Indicative Syllabus

Common topics: Student can choose any two of the following, according to her/his preference

i. Linear Algebra: Matrix Algebra, Systems of linear equations, Eigenvalues and Eigenvectors, Fundamental Subspaces

ii. Calculus: Mean value theorems, Theorems of integral calculus, Evaluation of definite and improper integrals, Partial Derivatives, Maxima and minima, Fourier series, and multiple integrals.

iii. Differential equations

iv. Probability and Statistics: Sampling theorems, Conditional probability, Joint Probability, Random variables, Discrete and continuous distributions, Uniform, Poisson, Normal and Binomial distribution, Evaluating expectations, conditional expectations.

v. Transform Theory: Fourier transform, Laplace transform, Z-transform, properties of these transforms, Parseval's theorem

Broad research areas:

- Deep Learning in Cancer Genomics; Deep Learning in Computer Vision; Deep Learning in Cancer Imaging/ Quantum Machine Learning
- Nanoelectronics & Spintronics
- VLSI Design and Neuromorphic Computing
- EdgeAI
- Remote Sensing
- Wireless Communication (Holographic MIMO)
- Signal processing for Reflective Intelligent Surfaces (RIS) and AI for Wireless
- Wireless power transfer; Computational modelling for biomedical applications
- Computer Architecture, system-on-chip design
- Federated Learning and Wireless communications
- Computer Vision and Deep Learning
- Radar

• 5G,6G, UAV communication, Non terrestrial networks

• Communication theory

• Antenna, Array/ RIS, RF Circuits

Specific topics for broad research areas

1. **5G,6G, UAV communication, Non terrestrial networks**
2. **Signal processing for Reflective Intelligent Surfaces (RIS) and AI for Wireless**

- Random signals and noise: probability, random variables, probability density function, autocorrelation, power spectral density.
- Digital communication systems: Source coding, Entropy, Kraft's inequality, pulse code modulation (PCM), differential pulse code modulation (DPCM), digital modulation/demodulation schemes: amplitude, phase, and frequency-shift keying schemes (ASK, PSK, FSK). Higher-order modulation schemes: QAM vs QPSK, advantages, disadvantages.
- Wireless Communication Systems: Fading (fast/slow/frequency selective/flat etc.), propagation models, path-loss, basics of mobile communication generations. Cellular and Wi-Fi standards.
- Signals and Systems: LTI systems, Convolution, Fourier analysis, Sampling
- Statistical Signal Processing: Likelihood, Linear Estimators, MMSE, Hypothesis testing, NP criterion
- Machine Learning: Supervised and unsupervised learning, Regression, Classification, Clustering, Dimensionality reduction
- Probability: Random variable, conditional probability, expectation, variance, pmf, pdf, cdf, typical random variables (Bernoulli, binomial, geometric, uniform, exponential, Gaussian), independence, Markov & Chebyshev inequality
- Communication systems: Basic understanding of the following: modulation schemes, OFDM, MIMO, information theory, wireless channel, components of a wireless system, and the Internet

---

Specific topics for broad research areas

1. **Deep Learning in Cancer Genomics; Deep Learning in Computer Vision; Deep Learning in Cancer Imaging/ Quantum Machine Learning**
2. **Federated Learning and Wireless communications**
3. **Computer Vision and Deep Learning**

- Signals and Systems: LTI systems, Convolution, Fourier analysis, Sampling, Fourier series, Fourier Transform, DFT, Convolution, LTI systems, sampling theorem
- Statistical Signal Processing: Likelihood, Linear Estimators, MMSE, Hypothesis testing, NP criterion
- Machine Learning: Supervised and unsupervised learning, Regression, Classification, Clustering, Dimensionality reduction, being able to clearly explain any hands-on experience with machine learning/deep learning

- Random signals and noise: Random Processes, autocorrelation, power spectral density.
- Probability: Common PDF/PMFs, Bayes' Theorem, Conditional probability, basic concepts of random variables, expectation

---

Specific topics for research areas

1. **Nanoelectronics & Spintronics**
2. **VLSI Design and Neuromorphic Computing**
3. **Computer Architecture, System on Chip Design**

- Circuits & Systems: Circuit analysis techniques, Op-Amp, data path elements, CMOS Circuits, Sequential elements, logic families, memory, FSM, pipeline basics, Digital circuits (FSM/FFs)
- Basic Quantum Mechanics: Schrodinger equation, quantum confined systems, quantum tunneling
- Band Theory of Solids: crystal structure, energy band structure, effective mass, carrier mobility, understanding of basic magnetism and magnetic materials
- Semiconductor Device Physics: drift-diffusion model of current flow in semiconductor, p-n junctions, MOSFETs, non-ideal behavior in MOSFETs, ballistic transport.
- Embedded and VLSI: Verilog, ARM, FPGA, Sequential and combinational circuits, FSM
- Electromagnetics
- Digital Circuits: Boolean Algebra, CMOS inverter, Flip-flops, Combinational and Sequential Circuits.

Specific topics for broad research areas

4. **EdgeAI**
5. **Remote Sensing**
6. **Wireless Communication (Holographic MIMO)**

- Electromagnetics: Standard undergraduate topics in electromagnetism, including electric fields, magnetic fields, potential, electromagnetic waves, Maxwell equations.

- Semiconductor physics: Crystal structure, energy band structure, Fermi-Dirac statistics of carriers, effective mass, carrier mobility, drift-diffusion model of current flow in semiconductor, p-n junctions, opto-electronic processes in semiconductors.
- Basic Quantum Mechanics: Postulates of QM, Measurement in QM, Uncertainty principle, Schrodinger’s equation, Tunneling.

7. **Radar**

- Wireless & Radar Systems: Digital Communication Systems, Digital circuits, Signals and Systems
- Hardware Architectures for AI/ML: Embedded Systems, Basics of Verilog, FPGA Design Flow
- Electrical circuits: Standard undergraduate topics of electrical circuits and circuit theory, including lumped elements, voltage and current sources, circuit parameters, and maximum power transfer.

- Electromagnetics: Standard undergraduate topics in electromagnetism, including electric fields, magnetic fields, potential, electromagnetic waves, Maxwell equations, and impedance matching.

8. Wireless power transfer; Computational modeling for biomedical applications

- Electrical circuits: Standard undergraduate topics of electrical circuits and circuit theory, including lumped elements, voltage and current sources, circuit parameters, and maximum power transfer.
- Electromagnetics: Standard undergraduate topics in electromagnetism, including electric fields, magnetic fields, potential, electromagnetic waves, Maxwell equations, and impedance matching.

---

9. Communication theory

- Random signals and noise: Random Processes, autocorrelation, power spectral density.
- Probability: Random variable, conditional probability, expectation, variance, pmf, pdf, cdf, typical random variables (Bernoulli, binomial, geometric, uniform, exponential, Gaussian), independence, Markov & Chebyshev inequality
- Signals and Systems: LTI systems, Convolution, Fourier analysis, Sampling
- Statistical Signal Processing: Likelihood, Linear Estimators, MMSE, Hypothesis testing, NP criterion
- Linear Algebra: Eigenvalues and eigenvectors, rank, linear independence, basis

---

10. Antenna, Array/ RIS, RF Circuits

- Electromagnetics, Maxwell equations, EM wave propagation, Transmission line theory,
- Fundamental parameters of antenna, Fields from current source, Linear wire antennas, loop antennas, antenna arrays, Fourier Transform in relating source and field, Mutual coupling
- Impedance matching, S-parameters, Microstrip line, basic 2-port, and 3-port passive RF circuits