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

S.No.	Broad Research Area
1	Neural Networks on Optical Networks, Advanced Optical Comm Testbed
2	Quantum Key Distribution
3	Non-terrestrial networks (satellite, UAVs) and 5G/6G wireless communication
4	Communication and Information Theory
5	Wireless Communication & System, Machine Learning for Wireless Systems, RF sensing
6	AI/DL/ML in Cancer Imaging; AI/DL/ML in Cardiology; AI/DL/ML in Genomics
7	Multimedia and Vision, Machine Learning
8	Wireless Networking for Robotic Applications (Industry 4.0, Vehicle-to-vehicle, V2X, Teleoperation, etc.)
9	End-to-End Autonomous Driving
10	Machine learning for Control systems and Robotics
11	Estimation and control for space robotics
12	Online Machine Learning, Adaptive Control, Networked Robotics
13	Nanoelectronics, Spintronics
14	Nanoelectronics, Machine Learning in VLSI Design
15	Single photon detector, All-optical transistor
16	Radar, communications, navigation
17	Synthetic aperture radar
18	RF microelectronics, Metamaterial/Metasurface
19	Edge AI

Specific topics for broad research areas

1. **Neural Networks on Optical Networks, Advanced Optical Comm Testbed**
2. **Quantum Key Distribution**
3. **Non-terrestrial networks (satellite, UAVs) and 5G/6G wireless communication, Communication and Information Theory**
4. **Wireless Communication & Systems, Machine Learning for Wireless Systems, RF sensing**
5. **Wireless Networking for Robotic Applications (Industry 4.0, Vehicle-to-vehicle, V2X, Teleoperation, etc.)**

- 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. **AI/DL/ML in Cancer Imaging, AI/DL/ML in Cardiology, AI/DL/ML in Genomics**
2. **Multimedia and Vision, Machine 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

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Specific topics for broad research areas

1. **Machine learning for Control systems and Robotics**
2. **Estimation and control for space robotics**
3. **Online Machine Learning, Adaptive Control, Networked Robotics**

- Signals and Systems: LTI systems, Convolution, Fourier analysis, Sampling
- Random signals and noise: Random Processes, autocorrelation, power spectral density.
- Control systems: Basic control systems, classical and state space methods
- Machine Learning: Supervised and unsupervised learning, Regression, Classification, Clustering, Dimensionality reduction, Neural Network

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Specific topics for research areas

1. **Nanoelectronics, Spintronics**
2. **Nanoelectronics, Machine Learning in VLSI Design**
3. **Single photon detector, All-optical transistor**

- 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. **Radar, communications, navigation**
2. **Synthetic aperture radar**
3. **RF microelectronics, Metamaterial/Metasurface**
4. **Edge AI**

- Wireless & Radar Systems: Digital Communication Systems, Digital circuits, Signals and Systems
- Hardware Architectures for AI/ML: Embedded Systems, Basics of Verilog, FPGA Design Flow
- Basic Quantum Mechanics: Dirac's notations, Postulates of QM, Measurement in QM, Uncertainty principle, Harmonic oscillator, Number states, creation and annihilation operators, Time evolution of quantum systems; Schrodinger, Heisenberg and interaction picture.
- Electromagnetics: Standard undergraduate topics in electromagnetism.
- Microwave Engineering: RF circuits and analysis. Antenna Theory: Radiation concept, antenna parameters