# Department of Electronics and Communication Engineering (EC)
# Bachelor of Technology in Electronics and Communication Engineering

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|---|---|---|
| **1st Semester (Physics Group)** | | |
| | Engineering Physics | (3-0-2) 4 |
| | Engineering Mathematics - I | (3-0-0) 3 |
| | Computer Programming | (0-0-6) 3 |
| | Introduction to Engineering | (2-0-2) 3 |
| | Biology and Environment | (3-0-0) 3 |
| | Life-skill activities/labs (4 types) | (0-0-8) 4 |
| **2nd Semester (Chemistry Group)** | | |
| | Engineering Chemistry | (3-0-2) 4 |
| | Engineering Mathematics - II | (3-0-0) 3 |
| | Data Science and AI | (2-0-2) 3 |
| | Design Thinking & Prototyping | (0-0-6) 3 |
| | Indian Knowledge System | (3-0-0) 3 |
| | Life-skill activities/labs (4 types) | (0-0-8) 4 |
| **Program Core Courses (PC)** | | |
| 26EC200 | Analog Communication | (2-1-0) 3 |
| 26EC201 | Digital System Design | (2-1-0) 3 |
| 26EC202 | Circuits, Systems and Signals | (2-1-0) 3 |
| 26EC203 | Probability and Random Processes | (2-1-0) 3 |
| 26EC204 | Analog Communication Lab | (0-0-3) 1.5 |
| 26EC205 | Digital System Design Lab | (0-0-3) 1.5 |
| 26EC206 | Electromagnetic Waves and Transmission Lines | (2-1-0) 3 |
| 26EC207 | Analog Electronics | (2-1-0) 3 |
| 26EC208 | Digital Signal Processing | (2-1-0) 3 |
| 26EC209 | Microprocessor based Systems | (2-1-0) 3 |
| 26EC210 | Microprocessor Lab | (0-0-2) 1 |
| 26EC211 | Digital Signal Processing Lab | (0-0-2) 1 |
| 26EC212 | Analog Electronics Lab | (0-0-3) 1.5 |
| 26EC300 | Control Systems and Automation | (2-1-0) 3 |
| 26EC301 | VLSI Design | (2-1-0) 3 |
| 26EC302 | Digital Communication | (2-1-0) 3 |
| 26EC303 | Foundations of Machine Learning | (2-1-0) 3 |
| 26EC304 | VLSI Design Lab | (0-0-2) 1 |
| 26EC305 | Digital Communication Lab | (0-0-3) 1.5 |
| 26EC306 | RF Components and Circuits | (2-1-0) 3 |
| **Programme Specific Elective Courses (PSE)** | | |
| 26EC320 | Computer Organization and Architecture | (3-0-0) 3 |
| 26EC321 | Computer Arithmetic | (3-0-0) 3 |
| 26EC322 | Embedded System Design | (3-0-0) 3 |
| 26EC323 | FPGA based System Design | (3-0-0) 3 |
| 26EC324 | Analog Integrated Circuits | (3-0-0) 3 |
| 26EC325 | Data Structures and Algorithms | (3-0-0) 3 |
| 26EC326 | Speech and Audio Processing | (3-0-0) 3 |
| 26EC327 | Image and Video Processing | (3-0-0) 3 |
| 26EC328 | Numerical Analysis and Computing | (3-0-0) 3 |
| 26EC329 | Satellite Communications | (3-0-0) 3 |
| 26EC330 | Principles of Modern Radar and Techniques | (3-0-0) 3 |
| 26EC331 | Communication Networks | (3-0-0) 3 |
| 26EC332 | Wireless Mobile Communication | (3-0-0) 3 |
| 26EC333 | Information Theory and Coding | (3-0-0) 3 |
| 26EC334 | Adhoc and Sensor Networks | (3-0-0) 3 |
| 26EC335 | Multimedia Communication Techniques | (3-0-0) 3 |
| 26EC336 | Software Defined and Cognitive Radio | (3-0-0) 3 |
| 26EC337 | Machine Learning for Wireless Communication Systems | (3-0-0) 3 |
| 26EC338 | Sparse Representations and Compressive Sensing | (3-0-0) 3 |
| 26EC339 | Deep Reinforcement Learning | (3-0-0) 3 |
| 26EC420 | VLSI CAD | (3-0-0) 3 |
| 26EC421 | Mixed Signal Design | (3-0-0) 3 |
| 26EC422 | Advanced Computer Architecture | (3-0-0) 3 |
| 26EC423 | VLSI Testing and Testability | (3-0-0) 3 |
| 26EC424 | Synthesis and Optimization of Digital Circuits | (3-0-0) 3 |
| 26EC425 | Techniques in Low Power VLSI | (3-0-0) 3 |
| 26EC426 | Submicron Devices | (3-0-0) 3 |
| 26EC427 | Active Filters | (3-0-0) 3 |
| 26EC428 | Heterogeneous and Parallel Computing | (3-0-0) 3 |
| 26EC429 | Algorithms and Architectures for Signal Processing | (3-0-0) 3 |
| 26EC430 | Advanced Digital Signal Processing | (3-0-0) 3 |
| 26EC431 | Real Time Signal Processing | (3-0-0) 3 |
| 26EC432 | Fourier and Wavelet Signal Processing | (3-0-0) 3 |
| 26EC433 | Mathematical Methods for Signal and Data Processing | (3-0-0) 3 |
| 26EC434 | Data Compression and Applications | (3-0-0) 3 |
| 26EC435 | Dynamical Systems, Chaos and Fractals | (3-0-0) 3 |
| 26EC436 | Statistical Analysis | (3-0-0) 3 |
| 26EC437 | Optimization Theory and Techniques | (3-0-0) 3 |
| 26EC438 | Unsupervised Learning | (3-0-0) 3 |
| 26EC439 | Spread Spectrum Communication | (3-0-0) 3 |
| 26EC440 | Error Control Coding | (3-0-0) 3 |
| 26EC441 | Optical Communication Systems and Networks | (3-0-0) 3 |
| 26EC442 | Radar Signal Processing | (3-0-0) 3 |
| 26EC443 | Algorithms for Parameter and State Estimation | (3-0-0) 3 |
| 26EC444 | Detection and Estimation Theory | (3-0-0) 3 |
| 26EC445 | Advanced Topics in Communication Engineering | (3-0-0) 3 |
| 26EC446 | Introduction to Photonics | (3-0-0) 3 |
| 26EC447 | MIMO Communication Systems | (3-0-0) 3 |
| 26EC448 | RF IC Design | (3-0-0) 3 |
| 26EC449 | Principles of Modern Radar- Advanced Techniques | (3-0-0) 3 |
| 26EC450 | Electronic Defense Systems | (3-0-0) 3 |
| 26EC451 | Millimeter Wave Communication | (3-0-0) 3 |
| 26EC452 | Computational Inverse Problems and Imaging | (3-0-0) 3 |
| 26EC453 | Advanced Deep Learning and Applications | (2-0-2) 3 |
| 26EC454 | Mathematics of Data Science | (3-0-0)3 |
| 26EC455 | Antennas for Wireless Communications | (3-0-0)3 |
| 26EC456 | Quantum Information Processing | (3-0-0)3 |
| 26EC457 | Quantum Electronics | (3-0-0)3 |
| 26EC458 | Quantum Neural Networks | (2-0-2)3 |
| 26EC459 | Introduction to GenAI | (2-0-2)3 |

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| **Project (MP)** | | |
| 26EC391 | Internship-I | 9 |
| 26EC392 | Major project-I | 9 |
| 26EC491 | Internship-II | 9 |
| 26EC492 | Major project-II | 9 |
| 26EC493 | Internship-III | 9 |
| 26EC494 | Major project-III | 9 |
| **Honor Courses (Hn)** | | |
| EC707 | Analog Integrated Circuit Design | (3-0-2) 4 |
| EC709 | Fabrication Technology and VLSI Integration | (3-0-2) 4 |
| EC710 | VLSI Design Automation | (3-0-2) 4 |
| EC711 | High Performance Computing Architectures | (3-0-2) 4 |
| EC769 | Computer Vision and Image Understanding | (3-0-2) 4 |
| EC770 | Optimization Models and Methods | (3-0-2) 4 |
| EC888 | Generative AI and Natural Language Processing | (3-0-2) 4 |
| EC879 | Compressed Sensing and Sparse Signal Processing | (3-0-2) 4 |
| EC737 | Signal Processing for Communication Systems | (3-0-2) 4 |
| EC739 | Next Generation Communication Networks | (3-0-2) 4 |
| EC740 | Advanced Wireless Communication | (3-0-2) 4 |
| EC741 | Photonic Circuits & Components | (3-0-2) 4 |

# Proposed B.Tech. (ECE) Curriculum Structure, NITK Surathkal

| First Year | | | | | | |
|---|---|---|---|---|---|---|
| **First Semester (Physics Group)** | | | | **Second Semester (Chemistry Group)** | | |
| **Course Name** | **L-T-P** | **Credits** | | **Course Name** | **L-T-P** | **Credits** |
| Engineering Physics | 3-0-2 | 4 | | Engineering Chemistry | 3-0-2 | 4 |
| Engineering Mathematics - I | 3-0-0 | 3 | | Engineering Mathematics - II | 3-0-0 | 3 |
| Computer Programming | 0-0-6 | 3 | | Data Science and AI | 2-0-2 | 3 |
| Introduction to Engineering | 2-0-2 | 3 | | Design Thinking and Prototyping | 0-0-6 | 3 |
| Biology and Environment | 3-0-0 | 3 | | Indian Knowledge System | 3-0-0 | 3 |
| Life skill Activities/ Labs (4 Types) | 0-0-8 | 4 | | Life skill Activities/ Labs (4 Types) | 0-0-8 | 4 |
| **Total Credits** | | **20** | | **Total Credits** | | **20** |
| | | | | | | |
| **Second Year** | | | | | | |
| **Third Semester** | | | | **Fourth Semester** | | |
| Analog Communication | 2-1-0 | 3 | | Electromagnetic Waves and Transmission Lines | 2-1-0 | 3 |
| Digital System Design | 2-1-0 | 3 | | Analog Electronics | 2-1-0 | 3 |
| Circuits, Systems and Signals | 2-1-0 | 3 | | Digital Signal Processing | 2-1-0 | 3 |
| Probability and Random Processes | 2-1-0 | 3 | | Microprocessor Based Systems | 2-1-0 | 3 |
| Analog Communication Lab | 0-0-3 | 1.5 | | Microprocessor Lab | 0-0-2 | 1 |
| Digital System Design Lab | 0-0-3 | 1.5 | | Digital Signal Processing Lab | 0-0-2 | 1 |
| Life Skill Activities/ Labs (4 types) | 0-0-8 | 4 | | Analog Electronics Lab | 0-0-3 | 1.5 |
| | | | | Life Skill Activities/ Labs (4 types) | 0-0-8 | 4 |
| **Total Credits** | | **19** | | **Total Credits** | | **19.5** |
| | | | | | | |
| **Third Year** | | | | | | |
| **Fifth Semester** | | | | **Sixth Semester** | | |
| Control Systems and Automation | 2-1-0 | 3 | | Internship-I/ Major project-I/ Elective | | 9 |
| VLSI Design | 2-1-0 | 3 | | Department / Institute Electives | 3-0-0 | 3 |
| Digital Communication | 2-1-0 | 3 | | Life Skill Activities/ Labs (4 types) | 0-0-8 | 4 |
| Foundations of Machine Learning | 2-1-0 | 3 | | | | |
| RF Components and Circuits | 2-1-0 | 3 | | | | |
| VLSI Design Lab | 0-0-2 | 1 | | | | |
| Digital Communication Lab | 0-0-3 | 1.5 | | | | |
| Life Skill Activities/ Labs (4 types) | 0-0-8 | 4 | | | | |
| **Total Credits** | | **21.5** | | **Total Credits** | | **16** |
| | | | | | | |
| **Fourth Year** | | | | | | |
| **Seventh Semester** | | | | **Eighth Semester** | | |
| Internship-II / Major project-II/ Elective | | 9 | | Internship-III/ Major project-III/ Elective | | 9 |
| Department / Institute Electives | | | | Department / Institute Electives | | |
| Life Skill Activities/ Labs (4 types) | 0-0-2 | 1 | | | | |
| **Total Credits** | | **19** | | **Total Credits** | | **15** |

## Department of Electronics and Communication Engineering

| 26EC200 | ANALOG COMMUNICATION | (2-1-0) 3 |
|---|---|---|
| Overview of the Fourier Series and Fourier Transform, Rayleigh Energy Theorem, Inverse relation between time and frequency, transmission of signals through linear systems. Hilbert Transform and the notion of pre-envelope, Canonical representation of band-pass signals, phase and group delay, various types of amplitude modulation, their virtues, and limitations. Amplitude modulation (AM), Frequency translation, baseband signal recovery, spectrum of an AM signal, types of modulators, SSB and VSB modulation and their applications, Simple circuits/ SDR implementations for AM signal generation and demodulation, Superheterodyne receiver. Angle modulation, phase and Frequency Modulation (FM), Spectrum of an FM signal with sinusoidal modulation, Bandwidth of a sinusoidally modulated FM signal, Phasor diagram for FM signals, Spectrum of Wideband FM, Simple circuits/ SDR implementations for FM generation and demodulation. Stereophonic FM broadcasting, Simple circuits/ SDR implementations for FM signal generation and demodulation, Phase locked loops and their applications, Introduction to random processes. Review of probability theory, random variables, statistical averages, transformation of random variables, random processes, stationarity, Mean, Correlation and Covariance functions, Ergodicity. Transmission of a random process through a linear filter, power spectral density, Gaussian process, Noise, Mathematical representation of noise, Spectral components of noise, representation of noise using orthonormal components, irrelevant noise components. Review of FM demodulator principles, calculation of output signal and noise powers, pre-emphasis and deemphasis, commercial standards for preemphasis and deemphasis. Resistor noise, networks with reactive elements, available power, noise temperature, noise bandwidth, noise temperature, noise figure, receiver system example, antenna temperature and its significance. The sampling process and the sampling theorem, Pulse amplitude modulation, Time division multiplexing, Pulse position modulation, Bandwidth-Noise trade-off. Pulse Code modulation (PCM), Noise considerations in PCM, Delta modulation, Adaptive delta modulation. Matched filter, error rate due to noise, Inter-symbol interference, Nyquist's criterion for distortion less baseband binary transmission, Correlative coding, Introduction to tapped delay line equalization. | | |
| S. Haykin, "Communication Systems", Wiley India Edition, 2009.<br>H. Taub, D.L. Schilling and G. Saha, Principles of Communication Systems, 3rd edition, Tata McGraw Hill, 2008<br>B. P. Lathi, Z. Ding "Modern Digital and Analog Communication Systems", Oxford University Press, 2010. | | |
| J. M. Wozencraft, I. M. Jacobs, Principles of Communication Engineering, Wavelend Press Inc. 1965. | | |
| NPTEL course on Analog Communications by Prof. Goutham Das, IIT Kgp.<br>Swayam course of Fundamentals of Communication system and its applications | | |

| 26EC201 | DIGITAL SYSTEM DESIGN | (2-1-0) 3 |
|---|---|---|
| Logic gates, Boolean algebra, Positional number systems, representation of negative numbers, binary arithmetic code, Switching algebras, Introduction to HDL (Verilog), Behavioral, structural and dataflow modeling and simulation. Combinational circuit analysis, Minimization techniques – K map, Combinational circuit synthesis using gates. Combinational circuit synthesis using MSI ICs. Modeling Combinational circuits using Verilog HDL. Latches and flip flops, Setup and Hold time, Clock period and frequency, Analysis of sequential circuits. Synchronous sequential circuit synthesis using flipflops and MSI ICs. Synchronous sequential circuit modeling with HDL Finite state machine (FSM) synthesis using flipflops.Finite state machine(FSM) modeling with HDL. ASM charts, state minimization, state assignment. Design case studies(ex. processor data path and control path) | | |
| Mano, M. Morris R., and Michael D. Ciletti. Digital Design: With an Introduction to the Verilog HDL, VHDL, and SystemVerilog. 6th ed., Pearson Education, 2018<br>Brown, Stephen D., and Zvonko G. Vranesic. Fundamentals of Digital Logic with Verilog Design. 4th ed., 2025<br>David A. Patterson; John L. Hennessy, Computer Organization and Design RISC-V Edition, 2nd ed., Morgan Kaufmann, 2021 | | |
| nptel.ac.in/courses/117106114 | | |

| 26EC202 | CIRCUITS, SYSTEMS AND SIGNALS | (2-1-0) 3 |
|---|---|---|
| Introduction to signals and types of signals , Basic signals, operations, and properties, Systems and their properties. Electric Circuit Analysis: Circuit concept, circuit elements, independent and dependent sources, network reduction techniques, network equations, node voltage and mesh current analysis, Network Theorems-Super position theorem, Norton, Thevenin, Maximum power transfer theorem. Time domain analysis of linear signals and systems: Impulse response, convolution, correlation, First order systems - Analysis of RL and RC circuits, representation of systems using differential equations, solution of differential equations, Transient and steady state response, time constant, initial conditions, Second order systems - RLC circuits, characteristic equation, damping, natural frequency, time domain specifications of systems, State variable description. Transform domain analysis of systems: Laplace Transform: Definition and properties, inverse transforms, partial fraction expansion. Transform domain analysis of systems, equivalent sources for initial conditions, transform circuits, Impedance functions and Network Theorems, transfer function stability. Frequency domain analysis of continuous time signals and systems: Steady state response | | |

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| of R,L,C elements to sinusoidal excitation, series and parallel resonance, frequency domain specifications. Periodic signals, Fourier series representation, properties of Fourier series. Non-periodic signals, Fourier transform, properties of Fourier transforms and applications to systems, Parsevaal's Theorem. |
| W.Nillson and SA Riedel, Electric Circuits, PHI, 2000<br>Oppenheim, A. V., Willsky, A. S., & Nawab, S. H. (2015). Signals and Systems (2nd ed.,), Pearson<br>B. P., Lathi. Signals, Systems and Communication. BS Publications, Second edition, 2001.<br>William H Hayt, et al. Engineering Circuit Analysis. McGraw Hill India, Ninth edition, 2020. |

| 26EC203 | **PROBABILITY AND RANDOM PROCESSES** | **(2-1-0) 3** |
|---|---|---|
| Review of elementary probability, Formal definition of a probability space, axioms, examples, properties, Conditional Probability, Independence and conditional independence, independence of more than two events, Partition formula, Discrete random variables, definition, examples - Bernoulli, Binomial, Poisson, Uniform and Geometric random variables, distributions and properties, Expectation of a random variable, mean, variance, moments examples - Bernoulli, Binomial, Poisson, Uniform and Geometric Random Variables, Continuous Random Variable, definition probability distribution function - Uniform, Exponential, Gaussian Random variables, Mean and Variance, moments, moment generating functions, Joint distribution of random variables, Conditioning of random variables, conditioning on events, other random variables, conditional distributions, examples, Random vectors, multi dimensional probability distribution, moments, mean vector, covariance matrix, Random sequences, Bernoulli process, properties, Time of Kth arrival, Merging and splitting of Bernoulli processes, examples, Poisson Process, Definition, Applications, Number of Arrivals and Poisson PMF, Mean and Variance, Time of Kth Arrival, examples, Sum of independent poisson random variables, Merging/Splitting a Poisson process, Different sampling methods, Poisson versus normal approximations, Introduction to Markov Processes, Discrete time finite state Markov chains, N step transition probabilities, Markov Process - Recurrent and Transient states, steady state probabilities, Birth-death processes. | | |
| Introduction to Probability, 2nd ed, Dimitri P. Bertsekas and John N. Tsitsiklis, MIT, 2008<br>Probability, Statistics, and Random Processes for Engineers, "Henry Stark and John W. Woods", Pearson Education, 2012 | | |
| https://ocw.mit.edu/courses/res-6-012-introduction-to-probability-spring-2018/<br>https://onlinecourses.nptel.ac.in/noc26_ma23/preview | | |

| 26EC204 | **ANALOG COMMUNICATION LAB** | **(0-0-3) 1.5** |
|---|---|---|
| Verification of sampling theorem. AM generation and detection with AGC. FM generation and demodulation. DSBSC modulation and demodulation using multiplier IC. Characterization of tuned amplifier circuit. Generation and detection of PAM, PWM and PPM. Performance analysis of analog communication systems in the presence of noise using MATLAB. Study of AM systems using Simulink. RF Mixer circuit. Characteristics of pre-emphasis and de-emphasis circuits. Frequency division multiplexing. Analysis of AM and FM signals with spectrum analyzer | | |
| M.F.Mesiya, "Contemporary Communication Systems", First Edition, McGraw-Hill India, 2014<br>Proakis and Salehi, "Fundamentals of Communication Systems", Second Edition, Pearson Education, 2014. | | |
| Communication lab manual | | |

| 26EC205 | **DIGITAL SYSTEM DESIGN LAB** | **(0-0-3) 1.5** |
|---|---|---|
| Familiarization of software and trainer kits, and HDL. Experiments implementing simple combinational circuits using logic gates. Implementation of comparator and code converter circuits. Implementation of multiplexer, demultiplexers, encoders & decoder circuits. Design and implementation of Arithmetic Building Blocks for Digital Systems. Implementation of various flip-flops circuits. Implementation of register & counters. Implementation of sequential circuits. Design and implementation of control logic FSMs. RTL Case study.Term project involving complete digital system design and implementation on a suitable FPGA board. | | |
| Mano, M. Morris R., and Michael D. Ciletti. Digital Design: With an Introduction to the Verilog HDL, VHDL, and SystemVerilog. 6th ed., Pearson Education, 2018<br>Brown, Stephen D., and Zvonko G. Vranesic. Fundamentals of Digital Logic with Verilog Design. 4th ed., 2025 | | |
| https://nptel.ac.in/courses/106105165 | | |

| 26EC206 | **ELECTROMAGNETIC WAVES AND TRANSMISSION LINES** | **(2-1-0) 3** |
|---|---|---|
| Course introduction, overview, and motivation. Review of static electric and magnetic fields and their properties. Coordinate systems, Vector operators. Maxwell's equations. Electric charges and currents, Maxwell's equations in differential and integral form, Material media, Boundary conditions at the interface between material media,<br>The Maxwell equations in steady state, Power, and the Poynting theorem, Propagation of plane electromagnetic waves-The wave equations, Introduction to plane waves, Plane waves in ideal dielectric media, Plane waves in media with losses, Wave Propagation in Linear/Homogeneous/Isotropic Media and plasmas. Wave Propagation in Conducting Media, Dispersion Phenomena in Linear/Homogeneous/Isotropic Media. Plane wave polarization, Reflection and transmission of plane waves at the interface between material media. Electromagnetic Fields Associated with a Circular | | |

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| Parallel-Plate Capacitor and Waveguide. Waveguides and Guided EM Waves, Electromagnetic Radiation, Hertizian Dipole, Electric Dipole Radiation, Antenna Parameters-gain, directivity, radiation pattern, and bandwidth & returnloss Antenna Arrays- broadside and end fire arrays, Planar arrays, Introduction to transmission lines, Distributed transmission-line circuit model, General transmission-line equations in time, Wave characteristics on an infinite transmission line, Time-harmonic transmission-line equations, Propagation constant. Wave Characteristics on Finite Transmission Lines and Input Impedance. |
| Ulaby, F. T., & Ravaioli, U. (2020). Fundamentals of Applied Electromagnetics. (8 ed.) Pearson<br>D.J. Griffiths, Introduction to Electrodynamics, 3a ed., Prentice-Hall, 1999 |
| C.A. Balanis, Advanced Engineering Electromagnetics, Wiley, 1989<br>Matthew N.O. Sadiku, Principles of Electromagnetics, 6th Edition, OUP, 2015. |
| https://nptel.ac.in/courses/117101056<br>https://nptel.ac.in/courses/108106157 |

| 26EC207 | **ANALOG ELECTRONICS** | **(2-1-0) 3** |
|---|---|---|
| Introduction to Linear/Non-linear Circuits, Amplifier fundamentals, Controlled Sources.Two-port Networks, Feedback Concepts: Feedback topologies. Positive and Negative feedback, Effect of Negative feedback on basic amplifiers, Instability in amplifiers, Barkhausen condition for Oscillations. Opamp ideal characteristics, Non idealities of Opamps and their effects: Finite gain, Finite bandwidth, Offset voltages and currents. Non-inverting and Inverting Amplifiers, Voltage Follower, Summing Amplifiers. Difference amplifiers, Opamp differentiator, Opamp integrator, All-pass filter (Active phase shifters), Passive Filters - First and Second order filter transfer functions (low pass, high pass, band pass and band reject), Butterworth response. Emulation of inductor using gyrators, Transconductor-Capacitor Filters,<br>Active-RC Filters, Sallen-Key biquadratic low and high-pass filters. Tow-Thomas biquad, Realization of higher order filters. Non-linear Applications of Opamps: Comparators, Schmitt trigger (Inverting & Non-Inverting). Astable Multivibrator, Triangular wave generator, Oscillators, RC Phase shift, Wienbridge, LC and Crystal oscillators, Precision rectifiers | | |
| Sedra and Smith, "Microelectronics Circuits", Oxford Univ. Press, 2013.<br>Behzad Razavi, Fundamentals of Microelectronics, Third edition, Wiley, 2021<br>Sergio Franco, "Design with OPAMPS and Linear Integrated circuits", McGraw Hill, 2017 | | |
| https://nptel.ac.in/courses/108101094<br>https://onlinecourses.nptel.ac.in/noc24_ee81/preview<br>https://nptel.ac.in/courses/108102112 | | |

| 26EC208 | **DIGITAL SIGNAL PROCESSING** | **(2-1-0) 3** |
|---|---|---|
| Introduction to DSP; Basic discrete-time signals, operations, and properties, introduction to sampling, aliasing<br>Discrete-time systems - properties, linear-time invariant systems, impulse response, convolution, correlation, causality and stability; Representation of LTI systems - difference equations, Z Transform: Definition and properties, ROC, inverse Z transform, transfer function, poles and zeros, relate system behaviour in time and frequency domains to pole-zero plot, Application of Z transforms to discrete-time systems, Representation of systems – signal flow graph, realisation of a Z-domain transfer function, Fourier series & Fourier transform, Discrete Fourier series (DFS), Properties of DFS, Relation between continuous and discrete time spectra, aliasing, reconstruction of continuous-time signal from samples, Discrete-time Fourier transform (DTFT), properties and applications of DTFT, Relationship between the three domains – h(n), H(z), H(), Sampling in frequency domain, Discrete Fourier Transform (DFT), DFT properties, linear convolution using DFT, Circular convolution, use of DFT in linear filtering, filtering of long data sequences, Efficient computation of DFT, Fast Fourier transform (FFT) algorithms – DIT, DIF, Characteristics of digital filters, Types, Filter Structures, design from pole-zero map, LPF, HPF and BPF, Digital resonators, Notch, and All-pass filters. FIR filter design: window method, frequency sampling method, optimal filter design, IIR filter design: H(s) H(z), Filter design using Butterworth, Chebyshev & Elliptic approximations, Direct design of IIR filters, Finite word length effects, Real-time implementation of SP algorithms - options, Application of DSP to Speech, Audio, Image, Video and Biomedical signal processing | | |

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| Proakis J. G. and D. G. Manolakis, Introduction to Digital Signal Processing (5e), Pearson Education, 2022<br>Oppenheim A. V. and R. W. Schafer, Discrete time signal processing (3e), Pearson, 2021.<br>P. P. Vaidyanathan, Signals, Systems and Signal Processing, CUP, 2024<br>Ashok Ambardar, Digital Signal Processing A modern Introduction, Thomson, 2007 |
| https://nptel.ac.in/courses/108101174<br>https://nptel.ac.in/courses/117102060<br>https://nptel.ac.in/courses/117105134<br>https://nptel.ac.in/courses/108105055<br>https://nptel.ac.in/courses/108106151 |

| 26EC209 | **MICROPROCESSOR BASED SYSTEMS** | **(2-1-0) 3** |
|---|---|---|
| Introduction to Microprocessors: Introduction to computer organization, CISC, RISC, Concept of pipelining , Evolution of Microprocessors. Introduction to stored program Concept: Instruction Set Architecture: Instruction formats and addressing modes. Introduction to ARM processor: ARM overview, Programming Model, Processor and memory organization, concept of stack. ARM Instruction set: Data-processing Instructions, Data Transfer Instructions, Control Instructions, Additional special instructions, Addressing modes & Instruction Encoding ARM Implementation, organization and execution:The data flow model for Data-processing Instructions, Data Transfer Instructions, Control Instructions , ARM Instruction Datapath Timing, The 3-stage pipe line organization, pipeline hazards, PC behaviour Introduction to Thumb instruction set (TIS): Need for TIS, Thumb implementation and its encoding, ARM Processor Modes and Exceptions: Processor Modes in Detail, Exception Types, vector table, exception Handling, Priority, ARM interfacing to peripherals: Interfacing ARM to GPIO, UART, DAC | | |
| Assembly Language Programming ARM Cortex-M3" by Vincent Mahout, ISTE Ltd and John Wiley & Sons, Inc<br>https://www.arm.com/products/silicon-ip-cpu/cortex-m/cortex-m3 | | |

| 26EC210 | **MICROPROCESSOR LAB** | **(0-0-2) 1** |
|---|---|---|
| Introduction: Introduction to ARM instructions and assembly level programming. Familiarization with software development platforms. Assembly Language Programming. Simple Assembly Language Programs involving arithmetic and logical operations. Array and matrix manipulations: sort, search delete/ insert, dot product, matrix addition and multiplication. Assembly programming involving strings. High precision arithmetic: long-long addition/ subtraction, multiplication, Division. Evaluation Boards: Downloading and Verification on the target board. Interfacing various peripherals in Assembly Language Programing -GPIO, UART.Apply high-level programming (C) to implement algorithms on microprocessors. Interface HLL code with peripherals to perform embedded applications. Term project: Implement and integrate a practical embedded system application | | |
| "Assembly Language Programming ARM Cortex-M3" by Vincent Mahout, ISTE Ltd and John Wiley & Sons, Inc<br>https://www.arm.com/products/silicon-ip-cpu/cortex-m/cortex-m3<br>J.R.Gibson, “ARM Assembly Language-An Introduction”, CENGAGE Learning.. | | |

| 26EC211 | **DIGITAL SIGNAL PROCESSING LAB** | **(0-0-2) 1** |
|---|---|---|
| Review of python programming, Numpy, Scipy, Pandas Library. Simulation of Basic discrete-time signals, operations, and properties, introduction to sampling, aliasing. Implementation of Discrete-time systems - properties, linear-time invariant systems, impulse response, convolution, correlation, causality and stability; Representation of LTI systems - difference equations. Implementation of Z Transform: Definition and properties, ROC, inverse Z transform, transfer function, poles and zeros, relate system behaviour in time and frequency domains to pole-zero plot. Implementation of Continuous Fourier series & Fourier transform, Discrete Fourier series (DFS), Properties of DFS, Relation between continuous and discrete time spectra. implementation and analysis Discrete-time Fourier transform (DTFT), Sampling in frequency domain, implementation of Discrete Fourier Transform (DFT), DFT properties, linear convolution using DFT, use of DFT in linear filtering, filtering of long data sequences, Implementation and analysis of radix -2 Fast Fourier transform (FFT) algorithms – DIT, DIF Implementation and analysis of digital FIR filters, Types,.Implementation and analysis of digital IIR filters, Implementation and analysis of discrete time signals and systems using DSP Board | | |
| Programming for everybody, Online course https://www.coursera.org/learn/python<br>Numpy Tutorial https://docs.scipy.org/doc/numpy-dev/user/quickstart.html<br>Proakis J. G. and D. G. Manolakis, Introduction to Digital Signal Processing (5e), Pearson Education, 2022<br>Oppenheim A. V. and R. W. Schafer, Discrete time signal processing (3e), Pearson, 2021.<br>Ashok Ambardar, Digital Signal Processing A modern Introduction, Thomson, 2007 | | |

| 26EC212 | **ANALOG ELECTRONICS LAB** | **(0-0-3) 1.5** |
|---|---|---|
| Review of analog components, demo of lab equipments (CRO, function generator, multimeter, DC power supply, transformer). Design and implement Half wave and Full wave rectifier along with capacitor filter and voltage regulator. Design and implement Bridge rectifier with capacitor filter and voltage regulator. Design and implement Op-amp based non-inverting buffer, inverting and non-inverting amplifier. Design and implement inverting and non-inverting summing amplifier with and without zener diode. Design and implement voltage controlled current source, current to | | |

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| voltage converter, and push pull amplifier. Design and implement self biasing circuit with and without bypass capacitor, cascade amplifier. Design and implement op-amp based current and difference amplifier, integrator and differentiator. Design and implement Wein bridge oscillator, phase shift oscillator using BJT and op-amp equivalent. Design and implement Colpitt's oscillator using BJT and op-amp and crystal oscillator. Design and implement filters - All pass phase shift, KRC- Low pass filter, High pass filter. Design and implement filters - Band pass filter |
| Sedra and Smith, "Microelectronics Circuits", Oxford Univ. Press, 2013.<br>Behzad Razavi, Fundamentals of Microelectronics, Third edition, Wiley, 2021<br>Sergio Franco, "Design with OPAMPS and Linear Integrated circuits", McGraw Hill, 2017 |

| 26EC300 | **CONTROL SYSTEMS AND AUTOMATION** | **(2-1-0) 3** |
|---|---|---|
| Introduction, motivation, history, representation of systems, physics principles, equivalence between mechanical, electrical, pneumatic, etc, Open loop and closed loop systems, feedback systems, types; linear and nonlinear, Time and frequency domain analysis, Fourier and Laplace transform, Transfer function, Block diagram representation, block diagram algebra, signal flow graphs, simplification methods, Poles, zeros, first and second order systems, response of systems to standard test inputs; impulse, step, sinusoidal etc, Transient and steady state response, stability criteria, BIBO stability, Time domain analysis: Transient & Steady-State Response, Performance, pecifications (Rise Time, Overshoot, Settling Time), Error Analysis & Constants, Stability using Routh-Hurwitz Criterion, Lyapunov Stability, Frequency Domain Analysis: Frequency Response (Bode Plot, Polar Plot, Nyquist Plot), Performance Specs (Gain Margin, Phase Margin), Stability using Nyquist Stability Criterion, Root Locus Techniques, Controller Design: PID Controllers (Proportional, Integral, Derivative), Root Locus Design (Adding Poles/Zeros), Frequency Domain Compensation (Lead, Lag, Lag-Lead), State-Space Methods: State-Space Representation (Modeling, Solution), Controllability & Observability, Pole Placement, Luenberger Observer, LQR, Digital Control: Z-Transforms, Discrete State-Space, Digital Controller Design. Design and simulation using appropriate tools like MATLAB/Simulink, Python etc | | |
| Ogata, Discrete - Time Control Systems, PHI 2005.<br>Modern Control Engineering - by Katsuhiko Ogata - Prentice Hall of India Pvt. Ltd., edition, 2010.<br>Gene Franklin, David Powell, Abbas Emami-Naeini, Feedback Control of Dynamic Systems, Pearson Education, 2019. | | |
| Automatic Control Systems- by B. C. Kuo and Farid Golnaraghi - John wiley and son's, 8th edition, 2003. | | |
| https://onlinecourses.nptel.ac.in/noc20_ee90/preview<br>https://onlinecourses.nptel.ac.in/noc24_ee62/preview | | |

| 26EC301 | **VLSI DESIGN** | **(2-1-0) 3** |
|---|---|---|
| MOS theory – input, output characteristics of NMOS & PMOS, second order effects. NMOS inverter with resistive load, enhancement NMOS load, depletion NMOS load, Pseudo-NMOS load. CMOS inverter, MOSFET modeling – GATE capacitances, SPICE parameters. CMOS fabrication process overview of N-well, twin-well, silicon on insulator processing technology. Spice simulation of logic gates and analysis, Layout & design rules, Latch-up, NMOS, CMOS logic gates – combinational logic circuits.. CMOS sequential logic circuits. Pass transistor logic & Transmission gates. Introduction to CAD tools – (Demo on Magic), Extraction, Circuit elements resistance, capacitance estimation. Switching characteristics. Delay Models, power dissipation, Interconnect delay, Timing analysis, charge sharing, scaling of MOS transistor dimensions, Pseudo-NMOS logic, Dynamic logic, Domino Logic, Clocked systems, Latches, Flipflops, Memory Architecture, ROMs, SRAM, DRAM memory elements, address decoders., System level perspective, switch level simulation (IRSIM), LVS using Netgen | | |
| Digital Integrated Circuits: A design perspective, (2nd Edition), Jan M Rabaey, A Chandrakasan, B Nikolic, Pearson Education 2002.<br>CMOS Digital Integrated Circuits (3rd ed.), Kang & Leblebici, Tata McGraw – Hill.<br>Principles of CMOS VLSI Design - A system perspective, (2nd Edition) Neil H.E Weste and Kamran Eshraghian, Pearson Education | | |

| 26EC302 | **DIGITAL COMMUNICATION** | **(2-1-0) 3** |
|---|---|---|
| Overview of Digital Communication Systems, Fundamental tradeoffs in Communication Systems, Geometric representation of Signal waveforms, Signals and Noise. Binary modulation schemes, Optimum receiver for binary modulated signals in AWGN. M-ary Digital modulation, Optimum receiver for M-ary signals in AWGN, Union bound on the Probability of error. Generation, detection and Probability of Error analysis for M-ary PAM and M-ary ASK systems. Generation, detection and Probability of Error analysis for M-ary PSK and DPSK systems. Geometric representation of QAM Signals, Demodulation and Detection of QAM Signals, Probability of Error for QAM. PLL, Costas loop, Carrier phase estimation for PAM, PSK and QAM. Symbol synchronization, Early-Late gate, MMSE and ML methods. Modulation, detection and performance analysis of M-ary FSK and CPFSK signals. Digital transmission through bandlimited AWGN channels, Design and performance analysis of Channel Equalizers. | | |

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| Introduction to Information Theory, Source coding theorem and algorithms, Channel capacity, Modeling of communication channels. Introduction to channel fading and diversity combining techniques. Introduction to Spread Spectrum Communication Systems. Introduction to OFDM systems. |
| Proakis and Salehi, "Fundamentals of Communication Systems", Second Edition, Pearson Education, 2014.<br>M.F. Mesiya, "Contemporary Communication Systems", McGraw-Hill Education, 2017.<br>Michael Rice, "Digital Communications: A Discrete Time Approach", Pearson Education, 2011.<br>Mehmet Safak, "Digital Communications", John Wiley & Sons, 2017. |
| Richard W. Middlested, "Digital Communications with Emphasis on Data Modems: Theory, Analysis, Design, Simulation, Testing, and Applications", John Wiley & Sons, 2017. |
| https://nptel.ac.in/courses/117101051 |

| 26EC303 | **FOUNDATIONS OF MACHINE LEARNING** | **(2-1-0) 3** |
|---|---|---|
| Decision theory, continuous features, discriminant features and surfaces, Models with gaussian density, Parameter estimation, ML/Bayesian estimation, Examples, Linear regression of one variable, cost function and solution, gradient descent, Multivariate regression, non linear features, underfitting, overfitting, regularization, Logistic regression, cost function, Regularization, Extension of linear models to non linear models, single layer neural network, artificial neural networks, loss functions, back propagation, examples of regression and classification tasks. Alternate Classification systems - Support vector machines, Decision trees, Random forests and Gradient Boosting, Deep learning, vanishing gradient descent problem – solutions, Special architectures, convolutional and recurrent neural networks, Imagenet data, Unsupervised learning algorithms - K means clustering, applications, imensionality reduction, Recommender systems, NN embeddings as features, Introduction to generative models - Autoencoder, Variational Autoencoders Generative Adversarial Networks (GAN) | | |
| Bishop, Christopher M., "Pattern Recognition and Machine Learning", Springer 2006<br>Duda, Richard O., Peter E. Hart and David G. Stork., "Pattern Classification", John Wiley & Sons, 2012<br>https://www.deeplearningbook.org/ | | |
| https://www.coursera.org/learn/machine-learning<br>https://www.deeplearning.ai/deep-learning-specialization/<br>https://onlinecourses.nptel.ac.in/noc26_cs76/preview | | |

| 26EC304 | **VLSI DESIGN LAB** | 0-0-2) 1 |
|---|---|---|
| Spice analysis of MOSFET input, output characteristics with parametric sweeps. Spice analysis of inverter (Ratioed logic families). Spice analysis of CMOS gates. Layout of CMOS gates, extraction and Spice analysis of extracted Layout of CMOS gates. Term Project (involves layout, LVS, switch level simulation | | |
| Digital Integrated Circuits: A design perspective, (2nd Edition), Jan M Rabaey, A Chandrakasan, B Nikolic, Pearson Education 2002.<br>CMOS Digital Integrated Circuits (3rd ed.), Kang & Leblebici, Tata McGraw – Hill.<br>Principles of CMOS VLSI Design - A system perspective, (2nd Edition) Neil H.E Weste and Kamran Eshraghian, Pearson Education | | |

| 26EC305 | **DIGITAL COMMUNICATION LAB** | **(0-0-3) 1.5** |
|---|---|---|
| Design and testing of 4-ary PAM, Design and testing of BPSK Modem, Design and testing of BFSK Modem, Design and testing of QPSK Modulator, PLL and Frequency Synthesizers, Montecarlo Simulation of Performance of Wireless Communication Systems, Implementation of FM Transceiver using SDR, Implementation of QAM Transceiver systems using SDR, Design and testing of real time communication systems using Microcontroller Boards, Measurement of frequency, guided wavelength, power, attenuation and VSWR, Radiation pattern and Gain measurement of waveguide Horn antenna, Characterization of passive microwave devices, Optical Fiber Communication | | |
| M.F.Mesiya, "Contemporary Communication Systems", First Edition, McGraw-Hill India, 2014.<br>Ananjan Basu, "An Introduction to Microwave Measurements", First Edition, CRC Press, 2017.<br>Robert W. Stewart, K W Barlee, and D S W Atkinson, "Software Defined Radio using MATLAB & Simulink and the RTL-SDR", Strathclyde Academic Media, 2015.<br>Rongqing Hui and Maurice O'Sullivan, "Fiber-Optic Measurement Techniques", 2nd Edition, Academic Press, 2022. | | |
| Analog and Digital IC Handbooks<br>Reports, Guides and White Papers on Latest Communication Standards | | |

| 26EC306 | **RF COMPONENTS AND CIRCUITS** | **(2-1-0) 3** |
|---|---|---|
| Review of electromagnetic theory and transmission line fundamentals, Introduction to printed transmission lines. Introduction to Smith chart, Transmission Line Solutions Using the Smith Chart. Wireless System Architecture and Friis Transmission Equation. Radio Wave Propagation Mechanisms and Channel Impairments. High-frequency effects in RF components and circuits. S-parameters and RF network measurement techniques. Impedance matching methods | | |

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| and bandwidth optimization criteria. RF passive component characterization: T-junction divider and directional coupler. Microwave resonators - line resonator, Q-Factor, excitation. Ferrite devices: isolators, circulators, and phase shifters. Noise and nonlinearity in RF systems. RF Mixers and Amplifiers. Introduction to microwave systems and radar fundamentals. |
| David M. Pozar, Microwave Engineering, An Indian Adaptation: Theory and Techniques, Wiley, 2022.<br>Charles. E. Free, Colin S. Aitchison, RF and Microwave Circuit Design-Theory and Applications, Wiley, 2022. |
| Michael Steer, Microwave and RF Design: A Systems Approach, SciTech Publishing, 2010.<br>Devendra K. Misra, Radio-Frequency and Microwave Communication Circuits: Analysis and Design, John Wiley & Sons, 2012. |
| NPTEL: Microwave Engineering: https://nptel.ac.in/courses/108101112<br>https://nptel.ac.in/courses/108103141 |

## List of Electives

| 26EC320 | **COMPUTER ORGANIZATION AND ARCHITECTURE** | **(3-0-0) 3** |
|---|---|---|
| Digital Computer Organization, CPU Design, CPU Design Timing and Control, Micro programmed Control, Pipeline Concept, Memory Organization, Cache Memory Architecture, RAM Architecture SRAM and DRAM Architectures, Secondary Storage Organization. | | |
| John Hayes, Computer Architecture and Organization, 3rd Ed. McGraw Hill 2017.<br>John Hennessy and David Patterson, Computer Architecture - A Quantitative Approach 6th Edition, Morgan Koufmann, 2017<br>John Hennessy and David Patterson, Computer Architecture - A Quantitative Approach 5th Edition, Morgan Koufmann, 2011 | | |

| 26EC321 | **COMPUTER ARITHMETIC** | **(3-0-0) 3** |
|---|---|---|
| Number Representation : Numbers and Arithmetic, Representing Signed Number, Redundant Number Systems, Residue Number Systems, Double base number systems, Addition/Subtraction: Basic Addition and Counting, Carry- Look ahead Adder, Variations in Fast Adders, Multi-Operand Addition, Multiplication: Basic Multiplication Schemes, High-Radix Multipliers, Tree and Array Multipliers, Variations in Multipliers, Division: Basic Division Schemes, High-Radix Dividers, Variations in Dividers, Division by Convergence, Real Arithmetic: Representing the Real Numbers, Floating-Point Arithmetic, Arithmetic Errors and Error Control, Precise and Certifiable Arithmetic, Function Evaluation: Square-Rooting Methods, The CORDIC Algorithms, Variations in Function Evaluation, Arithmetic by Table Lookup, Implementation Topics : High Throughput Arithmetic, Low-Power Arithmetic, Fault-Tolerant Arithmetic, Past, Present, and Future | | |
| I. Koren, Computer Arithmetic Algorithms, 2nd Edition, A. K. Peters (part of CRC Press), 2002<br>M. Ercegovac and T. Lang, Digital Arithmetic, Morgan Kaufman, 2003.<br>B. Parhami, Computer Arithmetic: Algorithms and Hardware Design, Oxford University Press 2000.<br>Literature from the web including the proceedings of IEEE Intl. Conference on Computer Arithmetic. | | |

| 26EC322 | **EMBEDDED SYSTEM DESIGN** | **(2-0-2) 3** |
|---|---|---|
| Introduction: Overview of embedded systems, embedded system design challenges, common design metrics and optimizing. Survey of different embedded system design technologies & trade-offs. Embedded microcontroller cores, embedded memories, Examples of embedded systems. Architecture for embedded system, High performance processors – strong ARM processors, programming, interrupt structure, I/O architecture, Technological aspects of embedded systems: interfacing between analog and digital blocks, signal conditioning, Digital signal processing, Subsystem interfacing, interfacing with external systems. Software aspects of embedded systems: real time programming languages and operating systems for embedded systems – RTOS requirements, kernel types, scheduling, context switching, latency, inter-task communication and synchronization, Case studies. | | |
| Jack Ganssle, The Art of Designing Embedded Systems, Elsevier, 1999.<br>J.W. Valvano, Embedded Microcomputer System: Real Time Interfacing, Brooks/Cole, 2000. David Simon, An Embedded Software Primer, Addison Wesley, 2000.<br>H. Kopetz, Real-time Systems, Kluwer, 1997<br>R. Gupta, Co-synthesis of Hardware and Software for Embedded Systems, Kluwer 1995. Gomaa, Software Design Methods for Concurrent and Real-time Systems, Addison-Wesley, 1993.<br>Steve Furber, "ARM System Architecture", Edison Wesley Longman, 1996.<br>Andrew N. Sloss, Dominic Symes, Chris Wright, "ARM System Developer's Guide: Designing and Optimizing System Software", Elsevier, 2004 | | |

| 26EC323 | **FPGA BASED SYSTEM DESIGN** | **(2-0-2) 3** |
|---|---|---|
| Digital system design options and trade-offs, Design methodology and technology overview, High Level System Architecture and Specification: Behavioral modeling and simulation, Hardware description languages, combinational and sequential design, state machine design, synthesis issues, test benches. Overview of FPGA architectures and technologies: FPGA Architectural options, granularity of function and wiring resources, coarse vs fine grained, vendor specific issues (emphasis on Xilinx and Altera), Logic block architecture: FPGA logic cells, timing models, power dissipation I/O block architecture: Input and Output cell characteristics, clock input, Timing, Power dissipation, Programmable interconnect - Partitioning and Placement, Routing resources, delays; Applications - Embedded system design using FPGAs, DSP using FPGAs, Dynamic architecture using FPGAs, reconfigurable systems, application case studies. Simulation / implementation exercises of combinational, sequential and DSP kernels on Xilinx / Altera boards. | | |
| M.J.S. Smith, Application Specific Integrated Circuits, Pearson, 2000 Peter Ashenden, Digital Design using VHDL, Elsevier, 2007 Peter Ashenden, Digital Design using Verilog, Elsevier, 2007<br>Clive Maxfield, The Design Warriors's Guide to FPGAs, Elsevier, 2004 | | |

| 26EC324 | **ANALOG INTEGRATED CIRCUITS** | **(3-0-0) 3** |
|---|---|---|
| MOSFET - Review of current equation, regions of operation, small signal model. Current mirrors, Single-ended amplifiers: CS amplifier CG and CD amplifiers, CMOS differential amplifiers: DC analysis and small signal analysis of differential amplifier with Resistive load, current mirror load and current source load, Input common-mode range and Common -mode feedback circuits. OTAs vs Opamps. Slew rate, CMRR, PSRR. Two stage amplifiers, Compensation in amplifiers (Dominant pole compensation). | | |
| Behzad Razavi, Fundamentals of Microelectronics, Second edition, Wiley, 2013 Sedra and Smith, Microelectronics Circuits, Oxford Univ. Press, 2004 | | |

| **26EC325** | **DATA STRUCTURES AND ALGORITHMS** | **(2-0-2) 3** |
|---|---|---|
| Algorithm analysis, Asymptotic notations. Divide and Conquer algorithms, Analysis of divide and conquer algorithms, master method, examples - merge sort, quick sort, binary search, Data structures, Linked list, stacks and queues, insertion/deletion and analysis, Binary search trees Hash Tables – hash function and properties, collision handling, bloom filters, Greedy algorithms and Dynamic programming examples. Graph traversal , DFS, BFS, shortest path algorithms Dijkstra's and Bellman Ford algorithm, Minimum spanning trees, min cut . | | |
| Sartaj Sahni, Data Structures, Algorithms and Applications in C++, Universities Press, 2005 A.V. Aho, J.E. Hopcroft and J. D. Ullman, Data structures and Algorithms, Pearson, 2004. T.H.Cormen, C.E. Leiserson, R.L. Rivest, C. Stein, Introduction to Algorithms, PHI, 2004. Mark Allen Weiss, Algorithms, Data structures and problem solving with C++, Pearson, 2002. | | |

| 26EC326 | **SPEECH AND AUDIO PROCESSING** | **(3-0-0) 3** |
|---|---|---|
| Speech Production–human speech production mechanism, acoustic theory of speech production, digital models for speech production. Speech perception– human hearing, auditory psychophysics, JND, pitch perception, auditory masking, models for speech perception. Speech Analysis–Time and frequency domain analysis of speech, speech parameter estimation, Linear prediction. Speech compression –quality measures, waveform coding, source coders, Speech compression standards for personal communication systems. Audio processing–characteristics of audio signals, sampling, Audio compression techniques, Standards for audio compression in multimedia applications, MPEG audio encoding and decoding, audio databases and applications. Speech synthesis–text to speech synthesis, letter to sound rules, syntactic analysis, timing and pitch segmental analysis. Speech recognition–Segmental feature extraction, DTW, HMMs, approaches for speaker, speech and language recognition and verification | | |
| Douglas O'Shaugnessy, Speech Communication–Human and Machine, IEEE Press, 2000<br>L R Rabiner, Digital Processing of Speech Signals, Pearson,1978 T.F Quatieri, Discrete-time speech signal processing: Principles and Practise Pearson,2002<br>Zi Nian Li, Fundamentals of Multimedia, Pearson Education, 2003 | | |

| 26EC327 | **IMAGE AND VIDEO PROCESSING** | **(3-0-0) 3** |
|---|---|---|
| Digital image fundamentals–image acquisition, representation, visual perception, quality measures, sampling and quantization, basic relationship between pixels, imaging geometry, color spaces, Video spaces, analog and digital video interfaces, video standards. Two dimensional systems – properties, analysis in spatial, frequency and transform domains. Image transforms - DFT, DCT, Sine, Hadamard, Haar, Slant, KL transform, Wavelet transform. Image enhancement–point processing, spatial filtering, Image restoration–inverse filtering, de-blurring Video processing– display enhancement, video mixing,video scaling, scan rate conversion, Image compression–lossless and lossy compression techniques, standards for image compression-JPEG, JPEG2000. Video compression–motion estimation, intra and interframe prediction, perceptual coding, standards- MPEG, H.264 Image segmentation–feature extraction, region oriented segmentation, descriptors, morphology, Image recognition. | | |
| R. C. Gonzalez and R E Woods, Digital Image Processing, Pearson Education, 2002 A K Jain, Fundamentals of Digital Image Processing, Pearson Education,1989 W Pratt, Digital Image Processing, Wiley , 2001<br>Al Bovik, Handbook of Image and Video, Academic Press, 2000 Keith Jack, Video Demystified, LLH 2001 | | |

| 26EC328 | **NUMERICAL ANALYSIS AND COMPUTING** | **(3-0-0)3** |
|---|---|---|
| Preliminaries on numerical analysis, Errors and measuring efficiency , Review of Linear Algebra, Iterative techniques in matrix algebra, elimination method, inverse of a matrix, ill conditioned systems, eigen values, eigen vectors, LU and QR factorization. Solving nonlinear equations, bisection, Newton's method, Muller's method, fixed point interpolation, steepest descent. Interpolation and curve fitting: interpolating polynomials, spline curves, interpolation on a surface, least square approximations. Approximation of functions: Fourier basis and orthogonal polynomials, rational function approximation. Numerical differentiation and integration, solution of ordinary differential equations: Taylor series method, Euler method, Runge-Kutta method. Solution of partial differential equations, finite element methods, optimization. Introduction to quantum computing, quantum mechanics to understand quantum computation, Quantum algorithms. | | |
| Francis B. Hildebrand, Introduction to Numerical Analysis, 2nd Ed, Dover.<br>SD Conte, C de Boor, Elementary numerical analysis: An algorithmic approach, 3rd Ed, Mc Graw Hill, 1981. | | |

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| R.L. Burden & J.D. Faires, Numerical Analysis, 9th Ed, Brooks/Cole, Cengage Learning, 2011. Phillip Kaye, Raymond Laflamme and Michele Mosca, An Introduction to Quantum Computing, Oxford 2006. |

| 26EC329 | **SATELLITE COMMUNICATIONS** | **(3-0-0) 3** |
|---|---|---|
| Introduction to satellite Communications, Satellite orbits, Satellite subsystems, The RF link, Link system performance, Transmission impairments, Propagation effects: Modeling and Prediction, Fading effect, Diversity, The composite link, Satellite communications signal processing, Satellite multiple access, The mobile satellite channel, Spectrum management, Interference mitigation, Satellite navigation and GPS, High throughput satellites. | | |
| Louis J. Ippolito, "Satellite Communications Systems Engineering", Second Edition, John Wiley, 2017.<br>Timothy Pratt and Jeremy E. Allnutt , Satellite communications, Third Edition, John Wiley, 2019. | | |

| 26EC330 | **PRINCIPLES OF MODERN RADAR AND TECHNIQUES** | **(3-0-0) 3** |
|---|---|---|
| Introduction and Radar Overview, The Radar Range Equation, Radar Search and Overview of Detection in Interference; External Factors: Propagation Effects and Mechanisms, characteristics of Clutter Target Reflectivity, Target Fluctuation Models, Doppler Phenomenology and Data Acquisition Subsystems: Radar Antennas, Radar Transmitters, Radar Receivers, Radar Exciters, and The Radar Signal Processor | | |
| Mark A Richards, Principles of modern radar (POMR)-Basic principles(Vol-1), Scitech publishers<br>R. Skolnik, Modern Radar Systems, 3rd edition, Mc-Graw Hill Publishers | | |

| 26EC331 | **COMMUNICATION NETWORKS** | **(3-0-0) 3** |
|---|---|---|
| Switching techniques, Multiplexing and Multiple Access techniques, Packet Switched Networks. OSI and TCP/IP Models, Internet protocols and addressing, networking devices, data links and transmission, LANs and Network of LANS, Wireless Networks and Mobile IP, Routing and internetworking, transport and end to end protocols, congestion control techniques, Application Layer and network management, Network Security. Packet Queues and delays, Little's theorem, Birth and death process, Queuing disciplines, M/M/1 Queues, Burkes and Jackson theorems. Traffic models, ISDN, ATM Networks, Quality of service and resource allocation, VPNs and MPLS, Cellular Telephone and Optical networks, VOIP and Multimedia networking. Mobile Adhoc Networks and Wireless Sensor Networks | | |
| Nader F. Mir, Computer and Communication Networks, Pearson Education, 2007<br>Garcia and Widjaja, Communication Networks, McGraw Hill, 2006<br>J.F. Hayes, Modelling and analysis of Computer Comm. Networks, Plenum, 1984.<br>Jean Walrand & Pravin Varaiya, High Performance Communication Networks , Morgan Kaufmann Publishers, 2002 | | |

| 26EC332 | **WIRELESS MOBILE COMMUNICATION** | **(3-0-0) 3** |
|---|---|---|
| Applications and requirements of wireless services, Propagation mechanisms and channel characterization, Channel models, Equalizers, Diversity, Spread spectrum techniques, OFDM, MIMO, Resource allocation, Principles of cellular networks, Cooperative communications, 4G, Cellular – 3GPP Long-Term Evolution (LTE), 5G Cellular – 3GPP New Radio (NR), Wireless Local Area Networks, PAN and Internet of Things – Bluetooth and Zigbee, Beyond 5G. | | |
| Andreas F. Molisch, "Wireless Communications: From Fundamentals to Beyond 5G", Third Edition, John Wiley & Sons, 2022.<br>Gordon.L. Stuber, Principles of Mobile Communication, Fourth Edition, Springer International, 2018.<br>Ke-Lin Du, M.N.S. Swamy, "Wireless Communication Systems: From Fundamentals to 6G", Second Edition, Springer International, 2026 | | |

| 26EC333 | **INFORMATION THEORY AND CODING** | **(3-0-0) 3** |
|---|---|---|
| Communication systems and Information Theory, Measures of Information, Coding for Discrete sources, Discrete memory-less channels and capacity, Noisy channel coding theorem, Techniques for coding and decoding, Waveform channels, Source coding with Fidelity criterion. | | |
| Thomas M Cover & Joy A Thomas, Elements of Information Theory, John Wiley,1991 R.G.Gallagher, Information Theory and Reliable Communication, Addison Wesley, 1987. A.J.Viterbi & J.K. Omura, Principles of Digital Communications and Coding, McGraw Hill, 1979. | | |

| 26EC334 | **ADHOC AND SENSOR NETWORKS** | **(3-0-0) 3** |
|---|---|---|
| Mobile ad hoc networks and wireless sensor networks concepts and architectures. Routing: proactive routing, Broadcasting and multicasting, TCP over mobile ad hoc networks, Wireless LAN (WiFi) standards, Medium Access Control Protocol issues power control, spatial reusability, and QoS, Bluetooth, Wireless sensor networks architecture: hardware and software components of a sensor node, OS for WSN, WSN MAC layer strategies; naming and addressing; Clock Synchronization; Node Localization; WSN Routing. | | |
| C Sivarama Murthy and B S Manoj, Ad-Hoc Wireless Networks, Architectures and Protocols, PH , 2004.<br>Labiod.H, Wireless Adhoc and sensor networks, Wiley, 2008.<br>Li,X , Wireless ad hoc and sensor networks: theory and applications, Cambridge University Press,2008 | | |

| 26EC335 | **MULTIMEDIA COMMUNICATION TECHNIQUES** | **(3-0-0) 3** |
|---|---|---|
| Representation of Multimedia Data, Concept of Non-Temporal and Temporal Media, Multimedia Presentations, Synchronization. Compression of Multimedia Data, Basic concepts of Compression, Audio Compression Introduction to Speech and Audio Compression, Multimedia System Design, General Purpose Architecture for Multimedia Processing, Operating System support for Multimedia, Data, Resource Scheduling with real-time considerations, File System, I/O Device, Management, Delivery of Multimedia data, Network and Transport Protocols, QoS issues, RTP and RSVP, Video-conferencing and video-conferencing standards, Overview of Voice over IP, Multimedia Information Management, Multimedia Data base Design, Content Based Information Retrieval, Image Retrieval, Video Retrieval, Overview of MPEG-7. | | |
| Ralt Steinmetz and Klara Nahrstedt, Multimedia : Computing, Communication & Applications, Pearson Education Publications, 2004. | | |

| 26EC336 | **SOFTWARE DEFINED AND COGNITIVE RADIO** | **(3-0-0) 3** |
|---|---|---|
| Cognitive radio: goals, benefits, definitions, architectures, Spectrum-Licensed, unlicensed, shared unlicensed, opportunistic unlicensed, Current spectral usage and issues, Regulations, regulation changes, Spectral awareness, Spectrum adaptation, Dynamic frequency selection, Spectrum Sharing priority allocation, Adaptive bandwidth control Policies, Adaptation and optimization- link adaptation, incremental redundancy, jointly adaptive source and channel coding, Digital signal processing role in SDR, Cross- layer optimization (adaptation), Current cellular cognitive features-Hand -off, Channel allocation, cellular network design, Link adaptation, incremental redundancy, Interference avoidance, detection, and cancellation, Power control, Femto cells and relation to cognitive radio. 2.5G/3G/4G cognitive features, Multi-carrier system adaptation (OFDM(A) adaptive features), Collaboration and cooperation in wireless devices, networks, and systems Interference awareness, Multi -dimensional channel variation and dispersion - relation with adaptive radio, Applications of CR into public safety and other applications of CR ,Vertical hand-off and network interoperability - network awareness, multi-tier networks, Biologically inspired cognitive features (like Bats, Ants, human being, etc). | | |
| Hoseyin Arslan (Ed.), "Cognitive Radio, Software Defined Radio, and Adaptive Wireless Systems," Ser. Signals and Communication Technology, xviii, I. edition, Springer, August 2007 Joseph Mitola, III, "Cognitive Radio Architecture: The Engineering Foundations of Radio XML," John Wiley and Sons Ltd., 2006.<br>Jeffrey H. Reed, "Software Radio: A Modern Approach to Radio Engineering," Prentice Hall PTR, 2002.<br>Walter H.W. Tuttlebee, "Software Defined Radio: Enabling Technologies," John Wiley and Sons Ltd., 2002. Markus Dillinger and Kambiz Madani and Nancy Alonistioti, "Software Defined Radio: Architectures, Systems and Functions," John Wiley and Sons Ltd., 2003 | | |

| 26EC337 | **MACHINE LEARNING FOR WIRELESS COMMUNICATION SYSTEMS** | **(3-0-0) 3** |
|---|---|---|
| Need for machine learning techniques in wireless communication, Introduction to machine learning, Supervised, unsupervised, and reinforcement learning, Gaussian model, HMM, Clustering, Sequence recognition and analysis, Bayesian networks, Factor graphs, Markov chain Monte Carlo (MCMC) methods, Channel modelling and prediction using machine learning algorithms, Deep learning based channel estimation, Spectrum sensing and signal identification in cognitive radios using machine learning, Machine learning techniques for adaptive modulation and coding techniques, CNN based equalizer design, DNN based channel coding techniques (LDPC and Polar codes), Machine learning algorithms for MIMO communications, Compressive sensing for wireless sensor networks, Reinforcement learning-based channel sharing in wireless vehicular networks. | | |
| Ruisi He, and Zhiguo Ding (Editors), “Applications of Machine Learning in Wireless Communications”, IET Press, 2019.<br>Fa-Long Luo (Editor), “Machine Learning for Future Wireless Communications”, IEEE Press & Wiley, 2020.<br>Osvaldo Simeone, "A Brief Introduction to Machine Learning for Engineers", Now Publishers, 2018.<br>A. C. Faul, “A Concise Introduction to Machine Learning”, CRC Press, 2020. | | |

| 26EC338 | **SPARSE REPRESENTATIONS AND COMPRESSIVE SENSING** | **(3-0-0) 3** |
|---|---|---|
| Introduction, mathematical preliminaries, Basis and Frames, Low dimensional signal models, Sensing matrices, Signal recovery via l1 minimization, Necessary and sufficient conditions for L0-L1 equivalence. RIP and random matrices. Johnson-Lindenstrauss Lemma, Stable signal recovery and restricted eigen value property. Recovery algorithms and their performance guarantees. Multiple measurement models and Applications. | | |
| S. Foucart and H. Rauhut, “A mathematical introduction to compressive sensing,” Birkhauser Press, 2013.<br>M. Elad, “Sparse and Redundant Representations” Springer 2010.<br>H. Rauhut, “Compressive Sensing and structured random matrices”,Radon series, Comp. Applied math. 2011.<br>Compressive Sensing Resources - http://dsp.rice.edu/cs/ | | |

| 26EC339 | **DEEP REINFORCEMENT LEARNING** | **(3-0-0) 3** |
|---|---|---|

**Introduction**: Course logistics and overview. Origin and history of Reinforcement Learning research. Its connections with other related fields and with different branches of machine learning.

**Markov Decision Process:** Introduction to RL terminology, Markov property, Markov chains, Markov reward process (MRP). Introduction to and proof of Bellman equations for MRPs along with proof of existence of solution to Bellman equations in MRP. Introduction to Markov decision process (MDP), state and action value functions, Bellman expectation equations, optimality of value functions and policies, Bellman optimality equations.

**Prediction and Control by Dynamic Programming**: Overview of dynamic programming for MDP, definition and formulation of planning in MDPs, principle of optimality, iterative policy evaluation, policy iteration, value iteration, Banach fixed point theorem, proof of contraction mapping property of Bellman expectation and optimality operators, proof of convergence of policy evaluation and value iteration algorithms, DP extensions.

**Monte Carlo Methods for Model Free Prediction and Control**: Overview of Monte Carlo methods for model free RL, First visit and every visit Monte Carlo, Monte Carlo control, On policy and off policy learning, Importance sampling.

**Temporal difference (TD Methods**: Incremental Monte Carlo Methods for Model Free Prediction, Overview TD(0), TD(1) and TD(λ), k-step estimators, unified view of DP, MC and TD evaluation methods, TD Control methods - SARSA, Q-Learning and their variants.

**Function Approximation Methods**: Getting started with the function approximation methods, Revisiting risk minimization, gradient descent from Machine Learning, Gradient MC and Semi-gradient TD(0) algorithms, Eligibility trace for function approximation, After states, Control with function approximation, Least squares, Experience replay in deep Q-Networks.

**Policy Gradients**: Getting started with policy gradient methods, Log-derivative trick, Naive REINFORCE algorithm, bias and variance in Reinforcement Learning, Reducing variance in policy gradient estimates, baselines, advantage function, actor-critic methods.


Richard S. Sutton and Andrew G. Barto, "Reinforcement learning: An introduction", Second Edition, MIT Press, 2019.

Wiering, Marco, and Martijn Van Otterlo. "Reinforcement learning." Adaptation, learning, and optimization 12 (2012).

Li, Yuxi. "Deep reinforcement learning." arXiv preprint arXiv:1810.06339 (2018). Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. "Deep learning." MIT press, 2016. Reinforcement Learning resource: https://web.stanford.edu/class/cs234/modules.html


| 26EC420 | **VLSI CAD** | **(3-0-0) 3** |
|---|---|---|

Introduction to VLSI design automation: VLSI design methodologies, use of VLSI EDA tools, Algorithmic Graph Theory, computational Complexity; Partitioning: KL algorithm, FM algorithm, EIG Algorithm, Simulated Annealing. Floorplanning and placement: Sliced and non-sliced planning, Polish expression, Simulated annealing, partition based placement; ILP & mathematical programming, partition based, force directed, Fast-Place, quadratic placement algorithms. Routing: Global routing, detailed routing, graph models, Line Search, Maze Routing, Channel routing; via minimization, clock and power routing. High Level Synthesis: Introduction to HDL, HDL to DFG, operation scheduling: constrained and unconstrained scheduling, ASAP, ALAP, List scheduling, Force directed scheduling, operator binding; Static Timing Analysis: Delay models, setup time, hold time, cycle time, critical paths, Topological vs logical timing analysis, False paths, Arrival time, Required arrival Time, Slacks.Advanced VLSI Design Automation: Physical Synthesis, Optical Proximity correction, Interconnect issues


Naveed Sherwani, Algorithms for VLSI Physical Design Automation, 3rd ed., Kluwer Academic Pub., 1999 Majid Sarrafzadeh and C. K. Wong, An Introduction to VLSI Physical Design, McGraw Hill, 1996.

Sabih H. Gerez, Algorithms for VLSI Design Automation, John Wiley, 1998

Sung Kyu Lim, Practical Problems in VLSI Physical Design Automation, Springer, 2008

Sadiq M. Sait & Habib Youssef, VLSI Physical Design Automation: Theory and Practice, World Scientific Publishing, 1999


| 26EC421 | **MIXED SIGNAL DESIGN** | **(3-0-0) 3** |
|---|---|---|

Sample and Hold Circuits: Basic S/H circuit, effect of charge injection, compensating for charge injection, bias dependency, bias independent S/H. D/A Converter – General considerations, Static non-idealities and Dynamic nonidealities; Current-steering DAC – Binary weighted DAC, Thermometer DAC, Design issues, Effect of Mismatches. A/D converter – General considerations, static and dynamic non-idealities. Flash ADC – Basic architecture, Design issues, Comparator and Latch, Effect of non-idealities, Interpolative and Folding architectures. Successive Approximation ADC; Pipeline ADC. Over sampling ADC – Noise shaping, Sigma-Delta modulator.


Behzad Razavi, Design of Analog CMOS Integrated Circuits McGraw-Hill International Edition 2016 David A. Johns and Ken Martin, Analog Integrated Circuit Design, John Wiley, 2002 Phillip E. Allen and Douglas R. Holberg, CMOS Analog Circuit Design, Oxford University Press, 2003. Behzad Razavi, Principles of Data Conversion System Design, Wiley-IEEE Press, 1995 Rudy J. van de Plassche, CMOS Integrated Analog-to-Digital and Digital-to-Analog Converters, Springer, 2003

| 26EC422 | **ADVANCED COMPUTER ARCHITECTURE** | **(3-0-0) 3** |
|---|---|---|
| Instruction Level Parallelism: Pipelining, Hazards, Instruction Level Parallelism, Branch prediction, Static and Dynamic Scheduling, Speculation, Limits of ILP. Multicore Memory Hierarchy: Cache trade-offs, Basic and Advanced optimizations, Virtual Memory, DRAM optimizations. Multiprocessors: Symmetric and Distributed architectures, Cache coherence protocols - Snoopy and Directory based, ISA support for Synchronization, Memory Consistency Models. Interconnection Networks: Architectures, Topologies, Performance, Routing, Flow control, Future of NoCs. | | |
| John Hennessy and David Patterson, Computer Architecture - A Quantitative Approach 6th Edition, Morgan Koufmann, 2017<br>John Hennessy and David Patterson, Computer Architecture - A Quantitative Approach 5th Edition, Morgan Koufmann, 2011<br>John Paul Shen and Mikko H. Lipasti, Modern Processor Design: Fundamentals of Superscalar Processors, Tata McGraw Hill, 2013<br>D. A. Patterson and J. Hennessy, Computer Organization and Design, Harcourt Asia, 1998. Behrooz Parhami, Computer Arithmetic Algorithms and Hardware Design, Oxford, 2000. | | |

| 26EC423 | **VLSI TESTING AND TESTABILITY** | **(3-0-0) 3** |
|---|---|---|
| Overview of testing and verification, Defects and their modeling as faults at gate level and transistor level. Functional V/s. Structural approach to testing. Complexity of testing problem. Controllability and observability. Generating test for a signal stuck-at-fault in combinational logic. Algebraic algorithms. Test optimization and fault coverage. Logic Level Simulation – Delay Models, Event driven simulation, general fault simulation (serial, parallel, deductive and concurrent). Testing of sequential circuits. Observability through the addition of DFT hardware, Adhoc and structured approaches to DFT – various kinds of scan design. Fault models for PLAs, bridging and delay faults and their tests. Memory testing, testing with random patterns. LFSRs and their use in random test generation and response compression (including MISRs ), Built-in self-test. | | |
| M. Abramovici, M. A. Breuer, and A. D. Friedman, Digital Systems Testing and Testable Design, IEEE Press, 1994.<br>M. L. Bushnel and V. D. Agarwal, Essentials of Testing for Digital, Memory and Mixed – Signal VLSI Circuits, Kluwer Academic Publishers, 2000.<br>Ajai Jain, Learning Module for the course - VLSI Testing and Testability, IIT, Kanpur, 2001. | | |

| 26EC424 | **SYNTHESIS AND OPTIMIZATION OF DIGITAL CIRCUITS** | **(3-0-0) 3** |
|---|---|---|
| Introduction to Computer aided synthesis and optimization. Hardware Modeling. Advanced Boolean Algebra and Applications – Boolean functions, representations, Shannon co-factors, satisfiability and cover, Binary Decision Diagrams, Representing Boolean functions, ROBDD, ITE operator, Variable ordering- choice of variables, application of BDD to synthesize Boolean functions, Two level combinational logic optimization, Multiple level combinational optimization. Sequential logic optimization. Cell Library Binding. Algorithms for Technology mapping – Structural and Boolean matching, Simulation & Static Timing analysis - Event driven simulation – zero delay, unit delay and nominal delay simulation, Timing analysis at the logic level, Delay models, Delay graph, static sensitization, State of the art and future trends: System level synthesis. | | |
| Giovanni De Micheli, Synthesis and Optimization of Digital Circuits, McGraw Hill, 1994. Srinivas Devadas, Abhijith Ghosh and Kurt Keutzer, Logic Synthesis", Kluwer Academic, 1998.<br>G. D. Hachtel and F. Somenzi, Logic Synthesis and Verification Algorithms, Kluwer Academic Publishers, 1996.<br>S. Hassoun and T. Sasao, (Editors), Logic Synthesis and Verification, Kluwer Academic publishers, 2002 | | |

| 26EC425 | **TECHNIQUES IN LOW POWER VLSI** | **(3-0-0) 3** |
|---|---|---|
| Introduction to Low Power VLSI. Modeling and Sources of Power consumption. Power estimation at different design levels. Power optimization for combinational circuits and sequential circuits Voltage scaling Approaches. Low energy computing using energy recovery techniques. Low Power SRAM architectures. Software design for low power. Computer Aided Design Tools. Case studies Recent trends in low-power design for mobile and embedded application. | | |
| Kaushik Roy, Sharat Prasad, Low-Power CMOS VLSI design, John Wiley, 2000. K.-S. Yeo and<br>K. Roy, Low-Voltage Low-Power Subsystems, McGraw Hill, 2004.<br>Anantha P.Chandrakasan & Robert W. Brodersen, Low Power Digital CMOS Design, Kluwer, 1995. Gary K. Yeap, Practical Low Power Digital VLSI Design, Kluwer Academic Publications, 1998<br>L. Benini and G. De Micheli, Dynamic Power Management Design Techniques and CAD Tools, Springer, 1998.<br>S. G. Narendra and A. Chandrakasan, Leakage in Nanometer CMOS Technologies, Springer, 2005.<br>Edgar Sánchez-Sinencio, Andreas G. Andreou, Low- Voltage/Low-Power Integrated Circuits and Systems: Low-Voltage Mixed-Signal Circuits IEEE Press Series on Microelectronic Systems 1999 | | |

| 26EC426 | **SUBMICRON DEVICES** | **(3-1-0) 4** |
|---|---|---|
| Review of basic device physics, Electronic structure of semiconductors, Diodes, MOS capacitor. Transistor theory. Scaling - Moore's law on technology scaling, MOS device scaling theory, Short channel effects, sub threshold leakage, Punch through, DIBL, High field mobility, Velocity saturation and overshoot. Reliability. Various definitions of channel length, Performance metric of digital technology, Transistor design trade- offs, Technology case studies, Silicon on Insulator (SOI) devices, Partially depleted and fully depleted SOI, Floating body effects, SOI for low power, Interconnects in sub-micron technology, Foundry technology, International Technology Roadmap for Semiconductors (ITRS). | | |
| J. A. del Alamo Integrated Microelectronic Devices: Physics and Modeling, Pearson, 2017 Yaun Taur, Tak H. Ning, Fundamentals of modern VLSI devices, Cambridge university press, 1998.<br>B. G. Streetman & S. Banerjee, Solid State Electronic Devices, Prentice Hall, 1999.<br>M. K. Achuthan and K. N. Bhat, Fundamentals of Semiconductor Devices, McGraw Hill, 2006 Nandita Dasgupta, Amitava Dasgupta, Semiconductor Devices: Modelling And Technology, Phi, 2009 A. K. Dutta, Semiconductor Devices and Circuits, Oxford Univ. Press, 2008. ITRS Road map - http://public.itrs.net/ | | |

| 26EC427 | **ACTIVE FILTERS** | **(3-1-0) 4** |
|---|---|---|
| Butterworth, Chebyshev & Inverse-Chebyshev filter response and pole locations, LC ladder filter – prototype & synthesis; Frequency transformation of lowpass filter. Impedance converters; Gm-C filters – Gm-C biquad, Q enhancement, Automatic Tuning; Active-RC filters – Comparison with Gm-C filter, Issues in realizing high frequency active-RC filters, Switched Capacitor Filters. | | |
| R. Schaumann and M.E. Van Valkenburg, Design of Analog Filters, Oxford University Press, 2003.<br>P.V. Ananda Mohan, Current-Mode VLSI Analog Filters - Design and Applications, Birkhauser, 2003 M.E. Van Valkenburg, Analog Filter Design, Oxford University Press, 1995. | | |

| 26EC428 | **HETEROGENEOUS AND PARALLEL COMPUTING** | **(3-0-2) 4** |
|---|---|---|
| Heterogeneous platform and GPU architecture. Introduction to OpenCL. OpenCL device architecture. Concurrency and execution model. Programming examples like vector addition, convolution and matrix multiplication. Application case studies. | | |
| Benedict R. Gaster, Lee Howes, David R. Kaeli, Perhaad Mistry, Dana Schaa, "Heterogeneous Computing with OpenCL" - Revised OpenCL 1.2 Edition, Morgan Kaufmann, 2013.<br>Aaftab Munshi, Benedict R. Gaster, Timothy G. Mattson, James Fung, Dan Ginsburg, "OpenCL Programming Guide", Addison-Wesley, 2012.<br>David B. Kirk and Wen-mei W. Hwu, "Programming Massively Parallel Processors - A Hands-on Approach", Second Edition, Morgan Kaufmann, 2013.<br>AMD Accelerated Parallel Processing OpenCL User Guide, AMD, 2014. | | |

| 26EC429 | **ALGORITHMS AND ARCHITECTURES FOR SIGNAL PROCESSING** | **(3-1-0) 4** |
|---|---|---|
| Representation of digital signal processing systems: block diagrams, signal flow graphs, data-flow graphs, dependence graphs; pipelining and parallel processing for high-speed and low power realizations; iteration bound, algorithms to compute iteration bound, retiming of data- flow graphs; unfolding transformation of data- flow graphs; systolic architecture design, architectures for real and complex fast Fourier transforms; stochastic logic based computing, computing digital filters, arithmetic functions and machine learning functions using stochastic computing; Neural Network architectures. | | |
| K.K. Parhi, VLSI Digital signal processing systems: Design and implementation, John Wiley, 1999. Lars Wanhammar, DSP Integrated Circuits, Academic Press, 1999<br>Sen M. Kuo Bob H. LeeWenshun Tian, "Real-Time Digital Signal Processing: Implementations and Applications", 2006 John Wiley & Sons, Ltd<br>Roger Woods, John McAllister, Gaye Lightbody, Ying Yi, "FPGA Based Implementation of Signal Processing Systems", John Wile, 2017.<br>U. Meyer-Baese, "Digital Signal Processing with Field Programmable Gate Arrays", 4th Ed. Springer, 2014 | | |

| 26EC430 | **ADVANCED DIGITAL SIGNAL PROCESSING** | **(3-1-0) 4** |
|---|---|---|
| Power spectral estimation; Parametric and non-parametric methods of spectral estimation, Linear prediction, Higher order spectral estimation; Adaptive filters and applications. Recursive estimation and Kalman filters Multirate Signal Processing: Decimation Interpolation, DFT filter banks, QMF filter banks, Multiresolution Signal analysis wavelets theory of sub band decompositions, Sub band coding and wavelet transforms, Application of wavelet transforms. | | |
| P.P. Vaidyanathan, Multirate systems and Filter banks, Prentice Hall, 1993. S.J. Orfanidis, Optimum Signal Processing, McGraw Hill, 1989.<br>S. Haykin, Adaptive Filter Theory, Pearson, 1996 | | |

| 26EC431 | **REAL TIME SIGNAL PROCESSING** | **(2-0-3) 4** |
|---|---|---|
| Introduction to DSP systems and architecture; Arithmetic: Fixed point, floating point and residue arithmetic, Cordic architectures; Real time implementation of SP algorithms on Digital Signal Processors: Architecture and programming; Real time implementation of SP algorithms on Reconfigurable architectures: Architecture and design flow; Issues in implementation of convolution, FIR, IIR and adaptive filters, DCT, Image Filtering, Dynamically reconfigurable architectures for SP, Software Configurable processors, Application case studies in multimedia compression and communication. | | |
| Behrooz Parhami, "Computer Arithmetic Algorithms and Hardware Design", Oxford, 2000. Rulph Chassaing, " Digital Signal Processing and Applications with the C6713 and C6416 DSK", Wiley, 2005<br>U. Meyer Baesse, "Digital Signal Processing with FPGAs", Springer, 2001<br>Shehrzad Qureshi, "Embedded Image Processing on the TMS320C6000 DSP" Springer, 2005 | | |

| 26EC432 | **FOURIER AND WAVELET SIGNAL PROCESSING** | **(3-0-0) 3** |
|---|---|---|
| Hilbert Spaces, Review of sequences and discrete time systems, functions, DTFT, convergence, multi rate systems, polyphase representation, stochastic processes and systems. Continuous time systems, Fourier transform, definition, existence, spectral decay, Fourier series. Sampling and Interpolation–finite dimensional vectors, sequences, functions, periodic functions, approximation and compression polynomial and spline approximation. Localization and uncertainty. Filter banks–Localization, two channel orthogonal filter banks, design, biorthogonal filter banks, design. Local Fourier bases–N channel filter banks, exponentially modulation filter banks, cosine modulated filter banks. Wavelet bases on sequences, Tree structured filter banks, orthogonal, biorthogonal bases, wavelet packets, frames. Wavelet bases on functions–local Fourier transforms. | | |
| Martin Vetterli Jelena Kovacevic & Vivek K. Goyal, Foundations of Signal Processing, Cambridge University Press, 2015.<br>J. Kovacevic, V. K. Goyal and Martin Vetterli, Fourier and Wavelet Signal Processing, Cambridge University Press, 2013<br>Todd Moon and WC Stirling, Mathematical Methods and Algorithms for Signal Processing, Pearson Education, 2000 Steven, M. Kay, Modern spectral estimation: theory and application, Prentice Hall, 1988 | | |

| 26EC433 | **MATHEMATICAL METHODS FOR SIGNAL AND DATA PROCESSING** | **(3-0-0) 3** |
|---|---|---|
| Mathematical Foundations–mathematical models, random variables and random processes, Markov and hidden Markov models. Representations and approximations - orthogonality, least squares, MMSE filtering, frequency domain optimal filtering, minimum norm solutions, Iterated reweighted least squares. Linear Operators – Operator norms, adjoint and transposes, geometry of linear equations, least squares and pseudo inverses, applications to linear models.<br>Subspace methods – Eigen decomposition, KL transform and low rank approximation, Eigen filters, signal subspace techniques – MUSIC, ESPRIT. SVD – matrix structure, pseudo inverse and SVD, system identification using SVD, Total least squares, partial total least squares. Special matrices–Toeplitz matrices, optimal predictors and lattice filters, circulant matrices, properties. | | |

| 26EC434 | **DATA COMPRESSION AND APPLICATIONS** | **(3-0-0) 3** |
|---|---|---|
| Data Compression. Speech & image waveform characterization. Predictive coding. Transform coding. Subband coding, VQ based compression, Fractal coding of images. High quality video & audio compression for digital broadcasting. Standards for digital signal compression-data, speech, audio, image & video. | | |
| D. Salomon, Data Compression – the complete reference, Springer, 2000.<br>K. Sayood, Introduction to Data Compression, Pearson Education, 2000. M.Nelson, The data compression book, BPB Publications, 2002.<br>Jayant & Noll, Digital coding of waveforms-Principles and applications to speech & video, PH, 1984. | | |

| 26EC435 | **DYNAMICAL SYSTEMS, CHAOS AND FRACTALS** | **(3-0-0) 3** |
|---|---|---|
| Preliminaries on systems, Eigen values and Eigen vectors, solutions of linear ODEs. Dynamics of linear and nonlinear systems, solutions, attractors, equilibrium point, limit cycles, stability, Linear systems: solutions, stability of autonomous systems, BIBO stability, relation to frequency domain analysis, Nonlinear systems: large-scale notions of stability (Lyapunov functions), linearization. Vector fields of nonlinear systems, limit cycles, Lorenz and Rossler equation, Chua's circuit, Discrete dynamical systems, logistic maps, two dimensional maps, bifurcations, flows, phase plane analysis. Introduction to fractals, Mandlebrot and Julia sets, iterated function systems, strange attractors, fractal dimension, stable and unstable manifolds, analysis of chaotic time series, multifractals. Applications in control theory, signal processing, digital image modelling, synthesis and compression, chaos communication and Cryptography. Other applications in engineering, natural and social sciences, medicine, economics, ecology, bio and life sciences, and environmental sciences. | | |
| S. Stenberg, Dynamical systems, Dover 2010.<br>MW Hirsch, S. Smale, RL Devaney, Differential equations, dynamical systems, and an introduction to chaos, Academic Press. 2012**.** | | |

Steven H. Strogatz, Nonlinear dynamics and chaos: with applications to physics, biology, chemistry, and engineering, West-view Press, 2015.
E. Ott, Chaos in dynamical systems, 2nd ed Cambridge University Press, 2002.
S. Wiggins, Introduction to applied nonlinear dynamical systems and chaos, Springer-Verlag, 1990.
Denny Gulick, Encounters with chaos and fractals, 2nd ed CRC Press, 2012.
J.M. Bahi, C. Guyeux, Discrete dynamical systems and chaotic machines: theory and applications, CRC Press, 2013.
M. Barnsley, Fractals everywhere, Academic Press, 1993.

| 26EC436 | **STATISTICAL ANALYSIS** | **(3-0-0) 3** |
|---|---|---|

Preliminaries on matrix theory and probability distributions. Sampling theory: random samples, sampling distribution, statistical inference, estimation of mean and variances, hypothesis testing, statistical tests, goodness of fit. Data analysis: correlation and regression, simple linear regression, multiple linear regressions, logistic regression, nonlinear regression. The Multivariate Normal Distribution, Estimation of the Mean Vector and the Covariance Matrix, The Distributions and Uses of Sample Correlation Coefficients, The Generalized T2-Statistic, Classification of Observations, The Distribution of the Sample Covariance Matrix and the Sample Generalized Variance, Testing the General Linear Hypothesis: Multivariate Analysis of Variance, Testing Independence of Sets of Variates, Testing Hypotheses of Equality of Covariance Matrices and Equality of Mean Vectors and Covariance Matrices, Principal Components, Canonical Correlations and Canonical Variables, The Distributions of Characteristic Roots and Vectors, Factor Analysis, Pattern of Dependence, Graphical Models.

Sam Kash Kachigan, Statistical Analysis: An Interdisciplinary Introduction to Univariate and Multivariate Methods, Radius Press, 1986.
RA Johnson, DW Wichern, Applied multivariate statistical analysis, 6th ed, PHI, 2012.
T. W. Anderson, An Introduction To Multivariate Statistical Analysis, 3rd Edition, Wiley, 2003.
Sam Kash Kachigan, Multivariate Statistical Analysis: A Conceptual Introduction, Radius Press, 1991.
Robert Nisbet, John Elder and Gary Miner, Handbook of Statistical Analysis and Data Mining applications, Elsevier Inc 2009.

| 26EC437 | **OPTIMIZATION THEORY AND TECHNIQUES** | **(3-0-0) 3** |
|---|---|---|

Convex sets and Convex functions, Level sets and Gradients, Unconstrained Optimization: Search methods, Gradients Methods, Newton Method, Conjugate Direction Methods, Quasi-Newton Methods. Linear Programming: Standard Form Linear Programs, Simplex method, Duality and Non Simplex Methods. Nonlinear Constrained Optimization: Problems with equality constraints, Problems with Inequality Constraints, Convex Optimization Problems, Algorithms for Constrained Optimization: Projected Gradient Methods and Penalty Methods.

Lieven Vandenberghe and Stephen P. Boyd, Convex Optimization, Cambridge University Press, 2004. Dimitris Bertsimas, John N. Tsitsiklis, Introduction to Linear Optimization, Athena Scientific Series, 1997. Aharon Ben-Tal and Arkadi Nemirovski, Lectures on Modern Convex Optimization: Analysis, Algorithms, and Engineering Applications, SIAM, 2001.

| 26EC438 | **UNSUPERVISED LEARNING** | **(3-0-0) 3** |
|---|---|---|

Clustering-K means, Hierarchical Clustering, Density-Based Spatial Clustering of Applications with Noise, Gaussian Mixture Models, Association Rule Learning, Dimensionality Reduction, Anomaly Detection, Principal Component Analysis (PCA), SVD, Autoencoders, Variational Autoencoders, Generative Adversarial Networks, Restricted Boltzmann Machines (RBMs) and Deep Belief Networks (DBNs), Self-Organizing Maps (SOMs), Hierarchical Temporal Memory (HTM), use cases: customer segmentation, image recognition, anomaly detection, scientific discovery. Semi-supervised learning, Gaussian mixtures, manifold learning, decomposing signals using matrix factorization problems, density estimation

M. Emre Celebi, Kemal Aydin, Unsupervised Learning Algorithms, Springer, 2018.
Geoffrey Hinton, Terrence J. Sejnowski, Unsupervised Learning: Foundations of Neural Computation, The MIT Press, 1999.
Matthew Kyan, Paisarn Muneesawang, Kambiz Jarrah, Ling Guan, Unsupervised Learning: A Dynamic Approach, Wiley-IEEE Press, 2014.
Giuseppe Bonaccorso, Hands-On Unsupervised Learning with Python, Packt Publishing, 2019.

| 26EC439 | **SPREAD SPECTRUM COMMUNICATION** | **(3-0-0) 3** |
|---|---|---|

Spread spectrum overview, Spreading techniques, Pseudo noise sequences, Direct sequence spread spectrum system, Frequency hop spread spectrum system, Hybrid systems, Synchronization, Jamming considerations, Commercial applications, Cellular systems, Performance of spread spectrum systems.

R.L.Peterson, Introduction to spread spectrum communication, PH,1995. B.Sklar, Digital Communications, Pearson Education, 2001.
M.K.Simon, Spread spectrum communications Handbook, McGraw-Hill, 2001. J.S.Lee, CDMA Systems Engineering handbook, Artech House, 1998

| 26EC440 | **ERROR CONTROL CODING** | **(3-0-0) 3** |
|---|---|---|
| Coding for reliable digital transmission and storage. Groups, Rings, Vector Spaces, Galois Fields, Polynomial rings, Channel models, Linear Block codes, Cyclic codes, BCH codes, Reed Solomon Codes, Berlekamp-Massey and Euclid decoding algorithm, Decoding beyond the minimum distance parameter, Applications of Reed-Solomon codes, Convolutional codes, Decoding algorithms for Convolutional codes, Viterbi, Stack and Fano algorithms, Application of Convolutional codes. Codes based on the Fourier Transform, Algorithms based on the Fourier Transform, Trellis coded modulation, Combinatorial description of Block and Convolutional codes, Algorithms for the construction of minimal and tail biting trellises, Soft decision decoding algorithms, Iterative decoding algorithms, Turbo-decoding, Two-way algorithm, LDPC codes, Use of LDPC codes in digital video broadcasting, belief propagation (BP) algorithms, Space-Time codes. | | |
| Shu Lin and Daniel J. Costello Jr., Error Control Coding: Fundamentals and Applications, Prentice Hall, 2003.<br>S. B Wicker, Error Control Systems for Digital Communication and Storage, Prentice Hall International, 1995.<br>Blahut R. E, Theory and Practise of Error Control Codes, Addison Wesley, 1983. | | |

| 26EC441 | **OPTICAL COMMUNICATION SYSTEMS AND NETWORKS** | **(3-0-0) 3** |
|---|---|---|
| Introduction to Optical Fibers, Ray Optics-Optical Fiber Modes and Configurations. Signal degradation in Optical Fibers. Optical Sources and Detectors. Optical Communication Systems and Networks. Basic concepts of SONET/SDH Networks. | | |
| J.Senior, Optical Communication, Principles and Practice, Prentice Hall of India, 1994/latest edition. Gerd Keiser, Optical Fiber Communication McGraw –Hill International, Singapore, 3rd ed., 2000/latest Edition<br>J.Gower, Optical Communication System, Prentice Hall of India, 2001. | | |

| 26EC442 | **RADAR SIGNAL PROCESSING** | **(3-0-0) 3** |
|---|---|---|
| Introduction to Radar Systems and Signal Processing, Signal Models, Pulsed Radar Data Acquisition Radar Waveforms, Doppler Processing, Detection Fundamentals, Introduction to Synthetic Aperture Imaging, and Introduction to Beamforming and Space-Time Adaptive Processing. | | |
| Mark A Richards, Fundamentals of radar signal Processing, McGraw Hill edition, 2nd edition, 2013 Peebles P. Z, Radar Principles, John Wiley and Sons, 1998. | | |

| 26EC443 | **ALGORITHMS FOR PARAMETER AND STATE ESTIMATION** | **(3-0-0) 3** |
|---|---|---|
| Maximum likelihood (ML) estimation, Maximum a posteriori (MAP) estimation, Least squares (LS) estimation, Minimum mean square error (MMSE) estimation, Linear MMSE (LMMSE) estimation. LS estimation for linear and nonlinear systems, modelling stochastic dynamic systems, the Kalman filter for discrete time linear dynamic systems with Gaussian noise. Steady state filters for noisy dynamic systems, adaptive multiple model estimation techniques. Nonlinear estimation techniques, computational aspects of discrete time estimation. | | |
| Y. Bar-Shalom, X. Rong Li and T. Kirubarajan, Estimation with Applications to Tracking and Navigation, John Wiley & Sons, 2001.<br>F. L. Lewis, Optimal Estimation, John Wiley & Sons, 1986.<br>R. G. Brown and P. Y. C. Hwang, Introduction to Random Signals and Applied Kalman Filtering, John Wiley & Sons, 1992. | | |

| 26EC444 | **DETECTION AND ESTIMATION THEORY** | **(3-0-0) 3** |
|---|---|---|
| Preliminaries on probability and random processes. Hypothesis testing: Neyman-Pearson theorem, likelihood ratio test and generalized likelihood ratio test, uniformly most powerful test, multiple- decision problem, detection of deterministic and random signals in Gaussian noise, detection in nonGaussian noise, sequential detection. Parameter estimation: unbiasedness, consistency, Cramer-Rao bound, sufficient statistics, Rao-Blackwell theorem, best linear unbiased estimation, maximum likelihood estimation, method of moments. Bayesian estimation: MMSE and MAP estimators, Levinson-Durbin and innovation algorithms, Wiener filter, Kalman filter. Applications in Wireless Communication, Radar Systems, Speech, Image and Video processing and applications relevant to Engineering. | | |
| Steven Kay, Fundamentals of Statistical Signal Processing - Detection Theory (Vol. 2), Prentice Hall, 1998. Steven Kay, Fundamentals of Statistical Signal Processing - Estimation Theory (Vol. 1), Prentice Hall, 1993.<br>H. V. Poor, An Introduction to Signal Detection and Estimation, Springer-Verlag, 2nd edition, 1994.<br>H. L. Van Trees, Detection, Estimation and Modulation Theory, Parts 1 and 2, John Wiley Inter- Science, 2002 M. D. Srinath, P. K. Rajasekaran and R. Vishwanathan, An Introduction to Statistical Signal Processing with Applications, Prentice-Hall, 1996.<br>Kailath,T. and Hassibi, Linear Estimation, Pearson, 2000 | | |

| 26EC445 | **ADVANCED TOPICS IN COMMUNICATION ENGINEERING** | **(3-0-0) 3** |
|---|---|---|
| Fading Channels, characterizing Mobile radio propagation, Signal time spreading, time variance of channel, mitigating the degradation effects of fading, characterizing fading channels, Fundamentals of Statistical Detection Theory, Baye's Theorem, Decision theory, Neyman Pearson Theorem, Receiver operating characteristics, Bayes's risk. Multiple hypothesis testing, minimum Baye's risk detection for binary hypothesis and multiple hypothesis, Orthogonal Frequency Division Multiplexing, OFDM transmission technique, synchronization, modulation, demodulation, amplitude limitation of OFDM signals. Space Time Wireless Communications, Introduction, space time propagation, space time channel and signal models, spatial diversity, space time OFDM | | |
| J.G.Proakis & M.Salehi, Digital Communication, 5th edition, McGraw Hill 2007.<br>Stevan M Kay, Fundamentals of Statistical signal processing, Vol. II, Detection Theory, PHI, 1998.<br>A.Paulraj, R.Nabar & D.Gore, ,Introduction to Space Time Wireless Communications, Cambridge University, 2003**.** | | |

| 26EC446 | **INTRODUCTION TO PHOTONICS** | **(3-0-0) 3** |
|---|---|---|
| Photonic Crystals: Electromagnetic wave in periodic medium, Symmetry, 1D photonic crystals: photonic band gap, omnidirectional reflector, 2D photonic crystals: photonic crystal waveguides, micro cavity, negative refraction, self-collimation, photonic crystal fibre, One-way waveguide, 3D photonic crystals: self-assembled photonic crystal, holographically fabricated photonic crystal. Plasmonics, - Optics in metal, Surface Plasmon polariton, Localized surface plasmon, Phonon polariton, Plasmon waveguides, Transmission through sub-wavelength aperture, Enhancement of fluorescence and nonlinearity, Applications in Biomedical Engineering. Metamaterials, Effective medium theory, Negative refractive index, Super lens, Transformation optics, Invisibility cloak. | | |
| Lukas Novotny and Bert Hecht, Principles of Nano-Optics, Cambridge University Press, 2012<br>Herve Rigneault, Jean-Michel Lourtioz, Claude Delalande, Juan ArielLevenson, Nanophotonics, Wiley-ISTE, 2006.<br>Mark L. Brongersma, Pieter G. Kik, Surface Plasmon Nanophotonics, Springer, 2007<br>P.N. Prasad, Nanophotonics, John Wiley and Sons, 2004<br>John D. Joannopoulos, Robert D. Meade, Joshua N. Winn, Photonic Crystals, Princeton University Press Princeton, NJ, USA 2008. | | |

| 26EC447 | **MIMO COMMUNICATION SYSTEMS** | **(3-0-0) 3** |
|---|---|---|
| Overview of fundamentals of Digital Communications, The Wireless Channel, Detection, Diversity and Channel Uncertainty, Capacity of Wireless channels, Spatial Multiplexing and Channel modelling, Capacity and Multiplexing architectures, Diversity-Multiplexing trade-off and Universal Space Time Codes, Multi-user Communication. | | |
| D. Tse, Pramod Viswanath, Fundamentals of Wireless Communications, Cambridge University Press, 2005. E. Biglieri, Coding for Wireless Channels, Springer, 2007<br>E. Biglieri et al., MIMO Wireless Communications, Cambridge University Press, 2007. | | |

| 26EC448 | **RF IC DESIGN** | **(3-0-0) 3** |
|---|---|---|
| Basic concepts in RF Design – harmonics, gain compression, desensitization, blocking, cross modulation, intermodulation, inter symbol interference, noise figure, Friis formula, sensitivity and dynamic range; Receiver architectures – heterodyne receivers, homodyne receivers, image-reject receivers, digital-IF receivers and subsampling receivers; Transmitter architectures – direct-conversion transmitters, two-step transmitters; Low noise amplifier (LNA) – general considerations, input matching, CMOS LNAs; Down conversion mixers – general considerations, spur-chart, CMOS mixers; Oscillators – Basic topologies, VCO, phase noise, CMOS LC oscillators; PLLs – Basic concepts, phase noise in PLLs, different architectures. | | |
| Behzad Razavi, RF Microelectronics, Prentice Hall PTR, 1997<br>Thomas H. Lee, The design of CMOS radio -frequency integrated circuit, Cambridge University Press, 2006 Chris Bowick, RF Circuit Design, Newnes, 2007 | | |

| 26EC449 | **PRINCIPLES OF MODERN RADAR - ADVANCED TECHNIQUES** | **(3-0-0) 3** |
|---|---|---|
| Advanced Techniques in Modern Radar, Advanced Pulse Compression Waveform Modulations and Techniques, Optimal and Adaptive MIMO Waveform Design, MIMO Radar, Synthetic Aperture Radar, Array Processing and Interference, Mitigation Techniques, Human Detection With Radar: Dismount Detection, Advanced Processing Methods for Passive Bistatic Radar Systems | | |
| Mark A Richards, Principles of modern radar(POMR)-Advanced Techniques(Vol-1I), Scitech publishers, | | |

| 26EC450 | **ELECTRONIC DEFENCE SYSTEMS** | **(3-0-0) 3** |
|---|---|---|
| Electronic Defence: Introduction, Systems in use in Armed forces; Sensors: Radar Sensors, Infrared sensors; Weapon systems: Artillery systems, missile systems; Electronic Intercept Systems: Introduction The Equation of a Passive System, Radar Warning Receivers; Electronic Countermeasures Systems Introduction, Operational Jamming Modes: SPJ, SOJ, and EJ, Onboard ECM Systems, .Electronic Counter-Countermeasures Systems: Introduction, Search Radar Counter-Countermeasures; New Electronic Defence Techniques and Technologies: Introduction, New Electronic Defence Architectures, ESM Antennas, Wideband Front End and Digital Receiver. | | |
| Filippo Neri, Introduction to Electronic Defence Systems, Second Edition, Artech House, London | | |

| 26EC451 | **MILLIMETER WAVE COMMUNICATION** | **(3-0-0) 3** |
|---|---|---|
| Millimeter wave characteristics and implementation challenges, radio wave propagation for mm wave, Millimeter wave generation and amplification, HEMT, transistor configurations, Analog mm wave components, Consumption factor theory, Trends and architectures for mm wave wireless, ADC's and DAC's, Modulation for millimeter wave communications, Millimeter wave link budget, Transceiver architecture, Massive MIMO Communications, Potential benefits for mm wave systems, Spatial, Temporal and Frequency diversity, Dynamic spatial, frequency and modulation allocation, Antenna beam width, polarization, advanced beam steering and beam forming, mm wave design consideration, On-chip and In package mm wave antennas, Techniques to improve gain of on-chip antennas, Implementation for mm wave in adaptive antenna arrays, Device to Device communications over 5G systems, Design techniques of 5G mobile. | | |
| K.C. Huang, Z. Wang, "Millimeter Wave Communication Systems", Wiley-IEEE Press, March 2011. Robert W. Heath, Robert C. Daniel, James N. T.S. Rappaport, Murdock, "Millimeter Wave Wireless Communications", PH, 2014.<br>Xiang, W.Zheng, K. Shen, X.S, "5G Mobile Communications", Springer, 2016. | | |

| 26EC452 | **COMPUTATIONAL INVERSE PROBLEMS AND IMAGING** | **(3-0-0)3** |
|---|---|---|
| Inverse Problems and Interpretation, Examples of inverse problems, III posed problems and numerical solutions. Classical Regularization Methods, Statistical Inversion Theory, nonstationary Inverse Problems, Regression, regularization, and iterative schemes for smooth optimization, numerical optimization, Bayesian approach to inverse problems. Physics of imaging, Imaging methods and modalities, computational aspects, theoretical and applied; modalities in medical imaging, geophysics, applied physics, biology, astronomy, remote sensing and optics; methods and applications in nuclear medical imaging physics and radiology, image guided radiotherapy; RADAR, computational photography, inverse problems and reconstruction, image informatics. | | |
| Curtis R.Vogel, Computational Methods for Inverse Problems, SIAM, 2002.<br>Per Christian Hansen, Discrete Inverse Problems: Insight and Algorithms, SIAM, 2010. Jennifer Mueller and Samuli Siltanen, Linear and Nonlinear Inverse Problems with Practical Applications, SIAM, 2012.<br>Kedar Khare, Fourier Optics and Computational Imaging, Wiley, 2015.<br>E. Russell Ritenour and William Hendee, Medical Imaging Physics, Wiley 2002. Thayalan K, The Physics of Radiology and Imaging, Jaypee Brothers 2014. | | |

| 26EC453 | **ADVANCED DEEP LEARNING AND APPLICATIONS** | **(2-0-2) 3** |
|---|---|---|
| Review of CNNs for classification and segmentation tasks, Advance concepts-depth-wise separable convolution, Atrous convolution, Group Convolution, Gated Atrous Pyramid Pooling, Attention and Self-attentions. Deep CNN Models for Regression, classification and Segmentations task: ResNet Models, Variants of UNet, BiSeNet V2. Advance CNNs for Object Detection and Text Classification, Graph Neural Networks. Vision Transformer and its Applications: object segmentation, detection and classification. | | |
| IanGoodfellow, YoshuaBengio, and Aaron Courville Deep Learning, MIT Press, 2016.<br>Mahmoud Hassaballah and Ali Ismail Awad, Deep Learning in Computer Vision: Principles and Applications, CRC Press, 2020.<br>Rowel Atienza, Advance deep learning with Keras, Packt, October 2018.<br>Wang,X.,Zhao, Y.&Pourpanah, F.Recent advances in deep learning. Int.J.Mach. Learn. & Cyber. 11,747-750 (2020).https://doi.org/10.1007/s13042-020-01096-5<br>Alexey Dosovitskiy, et al., An Image is Worth 16x16 Words: Transformers for Image Recognition at Scale, https://arxiv.org/abs/2010.11929<br>Xiangning Chen, Cho-Jui Hsieh, Boqing Gong, "When Vision Transformers Outperform ResNets Without Pre-Training or Strong Data Augmentations",2022 | | |

| 26EC454 | **MATHEMATICS OF DATA SCIENCE** | **(3-0-0)3** |
|---|---|---|
| Extracting information from data, Mathematics as a foundation of data science, Data Science models and methods, data science revolution, Topics from real analysis and functional analysis, matrix algebra, multivariate calculus, differential equations, geometry and topology. Data visualization, mining and knowledge discovery, geometry and high dimension, dimension reduction, high-dimensional statistics, Concentration of Measure, graphs and networks, dimension and Semi-supervised learning, Matrix concentration inequalities, Manifold Learning and Diffusion Maps, Compressive Sensing and Sparsity, tensor decomposition, learning for control and dynamical systems, physics of information, Quantum Machine Learning, Solving complex problems. | | |
| Avrim Blum, John Hopcroft, and Ravindran Kannan, Foundations of Data Science, 2018.<br>Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong, Mathematics for Machine Learning, 2020.<br>Jingli Ren, H Wang, Mathematical Methods in Data Science, Elsevier, 2023.<br>Daniela Calvetti and Erkki Somersalo, Mathematics of Data Science: A Computational Approach to Clustering and Classification, SIAM, 2020.<br>Barend Mons, Data Stewardship for Open Science: Implementing FAIR Principles, CRC Press, 2021.<br>Herbert Jones, Data Mining, Bravex Publications, 2020. | | |

| 26EC455 | **ANTENNAS FOR WIRELESS COMMUNICATIONS** | **(3-0-0)3** |
|---|---|---|
| Antenna fundamentals, antenna arrays, and basic types of antennas for wireless communication. Review of Electromagnetic theory. Mathematical solution of Maxwell's equations for radiation problems. Basic antenna parameters. Electrically small antennas. Theory of receiving antennas. Topics in antenna arrays include the array factor, pattern multiplication, multidimensional arrays, phased arrays, and smart antennas. Several types of antennas including wire, microstrip, and aperture antennas. Concepts, tools, and practice of antenna analysis, measurement, and design. | | |
| Antenna Theory and Design, Second Edition, Warren L. Stutzman and Gary A. Thiele, John Wiley & Sons, 1998.<br>Antenna Theory: Analysis and Design, Constantine A. Balanis, Second Edition, John Wiley & Sons, 1997.<br>Antennas for All Applications, Third Edition, John D. Kraus and Ronald J. Marhefka, McGraw Hill, 2002. | | |

| 26EC456 | **QUANTUM INFORMATION PROCESSING** | **(3-0-0)3** |
|---|---|---|
| Linear Algebra and Quantum Mechanics, Dirac Notation, Hermitian Operator, Pauli Matrices, Tensor product, Hilbert space, Quantum Mechanics— Postulates, Hamiltonian operator, dual space, bracket, Two-State System, Qubit and the Bloch Sphere, Quantum Entanglement, Computation on a Quantum Computer, Quantum algorithms and computing, Quantum error correction and fault tolerance, Quantum cryptography and communications, Decoherence and open quantum systems, quantum systems: Nuclear magnetic resonance (NMR), Spin control, Superconducting qubits, Quantum optics, quantum imaging and sensing, quantum computer science, Computational Complexity and Quantum Circuits, Universal Quantum Gates, Quantum Fourier Transforms and Phase Estimation Algorithms, Shor's Algorithm and Grover's Search, Ensembles of Quantum States, Spin and its dynamics, Density matrices and Von Neumann entropy. | | |
| John Watrous, The Theory of Quantum Information, Cambridge University Press, 2018. Mikio Nakahara, Tetsuo Ohmi, Quantum Computing: From Linear Algebra to Physical Realizations, CRC Press 2008.<br>Nielsen, Chuang, Quantum Computation and Quantum Information, 10th ed., Cambridge University Press, 2010.<br>David Mermin, Quantum computer science, An introduction, Cambridge University Press 2000.<br>Neil Gershenfeld, The physics of information technology, Cambridge University Press, 2000. Michel Le Bellac, A short introduction to quantum information and quantum computation, Cambridge University Press. 2012. | | |

| 26EC457 | **QUANTUM ELECTRONICS** | **(3-0-0)3** |
|---|---|---|
| Principles of Quantum Mechanics- Energy Quanta, Wave–Particle Duality, The Uncertainty Principle Schrodinger's Wave Equation, Extension of the Wave Theory to Atoms, Allowed and Forbidden Energy Bands-Formation of Energy Bands, The Kronig–Penney Model, K Space Diagram, Electrical Conduction in Solids-The Energy Band and the Bond Model, Electron Effective Mass, Density of States Function, Statistical Mechanics- The Fermi Dirac Probability Function, The Distribution Function and the Fermi Energy, Quasi Fermi Level, Quantum materials, Introduction to Qubits, Properties of Qubits. Architecture of Quantum Computers, Interfacing Quantum Processor with Classical Controllers, Quantum Gates and Operations, Quantum Entanglement, Single Qubit System, Extension to multi-Qubit systems, Multiplexing DC and I/O signal for 4 qubits, Future trends –Number of Qubits required, Quantum Gate Operations and Quantum Circuits, Introduction to quantum sensing, Qubit readout front-end circuits for Spin qubit and Transmon qubit, Sensing the Qubits, Recapitulation. | | |
| D. Neamen, "Semiconductor physics and devices: basic principles," McGraw Hill New York, NY: 2012. Chien, Wei Chen, Shun Jhou Jhan, Kuei Lin Chiu, Yu xi Liu, Eric Kao, and Ching Ray Chang. 2020. "Cryogenic Materials and Circuit Integration for Quantum Computers." Journal of Electronic Materials 49 (11): 6844–58.<br>Patra, Bishnu, Rosario M. Incandela, Jeroen PG Van Dijk, Harald AR Homulle, Lin Song, Mina Shahmohammadi, Robert Bogdan Staszewski et al. "Cryo-CMOS circuits and systems for quantum computing applications." IEEE Journal of Solid-State Circuits 53, no. 1 (2017): 309-321.<br>Introductory Quantum Optics, C. Gerry and P. Knight, Cambridge University Press, 2005. Quantum Electronics , A Yariv, John Wiley, NY, 1989. | | |

| 26EC458 | **QUANTUM NEURAL NETWORKS** | **(2-0-2)3** |
|---|---|---|
| Review of Machine Learning Algorithm, Introduction to Quantum Computing-state vectors, Hilbert space, quantum states, quantum entanglement and superposition, quantum gates, and quantum circuits, Introduction of quantum computing algorithms; Quantum machine learning (QML) basics; including representing classical data on quantum systems, quantum data encoding and embedding, quantum data representation and quantum feature maps.; Quantum Algorithms for Machine Learning; Quantum Classifiers, Quantum Kernel Methods, and Quantum Clustering.Quantum Variational Circuits, Quantum Neural Networks (QNNs), Quantum Convolutional Neural Networks (QCNNs), Quantum Federated Learning (QFL), Quantum Reinforcement Learning (QFL), Quantum Multimodal Learning. Applications and future research directions-Applications of QML in natural language processing, computer vision, healthcare, drug design, transportation, and intrusion detection. | | |
| Tom M. Mitchell, "Machine Learning", 2017, Mc-Graw Hill, Publisher<br>Chris Bernhardt's "Quantum Computing for Everyone", 2019, MIT Press. | | |

Claudio Conti, "Quantum Machine Learning" , 2024 edition, Springer Publisher
Santanu Pattanayak, "Quantum Machine Learning with Python", 2021, Apress Publisher
Sarah C. Kaiser and Christopher Granade, "Learn Quantum Computing with Python and Q: A hands-on approach",

| 26EC459 | **Introduction to Gen AI** | **(2-0-2)3** |
|---|---|---|

Deep learning Review - MLP/CNN/RNN, self-attention, scaled-dot product attention, multi-head blocks, positional encoding, Transformer architecture, seq2seq task in Colab Text Understanding & Generation in Colab - Encoder-only (BERT) fine-tuning for classification & QA, Decoder-only (GPT-2) text generation, sampling strategies, Seq2seq (T5/BART) summarization & translation, ROUGE Scoring Audio & Music Generation - wav2vec 2.0 for ASR (self-supervised pre-training + fine-tuning), VQ-VAE tokenization for raw audio synthesis, Music Transformer for symbolic melody generation Vision & Video Vision Transformer (ViT) for image classification, CIFAR-10 in Colab; compare to ResNet baseline Latent Diffusion (Stable Diffusion) for text-to-image, Hugging Face Diffusers; generate 256×256 images Video Transformers (ViViT/TimeSformer), Simple Video Transformer for action recognition on short clips.

Deep Learning by Goodfellow, Bengio, and Courville, Hardcover Book on Artificial Intelligence, MIT Press 2016.
Natural Language Processing with Transformers, Revised Edition 1st Edition, Lewis Tunstall, Leandro von Werra, Thomas Wolf, O'Reilly 2022
Hands-On Generative AI with Transformers and Diffusion Models Omar Sanseviero, Pedro Cuenca, Apolinario Passos and Jonathan Whitaker, O'Reilly 2024

## COURSES FOR MINOR STREAM

| 26EC391M | **ANALOG ELECTRONIC CIRCUITS** | **(3-0-0) 3** |
|---|---|---|

Introduction to operational amplifiers: The difference amplifier and the ideal operational amplifier models, concept of negative feedback and virtual short, Analysis of simple operational amplifier circuits, Frequency response of amplifiers, Bode plots. Feedback: Feedback topologies and analysis for discrete transistor amplifiers, stabillity of feedback circuits using Barkhausen criteria. Linear applications of operational amplifiers: Instrumentation and Isolation amplifiers, Current and voltage sources, Non-linear applications of operational amplifiers: Comparators, clippers and clampers, Precision rectifiers, Waveform Generation: Sinusoidal feedback oscillators, Relaxation oscillators, square-triangle oscillators. Practical perational amplifiers: Non-idealities and their on circuit performance. Analog and Digital interface circuits: Relays, S/H circuits, Opto-couplers, A/D, D/A Converters.

Ramakant A. Gayakwad, Op-Amps and Linear Integrated Circuits, Pearson, 2015

| 26EC392**M** | **DIGITAL ELECTRONICS** | **(3-0-0) 3** |
|---|---|---|

Introduction to Boolean Algebra and Switching Functions, Boolean Minimization, Finite State Machines, Design of synchronous FSMs, FSM Minimization, Bipolar Logic Families – TTL, MOS logic families (NMOS and CMOS), and their electrical behaviour. Memory Elements, Timing circuits, Elementary combinational and sequential digital circuits: adders, comparators, shift registers, counters. Logic Implementation using Programmable Devices (ROM, PLA, FPGA).

Morris. M. Mano, Michael D. Ciletti, Digital Design, Fourth Edition, Prentice-Hall India. 2008.
Charles. H. Roth, Jr., Fundamentals of Logic Design, Fifth Edition, Thomson Brooks/Cole, 2005.
J.F.Wakerly, Digital Design Principles and Practices, PH, 1999.
D.D. Givone, Digital Principles and Design, TMH, 2002

| 26EC393M | **SIGNALS AND SYSTEMS** | **(3-0-0) 3** |
|---|---|---|

Sinusoids –complex exponentials and phasor, Spectrum representation – spectrum of sum of sinusoids, Periodic signals, Fourier series representation, synthesis. Sampling and aliasing – sampling of sinusoidal signals, aliasing, sampling theorem, reconstruction. Discrete time FIR systems – moving average filter, general FIR filter, impulse filter, implementation of FIR filters, LTI systems, convolution, frequency response of FIR systems. Z Transform: Definition and properties, ROC, inverse Z transform, transfer function, poles and zeros, application of Z transforms to discrete-time systems. Discrete time IIR systems – Impulse response, step response, representation of LTI systems, frequency response of IIR systems. Applications of DSP – Sinusoidal synthesis, Image denoising,

Mc Chellan, R.W. Schafer & Yoder, Signal Processing First, Pearson 2003.
Sergio Franco, Design with OPAMPS and Linear Integrated circuits, Tata McGraw Hill, 2002. Ron Mancini, Op Amp for Everyone, Texas Instruments, 2002

| 26EC394M | **COMMUNICATION SYSTEMS** | **(3-0-0) 3** |
|---|---|---|

Amplitude Modulation, Time & Frequency domain description, Modulation techniques, Switching modulator, Demodulation techniques, Envelope detector, Coherent detection, Costas Receiver, The Superheterodyne Receiver, Quadrature Carrier Multiplexing, Single side band and vestigial sideband modulation, Frequency Translation,

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| Frequency Division Multiplexing. Angle Modulation, Basic definitions, Frequency Modulation, Narrow Band FM, Wide Band FM, Transmission bandwidth of FM Signals, Generation of FM Signals, Demodulation of FM Signals, FM Stereo Multiplexing, Phase–Locked Loops and their application in FM demodulation. Theme example: FM stereo broadcast. Noise in Analog Modulation, Introduction, Receiver Model, Noise in DSB-SC receivers, Noise in AM receivers, Threshold effect, Noise in FM receivers, Capture effect, FM threshold effect, FM threshold reduction, Pre-emphasis and Deemphasis in FM. Digital Representation of analog signals, The Sampling process, Pulse Amplitude Modulation, Time Division Multiplexing, Pulse-Position Modulation, Generation of PPM Waves, Detection of PPM Waves, Quantization Process, Quantization Noise, Pulse Code Modulation: Sampling, Quantization, Encoding, Regeneration, Decoding, Filtering, Multiplexing, Application to Vocoders. |
| M. F. Mesiya, "Contemporary Communication Systems", McGrawHill, 2013.<br>Steven W. Ellingson, "Radio Systems Engineering", Cambridge University Press, 2016.<br>Taub and Schilling, "Principles of Communication systems", Second Edition, Tata McGrawHill, 2006 Proakis and Salehi, "Fundamentals of Communication Systems", Second Edition, Pearson International, 2014.<br>Simon Haykin, "Communication Systems", Fourth Edition, Wiley, 2000. |

| 26EC395M | **DATA COMMUNICATION AND NETWORKS** | **(3-0-0) 3** |
|---|---|---|
| Data encoding and transmission concepts, Digital data transmission, NRZ encoding, Multilevel binary encoding, Biphase encoding, Scrambling techniques, Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), Performance of digital and analog modulation schemes, Quadrature Amplitude Modulation (QAM), Pulse Code Modulation, Non-linear encoding, Delta modulation, Asynchronous transmission, Synchronous transmission, Ethernet link layer frame example. Switching techniques, Multiplexing and Multiple Access techniques, Packet Switched Networks. OSI and TCP/IP Models, Internet protocols and addressing, networking devices, data links and transmission, LANs and Network of LANS, Wireless Networks and Mobile IP, Routing and internetworking, transport and end to end protocols, congestion control techniques, Application Layer and network management, Network Security. Packet Queues and delays, Little's theorem, Birth and death process, Queuing disciplines, M/M/1 Queues, Burkes and Jackson theorems. Traffic models, ISDN, ATM Networks, Quality of service and resource allocation, VPNs and MPLS, Cellular Telephone and Optical networks, VOIP and Multimedia networking. Mobile Adhoc Networks and Wireless Sensor Networks. | | |
| Nader F. Mir, Computer and Communication Networks, Pearson Education, 2007 Garcia and Widjaja, Communication Networks, McGraw Hill, 2006<br>J.F. Hayes, Modelling and analysis of Computer Comm. Networks, Plenum, 1984.<br>Jean Walrand & Pravin Varaiya, High Performance Communication Networks, Morgan Kaufmann Publishers, 2002 Taub and Schilling, "Principles of Communication systems", Second Edition, Tata McGrawHill, 2006 Proakis and Salehi, "Fundamentals of Communication Systems", Second Edition, Pearson International, 2014.<br>Simon Haykin, "Communication Systems", Fourth Edition, Wiley, 2000. | | |

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| **26EC391** | **Internship-I** | **9** |
| **26EC392** | **Major project-I** | **9** |
| **26EC491** | **Internship-II** | **9** |
| **26EC492** | **Major project-II** | **9** |
| **26EC493** | **Internship-III** | **9** |
| **26EC494** | **Major project-III** | **9** |