SIDDHARTHA
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An Institution DEEMED TO BE UNIVERSITY
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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

POOL I Courses:

S.No	Code	Title of the Course	L	T	P	C	SE	Total
1	24EC710A	Digital System Design with PLDs	3	0	0	3	100	100
2	24EC710B	Device Modelling	3	0	0	3	100	100
3	24EC710C	CMOS VLSI Design	3	0	0	3	100	100
4	24EC710D	Electronic Materials	3	0	0	3	100	100
5	24EC710E	Microstrip Components and Antennas	3	0	0	3	100	100
6	24EC710F	RF and Microwave Circuit Design	3	0	0	3	100	100
7	24EC710G	Detection and Estimation Theory	3	0	0	3	100	100
8	24EC710H	Mathematics for Machine Learning	3	0	0	3	100	100
9	24EC710I	Image Processing and Computer Vision	3	0	0	3	100	100
10	24EC710J	Fundamentals of Wavelets, Filter Banks, and Time Frequency Analysis	3	0	0	3	100	100

POOL II Courses:

S.No	Code	Title of the Course	L	T	P	C	SE	Total
1	24EC720A	Low Power VLSI Design	3	0	0	3	100	100
2	24EC720B	Analog and Mixed Signal Design	3	0	0	3	100	100
3	24EC720C	VLSI Signal Processing	3	0	0	3	100	100
4	24EC720D	Materials Design for Electronic, Electromechanical, and Optical Functions	3	0	0	3	100	100
5	24EC720E	Antennas for Wireless communication	3	0	0	3	100	100
6	24EC720F	Radiating Millimeter Wave Circuits	3	0	0	3	100	100
7	24EC720G	Modern Wireless Communications	3	0	0	3	100	100
8	24EC720H	5G Communication	3	0	0	3	100	100
9	24EC720I	Deep Learning	3	0	0	3	100	100
10	24EC720J	Optimization Theory And Algorithms	3	0	0	3	100	100

L – Lecture, T – Tutorial, P – Practical, SE–Semester End Exam, C – Credits, Total – Total Marks

POOL I — COURSES SYLLABUS

24EC710A - DIGITAL SYSTEM DESIGN WITH PLDS

Course Objectives:

- **CO1:** Design, model, and simulate digital circuits using Verilog HDL.
- **CO2:** Implement complex logic functions using FPGAs and programmable logic devices.
- **CO3:** Understand and apply the architecture of SPLDs, CPLDs, and FPGAs in digital system design.
- **CO4:** Analyze and optimize the performance and cost of FPGA-based systems.
- **CO5:** Develop, test, and validate digital systems through Verilog models and simulation tools.

UNIT-I:

Introduction to Verilog: Computer-Aided Design, Hardware Description Languages, Verilog Description of Combinational Circuits, Verilog Modules, Verilog Assignments, Procedural Assignments, Modeling Flip-Flops Using Always Block, Always Blocks Using Event Control Statements, Delays in Verilog, Compilation, Simulation, and Synthesis of Verilog Code, Verilog Data Types and Operators, Simple Synthesis Examples, Verilog Models for Multiplexers, Modeling Registers and Counters Using Verilog Always Statement, Behavioral and Structural Verilog, Constants, Arrays, Loops in Verilog, Testing a Verilog Model.

UNIT-II:

Additional Topics in Verilog: Verilog Functions, Verilog Tasks, Multivalued Logic and Signal Resolution, Built-in Primitives, User-Defined Primitives, SRAM Model, Model for SRAM Read/Write System, Rise and Fall Delays of Gates, Named Association, Generate Statements, System Functions, Compiler Directives, File I/O Functions.

UNIT-III:

Design Examples: BCD to 7-Segment Display Decoder, A BCD Adder, 32-Bit Adders, Traffic Light Controller, State Graphs for Control Circuits, Scoreboard and Controller, Synchronization and Debouncing, A Shift-and-Add Multiplier, Array Multiplier, A Signed Integer/Fraction Multiplier, Keypad Scanner, Binary Dividers.

UNIT-IV:

Introduction to Programmable Logic Devices: Brief Overview of Programmable Logic Devices, Simple Programmable Logic Devices (SPLDs), Complex Programmable Logic Devices (CPLDs), Field-Programmable Gate Arrays (FPGAs).

UNIT-V:

Designing with Field Programmable Gate Arrays: Implementing Functions in FPGAs, Implementing Functions Using Shannon's Decomposition, Carry Chains in FPGAs, Cascade Chains in FPGAs, Examples of Logic Blocks in Commercial FPGAs, Dedicated Memory in FPGAs, Dedicated Multipliers in FPGAs, Cost of Programmability, FPGAs and One-Hot State Assignment, FPGA Capacity: Maximum Gates versus Usable Gates, Design Translation (Synthesis), Mapping, Placement, and Routing.

Textbooks:

1. Stephen Brown and Zvonko Vranesic, *Fundamentals of Digital Logic with Verilog Design*, McGraw-Hill Education, 3rd Edition, 2013.
2. Samir Palnitkar, *Verilog HDL: A Guide to Digital Design and Synthesis*, Prentice Hall, 2nd Edition, 2003.
3. Charles H. Roth Jr. and Lizy Kurian John, *Digital Systems Design Using VHDL*, Cengage Learning, 2nd Edition, 2007.
4. Michael D. Ciletti, *Advanced Digital Design with the Verilog HDL*, Prentice Hall, 2nd Edition, 2010.

References:

1. Peter J. Ashenden, *The Designer's Guide to VHDL*, Morgan Kaufmann, 3rd Edition, 2008.
2. Wayne Wolf, *FPGA-Based System Design*, Prentice Hall, 1st Edition, 2004.
3. Clive Maxfield, *The Design Warrior's Guide to FPGAs: Devices, Tools, and Flows*, Newnes, 1st Edition, 2004.
4. Ming-Bo Lin, *Digital System Designs and Practices: Using Verilog HDL and FPGAs*, Wiley, 1st Edition, 2008.
5. Zainalabedin Navabi, *Verilog Digital System Design*, McGraw-Hill, 2nd Edition, 2008.

24EC710B - DEVICE MODELING

Course Outcomes:

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

- **CO1:** Understand MOS capacitor working principles, modes of operations, electrostatics of MOS, and leakage in it.
- **CO2:** Analyze the physics of the current-voltage characteristics of MOSFET, reliability issues, and advanced MOSFETs.
- **CO3:** Understand the principles of Silicon on Insulator MOSFET, analyze intrinsic MOSFET capacitances and resistances, and evaluate FDSOI MOS and its sub-threshold slope.
- **CO4:** Understand the theory of Ballistic nano transistors, evaluate the modeling of Ballistic planar and nanowire-FET, and analyze advanced MOSFETs such as Strain Engineered Channel materials, Electrostatics of double gate, and Fin-FET device.
- **CO5:** Apply the advanced semiconductor devices for different optoelectronic applications.

Unit 1: MOS Transistor Basics

Electrons and holes in silicon, Energy band diagram of PN Diode, Types of MOSFET, MOSFET Mode of Operations, CV characteristics of MOS capacitor, Low frequency and high frequency capacitor-voltage characteristics, Non-idealities in MOS, Oxide fixed charges, interfacial charges, Poly-Silicon contact, and poly silicon properties, Electrostatics of non-uniform substrate doping, carrier transport in insulating films, ultrathin gate-oxide.

Unit 2: MOSFET

Drift-Diffusion Approach for current-voltage analysis, Gradual Channel Approximation, channel conductance, trans conductance, MOSFET equivalent circuit, Subthreshold current and slope, Body effect, mobility behavior, temperature behaviors MOSFET two dimensional effects, Buried channels, effect of ion implantation on threshold voltage, High field effects and MOSFET reliability issues.

Unit 3: SOI (Silicon on Insulator)

Leakage mechanisms in thin gate oxide, High-K-Metal Gate MOSFET devices and technology issues, Intrinsic MOSFET capacitances and resistances, SOI, FDSOI and

PDSOI, VT definitions, Back gate coupling and body effect parameter, I-V characteristics of FDSOI-FET, FDSOI-sub-threshold slope, Floating body effect, SOI materials: sapphire, zirconia, spinel, and calcium fluoride.

Unit 4: Advanced Nano-Transistors

Modern bipolar transistor structures, Quasi Ballistic & Ballistic Transports, Theory of ballistic nano transistors, Ballistic planar and nanowire-FET modeling, Semi-classical and quantum treatments Advanced MOSFETs, Electrostatics of double gate, and Fin-FET device high-k/metal gate Fin-FET.

Unit 5: Device Application

Introduction, Photoconductor, Photodiodes, Phototransistor, Metal-Semiconductor-Metal Photodetector, Quantum-Well Infrared Photodetector.

Textbooks:

1. S.M. Sze & Kwok K. Ng, *Physics of Semiconductor Devices*, Wiley.
2. B. G. Streetman, S. K. Banerjee, *Solid State Electronic Devices*, Pearson, (2016).
3. Jean-Pierre Colinge, *Silicon-on-Insulator Technology: Materials to VLSI*, Springer Science Business Media, LLC.

References:

1. N. Arora, *MOSFET Modeling for VLSI Simulation: Theory and Practice*, World.
2. Mark S. Lundstrom and Jing Guo, *Nanoscale Transistors Device Physics, Modeling and Simulation*, Springer.
3. Yannis Tsividis, *Operation and Modeling of the MOS Transistor*, Oxford University Press.

24EC710C - CMOS VLSI DESIGN

Course Outcomes:

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

- **CO1:** Demonstrate knowledge in Static and dynamic characteristics of CMOS inverter, estimate delay and power.
- **CO2:** Design and analyze combinational MOS logic circuits.
- **CO3:** Design and analyze MOSFET based sequential logic circuits.
- **CO4:** Design and analyze various Datapath Subsystems.
- **CO5:** Classify different semiconductor memories.

Unit 1: The CMOS Inverter

The MOS (FET) Transistor, Introduction, The Static CMOS Inverter - An Intuitive Perspective, Evaluating the Robustness of the CMOS Inverter, The Static Behavior Performance of CMOS Inverter, The Dynamic Behavior, Power, Energy, and Energy-Delay, Technology Scaling, and its Impact on the Inverter Metrics.

Unit 2: Designing Combinational Logic Gates In CMOS

Introduction, Static CMOS Design, Dynamic CMOS Design, How to Choose a Logic Style, Designing Logic for Reduced supply voltages.

Unit 3: Designing Sequential Logic Circuits

Introduction, Static Latches and Registers, Dynamic Latches and Registers, Alternative Register Styles, Pipelining, Choosing a Clocking Strategy.

Unit 4: Designing Arithmetic Building Blocks

Introduction, Datapaths in Digital Processor Architectures, The Adder, The Multiplier, The Shifter, Other Arithmetic Operators.

Unit 5: Designing Memory and Array Structures

Introduction, The Memory Core, Read-Only Memories, Non-volatile Read-Write Memories, Read-Write Memories (RAM), Contents-Addressable or Associative Memory (CAM), Memory Peripheral Circuitry, Power Dissipation in Memories, Case Studies in Memory Design.

Textbooks:

1. *Digital Integrated Circuits – A Design Perspective*, Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic, 2nd Edition, PHI.

References:

1. *CMOS VLSI Design: A Circuits and Systems Perspective*, Neil H. E. Weste, David Money Harris, 4th Edition, Addison-Wesley, 2011.
2. *Digital Integrated Circuit Design*, Ken Martin, Oxford University Press, 2011.
3. *CMOS Digital Integrated Circuits Analysis and Design*, Sung-Mo Kang, Yusuf Leblebici, TMH, 3rd Ed., 2011.
4. *Introduction to VLSI Systems: A Logic, Circuit and System Perspective*, Ming-BO Lin, CRC Press, 2011.

24EC710D - ELECTRONIC MATERIALS

Course Outcomes:

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

- **CO1:** Classify the atomic and electronic structure of solids, interpret diffraction data, and understand how crystal structure and defects influence the properties of materials.
- **CO2:** Analyze both theoretical and applied aspects of each topic, and solve complex problems in material science and condensed matter physics.
- **CO3:** Understand quantum mechanics and its applications to solid-state physics, particularly in the context of electron waves, energy bands, and quantum behavior in materials.
- **CO4:** Apply theoretical knowledge and practical skills to both research and industry contexts related to semiconductor and electronic materials.
- **CO5:** Understand the fundamental principles of semiconductors and the significance of junctions in electronic devices.

Unit 1: Introduction to Electronic Materials

Introduction, Structure and Diffraction, Defects, Electronic Structure, Introduction to structure of solids, Order, The Lattice, Lattice Geometry, Planar Spacing Formulas, Close Packing, The Wigner-Seitz Cell.

Unit 2: Structure of Solids

Phase Difference and Bragg's Law, The Scattering Problem, Coherent Scattering from an Electron, Coherent Scattering from an Atom, Coherent Scattering from a Unit Cell, Structure Factor Calculations, Reciprocal Space, RESP, Why Reciprocal Space?, Definition of RESP, Definition of Reciprocal Lattice Vector, The Ewald Construction, Point Defects, Line Defects—Dislocations, Edge Dislocations, Screw Dislocations, Burger's Vector and the Burger Circuit, Dislocation Motion, Planar Defects, Grain Boundaries, Twin Boundaries.

Unit 3: Electronic Structure of Solids

Introduction, Waves, Electrons, and the Wave Function, Representation of Waves, Matter Waves, Superposition, Electron Waves, Quantum Mechanics, Normalization, Dispersion of Electron Waves and the SE, Classical and QM Wave Equations, Solutions to the SE, Electron Energy Band Representations, Parallel Band Picture, k

Space Representations, Brillouin Zones, Real Energy Band Structures, Other Aspects of Electron Energy Band Structure.

Unit 4: Electronic Properties of Materials

Introduction, Occupation of Electronic States, Density of States Function, DOS, The Fermi-Dirac Distribution Function, Occupancy of Electronic States, Position of the Fermi Energy, Semiconductors, Intrinsic Semiconductors, Extrinsic Semiconductors, Semiconductor Measurements, Electrical Behavior of Organic Materials.

Unit 5: Junctions and Devices and the Nanoscale

Introduction, Junctions, Metal–Metal Junctions, Metal–Semiconductor Junctions, Semiconductor–Semiconductor PN Junctions, Selected Devices, Passive Devices, Active Devices, Nanostructures and Nanodevices, Heterojunction Nanostructures, 2-D and 3-D Nanostructures.

Textbooks:

1. Eugene A. Irene, *Electronic Materials Science*, Wiley.

References:

1. Anil K. Maini, Varsha Agrawal, *Electronic Devices and Circuits*, 2nd ed., Wiley.
2. Christopher Siu, *Electronic Devices, Circuits, and Applications*, Springer.
3. Ashish Bagwari and Geetam Singh Tomar, *Fundamentals of Electronic Devices and Circuits*, Springer.

24EC710E - MICROSTRIP COMPONENTS AND ANTENNAS

Course Outcomes:

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

- **CO1:** Comprehend the properties of microstrip transmission lines and components.
- **CO2:** Analyze the performance characteristics of low pass, high pass, band pass and band stop filters.
- **CO3:** Analyze various parameters of rectangular microstrip antennas.
- **CO4:** Understand the behavior of broadband microstrip antennas.
- **CO5:** Investigate the operational properties of loaded microstrip antennas.

Unit 1: MICROSTRIP TRANSMISSION LINES AND COMPONENTS

Microstrip Lines- Microstrip Structure, Waves in Microstrip, Quasi-TEM Approximation, Effective Dielectric Constant and Characteristic Impedance, Guided Wavelength, Propagation Constant, Phase, Velocity, and Electrical Length, Synthesis of W/h, Effect of Strip Thickness, Dispersion in Microstrip, Microstrip Losses, Effect of Enclosure, Surface Waves and Higher-Order Modes, Coupled Lines - Even- and Odd-Mode Capacitances, Even- and Odd-Mode Characteristic Impedances and Effective Dielectric Constants, More Accurate Design Equations. Discontinuities and Components - Microstrip Discontinuities, Microstrip Components, Loss Considerations for Microstrip Resonators, Other Types of Microstrip Lines.

Unit 2: LOW PASS AND BAND PASS FILTERS

Low pass Filters- Stepped-Impedance L-C Ladder Type Low pass Filters, L-C Ladder Type of Low pass Filters using Open-Circuited Stubs. Band pass Filters- End-Coupled, Half-Wavelength Resonator Filters, Parallel-Coupled, Half-Wavelength Resonator Filters, Hairpin-Line Band pass Filters, Interdigital Band pass Filters. High pass Filters- Quasi lumped High pass Filters, Optimum Distributed High pass Filters. Band stop Filters- Narrow-Band Band stop Filters, Band stop Filters with Open-Circuited Stubs, Optimum Bandstop Filters, Bandstop Filters for RF Chokes.

Unit 3: MICROSTRIP RADIATORS

Review of various Microstrip antenna configurations, Feeding techniques and modelling, Radiation fields, Surface waves.

ANALYTICAL MODELS FOR MICROSTRIP ANTENNAS: Introduction, Transmission line model, Cavity model, generalized cavity model, multiport network model.

Unit 4: RECTANGULAR MICROSTRIP ANTENNAS

Introduction, Models for Rectangular patch antennas, Design considerations of rectangular patch antennas.
ANALYTICAL MODELS FOR MICROSTRIP ANTENNAS: Introduction, Transmission line model, Cavity model, generalized cavity model, multiport network model.

Unit 5: LOADED MICROSTRIP ANTENNAS & APPLICATIONS

Introduction, Polarization diversity using microstrip antennas, Frequency agile microstrip antennas, Radiation pattern control of microstrip antennas, loading effect of short, compact patch antennas.

Textbooks:

1. *Microstrip Filters for RF / Microwave Applications*, JIA-Sheng Hong, M.J. Lancaster, John Wiley & Sons, 2001. (Unit I and II).
2. *Microstrip Antenna Design Hand Book*, Ramesh Garg, Prakash Bhartia, Inder Bahl, Apisak Ittipiboon, Artech House, 2001. (Unit III, IV & V).

Reference Books:

1. Prakash Bhartia and Inder Bahl, *Microstrip Antennas*, Artech House.
2. Girish Kumar, K.P. Ray, *Broad Band Microstrip Antennas*, Artech House, 2003.
3. Charles A. Lee & G. Conrod Delman, *Microwave Devices Circuits and their Applications*, John Wiley & Sons.
4. Kin-Lu Wong, *Compact Broad Band Microstrip Antennas*, John Wiley & Sons, 2002.

24EC710F - RF AND MICROWAVE CIRCUIT DESIGN

Course Outcomes:

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

- **CO1:** Demonstrate on the RF design concept and impart knowledge on design and implementation of high frequency Transceiver system.
- **CO2:** Analyze various filter design types for RF communication system architecture.
- **CO3:** Analyze the characteristics of amplifiers used for RF design.
- **CO4:** Analyze the structure, characteristics, operation and other important aspects of microwave solid state active devices.
- **CO5:** Demonstrate on the MMIC, their applications, advantages, various fabrication techniques, encapsulation and mounting of active devices.

Unit 1:

Importance of RF Design,Dimension and Units, Frequency Spectrum, RF Behavior of Passive Components: High Frequency Resistors, High-Frequency Capacitors and High-Frequency Inductors. Chip Components and Circuit Board Considerations: Chip Resistors, Chip Capacitors and Surface-Mounted Inductors.

Unit 2:

A Brief Overview of RF Filter: Filter Types and Parameters, Low-Pass Filter, High-Pass Filter, Bandpass and Band stop Filters, Insertion Loss, Butterworth-Type, Chebyshev and Denormalization of Standard Low-Pass Design. Filter Implementations: Unit Elements, Kuroda's Identities and Examples of Microstrip Filter Design. Coupled Filter: Odd and Even Mode Excitation, Bandpass Filter Section, Cascading Bandpass Filter Elements, Design Examples.

Unit 3:

Characteristics of Amplifier. Amplifier Power Relations: RF Source, Transducer Power gain and Additional Power Relations. Stability Considerations: Stability Circles, Unconditional Stability and Stabilization Methods. Constant Gain: Unilateral Design, Unilateral Figure of Merit, Bilateral Design and Power Gain Circles. Noise Figure Circles. Constant VSWR Circles. Broadband, High-Power and Multistage Amplifiers.

Unit 4:

Semiconductor Basics:Physical Properties of Semiconductors, PN Junction and Schottky Contact. RF Diodes: Schottky, PIN, Varactor, IMPATT, Tunnel, TRAPATT, BARRITT and Gunn Diodes. Bipolar Junction, RF Field Effect and High Electron Mobility Transistors: Construction, Functionality, Frequency Response, Temperature Behavior and Limiting Values.

Unit 5:

Introduction Materials: Substrate Materials, Conductor Materials, Dielectric Materials and Resistive Materials. Monolithic Microwave Integrated Circuits (MMICs) and their advantages over discrete circuits. Monolithic Microwave Integrated Circuit Growth: MMIC Fabrication Techniques and Fabrication Examples. MOSFET Fabrication: MOSFET Formation, NMOS Growth, CMOS Development and Memory Construction. Thin-Film Formation: Planar Resistor Film, Planar Inductor Film and Planar Capacitor Film. Hybrid Integrated Circuit Fabrication.

Textbooks:

1. *RF Circuit Design: Theory & Applications*, Pearson, 2nd Edition, 2009 by Reinhold Ludwig and Gene Bogdanov. (Unit I-IV).
2. *Microwave Devices & Circuits*, Pearson, 3rd Edition, 2003 by Samuel Y. Liao. (Unit V).

Reference Books:

1. *Microwave Integrated Circuits*, Wiley by K. C. Gupta and Amarjit Singh. (For Unit 5).

24EC710G - DETECTION AND ESTIMATION THEORY

Course Outcomes:

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

- **CO1:** Understand the foundational concepts of unbiased estimation and learn to calculate the Cramer-Rao bound for various signal processing scenarios.
- **CO2:** Apply linear modeling techniques to estimate parameters and determine minimum variance unbiased estimators for practical applications.
- **CO3:** Analyze and apply unbiased and maximum likelihood estimation methods for parameter estimation in signal processing tasks.
- **CO4:** Develop expertise in Bayesian estimation methods and statistical decision-making techniques, applying them effectively in hypothesis testing scenarios.
- **CO5:** Understand and apply matched and energy detectors for signal detection in noisy environments, evaluating performance in practical scenarios.

Unit I: Fundamentals of Estimation Theory

Minimum variance unbiased estimation: minimum variance criterion, existence of minimum variance unbiased estimator, generalization to vector parameters. Cramer-Rao lower bound: scalar parameters, signal in white Gaussian noise, vector parameters.

Unit II: Advanced Estimation Techniques

Linear models: definition and properties, curve fitting; Fourier analysis; system identification; general linear models. General minimum variance unbiased estimation: sufficient statistic; finding minimum variance unbiased estimators; complete statistics; generalizations.

Unit III: Unbiased and Likelihood-Based Estimators

Best linear unbiased estimators: definition, finding the BLUE, example of source localization, generalization to vector parameters. Maximum likelihood estimators: definition, finding the MLE, properties, transformed parameters, vector parameters.

Unit IV: Bayesian Estimation and Statistical Decision Theory

Bayesian estimators: priors; posteriors, linear models, MAP estimator. Basics of statistical decision theory: simple hypothesis testing, Neyman-Pearson detectors, minimum Bayes risk detectors, receiver operating characteristics.

Unit V: Signal Detection Techniques in Noise

Detection of known signals in noise: matched filter, performance of matched filter, generalized matched filter, minimum distance detector. Detection of random signals: energy detector, estimator-correlator, canonical form of detector, performance analysis, examples from communications, radar/sonar, and pattern recognition.

Textbooks:

1. H. Vincent Poor, *An Introduction to Signal Detection and Estimation*, Springer, 1994.
2. Steven M. Kay, *Fundamentals of Statistical Signal Processing: Detection Theory*, Prentice Hall, 1998.

Reference Books:

1. Harry L. Van Trees, *Detection, Estimation, and Modulation Theory, Part I*, Wiley, 1968.
2. Louis L. Scharf, *Statistical Signal Processing: Detection, Estimation, and Time Series Analysis*, Addison-Wesley, 1991.

24EC710H - MATHEMATICS FOR MACHINE LEARNING

Course Outcomes:

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

- **CO1:** Understand the foundational concepts of learning theory, convexity, and formulate optimization problems relevant to machine learning.
- **CO2:** Apply gradient descent methods and regularization techniques to enhance model performance, particularly in medical data applications.
- **CO3:** Utilize accelerated optimization techniques and regression models for effective predictive modeling and classification tasks.
- **CO4:** Perform maximum likelihood estimation in various statistical models and utilize dimensionality reduction to optimize feature space.
- **CO5:** Analyze complex machine learning models, including Bayesian learning, and apply clustering and inference techniques for model selection and decision-making.

Unit I:

Introduction to Learning Theory and Optimization Basics:
Introduction to Theory of Learning: meaning of learning, overfitting; Convex functions and sets; Convex Optimization; Optimization problem formulations.

Unit II:

Gradient Descent Methods and Regularization Techniques:
Gradient and Sub-gradient descent for non-smooth functions; Regularization; Lasso and Ridge; Applications with medical data.

Unit III:

Advanced Optimization Techniques and Regression Models:
Accelerating Gradient Descent; Stochastic Gradient Descent and its applications (NN); Support Vector Regression; Logistic Regression for dichotomous variables.

Unit IV:

Maximum Likelihood Estimation and Dimensionality Reduction:
Maximum likelihood estimation (MLE) in Binomial, Multinomial, Gaussian models in exponential family; Dimensionality reduction techniques.

Unit V:

Advanced Machine Learning Concepts:
Dynamical systems and control; Fourier transform and its applications; Expectation Maximization (EM) based learning in Mixture models, Hidden Markov Model, Dirichlet processes (Clustering); Bayesian Machine Learning, estimating decisions using posterior distributions.

Textbooks and Reference Books

1. Jeeva Jose, *Introduction to Machine Learning*, Khanna Book Publishing, 2020.
2. Gilbert Strang, *Linear Algebra and Learning from Data*, Wellesley Cambridge Press, 2019.
3. Kevin P. Murphy, *Machine Learning: A Probabilistic Perspective*, MIT Press, 2021 edition.
4. Deisenroth MP, Faisal AA, Ong CS, *Mathematics for Machine Learning*, Cambridge University Press, 2020.

24EC710I - IMAGE PROCESSING AND COMPUTER VISION

Course Outcomes:

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

- **CO1:** Understand the fundamentals concepts of image processing and computer vision.
- **CO2:** Improve the quality of images in Spatial and Frequency domain by using various Image Enhancement and Restoration techniques.
- **CO3:** Develop Image Segmentation and morphological methods to solve different societal problems.
- **CO4:** Learn and understand various image transforms used in digital image processing.

Unit I:

Introduction to Image Processing and Computer Vision: Fundamental Steps in Digital Image Processing, Components of an Image Processing System, Image formation: Pinhole Perspective, Weak Perspective, Cameras with Lenses, Human eye, light and electromagnetic spectrum, image sensing and acquisition, sampling and quantization, basic relationships between pixels, linear and non linear operations. Color Image Processing: Color Fundamentals, Color models, color transformation, smoothing, sharpening, color segmentation, and noise in color images.

Unit II:

Image Enhancement:Background, Basic Intensity Transformation Functions, Histogram Processing, Fundamentals of Spatial Filtering, Smoothing Spatial Filters, Sharpening Spatial Filters. Image Enhancement in Frequency Domain: Basics of Filtering in the Frequency Domain, Image Smoothing using Frequency Domain Filters, Image Sharpening Using Frequency Domain Filters, Homomorphic Filtering. Image Restoration: A Model of the Image Degradation/Restoration Process, Noise Models, Restoration in the presence of Noise only - Spatial Filtering, Linear Position-Invariant Degradations, Inverse filtering, Minimum Mean Square Error (Wiener) Filtering, Constrained Least Squares Filtering.

Unit III:

Image Segmentation: Detection of discontinuities, edge linking and boundary detection, thresholding, region based segmentation, segmentation by morphological watersheds. Representation and description: Representation, boundary descriptors, regional descriptors.

Unit IV:

Morphological Image Processing: Dilation and erosion, opening and closing, basic morphological algorithms: boundary extraction, region filling, extraction of connected components, convex hull, thinning, thickening, skeletons, pruning. Applications of computer vision: Artificial Neural Network for Pattern Classification, Convolutional Neural Networks, Autoencoders.

Unit V:

Image Transforms: 2D-DFT, DCT, Hadamard, Walsh, slant, KLT, Haar transform and discrete wavelet transform.

Textbooks:

1. Gonzalez and Wood, *Digital Image Processing*, 3rd Edition, Pearson Education, 2009.
2. M.K. Bhuyan, *Computer Vision and Image Processing: Fundamentals and Applications*, CRC Press, USA, ISBN 9780815370840 - CAT K338147.

Reference Books:

1. S. Jayaraman, S. Esakkirajan, T. Veerakumar, *Digital Image Processing*, 3rd Edition, Tata McGraw Hill Education Private Limited, 2009.
2. Forsyth & Ponce, *Computer Vision-A Modern Approach*, Pearson Education.

24EC710J - FUNDAMENTALS OF WAVELETS, FILTER BANKS AND TIME FREQUENCY ANALYSIS

Course Outcomes:

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

- **CO1:** Analyse and apply time-frequency analysis techniques to interpret time-frequency representations for signal processing.
- **CO2:** Apply multiresolution analysis principles to map functions into multiresolution spaces.
- **CO3:** Implement DWT and filter bank algorithms for efficient signal decomposition and reconstruction.
- **CO4:** Apply Ensemble Empirical Mode Decomposition (EEMD) for multidimensional signal analysis in complex data sets.
- **CO5:** Use advanced digital signal processing techniques for applications in fault detection, image processing, and communication systems.

Unit I:

Time-Frequency Analysis: Window Function, Short-Time Fourier Transform, Discrete Short-Time Fourier Transform, Discrete Gabor Representation, Continuous Wavelet Transform, Discrete Wavelet Transform, Wavelet Series, Interpretations of the Time-Frequency Plot, Wigner-Ville Distribution, Properties of Wigner-Ville Distribution, Quadratic Superposition Principle, Ambiguity Function.

Unit II:

Multiresolution Analysis: Multiresolution Spaces, Orthogonal, Biorthogonal, and Semiorthogonal Decomposition, Two-Scale Relations, Decomposition Relation, Spline Functions and Properties, Mapping a Function into MRA Space.

Unit III:

DWT and Filter Bank Algorithms: Decimation and Interpolation, Signal Representation in the Approximation Subspace, Wavelet Decomposition Algorithm, Reconstruction Algorithm, Change of Bases, Signal Reconstruction in Semiorthogonal Subspaces, Two-Channel Perfect Reconstruction Filter Bank, Polyphase Representation for Filter Banks, Comments on DWT and PR Filter Bank.

Unit IV:

Ensemble Empirical Mode Decomposition:Introduction, The empirical mode decomposition, The ensemble empirical mode decomposition, The multi-dimensional ensemble empirical mode decomposition, Multivariate extensions of EMD, Mode-alignment property of MEMD, Filter bank property of MEMD and noise-assisted MEMD, Applications.

Unit V:

Digital Signal Processing Applications: Wavelet Packet, Wavelet-Packet Algorithms, Thresholding, Interference Suppression, Faulty Bearing Signature Identification, Edge Detection, Multicarrier Communication Systems, Three-Dimensional Medical Image Visualization.

Textbooks:

1. Jaideva C. Goswami, Andrew K. Chan, *Fundamentals of Wavelets: Theory, Algorithms, and Applications*, Wiley publications, 2010.
2. Norden E Huang, Samuel S P Shen, *Hilbert–Huang Transform and Its Applications*, World Scientific Publishing Co. Pvt. Ltd. 2014.

POOL II — COURSES SYLLABUS

24EC720A: Low Power VLSI Design

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

CO1: Apply different circuit techniques to manage the leakage currents.

CO2: Comprehend and analyze various low power adder and multiplier architectures.

CO3: Understand the architectural and circuit-level techniques for attaining low power ROM.

CO4: Design and analyze the different types of low power SRAM and DRAM circuits.

CO5: Decide at which level of abstraction is advantageous to implement low power.

Unit I:

Low power CMOS VLSI design: Introduction, sources of power dissipation, static power dissipation, active power dissipation.
Circuit techniques for low power design: Introduction, designing for low power, circuit techniques for leakage power reduction.

Unit II:

Low voltage low power adders: Introduction, standard adder cells, CMOS adder architectures, low voltage low power design techniques, current mode adders.
Low voltage low power multipliers: Introduction, overview of multiplication, types of multiplier architectures, Braun multiplier, Booth multiplier, Wallace tree multiplier.

Unit III:

Low-Voltage Low Power Read-Only Memories: Introduction, types of ROM, basic physics of floating gate non-volatile devices, floating gate memories, basics of ROM, low power ROM Technology.

Unit IV:

Low voltage low power static RAM: Basics of SRAM, memory cell, precharge and equalization circuit, address transition detection, sense amplifier, output latch, low power SRAM technologies.
Low voltage low power dynamic RAM: Types of DRAM, basics of DRAM, self-refresh circuit, half voltage generator, voltage down converter, future trends and developments of DRAM.

Unit V:

Architectural Techniques for Low Power: Parameters affecting power dissipation, Variable frequency, Dynamic voltage scaling, Dynamic voltage and frequency scaling, Reduced V_{DD}, Architectural clock gating, Power gating, Multi-voltage, Optimizing memory power.
Low Power Implementation Techniques: Library selection, Clock gating, Timing impact due to clock gating, Gate-level power optimization techniques, Power optimization for sleep mode.

Textbooks:

1. Kiat Seng Yeo, Kaushik Roy (2012), "Low Voltage, Low Power VLSI Subsystems", Tata McGraw-Hill.
2. Soudris D, Piguet C and Goutis C, "Designing CMOS Circuits for Low Power", Kluwer Academic Publishers, 2002.

0.1 Reference Books:

1. Yeo, Rofail, Gohl (2009), "CMOS/BiCMOS ULSI Low Voltage, Low Power", Pearson Education Asia, 1st Indian reprint.
2. Anantha P. Chandrakasan, Robert W. Brodersen, "Low Power Digital CMOS Design", Springer Science.
3. Jan M. Rabaey, Anantha P. Chandrakasan, Borivoje Nikolic, (2011), "Digital Integrated Circuits: a Design Perspective", Pearson Education, 2nd Edition.

24EC720B: Analog & Mixed Signal Design

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

CO1: Design CMOS single-stage amplifiers and current mirrors.

CO2: Design CMOS operational amplifiers to meet specific performance requirements.

CO3: Design feedback amplifiers, oscillators, and PLLs for practical analog and mixed-signal applications.

CO4: Design switched-capacitor circuits.

CO5: Implement advanced layout techniques for optimal analog and mixed-signal performance.

Unit I:

Single Stage Amplifiers and Current Mirrors: Common source, common gate, and source follower stages, Cascode and folded cascade structures, Frequency response, MOS current mirrors-sources.

Unit II:

MOS Differential Amplifiers and Operational Amplifiers: Single-ended and differential operation, Basic differential pair, Common mode response, Frequency response, CMOS operational amplifiers, One-stage op-amps and two-stage op-amps.

Unit III:

Feedback Amplifiers: General considerations, Feedback topologies.
Oscillators and PLLs: General considerations, Ring oscillators, LC oscillators, Voltage-controlled oscillators, Basics of PLLs.

Unit IV:

Switched-Capacitor Circuits: Sampling switches, Switched-capacitor amplifiers, Switched-capacitor integrators.

Unit V:

Layout Design: General layout considerations, Analog layout techniques, Substrate coupling.

Textbooks:

1. Behzad Razavi (2002), "Design of Analog CMOS Integrated Circuits", Tata McGraw-Hill.

2. Philip Allen & Douglas Holberg (2002), "CMOS Analog Circuit Design", Oxford University Press.

Reference Books:

1. David A. Johns & Ken Martin (2001), "Analog Integrated Circuit Design", John Wiley and Sons.

2. "CMOS Analog VLSI Design" by Prof. A.N. Chandorkar, Department of Electronics & Communication Engineering, IIT Bombay. For more details on NPTEL visit `http://nptel.ac.in`.

24EC720C: VLSI Signal Processing

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

CO1: Apply pipelining and parallel processing techniques to the design of FIR digital filters and low-power systems.

CO2: Solve systems of inequalities related to retiming and apply retiming techniques to optimize digital systems.

CO3: Apply folding transformations and register minimization techniques in digital system design, particularly in multirate systems.

CO4: Develop and design systolic architectures for FIR filters and matrix multiplication, effectively selecting scheduling vectors and handling space representations with delays.

CO5: Implement and design fast convolution algorithms, understand the principles behind Cook-Toom, Winograd, and other iterative cyclic convolution methods to create efficient convolution systems.

Unit I:

Pipelining and Parallel Processing: Introduction, Pipelining of FIR digital filters, Parallel processing, Pipelining and Parallel Processing for low power.

Unit II:

Retiming: Introduction, Definition and Properties, Solving System of Inequalities, Retiming Techniques.

Unit III:

Unfolding & Folding: Introduction to Algorithms for Unfolding, Properties of Unfolding, Critical Path, Unfolding and Retiming, Application of Unfolding, Introduction to Folding Transformation, Register Minimization Techniques, Register Minimization Technique in Folded Architectures, Folding in Multirate Systems.

Unit IV:

Systolic Architecture Design: Introduction, Systolic Array Design Methodology, FIR Systolic Arrays, Selection of Scheduling Vector, Matrix Multiplication, 2D Systolic Array Design, Systolic Design for Space Representations Containing Delays.

Unit V:

Fast Convolution: Introduction, Cook-Toom Algorithm, Winograd Algorithm, Iterated Convolution, Cyclic Convolution, Design of Fast Convolution.

Textbooks:

1. Keshab K. Parhi, "VLSI Digital Signal Processing Systems", Wiley-InterSciences, 1999.

References:

1. Kung S.Y., H.J. Whitehouse, T. Kailath, "VLSI and Modern Signal Processing", Prentice Hall, 1985.
2. Jose E. France, Yannis Tsividis, "Design of Analog Digital VLSI Circuits for Telecommunications and Signal Processing", Prentice Hall, 1994.

24EC720D
Materials Design for Electronic, Electromechanical, and Optical Functions

Course Outcomes

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

- CO1: Understanding and analyzing crystal structures.
- CO2: Comprehend and analyze the physical basis of band gaps, and the electronic structure of materials.
- CO3: Analyze semiconductor materials and devices, understanding doping and carrier dynamics.
- CO4: Evaluate the behavior of electrons in different material phases and interactions with phonons and electromagnetic waves.
- CO5: Analyze the optical interactions in materials, ability to interpret spectroscopic data, and knowledge of exciton dynamics.

Unit I: Crystal Structure

Periodic Array of Atoms, Lattice Translation Vectors, Basis and the Crystal Structure, Primitive Lattice Cell, Fundamental Types of Lattices, Two-Dimensional and Three-Dimensional Lattice Types, Index Systems for Crystal Planes, Simple Crystal Structures, Sodium Chloride Structure, Cesium Chloride Structure, Hexagonal Close-Packed Structure (hcp), Diamond Structure, Cubic Zinc Sulfide Structure, Direct Imaging of Atomic Structure, Non-ideal Crystal Structures, Random Stacking and Polytypism, the Concept of Brillouin Zone.

Unit II: Energy Bands

Nearly Free Electron Model, Origin of the Energy Gap, Magnitude of the Energy Gap, Bloch Functions, Kronig-Penney Model, Wave Equation of Electron in a Periodic Potential, Restatement of the Bloch Theorem, Crystal Momentum of an Electron, Solution of the Central Equation, Kronig-Penney Model in Reciprocal Space, Empty Lattice Approximation, Approximate Solution Near a Zone Boundary, Number of Orbitals in a Band, Metals, and Insulators.

Unit III: Semiconductor Crystals

Band Gap, Equations of Motion, Physical Derivation of Holes, Effective Mass, Physical Interpretation of the Effective Mass, Effective Masses in Semiconductors, Silicon and Germanium, Intrinsic Carrier Concentration, Intrinsic Mobility, Impurity

Conductivity, Donor States, Acceptor States, Thermal Ionization of Donors and Acceptors, Thermoelectric Effects, Semimetals, Superlattices, Bloch Oscillator, Zener Tunneling.

Unit IV: Plasmons, Polaritons, and Polarons

Dielectric Function of the Electron Gas, Definitions of the Dielectric Function, Plasma Optics, Dispersion Relation for Electromagnetic Waves, Transverse Optical Modes in a Plasma, Transparency of Metals in the Ultraviolet, Longitudinal Plasma Oscillations, Plasmons, Electrostatic Screening, Screened Coulomb Potential, Pseudopotential Component $U(0)$, Mott Metal-Insulator Transition, Screening and Phonons in Metals, Polaritons, LST Relation, Electron-Electron Interaction, Fermi Liquid, Electron-Electron Collisions, Electron-Phonon Interaction: Polarons, Peierls Instability of Linear Metals.

Unit V: Optical Processes and Excitons

Optical Reflectance, Kramers-Kronig Relations, Mathematical Example: Conductivity of Collisionless Electron Gas, Electronic Interband Transitions, Excitons, Frenkel Excitons, Alkali Halides, Molecular Crystals, Weakly Bound (Mott-Wannier) Excitons, Exciton Condensation into Electron-Hole Drops (EHD), Raman Effects in Crystals, Electron Spectroscopy with X-Rays, Energy Loss of Fast Particles in a Solid.

Textbooks

1. Solid State Physics by Charles Kittel: John Wiley and Sons.

Reference Books

1. Physical Properties of Crystals by J.F. Nye: Oxford Science Publications.
2. Electronic Properties of Engineering Materials by James D. Livingstone.
3. Solid State Physics by Ashcroft and Mermin.

24EC720E
Antennas for Wireless Communication

Course Outcomes

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

- CO1: Analyze the concepts of smart antennas for various means of beamforming.
- CO2: Evaluate the antennas required in different mobile communication and intelligent transportation systems such as Cars.
- CO3: Demonstrate the different types of Land Mobile Antenna Systems for Pagers and Portable Phones with safety aspects.
- CO4: Analyze various types of antennas used in Aeronautical Mobile Communication Systems.
- CO5: Evaluate the antennas required in Aeronautical Mobile Satellite Systems.

Unit I:

Introduction to Smart antennas: Spatial Processing for Wireless Systems: Key benefits of Smart Antenna Technology, Introduction to Smart antenna technology, The vector Channel Impulse Response and the Spectral Signature, Spectral Processing Receivers, Fixed Beamforming Networks, Switched beam Systems, Adaptive antenna Systems, Wideband Smart Antennas.

Unit II:

Land Mobile Antenna Systems-Basic Techniques and Application: Antennas, Propagation Problems, Base station antenna Techniques, Mobile Station Antenna Techniques, Development in Mobile Phone Antenna Car Installations. Land Mobile Antenna Systems for Cars: Antenna Systems for Broadcast Reception in Cars, Antenna Systems for TV Reception in Cars.

Unit III:

Land Mobile Antenna Systems for Pagers, Portable Phones and Safety: Practical Requirements and Constraints on Pager Antenna Design, Pager type and Performance, Design Techniques for Portable Phone Antennas, Portable Phone Antenna Systems.

Unit IV:

Antennas for Mobile satellite systems: Introduction, system requirements for vehicle antennas, Omnidirectional Antennas for mobile satellite communications, Directional antennas for mobile satellite communications, Antenna system for GPS, Antenna system for satellite broadcasting.

Unit V:

Antenna Systems for Aeronautical Mobile Communications: Propagation Problems, General Requirements and Remarks, Current Airborne Antennas, Advanced Circularly Polarized Antennas

Textbooks

1. Joseph C. Liberti & Theodore S. Rappaport, "Smart Antennas for Wireless Communication," Prentice Hall Communication Engineering Series, 1999.

2. K. Fujimoto & J.R. James, "Mobile Antenna Systems Handbook," IInd Edition, Artech House, 2001.

Reference Books

1. Kin-Lu Wang, "Planar Antenna for Wireless Communications," John-Wiley, 2002.

2. Girish Kumar & K.P. Ray, "Broadband Microstrip Antenna," Artech House, Boston, London, 2003.

3. J. Bhal & P. Bhartia, "Microstrip Antennas," Artech House, Dedham, 1980.

4. Balanis A., "Antenna Theory Analysis and Design," John Wiley and Sons, New York, 2000.

24EC720F
Radiating Millimeter Wave Circuits

Course Outcomes

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

- CO1: Analyze the mechanisms of electromagnetic radiation arising from surface and line currents on radiating structures.
- CO2: Analyze the radiation characteristics of rectangular and circular aperture antennas, including their beamwidth and directivity.
- CO3: Apply optimization techniques to improve the radiation patterns of antenna arrays for desired performance characteristics.
- CO4: Understand the principles and setup of antenna ranges for effective testing and evaluation of antenna performance.
- CO5: Analyze and design micro-strip lines, understand discontinuities, parallel coupled lines, power dividers, directional couplers, and millimeter-wave integrated circuits.

Unit I: Basic Components of Radiation

Radiation from surface current and line current distribution, Basic antenna parameters, Radiation mechanism-Current distribution of Antennas, Impedance concept-Balanced to Unbalanced transformer.

Unit II: Radiation from Apertures

Field equivalence principle, Rectangular and circular apertures, Uniform distribution on an infinite ground plane, Aperture fields of Horn antenna-Babinet's principle, Geometrical theory of diffraction, Reflector antennas, and Design considerations - Slot antennas.

Unit III: Synthesis of Array Antennas

Types of linear arrays, Current distribution in linear arrays, Phased arrays, Optimization of Array patterns, Continuous aperture sources, Antenna synthesis techniques.

Unit IV: EMI/EMC/Antenna Measurements

Log periodic, Bi-conical, Log spiral ridge Guide, Multi-turn loop, Traveling Wave antenna, Antenna measurement and instrumentation, Amplitude and Phase measurement, Gain, Directivity, Impedance and Polarization measurement, Antenna range, Design and Evaluation.

Unit V: Millimeter Wave Circuits

Wave Propagation in micro-strip lines, Discontinuities in Micro-strips, Parallel Coupled lines, Power Dividers and Directional Couplers, Millimeter Wave Integrated Circuits.

Textbooks

1. Balanis A., "Antenna Theory Analysis and Design," John Wiley and Sons, New York, 1982.
2. Roger F. Harrington, "Time-Harmonic Electromagnetic Fields," McGraw-Hill.

Reference Books

1. Peter Kinget, "RF System Design," Bell Laboratories, Lucent Technologies Murray Hill.
2. "Practical RF System Design," Wiley-IEEE, 2003.
3. Cam Nguyun, "Analysis Methods for RF, Microwave, and Millimeter-Wave Planar Transmission Line Structures."

24EC720G
Modern Wireless Communications

Course Outcomes

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

- CO1: Identify the evolution and basic principles of wireless communication and cellular concepts, including frequency reuse.
- CO2: Analyze cellular design strategies to optimize coverage and capacity, assessing their impact on quality of service.
- CO3: Examine the propagation models and evaluate multipath effects on wireless signals in different environments.
- CO4: Apply equalization and diversity techniques and examine error correction methods to enhance wireless communication reliability.
- CO5: Differentiate among multiple access techniques and recognize their applications in wireless.

Unit I: Introduction to Wireless Communication Systems

Introduction, Evolution of wireless communication systems, Examples of wireless communication systems, The Cellular Concept - System Design Fundamentals, Concept of Frequency Reuse, Channel Assignment Strategies.

Unit II: Cellular System Design and Capacity Enhancement

Handoff Strategies, Interference and system capacity, Trunking and Grade of Service, Improving Coverage and Capacity in Cellular Systems.

Unit III: Propagation Models and Multipath Effects

Free space propagation model, Two-ray ground reflection model, Distance power loss, Macro-cell propagation model, Micro-cell propagation model, Shadowing model, Multipath effects in mobile communication, Models of multipath reception.

Unit IV: Equalization, Diversity, and Channel Coding

Fundamentals of Equalization, Adaptive Equalizers, Linear and Nonlinear Equalization, Algorithms for adaptive equalization, Diversity Techniques, Fundamentals of channel coding, Overview of error detection and correction codes.

Unit V: Multiple Access Techniques and Wireless Standards

Introduction to multiple access, Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Spread Spectrum Multiple Access, Space Division Multiple Access (SDMA), Orthogonal Frequency Division Multiple Access (OFDMA), MIMO, NOMA, Wireless systems and standards.

Textbooks

1. Wireless Communications: Principles and Practice by Theodore, S. Rappaport, Pearson/PHI publication.

Reference Books

1. Wireless Communications and Networks: 3G and Beyond by Iti Saha Misra, Tata McGraw-Hill publication.
2. Mobile Cellular Telecommunications: Analog and Digital Systems by William C.Y. Lee, Tata McGraw-Hill publication.
3. Heath Jr. R.W., Lozano A., Foundations of MIMO Communication, Cambridge University Press, 2018.
4. Liang W., Ding Z., Poor H.V., Non-Orthogonal Multiple Access (NOMA) for 5G Systems, Cambridge University Press, 2017.
5. Wireless and Digital Communications by Dr. Kamilo Feher, PHI publication.

24EC720H
5G Communications

Course Outcomes

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

- CO1: Understand the evolution of mobile communication systems and the key features of 5G technology.
- CO2: Analyze the principles of advanced waveform design and multiple access techniques for 5G.
- CO3: Understand the 5G architecture, including the 5G NR and 5GCN components.
- CO4: Analyze the performance of massive MIMO systems in terms of capacity, coverage, and energy efficiency.
- CO5: Understand the principles and applications of V2X communications in 5G networks.

Unit I: Overview of 5G Wireless Communications

Evolution of mobile technologies (1G-5G), 3GPP Releases & its key aspects, Overview of 5G, Three high-level 5G usage scenarios (eMBB, URLLC, mMTC), Key capabilities & requirements, 5G vs. LTE-A Comparison, 5G frequency bands, 5G Use cases.

Unit II: Waveform Design for 5G & Beyond

Introduction - 5G Waveform Design and Waveform Requirements, Flexible OFDM comparison with CP-OFDM, Generalized Frequency Division Multiplexing (GFDM), Filter Bank Multicarriers (FBMC) and Universal Filtered Multi-Carrier (UFMC), Multiple Access Techniques – Non-Orthogonal Multiple Accesses (NOMA), Sparse Code Multiple Access (SCMA), Comparison of multiple access methods.

Unit III: 5G Architecture

Introduction, 5G Architecture Framework, 3GPP 5G Architecture, Non-Roaming 5G System Architecture, Overall RAN Architecture, Functional Split Between NG-RAN and 5G Core Network, 5G NextGen Core Network: Modern network requirements, SDN Architecture, NFV Benefits and Requirements, NFV Reference Architecture, Network Slicing Concepts & Requirements.

Unit IV: Massive Multiple-Input Multiple-Output (MIMO) Systems

Introduction to Multi-Antenna Systems, Theoretical Background: MIMO Requirements, MIMO vs. Massive MIMO, Massive MIMO Benefits, Single User and Multi-User MIMO, Capacity of MIMO for Unknown CSIT, Massive MIMO Capacity, Massive MIMO OFDM Transmitter Employing Digital Precoding, Analog Beamforming, and Hybrid of Digital Precoding and Analog Beamforming.

Unit V: V2X Communications

Vehicle-to-Vehicle (V2V) Communications, Vehicle-to-Infrastructure (V2I) Communications, Vehicle-to-Pedestrian (V2P) Communication, Self-Driving Vehicles & its Challenges, Vehicle-to-Network (V2N) Communications.

Textbooks

1. Saad Z. Asif, “5G Mobile Communications Concepts and Technologies,” CRC Press, 2019.

2. Suvra Sekhar Das and Ramjee Prasad, “Evolution of Air Interface Towards 5G: Radio Access Technology and Performance Analysis,” River Publishers Series in Communication, 2018.

3. Wei Xiang, Kan Zheng, Xuemin (Sherman) Shen, “5G Mobile Communications,” Springer Publications, 2016.

4. William Stallings, “5G Wireless: A Comprehensive Introduction,” Pearson Education, 2021.

5. Afif Osseiran, Jose F. Monserrat, Patrick Marsch, “5G Mobile and Wireless Communications Technology,” Cambridge University Press, 2016.

24EC720I
Deep Learning

Course Outcomes

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

- CO1: Understand the Machine Learning concepts.
- CO2: Design various Deep Learning architectures, selecting appropriate regularization methods.
- CO3: Develop and optimize CNN models, Recurrent and Recursive Nets for computer vision applications.
- CO4: Apply the Deep Learning algorithms to a real-world problem.

Unit I: Fundamental Concepts of Machine Learning

Machine Learning Basics: Learning Algorithms, Capacity, Overfitting and Underfitting, Estimators, Bias, Variance, Hyperparameters and Validation Sets, Maximum Likelihood Estimation, Bayesian Statistics, Supervised Learning Algorithms, Unsupervised Learning Algorithms, Stochastic Gradient Descent, Building a Machine Learning Algorithm, Challenges Motivating Deep Learning. (12 Hrs)

Unit II: Deep Feed Forward Networks

Introduction, Learning XOR, Gradient-Based Learning, Hidden Units, Architecture Design, Back-Propagation and Other Differentiation Algorithms. Regularization for Deep Learning - Parameter Norm Penalties, Dataset Augmentation, Bagging and Other Ensemble Methods, Early Stopping, Dropout. (12 Hrs)

Unit III: Convolutional Neural Networks

Convolutional Operation, Motivation, Pooling, Convolution and Pooling as an Infinitely Strong Prior, Variants of the Basic Convolution Function, Structured Outputs, Data Types, Efficient Convolution Algorithms, Random or Unsupervised Features, The Neuroscientific Basis for Convolutional Networks. (12 Hrs)

Unit IV: Sequence Modeling - Recurrent and Recursive Nets

Unfolding Computational Graphs, Recurrent Neural Networks, Bidirectional RNNs, Encoder-Decoder Sequence-to-Sequence Architectures, Deep Recurrent Networks, Recursive Neural Networks - The Challenge of Long-Term Dependencies, The Long Short-Term Memory and Other Gated RNNs, Optimization for Deep Learning - Optimizer, RMSProp for RNNs, SGD for CNNs. (12 Hrs)

Unit V: Deep Architectures in Vision

Deep Architectures in Vision - AlexNet to ResNet, Transfer Learning, Siamese Networks, RCNNs, CNN-RNN, Applications in Captioning and Video Tasks, 3D CNNs. (12 Hrs)

Textbook

1. Ian Goodfellow, Yoshua Bengio, Aaron Courville, "Deep Learning", MIT Press, 2016. http://www.deeplearningbook.org

References

1. Kevin P. Murphy, "Machine Learning: A Probabilistic Perspective", MIT Press, 2012.

2. Michael Nielsen, "Neural Networks and Deep Learning", Online Book, 2016. http://neuralnetworksanddeeplearning.com/

3. Li Deng, Dong Yu, "Deep Learning: Methods and Applications", Foundations and Trends in Signal Processing.

4. Christopher M. Bishop, "Pattern Recognition and Machine Learning", Springer Science Business Media, 2006.

24EC720J
Optimization Theory and Algorithms

Course Outcomes

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

- CO1: Apply basic mathematical concepts like calculus and linear algebra to understand and solve optimization problems.
- CO2: Identify local minima of functions and apply methods for solving unconstrained optimization problems.
- CO3: Apply line search and conjugate gradient methods to improve optimization accuracy and efficiency.
- CO4: Use advanced techniques like Newton and Quasi-Newton approaches to solve nonlinear optimization problems.
- CO5: Solve constrained optimization problems using the KKT conditions, duality concepts, and projected gradient techniques.

Unit I: Foundations of Optimization and Mathematical Review

Introduction to Optimization Theory, Types of Problems, Review of Linear Algebra and Calculus, Multivariate Differentiation, Gradient of Quadratic Form and Product Rule, Directional Derivative, Hessian and Mean Value Theorem.

Unit II: Unconstrained Optimization

Unconstrained Optimization, Taylor's Theorem, Identifying Local Minima: First and Second Order Conditions, Overview of Algorithms, Choosing a Descent Direction, Properties of Descent Direction, Trust Region Methods.

Unit III: Line Search and Conjugate Gradient Methods

Introduction to Line Search, Wolfe Conditions, Backtracking Line Search, Analysis and Convergence Rate of Line Search, Conjugate Gradient Methods, Visualizing Quadratic Forms, Orthogonality and Conjugacy, Conjugate Directions Method, Preconditioned Conjugate Gradient Method.

Unit IV: Nonlinear Optimization Methods

Nonlinear Conjugate Gradient Methods, Newton Methods and Convergence, Checks for Positive Definite Matrix, Hessian Modification, Quasi-Newton Methods, Least Squares Problems, Linear Least Squares, Solving Least Squares Using SVD, Nonlinear Least Squares.

Unit V: Constrained Optimization and Duality

Constrained Optimization, Single Equality Constraint, Single Inequality Constraint, Example with Two Inequality Constraints, Linearized Feasible Directions, Feasible Sequences and Tangent Cone, LICQ Conditions, KKT Conditions, Projected Gradient Descent, Subgradients and Subdifferential, Projection onto l_1 Ball, Soft Thresholding Example, Introduction to Duality and KKT Conditions, Intuition of Duality and the Dual Problem.

Textbook

1. Numerical Optimization by Jorge Nocedal and Stephen J. Wright, Springer, 2006.