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:

- Visible Light Communication
- Machine Learning for Wireless
- Deep learning in Digital Pathology, Quantum Machine Learning
- Federated Learning and Trustworthy AI
- Machine Learning and Computer Vision
- System on Chip Design for AI applications
- VLSI Design and Automation
- Wireless power transfer for biomedical implants
- 6G Communication
- Autonomous systems in space

Specific topics for broad research areas:

- **Visible Light Communication**
- **Machine Learning 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

---

- **Deep learning in Digital Pathology, Quantum Machine Learning**
- **Federated Learning and Trustworthy AI**
- **Machine Learning and Computer Vision**

- 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

---

- **System on Chip Design for AI applications**
- **VLSI Design and Automation**

- 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.

- **Wireless power transfer for biomedical implants**

- 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.

- **6G Communication**
- **Autonomous systems in space**

- 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