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:

Research Area
AI in management of Optical Networks
Communications Networks, Networks of Robots
Autonomous Driving
Machine Learning for Wireless Networks
Multimedia, Vision and Deep Learning
Deep Learning in Image Processing, Cancer Imaging, AI in Healthcare
Generative Speech AI and AudioLM
VLSI and Nanoelectronics
Digital Hardware, Embedded Systems and Edge AI
Information Theory/Optimization theory
Photonic qubits
Radar
Computational Modeling for Biomedical Prosthesis, Wireless Power Transfer

Specific topics for broad research areas

1. **AI in management of Optical Networks**
2. **Communications Networks, Networks of Robots**
3. **Autonomous Driving**
4. **Machine Learning for Wireless Networks**

- 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
- 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
- Communication systems: Basic understanding of the following: modulation schemes, OFDM, MIMO, information theory, wireless channel, components of a wireless system, and the Internet

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Specific topics for broad research areas

1. **Multimedia, Vision and Deep Learning**
2. **Deep Learning in Image Processing, Cancer Imaging, AI in Healthcare**
3. **Generative Speech AI and AudioLM**

- 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

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Specific topics for research areas

1. **VLSI and Nanoelectronics**
2. **Digital Hardware, Embedded Systems and Edge AI**

- 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

1. **Photonic qubits**

- 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.

2. **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.

3. **Computational Modeling for Biomedical Prosthesis, Wireless Power Transfer**

- 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.

Specific topics for broad research areas

1. **Information Theory/Optimization 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