Applications, Metal Nanoparticle-Based Sensors, Quantum Dots Sensors, Nanowire-Based Sensors, Carbon Nanotube-Based Sensors, Sensors Founded on Nanostructures of Metal Oxide, Sensors using Polymeric Nanostructures, Electronic Skin Based on Nanotechnology, Nanomaterials in Agriculture and Environment: Applications in Crop Improvement, Precision Agriculture, and Water Purification, Role in Environmental Monitoring and Pollution Control, Additionally, Energy and Material Applications: Photovoltaics, Fuel Cells, Batteries, Other Energy-Related Applications, High-Strength Nanocomposites, and Nanoenergetic Materials.

References:

1. The Physics and Chemistry of Nano Solids, Frank J. Owens and Charles P. Poole Jr., Wiley Interscience.
2. Nanomaterials- Synthesis, Properties and Applications, Ed.: A.S. Edelstein and R.C. Cammarata, Institute of Physics Publishing.
3. Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience, Edward L. Wolf, Wiley-VCH.
4. Relevant Research Papers & Journal Articles.

EEE 5102	Characterization of Materials and Semiconductor Devices	3 Credits, 3 Hours/Week

Introduction: Metrology, Accuracy and Precision, Uncertainty, Systematic & Random Errors, Repeatability & Reproducibility, Statistical Process Control (SPC), Design of Experiments (DOE).

Elemental and Structural Characterization:

Crystallography: Crystal Geometry, Miller Indices, Primitive and Non-Primitive Cells, Lattice Directions and Planes, Interplanar Distance, Gaps in Bravais Lattice, Symmetry-Based Classification of Bravais Lattice, Real Space Vs Reciprocal Space.

X-ray Diffraction (XRD): Diffraction Principle, Scattering by an Electron, Atom and Unit Cell Bragg's Law, Indexing of XRD Patterns, Rietveld Refinement, Energy-Dispersive and Time-Analysis Diffractometry Structure Factor Calculation, Rocking Curves, Multiplicity, Intensities of Powder Pattern Lines, Powder Diffraction File (PDF) Database, Peak Broadening, Quantitative Phase Measurement by X-Ray Diffraction, Residual Stress Measurement, Detection of Super Lattice Lines, Long-Range Order in $AuCu_3$, Detection of Super Lattice Lines, Short-Range Order and Clustering.

High-Resolution XRD (HRXRD): Principle, HRXRD vs XRD, Measurement of Strain and Composition in Epitaxial Thin Films, Analysis of Reciprocal Space Mapping, Grazing incidence X-ray Scattering (GIXS), X-ray Fluorescence (XRF), Auger Electron Spectroscopy (AES), X-ray Photoelectron Spectroscopy (XPS), Low Energy X-ray Emission Spectrometry (LEXES), X-ray Computed Tomography (X-CT), Mass Spectrometry, Secondary Ion Mass Spectrometry (SIMS), Focused Ion Beam (FIB), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM).

Scanning Probe Microscopy: Scanning Tunneling Microscope (STM), Atomic Force Microscopy (AFM), Magnetic Force Microscopy (MFM).

Optical Characterization: Ellipsometry, Scatterometry (Optical Critical Dimension), Raman Spectroscopy, Surface Enhanced Raman Spectroscopy (SERS), UV-Visible Spectroscopy, Photoluminescence (PL), Electroluminescence (EL), Dynamic Light Scattering (DLS).

Thermal Characterization: Differential Thermal Analysis (DTA), Differential Scanning Calorimetry (DSC).

Electrical Characterization: Resistivity and Type Measurements, Semiconductor Doping Measurements and Profiling, Barrier Height and Contact Resistance

Measurements, Series Resistance and Related Measurements, Deep-Level Parameter Measurements, Measurement of Oxide and Interface Parameters in MOS Devices, Measurement of MOSFET Channel Parameters, I-V and C-V Measurements, Carrier Lifetime Measurements, Carrier Mobility Measurements.

References:

1. Elements of X-Ray Diffraction, B. D. Cullity and S. R. Stock, Pearson.
2. Semiconductor Material and Device Characterization, D.K. Schroder, Wiley Interscience.
1. T.J. Shaffner, "Semiconductor Characterization and Analytical Technology," Proc. IEEE, 88, 1416-1437, Sept. 2000.
2. Encyclopedia of Materials Characterization, C.R. Brundle, C.A. Evans, Jr. and S. Wilson, Eds., John Wiley & Sons.
3. Handbook of Silicon Semiconductor Metrology, A.C. Diebold, ed., Marcel Dekker, New York.
4. Electrical Characterization of Silicon-on-Insulator Materials and Devices, S. Cristoloveanu and S. S. Li, Kluwer Academic Press.
5. Semiconductor Manufacturing Technology, M. Qurik and J. Sedra, Pearson.
6. X-ray Metrology in Semiconductor Manufacturing, K. Bowen and B. K. Tanner, Taylor and Francis, 2016.

EEE 5103	**Optical Integrated Circuit**	**3 Credits, 3 Hours/Week**

Introduction: Optical Properties of Materials for Integrated Optoelectronics (IOS) and Photonics (IPS), Advantage of Optical Integrated Circuits (OICs), Passive Optical Structures and Devices for Integrated Optics.

Optical Waveguides and OIC Element Design: Types of Optical Waveguides, Materials, and Optical Waveguide Fabrication Techniques; Design of OIC Elements- Optical Switch, Optical Directional Coupler, Light Divider, Light Combiner, Optical Polarizer, and Optical Isolator; Optoelectronic Modulators; Electro-Optically Controlled Devices- Their Properties and Technologies.

Numerical Techniques for OICs: Limitations of Miniaturization; Exact Analysis of Guided Beam in OICs, Finite Element Method- FEM; Beam Propagation Method- BPM; Finite Difference Method- FDM.

Semiconductors for Integrated Optoelectronics (IOs): Semiconductor Materials and Structures applicable for Integrated Optoelectronics, Active Semiconductor Devices Based on Heterostructures, Quantum Wells, and Superlattices Applicable for Integrated Optoelectronics.

IOs in Communication Systems: Integrated Optoelectronic Transmitters and Receivers for Optical Communication Systems, Integrated Optoelectronic Optical Systems for Recording, Processing, and Displaying the Information.

References:

1) Optical Integrated Circuits, H. Nishihara, M. Haruna and T. Suhara, McGraw Hill.
2) Electro-Optics Handbook, R.W. Waynant and M.N. Ediger, McGraw Hill.
3) Diode Lasers and Photonic Integrated Circuit, L.A. Coldren, S.W. Corzine, M.L. Mashanovitch, Wiley Series.
4) Integrated Optics Theory and Technology, R.G. Hunsperger, Springer.
5) Advances in Integrated Optics, S. Martellucci, A.N. Chester and M. Bertolotti, Springer.
6) Integrated Optics Physics and Applications, S. Martellucci and A.N. Chester, Plenum Press.
7) Encyclopedia Handbook of Integrated Optics, K. Iga and Y. Kokubun, Taylor & Francis.
8) Fundamentals of Optical Waveguides, K. Okamoto, Academic Press.

EEE 5104	**Biosensors and Bioelectronics**	**3 Credits,** **3 Hours/Week**

Introduction to Biosensors and Bioelectronics: Overview of Biosensors and Bioelectronics, Historical Development and Current Trends, Transducers and Signal Processing.
Transduction Principles: Labeled vs Label-Free Sensing, Optical, Electrochemical, Piezoelectric, Signal Amplification and Conditioning Techniques; Noise Reduction and Signal-To-Noise Ratio Considerations, Biological Recognition Elements.
Receptors and ligands for Biosensing: Antibodies, Enzymes, Nucleic Acids, and other Bio Affinity Molecules, Immobilization Techniques.
Electrochemical Biosensors: Amperometric, Potentiometric, Impedimetric Sensors; Electrode Materials and Fabrication Techniques; Organic Electrochemical FETs (OECTs), Applications in Healthcare; Environmental Monitoring, and Food Safety.
Optical Biosensors: Principles of Optical Biosensing; Fluorescence-Based Sensors; Surface Plasmon Resonance (SPR) and Surface-Enhanced Raman Spectroscopy (SERS).
Acoustic Wave Sensors: Concepts and Theories Behind Acoustic Wave Sensors; Communication Through Acoustic Waves; Applications in Biosensing and Bioelectronics.
BioMEMS and Lab-on-a-Chip Devices: Microfabrication Techniques for Biosensors; Integration of Multiple Sensing Modalities on A Chip; Microfluidic Devices, Miniaturized

Systems for Point-of-Care Diagnostics.

Flexible Electronics: Introduction to Flexible Electronics, Materials and Fabrication Techniques for Flexible Sensors**,** Applications in Wearable and Implantable Biosensors.
DNA microarrays: Gene Expression Analysis and DNA sequencing; Microarray Scanning and Detection Techniques, DNA FET.
Protein Microarrays: Concepts and Applications of Protein Microarrays; Detection and Quantification of Proteins, High-throughput Screening and Protein-Protein Interactions.
Next Generation Sequencing
Nanomaterials for Biosensing: Introduction to Nanoparticles and Quantum Dots; Principles of QD Biosensing, Applications in Bioimaging, Diagnostics, and Therapeutics**;** Implantable and Wearable Biosensors, Novel Nanomaterials: Graphene, Transition Metal Dichalcogenides for Disruptive Devices.
Synthetic Biology: Bioelectronics for Brain-Machine Interfaces; Brain Mapping and Control, Bioimplants, Biosensors for Synthetic Biology and Biotechnology.

References:

1. Introductory Bioelectronics: for Engineers and Physical Scientists, R. Pethig and S. Smith, Wiley.
2. Biosensors and Nanotechnology: Applications in Health Care Diagnostics, Zeynep Altintas (Editor), Wiley.
3. Printed and Flexible Sensor Technology, Subhas Mukhopadhyay and Anindya Nag, IoP.

EEE 5105	**Energy Materials**	**3 Credits, 3 Hours/Week**

Nanomaterials for Energy Applications: Functional Nanomaterials and Classifications, Metal and Metal-Free Nanomaterials, Carbon-Based Nanomaterials, Nanocomposites, Nanomaterials in Electrochemistry, Hybrid Nanomaterials, Applications in Sustainable Energy Generation.
Battery Materials: Electrochemical Fundamentals, Electrochemical Cell, Charging and Discharging, Phase Transition, Order-Disorder Transition, Electrode Processes at Equilibrium, Energy Efficiency, Cycle Life, Materials for Electrode, Materials for Non-Rechargeable Batteries and Materials for Rechargeable Batteries.

Fuel Cells: Overview of Fuel Cell Types, Charge Transfer and Mass Transport in Fuel Cells, Thermodynamics and Reaction Kinetics in Fuel Cell, Proton Exchange Membrane and Solid Oxide Fuel Cell Materials, Fuel Cell System Design and Characterization.

Solar Energy Conversion Materials: Materials for 1^{st}, 2^{nd}, and 3^{rd} Generation Solar Cells, Dye-Synthesized Solar Cells and Organic Solar Cells.

Materials for Hydrogen Technology: Hydrogen Production, Hydrogen Storage in Solids. Characterization of Storage Materials: Isotherms and Kinetics.

Thermal Energy Conversion Materials: Introduction to Absorption and Adsorption Technologies, Energy Cascade, Heat Pumps, Materials Used in Heat Pumps, PV-T Systems, Materials for PV-T Systems.

Thermoelectric Energy Conversion and Materials: Thermoelectric Energy Conversion Principles, Thermoelectric Energy Potentials and Applications, Thermoelectric Materials, Low-Temperature Materials, Moderate-Temperature Materials, High-Temperature Materials, Different Temperature Thermoelectric Material Comparison, Thermoelectric Material Processing Methods.

Mechanoelectric Energy Harvesting and Materials: Energy Harvesting for Low-Power Applications, Fundamental Mechanisms of Mechanoelectric Energy Conversion, Mechanoelectric Energy Harvesting Materials, Sources of Mechanoelectric Energy, Different Energy Harvesting Methods.

References:

1. Fuel cell fundamentals, Ryan O'Hayre, Suk-won Cha, Whitney G. Colella, Fritz B Prinz, Wiley.
2. Nanomaterials for sustainable energy applications, P. K. Sonkar, V. Ganesan, CRC Press.
3. Materials in Energy Conversion, Harvesting, and Storage, Kathy Lu, John Wiley & Sons.
4. Fundamentals of Materials for Energy and Environmental Sustainability, David S. Ginley, David Cahen, Cambridge University Press.
5. Advances in Adsorption Technology, Bidyut Baran Saha, Kim Choon Ng, Nova Science Publications.
6. Advances in Energy Materials, Shadia Jamil Ikhmayies, Springer
7. Materials for energy conversion devices, Charles C. Sorrell, Sunao Sugihara and Janusz Nowotny, Woodhead and Maney Publishing.

EEE 5106	**Analog CMOS Integrated Circuit Design**	**3 Credits, 3 Hours/Week**

Introduction to Analog CMOS Integrated Circuit Design: Introduction to CMOS Technology and its Advantages in Analog Design; Overview of Analog CMOS IC Design Flow and tools.

Gain Stages: Single-Stage Amplifiers: Common-Source, Common-Gate, and Common-Drain Configurations, Cascade Amplifiers and their Advantages; Design Considerations for Different Gain Stages, Design project: Design and Optimization of Gain Stages.

Operational Amplifiers (Op-Amps): Op-Amp Architecture and Basic Building Blocks, Op-Amp Design Considerations: Gain, Bandwidth, and Stability, Frequency Compensation Techniques for Op-Amps, Design Project: Op-Amp Design and Characterization.

Oscillators: Principles of Oscillator Operation, Analysis and Design of LC Oscillators, Ring Oscillators and Relaxation Oscillators, Design Project: Design and Analysis of Oscillators.

Analog-to-Digital (A/D) and Digital-to-Analog (D/A) Converters: Basic Concepts of A/D and D/A Converters, Nyquist Rate and Oversampling Techniques, Design Considerations for Different Converter Architectures; Design Project: Design and Analysis of A/D and D/A Converters.

Phase-Locked Loops (PLL) and Delay-Locked Loops (DLL): Working Principles of PLL and DLL; Phase Detection and Frequency Synthesis in PLLs, Design Considerations and Performance Analysis, Design Project: Design and Analysis of PLL and DLL Circuits.

Reference

1. Design of Analog CMOS Integrated Circuits RF Microelectronics, Behzad Razavi, McGraw Hill.

EEE 5107	**RF and Millimeter Wave Circuit Design**	**3 Credits, 3 Hours/Week**

Wireless Systems: Introduction to Wireless Systems; History and Evolution of Wireless Technologies, RF System Specifications and Design Considerations.

Transceivers: Path Loss, Interference Signals, Receiver Sensitivity, and Transmitter Output Power, Design Lab: System Design of a Wireless Tin Can Telephone

Amplifiers: Basic Concepts of Amplifiers and Types of Power Gain, Common Amplifier Topologies and Characteristics, Low Noise Amplifier (LNA) Matching Techniques, Power Amplifier (PA) Classes and Efficiency Considerations, Design Lab: Designing LNAs and PAs.

Mixers: Working Principle of RF Mixers: Active and Passive Mixers: Advantages and Drawbacks, Balanced and Unbalanced Mixers, Noise Performance of Mixers, Design Lab: Design of Up and Down-Conversion Mixers.

Oscillators: Working Principles of Frequency Oscillators, Oscillator Topologies and Condition for Sustaining Oscillation, Tuning Oscillators and Impact of Noise, Output Buffering and Breakdown Voltage Considerations, Design lab: Designing a Voltage

Controlled Oscillator (VCO).

Synthesizers: Working Principles of Frequency Synthesizers, Importance of Synthesizers in Wireless Communications, Phase-Locked Loop (PLL) Types I and II; All-Digital PLL and its Advantages and Drawbacks, Fractional-N PLL Frequency Synthesizers, Design lab: Design of a Frequency Divider and a Phase Detector.

Reference

1. RF Microelectronics, Behzad Razavi, Pearson.

EEE 5108	**Biophysics**	**3 Credits,** **3 Hours/Week**

Introduction: Evolution of Biosphere, Aerobic and Anaerobic Concepts, Models of Evolution of Living Organisms.

Physics of Polymers: Nomenclature, Definitions of Molecular Weights, Polydispersity, Degree of Polymerization, Possible Geometrical Shapes, Chirality in Biomolecules, Structure of Water and Ice, Hydrogen Bond and Hydrophobocity.

Static Properties: Random Flight Model, Freely-Rotating Chain Model, Scaling Relations, Concept of Various Radii (I.E., Radius of Gyration, Hydrodynamic Radius, End-To-End Length), End-to-End Length Distributions, Concept of Segments and Kuhn Segment Length, Excluded Volume Interactions and Chain Swelling, Gaussian Coil, Concept of Theta and Good Solvents with Examples, Importance of Second Virial Coefficient.

Polyelectrolytes: Concepts and Examples, Debye-Huckel Theory, Screening Length in Electrostatic Interactions.

Transport Properties: Diffusion: Irreversible Thermodynamics, Gibbs-Duhem Equation, Phenomenological Forces and Fluxes, Osmotic Pressure and Second Virial Coefficient, Generalized Diffusion Equation, Stokes-Einstein Relation, Diffusion in Three-Component Systems, Balance of Thermodynamic and Hydrodynamic Forces, Concentration Dependence, Smoluchowski Equation and Reduction to Fokker-Planck Equation, Concept of Impermeable and Free-Draining Chains, Viscosity and Sedimentation: Einstein Relation, Intrinsic Viscosity of Polymer Chains, Huggins Equation of Viscosity, Scaling Relations, Kirkwood-Riseman Theory, Irreversible Thermodynamics and Sedimentation, Sedimentation Equation, Concentration Dependence.

Physics of Proteins: Nomenclature and Structure of Amino Acids, Conformations of Polypeptide Chains, Primary, Secondary and Higher-Order Structures, Ramachandran Map, Peptide Bond and its Consequences, pH-pK Balance, Protein Polymerization Models, Helix-Coil Transitions in Thermodynamic and Partition Function Approach, Coil-Globule Transitions, Protein Folding, Protein Denaturation Models, Binding Isotherms, Binding Equilibrium, Hill Equation and Scatchard Plot.

Physics of Enzymes: Chemical Kinetics and Catalysis, Kinetics of Simple Enzymatic Reactions, Enzyme-Substrate Interactions, and Cooperative Properties.

Physics of Nucleic Acids: Structure of Nucleic Acids, Special Features and Properties, DNA and RNA, Watson-Crick Picture and Duplex Stabilization Model, Thermodynamics of Melting and Kinetics of Denaturation of Duplex, Loops and Cyclization of DNA, Ligand Interactions, Genetic Code and Protein Biosynthesis, DNA Replication.
Experimental Techniques: Measurement Concepts and Error Analysis, Light and Neutron Scattering, X-Ray Diffraction, UV Spectroscopy, CD And ORD, Electrophoresis, Viscometry and Rheology, DSC and Dielectric Relaxation Studies.

References:

1. General Biophysics, M.V. Volkenstein, Academic Press.
2. Biophysical Chemistry Part III: The Behavior of Biological Macromolecules, C.R. Cantor and P.R. Schimmel, W. H. Freeman.
3. Biophysics: An Introduction, Roland Glaser, Springer.

EEE 5109	Advanced Solid State Physics	3 Credits, 3 Hours/Week

Tight Binding Model in Solid: Linear Combination of Atomic Orbitals (LCAO), Tight Binding Model (TBD) in 1D, Discretization of Schrödinger Equation, Plane Wave Ansatz, TBD Solution, Energy Bands and Band Filling.

Magnetism in Solid: The Bohr-van Leeuwen theorem, Adiabatic Diamagnetism, Landau Diamagnetism, Brillouin Paramagnetism, Van Vleck Paramagnetism, Magnetic Dipole Interaction, Exchange Interaction, Weiss model Spontaneous Magnetism: Ferromagnetism and Anti-ferromagnetism.

Phonons in Solid: Infrared Active Phonons, Oscillator Model, Classical Oscillator Model, The Lyddane–Sachs–Teller relationship, Reststrahlen, Lattice Absorption, Polaritons and Polarons, Stokes Scattering, Anti-Stokes, Raman and Brillouin Scattering.

Plasmons in Solid: Plasma Reflectivity, Drude-Lorentz model, Plasma Frequency, Ultraviolet Transparency, Free carrier Reflectivity and Absorption, Plasm Oscillation, Bulk Plasmons and Surface Plasmons, Plasmons in Nanostructure and Plasmonic Sensors.

Magnons in Solid: Goldstone Modes, Semi classical Formulation of Magnon, Quantum Mechanical Approach to Magnon, The Bloch $T^{3/2}$ Law, Mermin-Wagner-Berezinskii Theorem and Magnon Wave Measurements.

Superconductivity in Solid: Concept of Phase Transition, Condensation Energy, Order Parameter, Ginzburg-Landau Theory (GLT) of Phase Transition, GLT of Inhomogeneous

System, Non-linear Schrodinger Equation, GL Coherence Length and GLT in Magnetic Field.

References:

1. The Oxford Solid State Basic, Steven H. Simon, Oxford University Press.
2. Magnetism in Condensed Matter, Stephen Blundel, Oxford University Press.
3. Optical Properties of Solids, Mark Fox, Oxford University Press.
4. Solid State Physics, Neil. W. Ashcroft and N. David Mermin, Cengage Learning.
5. Superconductivity, Superfluids and Condensates, James F. Annett, Oxford University Press.
6. Advanced Solid State Physics, Philip Phillips, Cambridge University Press.
7. Introduction to Solid State Physics, Charles Kittel, Wiley.

EEE 5110	**Computational Materials Science**	**3 Credits, 3 Hours/Week**

Methods in Computational Materials Science: Finite Element Analysis, Monte Carlo (MC), Molecular dynamics (MD) and First-principles ab Initio Methods.

The Random-walk Model: Random-walk Model of Diffusion, Bulk Diffusion, Random-walk Simulation, Random-walk models for Materials, Random-walk Models of Polymers, Atomistic Simulations of Macromolecules

Simulation of Finite Systems: Sums of Interacting Pairs of Objects, Perfect Crystals, Cutoffs, Periodic Boundary Conditions and Long-ranged Potentials.

Modelling Many Electron System: Many-body Schrodinger Equation, Clamped Nuclei Approximation, Independent Electrons Approximation, Mean-field Approximation, Hartree–Fock Equation, Hohenberg-Kohn theorem, Kohn-Sham method, The Greatest Challenge: Electron Correlation, Wave Functions and Pseudopotential.

Density Functional Theory: Total Energy of the Electronic Ground State, Kohn–Sham Equations, Exchange-Correlation Functionals, Local Density Approximation, Generalized Gradient Approximations, Solving Kohn–Sham Equations, Self-Consistent Calculations and Variational Approach.

Molecular Dynamic Simulation: Atomic Model in Molecular Dynamic (MD) System, Different Potentials: Embedded Atom and Tersoff Potential, Verlet Algorithm, Predictor–Corrector Algorithm, Velocity Rescaling, Accelerated Dynamics, Basic Steps of MD Simulation: Initialization, Integration Equilibration, Total Energy Calculation, Structural and Elastic Properties Calculation, Energetics and Thermodynamic Properties and Limitations of Molecular Dynamics.

Monte Carlo Method: Motivations of Monte Carlo (MC), Ensemble Averages, Metropolis Algorithm, Ising Model, MC for Atomic Systems, Kinetic MC, Time in Kinetic MC, Kinetic MC Calculations, Application of MC in Materials Science.

References:

1. Introduction to Computational Materials Science, Richard Lesar, Cambridge University Press.
2. Electronic Structure: Basic Theory and Practical Methods, Richard M. Martin, Cambridge University Press.
3. Materials Modelling using Density Functional Theory, Feliciano Giustino, Oxford University Press.
4. Computational Materials Science: An Introduction, June Gunn Lee, CRC Press.
5. An Introduction to Computational Physics, Tao Pang, Cambridge University Press.
6. Computational Physics, J. M. Thijssen, Cambridge University Press.

EEE 5111	**Quantum Computation and Information**	**3 Credits, 3 Hours/Week**

Perspective of Computation: Models for Computation, Turing Machines, Circuits, Computational Complexity, Decision Problems and the Complexity Classes P and NP.

Mathematical Framework: Matrix formulation of Quantum Mechanical Operators, Operator Language in Quantum Mechanics, Postulates of Quantum Mechanics, State Preparation, Time Evolution, Measurements, Density Operator Framework, Schmidt Decomposition and Purifications, EPR and the Bell inequality.

Quantum Circuits: Quantum Algorithms, Single Qbit Operations, Reversible Operations and Manipulations on Cbits and Qbits, Measurement Gates and the Born Rule, Measurement Gates and State Preparation, Controlled Operations, Measurements and Universal Quantum Gates.

Quantum Algorithms: Quantum parallelism**,** Deutsch's Problem**,** The Deutsch–Jozsa Algorithm**,** The Bernstein-Vazirani Problem, Simon's problem, The Grover Search Algorithm, The Quantum Fourier Transform, Period Finding and Shore's Algorithm.

Quantum Noise and Operations: Environments and Quantum Operations, Axiomatic Approach, Trace and Partial Trace, Bit Flip, Phase Flip, Depolarizing Channel, Amplitude Damping and Phase Damping.

Quantum Error Correction: Miracle of Quantum Error Correction, Physics of Error Generation, Diagnosing Error Syndromes and Simple Examples of Error Corrections, Universal Fault Tolerant Quantum Computation.

Quantum Information: Teleportation, Shannon entropy and von Neumann Entropy

References:

1. Quantum Computation and Quantum Information, Michael A. Nielsen & Isaac L. Chuang, Cambridge University Press.
2. Classical and Quantum Computation, A. Yu. Kitaev, A. H. Shen and M. N. Vyalyi, Amer Mathematical Society.
3. The Theory of Quantum Information, John Watrous, Cambridge University Press.
4. Quantum Information Theory, Mark M. Wilde, Cambridge University Press.
5. Quantum Computing Since Democritus, Scott Aaronson, Cambridge University Press
6. Quantum Computer Science: An Introduction, N. David Mermin, Cambridge University Press.
7. A Short Introduction to Quantum Information and Quantum Computation, Michel Le Bellac, Cambridge University Press.

EEE 5112	**Applied Quantum Mechanics**	**3 Credits,** **3 Hours/Week**

Second Quantization: The Schrodinger Equation in 1st and 2nd Quantization, Bosoninc and Fermionic Operators, Fields, and Non-Interacting Electron Gas.

Non-Interacting Electron Model: Sommerfeld Model, Heat Capacity, Non-interacting Limit, and Hartree-Fock Approximation.

Dielectric and Optical Properties: Dielectric Functions, Fluctuation-dissipation Theorem, Self-Consistent Response, The Random Phase Approximation (RPA) and the RPA Dielectric Function.

Screening and Plasmons: Thomas-Fermi Screening, Plasma Oscillation and Collective Coordinate, Linear Reponses Theory, Linear Response Theory and Kubo Formula.

Interacting Electron Model: Fermi Liquid Theory, Many-electron Atoms, Metals in the Hartree–Fock Approximation, Correlation Energy of Jellium and Inhomogeneous Electron Systems.

Electron-Lattice Interaction: Harmonic Chain, Acoustic Phonon, Electron-Phonon Interaction, Ultrasonic Attenuation and Boltzmann Transport Theory.

References:

1. Quantum Theory of Many Particle System, Alexander L. Fetter and John Dirk Walecka, Dover Publisher.
2. Advanced Condensed Matter Physics, Leonard M. Sander, Cambridge University Press.
3. Advanced Solid State Physics, Philip Phillips, Cambridge University Press.

EEE 5113	**Quantum Electronics**	**3 Credits, 3 Hours/Week**

Quantum Mechanical States of Light: Light as a Quantum Harmonic Oscillator, Vacuum State, Coherent State, Squeezed State and Photon Number State.
Atoms in Cavities: Optical Cavities, Atom–cavity Coupling, Weak Coupling Regime, Purcell Effect and Strong Coupling Regime.

Laser Oscillation: Laser Oscillation Condition, General Treatment of Laser Oscillation, Laser Power, Pumping and Laser Efficiency.

Laser Systems: Ruby Laser, Nd^{3+}: YAG, Helium–Neon Laser and CO_2 Laser

Semiconductor Diode Laser: Optically Induced Band to Band Transition in Semiconductor, Optical Gain and Loss in Semiconductor, Double Heterostructure Laser and Laser Diode Current Modulation.

Quantum Well Laser: Schrodinger Equation in Quantum Well (QW), Selection Rule and Density of States in QW, Gain and Efficiency of QW Laser and Multiple QW Laser.

Second Oder Optical Non-linearity: Non-linear (NL) Optical Susceptibility Tensor, NL Field Hamiltonian, Origin of NL Optical Coefficients, Electromagnetic Formulation of NL Optical Interaction, Second Harmonic Generation and Phase Matching, Kerr Effect, Pockels Effect. Parametric

Oscillation, Parametric Amplification, Frequency Up-conversion and Spontaneous Parametric Fluorescence.

References:

1. Quantum Optics: An Introduction, Mark Fox, Oxford University Press.
2. Introductory Quantum Optics, Christopher Gerry and Peter Knight, Oxford University Press.
3. Quantum Electronics, Amnon Yariv, Wiley.
4. Nonlinear Optics, Robert W. Boyd, Academic Press.
5. Nonlinear Optics and Photonics, Guang S. He, Oxford University Press.
6. Photonics: Optical Electronics in Modern Communications, Amnon Yariv an Pochi Yeh, Oxford University Press.
7. Fundamentals of Photonic, Bahaa E. A. Saleh and Malvin Carl Teich, Wiley.
8. Optical Electronics, Ajoy Kumar Ghatak and K. Thyagarajan, Cambridge University Press.

Instrumentations and Control Stream

EEE 5201	Autonomous and Intelligent Systems	3 Credits, 3 Hours/Week

Introduction to Autonomous Systems: Architecture of Autonomous Systems, Control of Robotic Manipulators, Machine Vision, the Dynamics of Wheeled, Air, Space and Underwater Robots, Navigation and Localization, and Autonomous Satellite Control.

Introduction to Artificial Intelligence: Intelligent agents, Problem-Solving and Search: Search Space, States vs Nodes, Tree Search: Breadth-First, Uniform Cost; Depth-First, Depth-Limited; Iterative Deepening, and Graph Search, Informed search, Greedy Search, A* Search, Heuristic Function, Admissibility and Consistency, Deriving Heuristics Via Problem Relaxation, Evolutionary Algorithms, Machine Learning, Supervised Learning, Unsupervised Learning, Reinforcement Learning, Support Vector, Artificial Neural Networks, Computer Vision, and Natural Language Processing.

References:

1. Artificial Intelligence: A Modern Approach, S.J. Russell and P. Norvig, Prentice-Hall.
2. Introduction to Autonomous Mobile Robots, by Roland Siegwart, Illah Reza Nourbakhsh and Davide Scaramuzza, The MIT Press.

3. Verifiable Autonomous Systems: Using Rational Agents to Provide Assurance about Decisions Made by Machines, Dennis, L.A. and Fisher, M., Cambridge University Press.
4. Artificial Intelligence: A Guide to Intelligent Systems, Negnevitsky, Michael, Pearson Education.

EEE 5202	**Biomedical Instrumentation**	**3 Credits, 3 Hours/Week**

Basic Concepts of Medical Instrumentation: Basic Sensors and Principles, Microcontrollers in Medical Instrumentation.
Biopotentials: Origin of Biopotentials, Biopotential Electrodes, and Biopotential Amplifiers.
Cardiovascular Measurements: Measurement of Blood Pressure, Cardiac Output, Heart Rate, Heart Sound, Pulmonary Function Measurements, Spirometer, Photo Plethysmography, Body Plethysmography, Finger-tip Oximeter, ESR (Erythrocyte Sedimentation Rate), GSR (Galvanic Skin Response), Standard HL7, Measurement of Flow, and Volume of Blood.
Respiratory System Measurements: Measurements of the Respiratory System, and Chemical Biosensors.
Clinical Laboratory Instrumentation: Standard HL7, Blood Gas Analyzers (pH, pCO_2, pO_2), and Chemical Biosensors.
Medical Imaging Systems: Radiographic and Fluoroscopic Techniques, X-rays, Computer Tomography (CT), Mammography, MRI (Magnetic Resonance Imaging), fMRI (Functional Magnetic Resonance Imaging), Ultrasonography, Endoscopy, and Thermography.
Biotelemetry Systems and Patient Monitoring: Different Types of Biotelemetry Systems, and Patient Monitoring.
Therapeutic and Prosthetic Devices: Pacemakers, Defibrillators, Ventilators, Nerve and Muscle Stimulators, Diathermy, Heart-Lung Machine, Audio Meters, Dialyzers, and Lithotripsy.
Electrical Safety: Electrical Safety in Medical Instruments.

References:

1. Medical Instrumentation Application and Design, John G. Webster, Wiley.
5. Encyclopedia of Medical Devices and Instrumentation, John G. Webster.
6. Design of Biomedical Devices and Systems, Paul King, Richard C. Fries, Marcel Dekker.
7. Introduction to Biomedical Equipment Technology, Joseph J. Carr, John M. Brown, Pearson Education.
8. Biomedical Instrumentation and Measurement, Leslie Cromwell, Prentice Hall of India.

9. Handbook of Biomedical Instrumentation, R.S. Khandpur, Tata McGraw Hill Publishing Co Ltd.

EEE 5203	Industrial Process Instrumentation and PLC	3 Credits, 3 Hours/Week

Instrumentation and Process Control: Pressure Measurements, Techniques and devices for measuring pressure, Pressure Sensors, Level Sensing Devices, Flow Measurement Instruments, Temperature Measuring Devices, Measurement of Humidity, Density, Viscosity, and pH, Position and Motion Sensing, Safety Hazards, Smoke and Fire Sensors, Heat Sensors, Gas Sensors, Artificial Senses - Chemical Sensors, and Radiation Detectors.
Electrical Instruments and Control Elements: Electrical Instruments and Conditioning, Regulators, Valves, and Actuators, Process Control Basics, PID Action, Implementation of Control Loops, PID Action Pneumatic Controller, PID Action Control Circuits, PID Electronic Controller, Digital Controllers, Signal Transmission, Programmable Logic Controllers (PLCs), Basic PLC Programming, PLC Motor Control, Control of motors using PLCs, Discrete I/O Interfacing, PLC Timer Instructions, PLC Counter Instructions, Introduction to PLC Troubleshooting, Event Sequencing, and Application Development.
References:

1. Fundamentals of Industrial Instrumentation and Process Control, Dunn WC, McGraw-Hill Education.
2. Instrumentation and Process Control, Thomas A. Weedon, Philip Kirk, Franklyn W. Kirk.
3. Chemical Process Control: An Introduction to Theory & Practice, Stephanopoulos, G, Prentice-Hal.
4. Process Dynamics & Control, Seborg, DE, Edgar TF, Mellichamp DA, John Wiley.
5. Programmable Logic Controllers: Industrial Control, Kamel, Khaled, Eman Kamel, McGraw Hill Professional.
6. Automating Manufacturing Systems with PLCs, Jack, Hugh, Lulu.com.

EEE 5204	Fuzzy Logic, Neural Networks and Deep Learning	3 Credits, 3 Hours/Week

Fuzzy Systems: Classical Sets and Fuzzy Sets, Basic Mathematical Concepts of Fuzzy Sets, Fuzzy Relations, Properties of Membership Functions, Fuzzification and Defuzzification, Decision-making with Fuzzy Information, Fuzzy Classification and Pattern Recognition, The Structure and Operation of a Fuzzy Controller, Fuzzy Control Systems Design: Aircraft Landing Control Problem, Fuzzy Engineering Process Control, Multi-input, Multi-output (MIMO) Control Systems, Fuzzy in Biomedical, and

Healthcare.
Neural Networks: The Human Brain, Models of a Neuron, Network Architectures, Learning Processes, Rosenblatt's Perceptron, The Perceptron Convergence Theorem, Model Building through Regression, The Least-Mean-Square Algorithm, The Wiener Filter, Multilayer Perceptrons, The Back-Propagation Algorithm, Kernel Methods and Radial-Basis Function Networks, Cover's Theorem on the Separability of Patterns, Radial-Basis-Function Networks, Deep Feedforward Networks, Regularization for Deep Learning, Optimization for Training Deep Models, Convolutional Networks, Applications: Large Scale Deep Learning, Computer Vision, Speech Recognition, Natural Language Processing.

References:

1. Fuzzy Logic with Engineering Applications, T.J. Ross, John Wiley & Sons.
2. Computational Intelligence: Synergies of Fuzzy Logic, Neural Networks and Evolutionary Computing, Siddique N, Adeli H, John Wiley & Sons.
3. Neural Networks and Learning Machines, Simon Haykin, Pearson Education.
4. Fuzzy Controllers Handbook: How to Design Them, How They Work, L. Reznik, Elsevier.
5. Deep Learning, Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press.

EEE 5205	**Introduction to Artificial Intelligence with Python**	**3 Credits,** **3 Hours/Week**

AI with Python - Primer Concepts: Basic concepts of AI, What's Involved in AI, Why Python for AI, Installing Python, Running Python, and Integrated Development Environment.
AI with Python - Machine Learning: Types of ML, Most Common Machine Learning Algorithms, Preprocessing the Data, Techniques for Data Processing, Labeling the Data.
AI with Python - Supervised Learning: Steps for Building A Classifier in Python, Logistic Regression, Decision Tree Classifiers, Random Forest Classifiers, Classifier Performance, Class Imbalance Problem, and Ensemble Techniques.
AI with Python - Unsupervised Learning: Clustering, Algorithms for Clustering Data, Measuring Clustering Performance, Calculating Silhouette Score, and K-Nearest Neighbour Classifier.
AI with Python - Analyzing Time Series Data: Introduction to Time Series Data, Handling, Slicing, and Extracting Statistics from Time Series Data, Analyzing Sequential Data by Hidden Markov Model (HMM).
AI with Python - Heuristic Search: Concepts of Heuristic Search in AI, Difference Between Informed and Uninformed Search, Real-World Problems Satisfied with Constraint Equations.
AI with Python - Neural Networks: Artificial Neural Network (ANN), Building Neural Networks, Perceptron-Based Classifier, Single-Layer Neural Network, Multi-Layer

Neural Network, Basics of Reinforcement Learning, Environment and Agent.
AI with Python - Genetic Algorithm: Genetic Algorithms, GA for Optimization Problems, Implementing Solutions using Genetic Algorithm.
AI with Python - Deep Learning: Machine Learning vs. Deep Learning, Convolutional Neural Network (CNN), Building Linear Regressor using ANN, and Image Classifier Application of Deep Learning.
References:

1. Artificial Intelligence with Python: A Comprehensive Guide to Building Intelligent Apps for Python Beginners and Developers, Alberto Artasanchez, Prateek Joshi, Packt Publishing.
2. Artificial Intelligence Programming with Python: From Zero to Hero, Perry Xiao, Wiley.

EEE 5206	**Industrial Quality Control**	**3 Credits,** **3 Hours/Week**

Quality Improvement in the Modern Business Environment: A Brief History of Quality Control and Improvement, Statistical Methods for Quality Control and Improvement, Management Aspects of Quality Improvement, The DMAIC Process, Statistical Methods Useful in Quality Control and Improvement, Modeling Process Quality, and Inferences about Process Quality.
Basic Methods of Statistical Process Control and Capability Analysis: Methods and Philosophy of Statistical Process Control, Control Charts for Variables, Control Charts for Attributes, Process, and Measurement System Capability Analysis.

Statistical Process-Monitoring and Control Techniques: Cumulative Sum and Exponentially Weighted Moving Average Control Charts, Univariate Statistical Process-Monitoring and Control Techniques, Statistical Process Control for Short Production Runs, and Multivariate Process Monitoring and Control.
Engineering Process Control and SPC: Factorial and Fractional Factorial Experiments for Process Design and Improvement, and Process Optimization with Designed Experiments.
Acceptance Sampling: Lot-by-Lot Acceptance Sampling for Attributes, and Acceptance-Sampling Techniques.
Case Studies: Quality Control in Electronics Industry, Quality Control in Apparel Industry, Quality Control in Leather Industry, and Quality Control in the Pharmaceutical Industry.

References:

1. Introduction to Statistical Quality Control, Douglas C. Montgomery, John Wiley & Sons.

2. Fundamentals of Quality Control and Improvement, A. Mitra, John Wiley & Sons.
3. Fundamentals of Industrial Quality Control, LS Aft, CRC Press.

EEE 5207	Multivariate and Adaptive Control System	3 Credits, 3 Hours/Week

Introduction: Classical Feedback Control, Introduction to Multivariable Control, Elements of Linear System Theory.
Limitations on Performance: Limitations on Performance in SISO Systems, Limitations on Performance in MIMO Systems.
Uncertainty and Robustness: Uncertainty and Robustness for SISO Systems, Robust Stability, and Performance Analysis.
Controller Design: LQG control, $\mathcal{H}2$ and $\mathcal{H}\infty$ control, $\mathcal{H}\infty$ loop-shaping design, Control structure design.

Model Reduction: Linear Matrix Inequalities.
Case Studies: Helicopter Control, Aero-Engine Control, and Distillation Process.
Adaptive Control: Adaptive Parameter Estimation, Adaptive State Feedback Control, Continuous-Time Model Reference Adaptive Control, Discrete-Time Model Reference Adaptive Control, Indirect Adaptive Control, and Multivariable Adaptive Control.
References:

1. Multivariable Feedback Control: Analysis and Design, S. Skogestad and I. Postlethwaite, John Wiley & Sons.
2. Essentials of Robust Control, K. Zhou and J.C. Doyle, Prentice Hall.
3. Adaptive Control Design and Analysis, G. Tao, John Wiley & Sons.

EEE 5208	Robotics and Embedded System	3 Credits, 3 Hours/Week

Introduction to Embedded Systems & Robotics: Actuators and Drives, Control Components, Sensors, Kinematics, Configuration Space of a Rigid Object, Obstacles in Configuration Space, Multiple Moving Objects, Differential Motion, Dynamics, Dealing with Uncertainty.
Introduction to Circuits: Arm Cortex Architecture & Assembly Programming, Embedded Software Design, Power sources and voltage regulation, GPIO, FSM.
Interfacing & Management: Interfacing I/O, Managing Time, Concurrent Multithreading, Serial Port Interfacing, Motor Interfacing, and Timers.
References:

1. Embedded Systems: Introduction to Robotics, Jonathan W. Valvano.
2. Embedded Controllers Using C, James M. Fiore.
3. Robot Analysis and Control, H. Asada and J. J. Slotine, Wiley.
4. Robot Motion Planning, Latombe, Kluwer Academic Publishers.

5. Artificial Intelligence: A Modern Approach, Russell & Norvig, Prentice Hall.
6. Introduction to Embedded Systems using ANSI C, David Russell and Mitchell Thornton Morgan and Claypool Publishers.

EEE 5209	**Optimal Control Theory**	**3 Credits, 3 Hours/Week**

Optimal Control Problem: Definition and Applications, Principle of Optimality and Dynamic Programming, HJB Equation, and LQR.
Calculus of Variations: Euler-Lagrange Equation, Conditions of Optimality for Various Cases, LQR/LQG- Stochastic Optimization.
Hamiltonian Formulation and Minimum Principle: LQR Revisited, Minimum Time Problem and Other Examples, Infinite-Horizon LQR, Algebraic Riccati Equation, Hamiltonian Matrix, and Conditions for the Existence of Solutions.
Optimization-Based Feedback for Discrete-Time Systems: Least Squares Estimation, Minimum Energy Control, On-Line Optimization and Control, and Model Predictive Control.
References:

1. Optimal Control Theory: An Introduction, D.E. Kirk, Dover.
2. Applied Optimal Control: Optimization, Estimation, and Control, Arthur Bryson and Yu-Chi Ho, Taylor & Francis.
3. Stochastic Optimal Control, Robert Stengel, Wiley.

EEE 5210	**Unmanned and Autonomous Systems Engineering**	**3 Credits, 3 Hours/Week**

Introduction to Unmanned Aircraft Systems (UAS): Unmanned Aircraft System Design, Selection of the System.
Autonomous System Fundamentals: Introduction to Legged Robotics, Example of Wheeled, Legged, and Flying Robotics, Fundamentals of Locomotion in Legged Robotics.
Mobile Robot Kinematics: Differential Kinematics, Wheeled Kinematics, Line Tracking Algorithms, Wheeled Mobile Robot Motion Control.
Autonomy: Probabilistic Formulation of Standard ML/AI Problems, Types of Uncertainty, Probabilistic Automata, Markov Chain and Decision Process, Hybrid Automata, Learned Perception and Control, Application Domains for Autonomy.
Autonomous Systems Sensors: IMU, RADAR, GPS, LIDAR, Motion Capture Systems, Laser Range Finders, Sonar, Line Tracking with Obstacles.
Computer Vision and Fundamentals of Image Processing: Camera Image Formation, Fundamentals of Image Processing, Correlation and Convolution in Image Processing, Place Recognition, and Line Fitting.
Localization: Introduction to Map-Based Localization, Broken Line Tracking Algorithm,

Collision Avoidance.
Optimization: Linear Programming and Convex Optimization.
Embedded and Cyber-Physical Systems: Network Embedded System Design, Energy-Aware Computing, and Cyber-Physical Systems.

References:

1. Mobile Intelligent Autonomous Systems, Jitendra R. Raol, CRC Press.
2. Introduction to Autonomous Mobile Robots, Nourbakash, Siegwart, Scaramuzza, MIT Press.
3. Unmanned Aircraft Systems: UAVs Design, Development and Deployment, Austin R. John, Wiley & Sons.
4. Advances in Intelligent Autonomous Systems, Spyros G. Tzafestas, Springer.
5. Intelligent Autonomous Systems, Y. Kakazu and M. Wada, IOS Press.

EEE 5211	**Radar System Engineering**	**3 Credits, 3 Hours/Week**

MTI and Pulse Doppler Radar: Power Amplifier Transmitter and Power Oscillator Transmitter for Radar, Delay Line Cancellers – Filter Characteristics, Double Cancellation, Range Gated Doppler Filters, MTI Radar Parameters, MTI versus Pulse Doppler Radar.
Tracking Radar: Monopulse Tracking Radar – Amplitude Comparison Monopulse (One- and Two-Coordinates), Phase Comparison Monopulse, Tracking in Range, Acquisition and Scanning Patterns, Comparison of Trackers.
Direction of Arrival (DOA) Estimation Techniques: Beamscan, Multiple Signal Classification (MUSIC), Capon Algorithm, Root MUSIC, Minimum Variance Distortionless Response Beamformer (MVDR), Matrix Pencil Method for Beamforming, Estimation of Signal Parameters Using Rotational in-Variance Technique (ESPIRIT).
Detection of Radar Signals in Noise: Introduction, Matched Filter Receiver – Response Characteristics and Derivation, Correlation Function and Cross-Correlation Receiver, Efficiency of Non-Matched Filters, Matched Filter with Non-White Noise.
Radar Receivers and Clutters: Homodyne and Heterodyne Radar Receivers, Noise Figure and Noise Temperature in Radar Receivers, Duplexers – Branch Type and Balanced Type, Circulators as Duplexers, Surface-Clutter Radar Equation, Sea Clutter, Detection of Targets in Sea Clutter, Land Clutter, Effects of Weather on Radar, Detection of Targets in Precipitation.
Introduction to Phased Array Antennas: Beam Steering, and Beam Width Changes Series versus Parallel Feeds, Applications, Advantages, and Limitations of Phased Array Radar, Electronically Steered Phased Array Antenna, Simultaneous Multiple Beams for Array Antenna, Frequency Scan Arrays, Computer Control of Phased Array Radar.
Other Radar Systems: Synthetic Aperture Radar (SAR), HF Over-the-Horizon Radar, Air Surveillance Radar, Height Finders and 3D Radar, Bistatic Radar, Ground Penetrating Radar (GPR), Millimeter-Wave Radar, and Beyond.

References:

1. Introduction to Radar Systems, Merrill I. Skolnik, TMH Special Indian Edition.
2. Radar Principles, Technology, Applications, Byron Edde, Pearson Education.
3. Radar Principles, Peebles, Jr., P.Z, Wiley.

Communications and Signal Proessing Stream

EEE 5301	Advanced Digital Signal Processing	3 Credits, 3 Hours/Week

Statistical Signal Processing: Orthogonality Principle, Wiener Filter, Adaptive Filtering, Recursive Least Squares Estimation, Kalman Filter Theory, Adaptive Algorithms: LMS, RLS and their Variants, Applications: Acoustic Echo Cancellation, Signal Enhancement, Inverse System Modeling, Denoising.

Multirate Digital Signal Processing: Multirate Processing, Fundamentals of Decimation and Interpolation, Fractional Sampling Rate Alteration Techniques, Polyphase Decomposition, Spectrum Analyzers and Synthesizers, Multirate Techniques in Filter Banks, QMF Filter Banks, Structures and Network Theory for Multirate Digital Systems, Wavelets.

Power Spectrum Estimation: Estimation of Autocorrelation and Power Spectrum of Random Signals, Non Parametric Methods for Power Spectrum Estimation, Parametric Methods for Power Spectrum Estimation.

Linear Prediction Theory: Representation of A Stationary Random Process, Discrete Random Signals, Moments, Bias-Variance, Linear Stochastic Models, ARMA (Auto Regressive Moving Average) Modeling, Properties of Estimators Bias/Variance, Cramer Rao Lower Bound, MVU (Minimum Variance Unbiased) Estimator, BLUE (Best Linear Unbiased Estimator), ML (Maximum Likelihood) Estimation, Bayesian Estimation, Forward and Backward Linear Prediction, Levinson-Durbin Algorithm, Properties of the Linear Predictors, The Concept of a Whitening Filter.

Finite Arithmetic Error Analysis: Analog-To-Digital Conversion Errors, Quantization Effects of Finite Arithmetic for Common Digital Signal Processing Algorithms Including Digital Filters and FFTs, Methods of Calculating the Noise at the Digital System Output due to Arithmetic Effects.

References:

1. Digital Signal Processing: A computer-based approach, Sanjit K. Mitra, McGraw-Hill.
2. Digital Signal Processing - Principles, Algorithms and Applications, John G.

Proakis and Dimitris G, Manolakis, Macmillan.
3. Theory and Application of Digital Signal Processing, L.R. Rabiner and B. Gold., Prentice Hall.
4. Discrete-Time Signal Processing, Oppenheim, Schafer & Buck, Prentice-Hall.
5. Statistical and Adaptive Signal Processing, Manolakis, D., Ingle, M., Kogon, S., McGraw-Hill.
6. Adaptive Filter Theory, Haykin, S., Prentice Hall.
7. Advanced Digital Signal Processing, Proakis, J. G., Rader, C. M., Ling, F., Nikias, C. and L., Macmillan.
8. Digital Signal Processing: A System Design Approach, De Fatta, D. J., Lucas, J. G., Hodgkiss and W. S., John, Wiley and Sons.
9. Introductory Digital Signal Processing with Computer Applications, P.A. Lynn, W. Fuerst and B. Thomas, John Wiley.
10. Digital Signal Processing, M.H. Hayes, Schaum's Outline Series, McGraw Hill.
11. Statistical Signal Processing, Scharf, L. L., Addison-Wesley.
12. Digital Processing of Random Signals, Porat, B., Prentice Hall.
13. Adaptive filters: Theory and Applications, B. Farhang-Boroujeny, Wiley.
14. Fundamentals of Statistical Signal Processing: Estimation Theory, S. Kay, Prentice Hall.
15. Statistical Digital Signal Processing and Modelling, Monson Hayes, Wiley.

EEE 5302	**Digital Image Processing**	**3 Credits,** **3 Hours/Week**

Introduction: Image Formation and Representation, Brightness Adaptation and Discrimination, Pixels, Coordinate Conventions, Imaging Geometry, Perspective Projection, Image Acquisition and Quantization, Human Eyes and Visual Perception.
Image Enhancement: Intensity Transformations, Histogram Equalization, Spatial Filtering, Filtering in Frequency Domain and Image Restoration.
Image Transformation: DFT, Hadamard, Haar, DCT, Wavelet Transformation.
Image Compression: Fundamental Coding Theorem, Different Lossy and Lossless Compression Techniques.
References:
1. Digital Image Processing, Rafeal C. Gonzalez, Richard E. Woods, Pearson Education.
2. Fundamentals of Digital Image Processing, A. K. Jain, Prentice Hall of India.

EEE 5303	**Advanced Digital Image Processing**	**3 Credits,** **3 Hours/Week**

Image Transform: Wavelets, The Basis Functions, Continuous Wavelet Transform (CWT), Discrete wavelet transform (DWT). Wavelet Decomposition and Reconstruction

of Functions, Construction of Wavelets, Two Dimensional DWT, KLT.
Image compression: Fundamental Coding Theorem, Lossless Compression: Huffman Coding, Arithmetic Coding, Bit Plane Coding, Run Length Coding, Lossy Compression: JPEG, JPEG2000.
Image Segmentation: Pixel Classification, Point, Line and Edge Detection, Thresholding, Region Based Segmentation, Segmentation using Morphological Watersheds and Motion.
Object Recognition: Patterns and Patterns Classes, Recognition Based on Decision–Theoretic Methods, Matching, Optimum Statistical Classifiers, Neural Networks, Structural Methods.

Color Image Processing: Color Fundamentals, Color Models, Pseudo Color Image Processing, Vector Quantization, Color Transforms and Segmentation.
Morphological Image Processing: Preliminaries, Dilation, Erosion, Open and Closing, Hit or Miss Transformation, Basic Morphological Algorithms.
References:

1. Digital Image Processing, Rafeal C. Gonzalez, Richard E. Woods, Pearson Education.
2. Wavelets and Subband Coding, M. Vetterli, J. Kovacevic, Prentice Hall Inc,
3. Wavelets and Filter Banks, Gilbert Strang and Truong Q. Nguyen, Cambridge U niversity Press.
4. A Wavelet Tour of Signal Processing, Stephen G. Mallat, Academic Press.

EEE 5304	**Computer Vision**	**3 Credits,** **3 Hours/Week**

Introduction to Computer Vision: The Nature of Computer Vision, Visual Perception, Vision Systems, Sensing Devices, Interpreting Devices, Applications of Computer Vision.

Image Formation: Geometric Primitives and Transformations, Photometric Image Formation: Lighting, Reflectance, Shading and Optics, The Digital Camera: Sampling and Aliasing, Color and Compression.

Image Processing: Point Operators, Linear Filtering, Neighborhood Operators, Fourier Transforms and Wavelet Transforms.

Feature Detection, Matching and Segmentation: Points and Patches, Edge Detection and Linking, Lines: Successive Approximation and Hough Transforms, K-means and Mixtures of Gaussians.

Structure from Motion: Camera models, Camera Calibration, Optical Flow, Stereo from Motion, Time-to-Adjacency Analysis, Calibrated Perspective Cameras, Uncalibrated

Weak-Perspective Cameras and Uncalibrated Perspective Cameras.

Recognition: Face detection and Recognition, Instance Recognition, Category Recognition: Bag of Words Model

Classifying Images: GIST Features, Spatial Pyramid Kernel, Dimension Reduction with Principal Components, Image Classification Strategies and Evaluating Image Classification Systems.

Deep Learning Explosion in Computer Vision: Convolutional Neural Networks (CNN), CNN Architectures, Hyperparameter Tuning, Transfer Learning and Generative Adversarial Networks (GANs) in Computer Vision.

References:

1. Computer Vision: Algorithms and Applications, Richard Szeliski, Springer-Verlag London Ltd.
2. Computer Vision: Principles, Algorithms, Applications, Learning, E.R. Davies, Academic Press, Elsevier
3. Computer Vision: A Modern Approach, David A. Forsyth & Jean Ponce, Pearson.
4. Digital Image Processing, Rafael C. Gonzalez & Richard E. Woods, Prentice Hall.

EEE 5305	**Biomedical Signal and Image Processing**	**3 Credits, 3 Hours/Week**

Biomedical Signal and Images:
Biopotential and Origin of Biomedical Signals: Origin and Dynamic Characteristics of Biomedical Signals. ECG: Cardiac Electrophysiology, Relation of Electrocardiogram (ECG) Components to Cardiac Events, QRS Detection Algorithms, Clinical Applications.

EEG: Brain Neurophysiology, Relation of Electroencephalogram (EEG) Components to Neurological Activity Events, Peak Detection Algorithm for EEG Analysis, and Clinical Applications.

Speech Signals: The Source-Filter Model of Speech Production, Spectrographic Analysis of Speech, Speech Coding: Analysis-Synthesis Systems, Channel Vocoders, Linear Prediction of Speech, Linear Prediction Vocoders.

Imaging Modalities: Survey of Major Modalities for Medical Imaging: Ultrasound, X-ray, CT, MRI, PET, and SPECT.MRI: Physics and Signal Processing for Magnetic Resonance Imaging. Surgical Applications: A Survey of Surgical Applications of Medical

Image Processing.

Time-Frequency Analysis and Image Processing:

Joint Time-Frequency Analysis: Short-Time Fourier Transform (STFT), Wavelet Transform, Harr wavelet, Harr Decomposition and Reconstruction Algorithms, Dube chies Wavelet. Medical Image Coding and Compression Techniques.
Image Processing I: Extension of filtering and Fourier methods to 2-D signals and systems, Medical Image Compression Technique.

Image processing II: Interpolation, Noise Reduction Methods, Edge Detection, Homomorphic Filtering,
Blind Source Separation: Use of Principal Component Analysis (PCA) and Independent Component Analysis (ICA) for Filtering, Empirical Mode Decomposition (EMD), Multiresolution Discrete Wavelet Transform (MODWT).
Medical Imaging Methods:

Image Registration I: Rigid and Non-Rigid Transformations, Objective Functions.

Image Registration II: Joint Entropy, Optimization Methods.

Advanced Imaging Methods: Magnetoencephalography, Diffuse Optical Tomography, Optical Coherence Tomography, Elastography, Tactile Imaging, Photoacoustic Imaging and Emerging Imaging Technologies, Doppler Ultrasound and Flow Imaging (color Doppler), Doppler Radar Imaging, X-ray Computed Tomography (2-D and 3-D imaging), Filtered Back Projection, SPECT, PET, Functional MRI.

References:

1. Medical Physics and Biomedical Engineering, B. H. Brown, R. H. Smallwood, D.C. Barber, P. V. Lawford, D.R. Hose, CRC press.
2. The essential Physics of Medical Imaging, Jerrold T. Bushberg, J. Anthony Seribert, LWW Publisher.
3. Biomedical Signal Processing for Helathcare Applications, Varun Bajaj, G. R. Sinha, Chinmoy Chakraborty, CRC Press.

EEE 5306	**Video Processing and CodingTechnology**	**3 Credits, 3 Hours/Week**

Video Processing: Representation of Digital Video, Spatio-Temporal Sampling, Motion Estimation Algorithms, Motion Compensation, Intra Frame Prediction, Faster Algorithms for Motion Estimation, Deblocking and Video Filtering.
Color Video: Basics of Color, Color Models in Video (RGB, YUV, YCrCb).

Video Compression: Basic Video Compression Techniques, Introduction to Video Compression, Video Compression Based on Motion Compensation, Search for Motion Vectors, Video Coding Standards, MPEG-2, H.264.
Video Quality: Subjective and Objective Evaluations.
References:

1. Digital Video Processing, A. M. Tekalp, Prentice-Hall.
2. Video Processing and Communications, Yao Wang, Joern Ostermann, and Ya-Qin Zhang, Prentice Hall.
3. Multidimensional Signal, Image, and Video Processing and Coding, John W. Woods, John W. Woods.
4. Modern Image Quality Assessment, Zhou Wang, and Alan C. Bovik, Springer.
5. Image and Video Compression Standards: Algorithms and Architectures, V. Bhaskaran and K. Konstantinides, Kluwer Academic Publishers.

EEE 5307	**Random Signals and Processes**	**3 Credits, 3 Hours/Week**

Random Variables: Random Variables with Distributions, Discrete and Continuous Random Variables, Functions of a Random Variable, Two Random Variables and Sequences of random variables.

Stochastic Processes: Shot Noise, Modulation, Cyclostationary Process, Bandlimited Processes and Poisson Points.

Spectrum Estimation: Spectral Representation, Ergodicity, Extrapolation and Power Spectrum Estimation.

Mean Square Estimation: Mean-square Estimation, Prediction and Filtering and Kalman Filter.

Markov Chain and Markov Processes: Transition Probabilities, States Classification, Stationary and Transient Distribution, Markov Processes and Queueing Theory

References:

1. Probability, Random Variables and Stochastic Processes, Athanasios Papoulis and Unnikrishna Pillai, McGraw-Hill.
2. Probability and Random Processes, Geoffrey R. Grimmett and David R. Stirzaker, Oxford University Press.

EEE 5308	Information Theory and Coding	3 Credits, 3 Hours/Week

The Statistical Nature of Communications: Elements of Information Theory of Discrete Systems; Information Measures, Memoryless and Memory Sources, The Noiseless Coding Theorem, Methods of Source Coding, Information Theory of Continuous Systems, Shannon's Capacity Theorem and its Interpretation, Comparison of Communication Systems with the Ideal, Applications of Information Theory in Communications and Signal Processing.

Elementary Ideas of Redundancy: Fundamental Problems in Coding Theory and Practice. Distance Measures, Bounds to The Performance of Codes, Important Linear Codes, Construction and Properties of Finite Fields, Cyclic Codes, BCH and Reed Solomon codes, Error correction for BCH and RS codes.

References:

1. Elements of Information Theory, T M Cover & J A Thomas, Wiley.
2. Information Theory, Inference, and Learning Algorithms, D MacKay, Cambridge University Press,
3. Probability, Information and Coding Theory, P. S. Sathyanarayana, Dynaram Publication.
4. Error-Correcting Codes, W. Wesley Peterson and E. J. Weldon, The MIT Press.
5. Error-Control Coding for Data Networks, Irving S. Reed and Xuemin Chen, Springer.

EEE 5309	Traffic Theory and Queuing Systems	3 Credits, 3 Hours/Week

Introduction: Teletraffic analysis, Mathematical Basis of Traffic Theory, Markov Processes.

Loss System Analysis: Route Congestion in Circuit-Switched Systems, Models for Overflow Traffic, Restricted Availability; Congestion in Circuit Switches.

Delay-System Analysis: Introduction to Queueing Theory, Congestion in Message-Switched Systems and Packet-Switched Systems, Queueing Network Models, Analysis of Random Access Protocols, Traffic Characterisation of Broadband Services, Admission and Access Control in Broadband Networks.

Routing in ATM Networks: Performance/Reliability (Performability) Models.

References:

1. Communication networks, Alberto Leon-Garcia & Indra Widjaja, McGraw-Hill.
2. Data Networks, Bertsekas, D.P. and Gallger, R., Englewood Cliffs, NJ.
3. An introduction to Queueing Theory and Stochastic Teletraffic Models, Moshe Zukerman, arXiv:1307.2968.
4. Queueing Systems, Volume 1: Theory, Leonard Kleinrock, John Wiley & Sons.
5. Introduction to Queueing Theory, Cooper, R. B, North Holland.
6. Routing in Dimensioning in Circuit-Switched Networks, Girard, A., Addision-

Wesley.
7. Multiple Loss Model for Broadband Telecommunication Networks, Ross, K. W., Springer-Verlag.
8. Broadband Integrated Networks, Schwartz, M., Prentice Hall.
9. Performance and Reliability Analysis of Computer Systems, Sahner R. A., Trivedi, K. S. and Puliafito A., Kluwer Academic.

EEE 5310	Network and Information Security	3 Credits, 3 Hours/Week

Overview: Security Goals, The OSI Security Architecture, Security Attacks, Services and Mechanism, A Model for Network Security.
Symmetric Ciphers: Classical Encryption Techniques, Block Ciphers and the Data Encryption Standard (DES), Basic Concepts in Number Theory and Finite Fields, Advanced Encryption Standard (AES), Block Cipher Operation, Pseudorandom Number Generation and Stream Ciphers.

Asymmetric Ciphers: Mathematics of Asymmetric-Key Cryptography, Public-Key Cryptography and RSA, Diffie-Hellman Key Exchange Algorithm, Man-in-the-Middle Attack, other Public-Key Cryptosystems.
Cryptographic Data Integrity Algorithms: Cryptographic Hash Functions: Secure Hash Algorithm (SHA), Message Authentication Codes: Security, Requirements, HMAC, Digital Signatures: Properties, Attacks and Forgeries, Digital Signature Standards.
Mutual Trust: Key Management and Distribution: Symmetric-Key Distribution, Public Key Distribution, Public Key Infrastructure, X.509 Certificates, User Authentication: Kerberos, Personal Identity Verification.
Network and Internet Security: Network Access Control and Cloud Security, Transport-Level Security: SSL, TLS, HTTPS and SSH, Wireless Network Security: IEEE 802.11i, Electronic Mail Security: PGP, S/MIME and DKIM, Network Layer Security: IPsec and Internet Key Exchange (IKE).
System Security: Intruders, Intrusion Detection System (IDS), Password Management, Malicious Software, Viruses, Worms, Antivirus Approaches, Distributed Denial of Service (DDoS) Attacks, Firewalls, Cybercrime: Legal and Ethical Aspects.
References:
1. Network Security: Private Communication in a Public World, Kaufman, C, Perlman, R and Speciner, M., Prentice Hall.
2. Applied Cryptography, Schneier, B., John Wiley.
3. Cryptography and Network Security Principles and Practice, William Stallings, Pearson Education.
4. Cryptography and Network Security, Behrouz A. Forouzan and Debdeep Mukhopadhyay, McGraw Hill Education

EEE 5311	Digital Speech and Audio Signal Processing	3 Credits, 3 Hours/Week

Fundamentals of Speech Processing: The Human Vocal And Auditory Systems, Characteristics of Speech Signals: Phonemes, Prosody, IPA Notation; Lossless Tube Model of Speech Production; Time And Frequency Domain Representations of Speech, Window Characteristics and Time/Frequency Resolution Tradeoffs, Properties of Digital Filters: Mean Log Response, Resonance Gain And Bandwidth Relations, Bandwidth Expansion Transformation, All-Pass Filter Characteristics; Autocorrelation and Covariance Linear Prediction of Speech; Optimality Criteria in Time and Frequency Domains; Alternate LPC Parameterization;
Speech coding and Synthesis: PCM, ADPCM, CELP, Language Processing, Prosody, Diphone and Formant Synthesis, Time Domain Pitch and Speech Modification.
Speech Recognition: Hidden Markov Models and Associated Recognition and Training Algorithmsa and Dynamic Programming.
Fundamentals of Audio: Loudness, Pitch, Timbre, Fundamentals of Digital Audio, Digital Audio Recording, Low-Bit Conversion and Noise Shaping.
Perceptual Audio Coding: Physiology of Human Ear, Amplitude and Temporal Masking, Perceptual Coding, Subband Coding, MPEG Audio Standardsa and Dolby Audio Coders.

References:

1. Discrete-Time Processing of Speech Signals, JR Deller, Jr., JG Proakis & JHL Hansen, Macmillan.
2. Digital Processing of Speech Signals, LR Rabiner & RW Schafer, Prentice-Hall.
3. Statistical Methods for Speech Recognition, F Jelinek, MIT Press.

EEE 5312	High Speed Computer Networking	3 Credits, 3 Hours/Week

High Speed Networks: High Speed LANs, Fast Ethernet and Gigabit Ethernet, FDDI and DQDB, Frame Relay Architecture, Standards and Protocols, Switched Multi Megabit Data Services, ATM Standards & Protocols, ATM LANs, Traffic and Congestion Control in ATM Networks, Optical Communication and SONET/SDH, Broadband Access Technologies, X-DSL, B ISDN Protocol and Architecture, Broadband Service Aspects and Access Architecture, Broadband Transmission Network, Broadband Access Network Technology, Cable TV Networks, and Hybrid Fiber Coaxial (HFC) Network.
Transmission Schemes: DOCSIS, Congestion Control and QoS in Data Networks and Internets, Advanced Network Architectures, Overlay Model, MPLS, RSVP, Differentiated Services, VOIP, H.323, Session Initiation Protocol, PSTN vs. VoIP and VSAT Networks.

Congestion and Traffic Management: Queuing Analysis, Queuing Models, Single Server Queues, Effects of Congestion, Congestion Control, Traffic Management, Congestion Control in Packet Switching Networks, and Frame Relay Congestion Control.

TCP and ATM Congestion Control: TCP Flow control, TCP Congestion Control, Retransmission, Timer Management, Exponential RTO backoff, KARN's Algorithm, Window Management, Performance of TCP over ATM. Traffic and Congestion control in ATM, Requirements, Attributes, Traffic Management Frame Work, Traffic Control, ABR traffic Management, ABR Rate Control, RM Cell Formats, ABR Capacity Allocations, and GFR Traffic Management.

IEEE 802.11 (WiFi) & IEEE 802.16 (WiMAX): Network Structure, Protocol Stack, PHY Layer, MAC Layer, QoS, Mobility, OFDMA, SOFDMA, Subchannelization, Adaptive Modulation and Coding, Frame Structure, Spectral Efficiency, Network Capacity, LTE, and Beyond 4G.

IEEE 802.15 (WPAN / Bluetooth): Architecture, Piconets, Scatternet, Bluetooth Layers, Radio Layer, Baseband Layer, Frame Format, L2CAP, QoS, High Rate WPAN, Low Rate WPAN, Mesh Networking, Body Area Networks, Visible Light Communication and Wireless Next Generation.

IEEE 802.20 (MBWA): Technical Specification and Advantages, Network Structure, Co-Existence, Comparison with Other Wireless Systems, Spectral Efficiency, and Network Capacity.

References:

1. High Speed Networks and Internet, William Stallings, Pearson Education.
2. High-Speed Networks TCP/IP and ATM Design Principles, William Stallings, Prentice Hall, Cisco Press.
3. Quality of Service Control in High-Speed Networks, H. Jonathan Chao and Xiaolei Guo, Wiley-Interscience.
4. Computer Networks, Andrew Tanenbaum and David Wetherall, Pearson.
5. Computer Networks: A Systems Approach, Larry L. Peterson and Bruce S. Davie, Morgan Kaufmann.
6. Computer Networks and Internets, Douglas E. Comer, Pearson.

EEE 5313	**Advanced Data and Mobile Communications**	**3 Credits, 3 Hours/Week**

Discrete Data Transmission: Modulation, Demodulation, Discrete Data Detectors, ML and MAP Detectors, AWGN Noise and Bit Error Rate as a Function of SNR, Union Bound Approximation, PSK, PAM and QAM Systems.

Transmission through ISI Channels: Inter Symbol Interference, ISI model, Nyquist Criterion, Raised Cosine Pulse, Zero Forcing Equalizer (ZFE), MMSE Linear Equalizer, Decision Feedback Equalizer, Error Propagation, Precoders: Tomlinson, Larcia.

Multi Channel Modulation: Basic Multi Tone, Gap Analysis, Water Filling

Optimization, Rate Adaptive, Margin Adaptive Water Filling Algorithm, Discrete Loading: Chow's algorithm, Levin Campello Algorithm, Dynamic Loading, Channel Partitioning, Modal Modulation, Discrete Multi-Tone.

Coding and Sequences, Sequential Detection: Convolution Codes, Maximum Likelihood (ML) Algorithm for Sequential Detection, Viterbi Algorithm, MAP Algorithm for Sequential Detection, Iterative Decoding, Turbo Codes, Low Density Parity Check Codes, Partial Response Decision Feedback Turbo Equalization.

Mobile Radio Channels: Path Loss, Slow-Fading, Fast-Fading, Doppler Spread and Coherence Time, Delay Spread and Coherence Bandwidth, Flat Fading and Frequency Selective Fadinga and The Power Budget Design of Mobile Radio Channels.

System Capacity: Average Capacity, Shannon Capacity /Water Filling Approach, Rate Adaptive Loading and Power Allocation, Capacity for Narrow and Wideband Systems.

Advanced wireless transmission and systems: CDMA Technology, Advanced Orthogonal Multicarrier Modems, Spectral Efficiency of Wireless Systems, Comparison of Existing Wireless Systems and Standards, Future Narrow- and Wide-Band Wireless Multimedia Systems, UMTS, Wideband System 1 (2G/GSM 2.5G): Air Interface, 2.5G-Transition from 2G to 3G, Backbone Networks, Wideband System 2: Backbone Networks and 3G Air Interface, DSSS for 3G, Link Optimization, Iterative Water Filling for Power Allocation.

References:

1. Signal Processing and Detection, John Cioffi.
2. Communication Systems Engineering, Proakis and Salehi, Pearson.
3. Modulation and Coding for Wireless Communications, Burr A, Prentice Hall.
4. Digital Communications Fundamentals and Applications, Sklar B, Prentice Hall.
5. Digital Communications, Haykin S, Wiley.
6. Digital Communications, Bateman A, Addison-Wesley.
7. Digital Communications, Proakis JG, McGraw Hill.
8. Digital Communications, Glover IA and Grant PM, Prentice Hall.
9. Wireless Communications, Principles and Practice, Rappaport TS, Prentice Hall.
10. An Introduction to GSM, Redl SM, Weber MK and Oliphant MW, Artech House.

EEE 5314	**Advanced Communications Theory**	**3 Credits, 3 Hours/Week**

Introductory concepts: Modeling of Information Sources, Communication Channels and Sinks, Definitions of Priori and Posterior Probabilities in Relation to the Model of a Communication Channel, MAP criterion, Likelihood Functions and Likelihood Ratio, An Initial Study on The Performance of a Digital Communication System and Expansion to a Spread Spectrum System.

Optimum detection theory: Detection Criteria, Receiver Operating Characteristics (ROC), Detection of Known Signals in The Presence of White Noise and The Concept of an Optimum Receiver, Matched Filter Receivers and Their Mathematical Analysis, Extension to Non-White Noise, Orthogonal Signals and the Approximation Theorem, M-Ary Signals and Signal Constellation, Basic Concepts and Analysis of Orthogonal and Biorthogonal M-Ary Communication Systems, 64-Ary Walsh-Hadamard Signal Set.

PN-sequences and Signals: Galois Field GF(2) Basic Theory, Shift Registers, Basic Properties of M-Sequences,Statistical Properties of m-Sequences, Gold Sequences, Modeling of PN-Signals, Cross/Autocorrelation Functions and Power Spectral Density of PN Signals, Partial Correlation Properties.

Spread spectrum systems (SSS): Basic Concepts and Parameters, Classification and Modeling of Jammers, Modeling of BPSK and QPSK Direct Sequence SSS in a Jamming Environment, Estimation of SNIR and Bit-Error-Probability, Direct Sequence SSS on the (SNR/Pe, EUE, BUE) Parameter Plane, Frequency Hopping SSS.

Principles of CDMA System: Investigation of Important System Components With Special Attention Given To RAKE Receiver, Modeling And Analysis With Emphasis Given on Capacity Issues, An Overview of The TIA/ISA IS-95 CDMA Standards, Wideband CDMA (3G).

Space-time Communications: Definitions, Notation, Spaces and Projection Operators, Modeling an Array Received Signal-Vector and the Concept of the Array Manifold, Multidimensional Correlators, Estimation of Signal Parameters Including Directions of Arrival, Powers, Cross-Correlations, etc., Array Pattern and Beamformers, Vector-Channel Effects (Including Multipaths, Angular Spread, Doppler Spread And Fading), Outage Probability, Integrated Array CDMA Systems, Single-User and Multi-User Array CDMA Receivers.

References:

1. Introduction to Spread Spectrum Communications, R.L. Peterson, R.E. Ziemer and D.E. Borth, Prentice Hall.
2. Fundamentals of Wireless Communication, D. Tse and P. Viswanath, Cambridge University Press.
3. Differential Geometry in Array Processing, A. Manikas, Imperial College Press.
4. Digital Communications, I. A. Glover & P.M. Grant, Pearson and Prentice Hall.
5. Communication Systems, S. Haykin, J. Wiley and Sons.
6. Introduction to Digital Communications, R.E. Ziemer & R.L. Peterson, MacMillan.

EEE 5315	**MIMO Wireless Communications**	**3 Credits, 3 Hours/Week**

Introduction to MIMO systems: Diversity, Wireless Fading Channel Characterization, MIMO Transmit Diversity Schemes, Classical and Generalized Fading Distributions, Applications of MIMO.

Analytical MIMO Channel Representations: Independent and Identically Distributed (Uncorrelated) MIMO Fading Model, Types of Channel Models, MIMO Channel Parallel

Decomposition.

Power Allocation and Capacity Estimation for Simplified MIMO Systems: Uniform, Adaptive and Near Optimal Power Allocation, Capacity for Deterministic and Random MIMO Channels, Capacity of I.I.D. Rayleigh Fading MIMO Channels, Capacity of Separately Correlated Rayleigh Fading MIMO Channel, Capacity of Keyhole Rayleigh Fading MIMO Channel, Ergodic Capacity and Outage Capacity.

Space Time Coding: Space-Time Block and Trellis Codes, Performance Analysis of Space-Time Codes Over Separately Correlated MIMO Channels, Introduction to Space-Time Turbo Encoders, Algebraic Space-Time Codes.

MIMO Detection: Maximum Likelihood (ML) Detector, Linear Sub-Optimal Detectors, Introduction to Spatially Multiplexed MIMO Systems, Vertical/Horizontal Layered Space-Time Transmission, Diagonal Bell Labs Layered Space-Time Transmission, Successive Interference Cancellation Detection, Ordered Successive Interference Cancellation Detector, Lattice Reduction Based Detector and Lattice Reduction Algorithms.

References:

1. Foundations of MIMO, Robert W. Heath Jr. and Angel Lozano, Cambridge University Press.
2. Fundamentals of Wireless Communication, David Tse and Pramod Viswanath, Cambridge University Press.
3. Fundamentals of MIMO Wireless Communications, Rakhesh Singh Kshetrimayum, Cambridge University Press.
4. Baseband Receiver Design for Wireless MIMO–OFDM Communications, Tzi–Dar Chiueh and Pei–Yun Tsai, Wiley-IEEE.
5. Coding for MIMO Communication Systems, Tolga M Duman and Ali Ghrayeb, Wiley.
6. Space–Time Processing for MIMO Communications, Alex Gershman and Nikos Sidiropoulosn, Wiley.

EEE 5316	**Human Computer Interaction**	**3 Credits, 3 Hours/Week**

Introduction: What is Human Computer Interaction (HCI), Its History Relation to Ergonomics and Human Factors Problems and challenges, The Human Brain vs. the Computer: Human Information Processing, Differences Between Humans and Computers, Philosophy of Mind, Brains vs. Circuit Boards, The User as an Information Processing

System, Human Sensation, Perception, and Cognition, Problem Solving and Reasoning, Attention and Change Blindness
Relation of memory to HCI.

Human Memory: Three Forms of Human Memory: Sensory Buffers, Short-Term Memory (Working Memory), and Long-Term Memory (LTM). How Information Gets to LTM: Rehearsal, Unconscious Consolidation, Meaningful Associations, Two Types of LTM: Declarative and Implicit Memory, Ways to Improve the Learning/Storage Process. Forgetting: is Memory Loss Due to Decay, Interference, Access Problem, Information Access/Retrieval: Recall vs. Recognition, Methods for Improving Recall: Association, Categorization, and Visualization, Reasoning and Logic Structures: Humans vs. Computers.

Interaction Styles: Types of Interaction (Or Dialog Styles) Commandline, Menus, Form Filling and GUIS, Good and Bad Examples of Interaction Styles.

Design Rules: Authority vs. Generality, Principles, Standards, and Guidelines, Golden Rules and Heuristics, Three Categories of Primary Usability Principles: Learnability, Flexibility, and Robustness

Design and Usability: Why Physical Design is Easier Than HCI Design: Human Error and Mistakes, Know Your User: What They Want, How They Think, How to Implement, Designer Bias/Egocentrism, Techniques to Gather User Needs: Interviews, Focus Groups, Observation, Participatory Design, Use of Persona, Scenarios, and Storyboards During the Design Process,
Three Types of Prototyping Design: Throw-Away, Incremental, and Evolutionary.

Design Evaluation: Two Forms of Design Evaluation: Expert Analysis and User Participation. Approaches to Expert Analysis: Cognitive Walkthroughs, Heuristic Evaluation, Model-Based Evaluation, and Evaluation Based on Existing Research. Lab vs. Field Research, Types of User-Based Evaluation: Observational Methods, Query Techniques, Physiological and Direct Recording, and Experimental Methods.

Experimental Evaluation and Empirical Methods: Hypothesis Testing, Choosing Participants and Sample Size, Variables: Independent and Dependent Measures Types of Experimental Designs and When You Use Them, Data Analysis.

Universal Design (UD): Universal Design (UD) is Not Specialized Design: Approaches to UD Implementation: Shared Purpose, Built-in Redundancy, Augmenting Existing Information, Compatibility with Third Party Assistive Technology (AT) Seven UD Principles: Overlap with General Design Principles, Tips for Improving Visual, Auditory, Haptic, and Multimodal Displays, Speech Recognition and Speech Synthesis, Universal Design on the Web Better Realism

Multimodal Interfaces: Multimodal Displays: Providing Feedback, Supporting Different Learning Styles, Cross Modal Interactions Multimodal Visualization, Better Realism Behavioral and Physiological Evidence.

Human Vision and Visual Displays: Difference Between Sensation, Perception, and Cognition: Relation of Each to HCI Design. Physiology of Visual System, Information Transduction, and Cortical Representation. Perceptual Distortions and Visual Illusions, Visual Design, Info Graphics Visualization Issues, Guidelines for Font and Reading, Color Usage, and Display Structure and Layout. Good Design for Buttons, Icons, and Lists and Fitt's Law.

Human Audition and Auditory Displays: Auditory Sensation, Perception, and Cognition. Physiology of Hearing. Text-to-Speech and Speech-to-Text Auditory Displays: Verbal Interfaces vs. 3D Spatialized Sound.

Human Touch and Tactual Displays: Three Subsystems of Touch: Cutaneous, Kinesthetic, and Haptic, Mechanoreceptors Most Relevant to HCI and Touch-Based Interfaces, Consideration of Exploratory Procedures,Patterns of Hand Movement that Facilitate Encoding of Spatial Properties through Touch in The Design of Tactual Interfaces, Perceptual Illusions with Touch, Types of Touch-Based Interfaces: Force-Feedback Haptic Devices, Cutaneous Devices, and Vibro-Tactile Devices.

Brain-Computer Interaction (BCI) and Neuroprosthetics/ Sensory Substitution: What is BCI?, BCI and Brain Plasticity, Neuroergonomics and Neurocognitive Engineering, Medical Applications of BCI: Neuroprosthetics, Commercial Applications of BCI, Ethical Implications of These Interfaces Neuroprosthetics vs. Sensory Substitution, Most Sensory Substitution Devices Compensate For Loss of Vision: Discussion of Visual to Tactile And Visual to Auditory Devices Components of Sensory Substitution Devices Underlying Theories and Why it Works.

Virtual and Augmented Reality and Ubiquitous Computing: Virtual Reality: Pros and Cons, Augmented Reality: Pros and Cons, Ubiquitous Computing and Ambient Intelligence, Wearable Devices and the Miniaturization of Computing Platforms Uses and Benefits of these Technologies Disadvantages and Problems.

Smart Phones, PDAs and HCI: Information Input and its Evolution on the Cell Phone, Output Displays and their Problems Other Interface Considerations, and Future Smart Phone Designs

HCI and the Web: HCI Challenge: Many Different Users, Tasks, and Technologies, What is Good Web Design?, Some Guidelines and Good Practices.

Future Directions of HCI: Future HCI Themes., The Aging of Our Population, Greater Reliance on Computers for More Tasks, Natural Language Processing.

Power Systems Stream

EEE 5401	Smart Grid Design and Analysis	3 Credits, 3 Hours/Week

Smart Grid Architectural Designs: Introduction, Comparison of Power grid with Smart Grid General View of the Smart Grid Market Drivers, Stakeholder Roles and Function - Measure, Representative Architecture, Functions of Smart Grid Components.
Smart Grid Communications and Measurement Technology: Communication and Measurement, Monitoring, Phasor Measurement Unit (PMU), Smart Meters, Wide area monitoring systems (WAMS), and Advanced metering infrastructure.
Performance Analysis of Smart Grid Design: Introduction to Load Flow Studies, Challenges to Load Flow in Smart Grid and Weaknesses of the Present Load Flow Methods, Load Flow State of the Art: Classical, Extended Formulations, and Algorithms, Load Flow for Smart Grid Design-Contingencies Studies for Smart Grid, Optimization Problem and its Application to Power Systems, Modeling of Uncertainties.
Stability Analysis Tools for Smart Grid: Voltage and frequency Stability Analysis Tools, Voltage Stability Assessment Techniques, Voltage Stability Indexing, Application and Implementation Plan of Voltage Stability in Smart Grid, Angle Stability Assessment in Smart Grid, and Energy Management in Smart Grid.
Renewable Energy and Storage: Renewable Energy Resources, Sustainable Energy Options for the Smart Grid, Penetration and Variability Issues Associated with Sustainable Energy Technology, Demand Response Issues, Electric Vehicles and Plug-in Hybrids-PHEV Technology-Environmental Implications, Storage Technologies, Grid Integration Issues of Renewable Energy Sources.
Cyber Security for Smart Grid: Cyber Security Risk Assessment, Security Index Computation, and Network Security Automation.

References:

1. Smart Grid: Fundamentals of Design and Analysis, James Momoh, John Wiley & sons Inc.
2. Smart Grid: Technology and Applications, Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, John Wiley & Sons Inc.
3. Smart Grid: Integrating Renewable, Distributed & Efficient Energy, Fereidoon P. Sioshansi, Academic Press.
4. The Smart Grid: Enabling Energy Efficiency and Demand Response, Clark W. Gellings, Fairmont Press Inc.

EEE 5402	**Power System Stability**	**3 Credits, 3 Hours/Week**

Introduction to Stability: Basic Concepts and Definitions of Stability, Classification of Stability.
Synchronous Machines: Overview of Machine Modelling, Park's Transformation of Machine Performance Equations, Transient Effects, Reactance and Time Constants of Synchronous Machines, Machine Performance Equations Under Steady State and Transient Conditions, Effect of Magnetic Saturation, and Dynamic Load Modeling.
Steady State and Dynamic Stabilities: Fundamental Concepts of Stability of Dynamic Systems. Small Signal Stability of a Single Machine Connected to Infinite Bus, Effect of Synchronous Machine Field Circuit on Stability, Small Signal Stability with Multi-Machine System.
Transient Stability: Introduction to Transient Stability, Solution of Swing Equations, Multi Machine Transient Stability Analysis using Numerical Methods: Modified Euler Method, Runge – Kutta Fourth Order Method etc.
Methods of Improving Power System Stabilities: Series Capacitor Compensation of Lines, Excitation Control, Power Stabilizing Signals, High-Speed Circuit Breaker, Auto Reclosing Circuit Breaker, Single Pole and Selective Pole Operation, Bypass Valving, and Dynamic Braking.
Voltage Stability and Reactive Power Control: Analytical Concept of Voltage Stability, Power Transmission Versus Voltage Collapse, Critical Voltage and Critical Power Angle, Voltage Stability Limit, Voltage Stability Enhancement, Sensitivity Indicator, and Optimal Power Flow and Stability.

References:

1. Power System Stability and Control, Kundur, P., McGraw-Hill International Editions.
2. Power System Control and Stability, Anderson, P.M. and Fouad, A.A., Galgotia Publications.
3. Voltage Stability of Electric Power Systems, Van Cutsem, T. and Vournas, C., Kluwer Academic Publishers.

EEE 5403	**Electrical Power Quality**	**3 Credits, 3 Hours/Week**

Power Quality: Phenomenon and Effects of Power Quality Problems, Types of Power Quality Disturbances-Voltage Sag (or Dip), Swell, Transients, Short Duration Voltage Variation, Long Duration Voltage Variation, Voltage Imbalance, Waveform Distortion, and Voltage Flicker, IEEE Guidelines, Standards, and Recommended Practices.
Harmonics: Overview of Harmonics, Mechanism of Harmonic Generation, Harmonic

Indices (THD, TIF, DIN, C-Message Weights), Harmonic Sources, Switching Devices, Arcing Devices, Saturation Devices. Effect of Harmonics on Power System Equipment and Loads. Harmonic Analysis Using Different Techniques- Fourier Series and Coefficients, The Fourier Transforms, Discrete Fourier Transform, Fast Fourier Transform, Window Function, Numerical Methods, and Special Transforms (Wavelets, Hartley).
Harmonic Elimination - Design and Analysis of Filters to Reduce Harmonic Distortion, Power Conditioners, Passive Filter, Active Filter - Shunt, Series, Hybrid Filters.
Voltage Sags and Swells: Fault-Induced Sags and Swells, Transferred Voltages, Impact of Grounding. Mitigation Techniques (Filters, Active Compensators, Voltage Restorers, etc.).
Electrical Transients: Switching and Lightning Induced Transients, Mitigation of Electrical Transients.
Power Quality Cost Evaluation: Techniques, Constraints, Financial Impact.
Instruments and Analyzers: Power Line Disturbance Analyzer, Power Quality Measurement Equipment, Harmonic Spectrum Analyzer, Flicker Meters, and Disturbance Analyzer.
Power Quality Management in Smart Grid: Power Quality in Smart Grid, Power Quality Issues of Grid-Connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Electromagnetic Interference (EMI), Introduction, Frequency Classification, Electrical Fields, Magnetic Fields, EMI Terminology, Power Frequency Fields, and High Frequency.

References:

1. Handbook of Power Quality, Angelo Baggini (Ed.), Wiley.
2. Power Quality, C. Sankaran, CRC Press.
3. Power Quality, G. T. Heydt, Stars in Circle Publication.
4. Power System Harmonics, Jose Arillaga, Neville R. Watson, Wiley.
5. Understanding Power Quality Problems, Math H. Bollen, Wiley-IEEE Press.
6. Electrical Power System Quality, R. C. Durgan, M. F. Me Granaghen, H. W. Beaty, McGraw-Hill.

EEE 5404	**Power System Planning and Reliability**	**3 Credits, 3 Hours/Week**

Load Forecasting: Load Characteristics, Load Forecasting Categories, Applications of Load Forecasting, Factors Affecting Load Patterns, Mid and Long-Term Load Forecasting (MTLF and LTLF) Methods: End Use Models, Econometric Models, Statistical Model-Based Learning, Short Term Load Forecasting (STLF) Methods/Technologies: Similar Day Approach, Regression Methods, Time Series, Artificial Neural Network (ANN).

Power System Reliability: Basic Notions of Power System Reliability Sub-Systems, Reliability Indices, Outage Classification, Value of Reliability Tools, Concepts and Methodologies, Power System Structure, Reliability Based Planning in Power Systems,

Effect of Failures on Power System, Planning Criteria, Risk Analysis in Power System Planning, and Multi-State Systems.
Basic Tools and Techniques: Random Processes Methods and Markov Models, Computation of Power System Reliability Measures by using Markov Reward Models, Evaluation of Reliability Indices, Universal Generating Function (UGF) Method, and Monte Carlo Simulation.
Reliability of Generation Systems: Capacity Outage Calculations, Reliability Indices using The Loss of Load Probability Method, Unit Commitment and Operating Constraints, Optimal Reserve Management, Single and Multi-Stage Expansion,
Reliability Assessment for Elements in Power Transmission Systems: Reliability Indices of Substations Based on The Overload Capability of the Transformers, Evaluation and Analysis of Substation Configurations, Reliability Analysis of Protection Systems for High Voltage Transmission Lines.

References:

1. Markey Operations in Electric Power Systems Forecasting, Scheduling, and Risk Management by Shahidehpour M, Yamin H, Li z, John Wlley & Sons.
2. Power System Planning, R.L. Sullivan, McGraw-Hill.
3. Reliability Evaluation of Engineering Systems by Billinton R, Allan R, Plenum Press.
4. Reliability Evaluation of Power Systems, Billinton R, Allan R, Plenum Press.
5. Computational Methods in Power System Reliability, D. Elmakias, Springer-Verlag.

EEE 5405	**Economics and Planning of Energy Systems**	**3 Credits, 3 Hours/Week**

System Economics: Review of The Basics of Supply, Demand, and Price Formation in Competitive Markets, Criteria for Economic Growth, Input-Output Economics, Macro-Economic Growth Models, Econometric Models, Policy Options and Budgetary Implication, Some Illustrations of Economic Research for Identifying Demand Functions, Supply Functions, Cost Functions, Production Functions, Utility Functions, and Engel Curves. Dynamic Models of the Economy and Simple Theory of Business Fluctuations.

Energy Demand: Short Run, Long Run Price Income Elasticities, Introduction to Multivariate Regression Analysis, Energy Supply and the Economics of Depletable Resources, World Oil Markets and Energy Security, Natural Gas Price Regulation, Deregulation and Markets, Energy and Climate Change, Environmental Repercussions, the Economic Structure, Conflict Between Energy Consumption and Pollution, Internalizing Environmental Externalities with a Focus on CO_2 Emissions Cap and Trade Mechanisms, Systems Design and Quantitative Economic Policy With References to

Energy. Econometric in the Context of Multiple Objectives, Conflicting Goals, and Decisions Under Uncertainty, Risk Management, Future Markets and Derivatives.

References:

1. Energy Economics, Subhes C. Bhattacharya, Springer.
2. Energy Economics, Peter M. Schwarz, Routledge.
3. Handbook of Energy Economics and Policy, Alessandro Rubino, Alessandro Sapio and Massimo La Scala, Academic Press.
4. The Handbook of Energy Policy, Farhad Taghizadeh-Hesary and Dayong Zhang, Springer Nature.
5. Microeconomics, Pindyck, R., and D. Rubinfeld, Upper Saddle River, Prentice Hall.
6. Energy Economics and Policy, James M. Griffin, Henry Steele, Henry B. Steele, Academic Press.

EEE 5406	Advanced Power System Analysis	3 Credits, 3 Hours/Week

Grid Components: Transmission Lines: Introduction to Transmission Lines, Performance Requirements of Power Transmission Lines, Voltage and Current Profiles, Power Transfer and Stability Considerations, Effect of Line Loss on V-P and Q-P Characteristics, Thermal Limits, Load Ability Characteristics, Transformers: Representation of Two-Winding Transformers, Representation of Three-Winding Transformers, and Regulating Transformers,

Power Network Matrix Operation: Admittance Model: Overview on Formation of Admittance Matrix, Formation of Ybus Includes Regulating Transformer, Network Incidence Matrix, Y_{bus} Modification using Gaussian Elimination, Kron Reduction, Triangular Factorization, Sparsity, Near-Optimal Ordering, Calculation of Z_{bus} Elements from Y_{bus}, Power Invariant Transformations.

Complex Power Flow: Analytical Formulation of Complex Power Flow Solution**,** Overview on Gauss-Seidel and N-R Method in Load Flow Analysis, Sensitivity Analysis using the Jacobian, Fast De-Coupled Load Flow Method, Ill-Conditioned System, Solution of Load Flow for Ill-Conditioned System.

Analysis of Optimal Power Flow: Formulation of the Optimal Power Flow Problem, Solution of Optimal Power Flow Problem using Gradient Method and Linear Programming Technique.

Procedures of Power Flow Analysis: Pre-Fault Power Flow and Post-Fault Power Flow.

Power System Contingency Analysis: Review of Fault Analysis, Z_{bus} Methods in Contingency Analysis: Adding and Removing Multiple Lines, Piecewise Solution of Interconnected Systems, Analysis of Single and Multiple Contingencies, Contingency Analysis by DC Model, System Reduction for Contingency and Fault Studies.

References:

1. Power system Analysis, Hadi Saadat, Tata McGraw-Hill.
2. Power system Analysis, Charles A. Gross, John Wiley & Sons.
3. Power system Analysis, John J. Grainger and William D. Stevenson, JR., Tata McGraw-Hill.
4. Power system Analysis Operation and Control, Abhijit Chakrabarti and Sunita Halder, Prentice-Hall of India.
5. Computer Techniques in Power System Analysis, Pai, M.A. and Dheeman Chatterjee McGraw Hill
6. Elements of Power System Analysis, William D. Stevenson, Jr., McGraw Hill.

EEE 5407	**Electrical Distribution System**	**3 Credits, 3 Hours/Week**

Scheme of Distribution Systems: Introduction to AC and DC distribution system, Primary and Secondary Distribution Network, Underground Distribution Network, Radial network, Primary loop network, Primary Selective, Secondary Selective, Spot Network, Grid network, Industrial and Commercial Distribution Systems.

Distribution Feeders: Development of MDEPL Model, Calculation of Total Technical Losses, Commercial Losses, Techniques of Minimization of Losses in Distribution Systems, Feeder Loading, and Voltage Drop Consideration, Feeder Rating with Different Distribution System.

Distribution Substation: Substation Type, Substation Component, Equipment and Layout, Substation Location and Size, Gas Insulated Substation, Design of Earth Electrode Systems, Temporary Grounding, Solidly Earthed, Resistive Earthed Systems, Comparison of Overhead and Underground Distribution Systems, Short Circuit, and Loss Calculations.
Distribution System Reliability: Probability Concepts, Markov Model, Reliability Measurement, Power Quality, Distribution System Expansion Planning, Design Concepts, Design Consideration, Optimal Location of Substation, Design of Radial Lines, and Load Forecasting.
Voltage Control: Application of Shunt Capacitance, Static VAR Systems, Loss Reduction and Voltage Improvement, Harmonics in the System, Sub-Harmonic Oscillations, and Ferro-Resonance Due to Capacitor Bank, use of Synchronous Condenser, Optimum Power Factor for Distribution Systems.
System protection: Fault Analysis for Distribution System, Fuses, and Section Analyzers, Over Current, Over and Under Voltage, Under Frequency Protection, Coordination of Protective Devices.
System Planning and Automation: Measurement of Power and Energy, Maximum Demand and Trivector Meters, Tariffs and billing, Distribution Planning, Distribution Automation, Distribution Optimization.

References:

1. Electrical Power Distribution System, Pabla, A.S, Tata McGraw Hill.
2. Electrical Power Distribution System Engineering, TMH Tuvar Goner, CRC Press.
3. Power System Control, Sterling, M.I.H. Peter Peergisus, IET Publisher.

EEE 5408	Energy Harvesting and Storage	3 Credits, 3 Hours/Week

Energy Resources, Greenhouse Gases, and Material: Energy Supply and Consumption, Energy Problems and Challenges, Current State of Improving Energy Efficiency, Inseparable Links between Energy and Materials

Fossil Energy: Fossil Fuels, Existing Coal-Fired Power Plants, Materials for Integrated Gasification Combined Cycle Plants, Materials in Oil and Gas Energy Conversion, Carbon Capture and Storage

Nuclear Energy Conversion: Nuclear Fission and Fusion, Fission Process for Nuclear Energy Generation, Nuclear Fuel Supply, Uranium and Plutonium, Thorium, Nuclear Materials, Fusion Reactors, and Material Issues.

Solar Energy and Materials: Materials for 1st, 2nd and 3rd Generation Solar Cells, Dye-Synthesized Solar Cells, Organic Solar Cells.

Bioenergy Conversion: Bioenergy, Biomass and Thermal Conversion, Biofuel, Bioenergy Sustainability

Wind Energy Conversion: Wind Energy Resources, Issues of Wind Energy Generation, Wind Turbines and Material Issues

Hydro, Geothermal, Ocean Energy and Materials: Material Challenges in Hydropower Conversion, Geothermal Energy Production and Ocean Energy Conversion.

Fuel Cells and Materials: What is a Fuel Cell, Applications and Characteristics of Fuel Cells, Alkaline Fuel Cells, Proton Exchange Membrane Fuel Cells, Direct Methanol Fuel Cells, Solid Oxide Fuel Cells.

Mechanoelectric Energy Harvesting: Energy Harvesting for Low-Power Applications, Fundamental Mechanisms of Mechanoelectric Energy Conversion, Mechanoelectric Energy Harvesting Materials, Sources of Mechanoelectric Energy, Different Energy Harvesting Methods

Thermoelectric Energy Conversion: Thermoelectric Energy Conversion Principles, Thermoelectric Energy Potentials and Applications, Thermoelectric Materials, Low-Temperature Materials, Moderate-Temperature Materials, High-Temperature Materials, Different Temperature Thermoelectric Material Comparison, Thermoelectric Material Processing Methods.

Energy Storage: Energy storage, Battery, Electrochemical capacitors, Li-ion capacitors.

Hydrogen Storage Hydrogen Storage as High-Pressure Gas, Hydrogen Storage as Liquid, Hydrogen Storage in Hydrides, Hydrogen Storage in Carbonaceous Materials, Hydrogen Storage in Zeolites, and Glass Microspheres

References:

1. Materials in Energy Conversion, Harvesting, and Storage, Kathy Lu, John Wiley & Sons.
2. Advances in Energy Materials, Shadia Jamil Ikhmayies, Springer Nature.
3. Fundamentals of Materials for Energy and Environmental Sustainability, David S. Ginley, David Cahen, Cambridge University Press.
4. Materials for Energy Conversion Devices, Charles C. Sorrell, Sunao Sugihara and Janusz Nowotny, Woodhead Publishing and Maney Publishing.

EEE 5409	**Power System Instrumentation**	**3 Credits,** **3 Hours/Week**

Transducer Instrumentation: Primary sensors, voltage and current generating analogue Transducers, variable parameter analogue Transducers, Frequency generating and Digital Transducers, Transducer Selection Factors.

Digital Instrumentation: Introduction, Basic measurement system, Digital Voltage Measurement, Frequency Measurement, Time Measurement, Digital Phasemeter, Digital Multimeter, Digital Displays, Telemetry System: Introduction to Information Transmission and Basic Ideas.

Point to Point Telemetering: Basic Principles, Pneumatic and Electrical System, Voltage and Current Telemetry, Impulse Codal Telemetry.

Radio Telemetering: Basic Principles of AMFM Systems. Instrumentation Associated with Power Plant: Centralized Control and Measurement in Thermal, Hydro and Nuclear Power Plants, Power Line Carrier Principles.

References:

1. Electrical Instrumentation and Measuring Techniques by Cooper Helfrick, Prentice Hall.
2. Instrumentation, Measurement, and Analysis by D. C. Nakra and K. K. Chowdhry, Tata-McGraw Hill.
3. Electrical and Electronic Measurements and Instrumentation, A.K. Sawhney, Dhanpat Rai and Sons.
4. Modern Power Station Practice, Volume F, British Electricity International Ltd., Central Electricity Generating Board, Pergamon Press.
5. Control & Instrumentation, NPTI Manuals Volumes I, II, III.

EEE 5410	High Voltage Engineering	3 Credits, 3 Hours/Week

Wave Terminology: Development of Wave Equations, Terminal Problems, Lattice Diagrams.
Origin and Nature of Power System Surges: Wave Shapes, Attenuation, Effect of Shielding by Ground Wires and Masts, Tower Footing Resistance.
Traveling Waves: Multi-Velocity Waves, Methods of Measuring Tower Footing Resistance, Voltages Across Insulator Strings.
Dynamic Over Voltages: Pattern of Over Voltages During Surges, System Faults, and System Recovery, Methods of Neutral Grounding and Their Effect on System Behavior, Insulation Coordination, Requirement in Surge Protection of Lines and Equipment.
Impulses Generation and Testing: Impulse Generators Development, Testing Technique. Power Frequency HV Transformers, Cascade Connection, H.V.D.C. Generators, Tests with Power Frequency and DC Voltages, Large Current Generating and Measurement Techniques, High Voltage and High Current Testing of Power Equipment.
Partial Discharge (PD) Testing: PD Test Circuit, PD Measurement, Calibration, PD Standards, Sources and Reduction of Disturbances, PD Instruments.
Field Investigations: Magnetic Links, Their Calibration and Mounting, Klydonograph, Potential Dividers and Cathodes Ray Oscillograph.
References:

1. High Voltage Engineering, E. Kuffel, W. S. Zaengl and J. Kuffel, Pergamon.
2. Electrical Transients in Power Systems, Allan Greenwood, Wiley Interscience.
3. Extra High Voltage AC Transmission Engineering, Begamudre, R.D., NewAge International.
4. High Voltage Engineering, Naidu, M.S. and Kamaraju, V., Tata McGraw Hill.

EEE 5411	Advanced Power Electronics	3 Credits, 3 Hours/Week

Introduction: Overview of Power Semiconductor Devices (Thyristor, IGBT, MOSFET, IGCT, GTO, Sic Transistors), Converter Topologies, Classification of Static Power Converters and Their Applications, Design of Control Circuits for Power Converters, Performance Analysis, Harmonic Analysis (Fourier Series and Coefficients, Harmonic Factor, Total Harmonic Distortion), Protection Circuit for Converters.
Rectifiers: Review of 1Ø And 3Ø Controlled Rectifiers, Introduction to Pulse Width Modulation (PWM), PWM Techniques, PWM Control of 1Ø Controlled Rectifiers, Multipluse Converters, Configuration of 12 Pulse Converter.
DC-DC Converters: Review of Basic DC-DC Voltage Regulator Configurations, Introduction to C'uk and SEPIC Converters, Analysis and Detailed Design of Isolated DC-DC Converters Including Forward Flyback, Push-Pull, Full Bridge and Dual Active Bridge

Topologies, Multi-Quadrant, Multi-Phase Choppersm Resonant Converters and Soft Switching, Concept of Zero-Voltage Switching (ZVS) and Zero Current Switching (ZCS), Applications of Resonant Converters.
Inverters: Review of Voltage Source Inverters (VSI), PWM Control of Vsis, Cycloconverters, Harmonic Reductions, Multilevel Inverters (Mlis), Introduction to Diode Clamped, Flying Capacitor and Cascaded H-Bridge MLIs, Applications of MSIs.

Power Electronics as Grid Interface: Applications of Power Electronic Devices in Renewable Energy Sources, Power Converters for Solar Photovoltaic Power Systems and Wind Power Systems, Power Converters for HVDC Transmission, High Voltage Direct Current (HVDC) System Configurations and Components, Power Converters for Flexible AC Transmission Systems (FACTS), Brief Overview of Thyristor- Controlled Reactor (TCR), Fixed Capacitor-Thyristor-Controlled Reactor (FC-TCR), Thyristor-Switched Capacitor (TSC).
References:

1. Power Electronics Circuits, Devices and Applications, Muhammad H. Rashid, Prentice Hall.
2. Power Electronics Design Handbook, Nihal Kularatna, Newnes.
3. HVDC and FACTS Controllers, Vijay K. Sood, Springer.
4. High Voltage Engineering, Farouk A.M. Rizk and Giao N. Trinh, CRC Press.
5. High Voltage Direct Current Transmission: Converters, Systems and DC Grids, Dragan Jovcic and Khaled Ahmed, Wiley.

EEE 5412	**Power System Regulation and Policy**	**3 Credits, 3 Hours/Week**

Bangladesh Power Sector: Past and Present Status, Overview of Growth of Power Section in Bangladesh, Reforms in The Bangladesh Power Sector.
Ancillary Services: Introduction of Power System Ancillary Service, Classification of Ancillary Services, Load Generation Balancing Related Services, Voltage Control and Reactive Power Support Devices, Black Start Capability Service, Co-Optimization of Energy and Reserve Services.
Deregulation: Deregulation of Power Industry, Restructuring Process, Issues Involved in Deregulation, Competitive Market Structure of Deregulated Power System, Operation, and Control Aspects of Deregulated Power System.
Transmission Open Access and Pricing Issues: Introduction, Power Wheeling, Transmission Open Access, Cost Components in Transmission, Pricing of Power Transactions, Pricing Mechanisms in Various Countries.
Transmission Congestion Management and Pricing: Transmission Cost Allocation Methods, LMP, FTR and Congestion Management. Role of FACTS Devices in Competitive Power Market, Available Transfer Capability, Distributed Generation in Restructured Markets.
References:

1. Power System Economics: Designing Markets for Electricity, Steven Stoft, John Wiley.
2. Restructured Electrical Power Systems: Operation, Trading and Volatility, Mohammad Shahidehpour, Muwaffaq Alomoush, Marcel Dekker, Taylor and Francis.
3. Impact of Market Restructuring on Power Systems Operation, W. H. J. R. Dunn, M. A. Rossi, B. Avaramovic, IEEE Press.
4. Understanding Electric Utilities and De-Regulation, Lorrin Philipson, H. Lee Willis, Marcel Dekker.

Optional Courses

EEE 5501	**Electronics for Smart Cities**	**3 Credits, 3 Hours/Week**

Introduction: Smart Governance, Smart Environment, Smart Economy, Smart Living, Smart People, Smart Mobility, Smart Energy and Smart Water, Smart Services.

Electronics for Smart Cities: Smart Infrastructure, Soft and Hard Infrastructure of Smart City, Data Organizations & Databases, City Wide Network, Wireless Networks, IoT and Smart City, Sensor Networks, Urban Platforms, Data Grids, Information Analytics, Cloud Computing, Machine Learning & Deep Learning, Visual Informatics, Urban Planning, Coherence, Efficiency and Networks, Standards & Normalization, E-Government and Smart City.

References:

1. Smart Cities, Smart Future: Showcasing Tomorrow, Mike Barlow and Cornelia Levy-Bencheton, Wiley.
2. Townsend Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia, Anthony M. Townsend, W. W. Norton & Company.
3. Smart Cities: Introducing Digital Innovation to Cities, Oliver Gassmann, Jonas Böhm, and Maximilian Palmié, Emerald Publishing.

EEE 5502	**Research Methodology in Engineering**	**3 Credits, 3 Hours/Week**

Introduction: Research Engineer vs Professional Engineer, Research Engineer vs Research Scientist, Career path of a research engineer, Qualities of a Research Engineer.

Introduction to Research Methodology: Research Methodology vs Research Method, Qualitative vs Quantitative Research, Different Qualitative Research Methodology, Different Quantitative Research Methodology, Data Driven Research, Artificial Intelligence, Big Data and Machine Learning as Engineering Research Tool, Text Mining and Computational Text Analysis, Evidence Synthesis/ Systemic Reviews. Mixed Method Research, Multi Method Research, Data Triangulation. Research on Knowledge Question vs Research on Applied Problem. Theory of Knowledge: Ontology and Epistemology, Identifying Research Problem. Scanning for Topic, Scope, Justification and Objective, Techniques of Literature Review, Technical Reading, Critical and Creative Reading, Keywords, Relevance, and Meta Analysis.

Philosophy of Science: The Epistemology of Science, the Metaphysics of Science, Science and Pseudoscience, Major Positions about Science, Inductivism (Bacon), Logical Empiricism (Ayer and Quine), Falsificationism (Popper), Incommensurability (Kuhn) And Relativism (Feyerabend).

Philosophy of Technology: Major Thinkers on Philosophy of Technology: Carl Mitcham, Lewis Mumford, Martin Heidegger, Alasdairmclantyre, Herbert Simon, Bruno Latour, Larry Hackman, Albert Borgmann, Don Ihde, Langdon Winner, Jacques Illul, Gilbert Simondon, Egbert Shuurmann, Andrew Feenberg. Empirical Turn in the Philosophy of Technology.

Sociology of Technology: Basic Sociological Frame Work for Technology, Different Issues of Society and Technology. Technology and Social Change, Appropriate Technology, Humanitarian Engineering, and Concepts of Digital Sociology.

Anthropology of Technology: Anthropological Framework for Technology, Anthropology of Man Machine Interaction, Artefact and Human Interaction, Anthropometry in Technology Development and Ergonomics, and Digital Anthropology.

Archeology of Technology: An Archeological History of Technology, Archeological Theories in Intepreting Artefacts and Material Culture. Archeological Theories in Technology Development and Innovation Thinking.

Psychology of Technology: Psychology of Technology use by People, Aspects of Engineering Psychology   Cognitive Psychology and Cognitive Ergonomics.

Computer Simulation: Computer Simulation as a Research tool in Engineering. Different Simulation techniques in Engineering

Laboratory Studies: Structure of A Research Laboratory, Laboratory as Research Set Up vs Laboratory as a Welfare Product, Development Structure, Society, State and Laboratory

Relation and Interaction.

Communicating Research: How to Publish in a Journal, Different Referencing System, Bibliometrics and Research Quality and Journal Ranking, Impact Factor Public Outreach and Science Communication, and Linguistic Relstivism.

Handling Criticism: Dealing with Criticism, Criticism by Supervisor, Criticism by Reviewer. Peer Review Process, Research Management and Collaboration, Scientific Collaboration and Science Diplomacy and Intellectual Property Rights Development and Patenting.

Research Ethics: Ethical Issues in Research, Originality of Research Work, Idea of Plagiarism, Social Responsibility and Market Demand Issue in Engineering Research Planning, Sustainability and Environmental Ethics.

References:

1. Engineering Research Methodology: A Practical Insight for Researchers, Dipankar Deb, Rajeeb Dey and Valentina E. Balas, Springer.
2. Research Methods for Engineers, David V. Thiel, Cambridge University Press.
3. Understanding Research Methods, Mildred L. Patten and Michelle Newhart, Routledge.
4. Technical Writing for Engineers & Scientists, Leo Finkelstein, McGraw Hill.

EEE 5503	**Project Management**	**3 Credits, 3 Hours/Week**

Introduction: Engineering Design, and Project Management Overview.

Project Management Types: Project Integration Management, Project Scope Management, Project Time Management, and Project Cost Management, Earned Value Analysis, Project Quality Management, Project Procurement Management, Project Human Resource Management, Project Communication Management, and Project Risk Management.

Project Design and Decision: Project Closeout, Project Design Reviews, Making Technical Decisions, and Management of Team Conflict.

References:

1. Project Management for Engineering Design, Charles Lessard, Joseph Lessard, Morgan and Claypool Publishers.

EEE 5504	Industrial Ecology and Sustainable Engineering	3 Credits, 3 Hours/Week

Introduction: Technology and Sustainability, Industrial Ecology (IE) and Sustainable Engineering (SE) Concepts.
Sustainable Engineering: Relevance of Biological Ecology to Technology, Metabolic Analysis, Technological Change and Evolving Risk, Social Dimensions of Industrial Ecology, Concept of Sustainability, SE, Industrial Product Development, Design for Environment and for Sustainability.
Introduction to Life-Cycle: Life-Cycle Assessment, LCA Impact and Interpretation Stages, Streamlining the LCA Process, Systems Analysis, Industrial Ecosystems, Material Flow Analysis, National Material Accounts.
Industrial Ecology: Energy and IE, Water and IE, Urban IE, Modeling in IE, Scenarios for IE, Status of Resources, IE and SE in Developing Countries, IE and Sustainability in the Corporation, Government, Society.
References:

1. Industrial Ecology and Sustainable Engineering, Braden R. Allenby and Thomas E. Graedel, Pearson.

EEE 5505	Technology History and Industrial Archaeology	3 Credits, 3 Hours/Week

Industrial Archaeology: The Scope of Industrial Archaeology, Industrial Archaeology and Archaeological Theory, Landscapes and Townscapes, Types of Industrial Landscapes, Buildings Structures and Machinery, Kilns and Furnaces, Food processing, Textiles and Steam Power,
Technology History: Dating, Documentary Research, Locating Written Sources, Secondary Sources, Printed Primary Sources, Pictorial Sources, Maps and Plans, Manuscript Sources, Field Techniques, Site Identification, Recording Site surveying Methods, Building Recording Methods, Recording Machinery And Processes, Written Report, Excavation Industrial Archaeology in Practice, the Cultural Context, Cultural Resource Management of the Industrial Heritage, Artefacts, Buildings Landscapes, and Documents.
References:

1. Industrial Archaeology: Theory and Practice, Marilyn Palmer, Routledge.

EPEE 5506	Public Policy and Development	3 Credits, 3 Hours/Week

Introduction: Public Policy Concept, Contexts of Public Policy, Government Institutions and Policy actors, Theories of Politics and Public policy: Elite Theory, Group Theory, Institutional Theory, Rational Choice Theory, Political Systems Theory,

The Policy Process Model: Problem Definition and Agenda Setting, Policy Formulation, Policy Legitimation, Policy Implementation, Policy Evaluation, Policy Change, Instruments of Public Policy: Regulation, Government Management, Taxing and Spending, Market Mechanisms, Education, Information and Persuasion Policy Typologies.

Policy Analysis: Types of Policy Analysis, Steps in the Policy Analysis Process, Policy Problems and Policy Alternatives, Assessing Policy Alternatives: Evaluating Criteria for Judging Policy Proposals, Politics, Analysis and Policy Choice.

Policy Development: Meaning of Development, Millennium Development Goals, Modernity, Development as an Economic Process, Human Development, Human Development Index, Importance of Scale, Gini Coefficient and Gini Index, Measuring Development, Actors in Development, Approaches to Development, Post Colonialism and Post Modernism Modernization, Keynesianism and Neo Liberalism Structuralism, Neo Marxism and Socialism, Grassroots Development, Social and Cultural Dimensions of Development, Environmental and Development Theory, Globalization and Development Economic, Social and Environmental Impact Analysis of Engineering Projects.

References:

1. Public Policy, Michel E Craft, Scot E. Farlong, SAGE.
2. Theories and Practices of Development, Katie Willis, Routledge.

EEE 5XXX	Fuzzy Logic, Neural Networks and Deep Learning	3 Credits, 3 Hours/Week

Fuzzy Systems: Classical Sets and Fuzzy Sets, Basic Mathematical Concepts of Fuzzy Sets, Fuzzy Relations, Properties of Membership Functions, Fuzzification and Defuzzification, Decision-making with Fuzzy Information, Fuzzy Classification and Pattern Recognition, The Structure and Operation of a Fuzzy Controller, Fuzzy Control Systems Design: Aircraft Landing Control Problem, Fuzzy Engineering Process Control, Multi-input, Multi-output (MIMO) Control Systems, Fuzzy in Biomedical, and

Healthcare.
Neural Networks: The Human Brain, Models of a Neuron, Network Architectures, Learning Processes, Rosenblatt's Perceptron, The Perceptron Convergence Theorem, Model Building through Regression, The Least-Mean-Square Algorithm, The Wiener Filter, Multilayer Perceptrons, The Back-Propagation Algorithm, Kernel Methods and Radial-Basis Function Networks, Cover's Theorem on the Separability of Patterns, Radial-Basis-Function Networks, Deep Feedforward Networks, Regularization for Deep Learning, Optimization for Training Deep Models, Convolutional Networks, Applications: Large Scale Deep Learning, Computer Vision, Speech Recognition, Natural Language Processing.

References:

1. Fuzzy Logic with Engineering Applications, T.J. Ross, John Wiley & Sons.
2. Computational Intelligence: Synergies of Fuzzy Logic, Neural Networks and Evolutionary Computing, Siddique N, Adeli H, John Wiley & Sons.
3. Neural Networks and Learning Machines, Simon Haykin, Pearson Education.
4. Fuzzy Controllers Handbook: How to Design Them, How They Work, L. Reznik, Elsevier.
5. Deep Learning, Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press.