# Electrical Engineering

| Sl. No | Course code | | Name of Course | L-T-P-C | Proposed Level (UG/PG) |
|---|---|---|---|---|---|
| 1 | EE 101 | EE101T | Introduction to Electrical Systems and Electronics | 3-0-1-7 | UG |
| 2 | EE 103 | | Introduction to Programming-2 | 3-0-2-4 | UG |
| 3 | EE 201 | EE102T | Data Analysis<br>**Data Analysis** | 3-0-0-6 | UG |
| 4 | EE 202 | EE201T | Introduction to Analog Circuits (Pre Mid Sem) | 3-0-0-3 | UG |
| 5 | EE 204 | EE103T | Digital Systems | 2-1-0-6 | UG |
| 6 | EE 205 | EE104T | Network Theory | 2-1-0-6 | UG |
| 7 | EE 206 | EE202T | Introduction to Electrical Machines | 2-1-0-3 | UG |
| 8 | EE 208 | | Engineering Electromagnetics | 3-0-0-3 | UG |
| 9 | EE 209 | EE203T | Introduction to Power Electronics | 2-1-0-3 | UG |
| 10 | EE 210 | EE204T | Signals and Systems | 2-1-0-6 | UG |
| 11 | EE 212 | EE201L | Devices and circuits Lab | 0-0-3-3 | UG |
| 12 | EE 214 | EE101L | Digital Circuits Laboratory | 0-0-3-3 | UG |
| 13 | EE 216 | | Communications Lab | 0-0-4-2 | UG |
| 14 | EE 221 | EE205T | Introduction to Probability | 3-0-0-3 | UG |
| 15 | EE 223 | EE206T | Introductions to Power Systems | 3-0-0-3 | UG |
| 16 | EE 226 | | Control Systems and Laboratory | 2-0-2-6 | UG |
| 17 | EE 227 | EE207T | Data Analysis | 3-0-0-3 | UG |
| 18 | EE 229 | EE105T | Electronic Devices | 3-0-0-3 | UG |
| 19 | EE 231 | | Control Systems | 3-0-0-6 | UG |
| 20 | EE 232 | | Introduction to Communication Systems | 3-0-0-3 | UG |
| 21 | EE 233 | | Electronic Devices and Circuits | 3-0-0-6 | UG |
| 22 | EE 301 | | Smart Systems Design Lab | 1-0-5-6 | UG |
| 23 | EE 306 | | Power Systems | 2-1-0-6 | UG |
| 24 | EE 311 | EE202L | Electrical Machines and Power Electronics Lab | 0-0-3-3 | UG |
| 25 | EE 312 | | Control Systems and Laboratory | 0-0-3-3 | UG |
| 26 | EE 314 | EE301L | Electronic Design Laboratory | 1-0-4-6 | UG |
| 27 | EE 315 | | DSP Lab | 0-0-4-2 | UG |
| 28 | EE 319 | EE302L | Microprocessors and microcontrollers lab | 0-0-3-3 | UG |
| 29 | EE 321 | EE305T | Digital Signal Processing | 3-0-0-3 | UG |

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| 30 | EE 324 | | Introduction to Industry 4.0 and Industrial Internet of Things | 3-0-0-6 | UG |
| 31 | EE 325 | EE301T | Microprocessors and Microcontrollers | 3-0-0-6 | UG |
| 32 | EE 331 | EE301P | Research and Development Project | 6 credits | UG |
| 33 | EE 332 | | Project in Machine Learning | 6 credits | UG |
| 34 | EE 333 | EE302P | Research and Development Project II | 6 credits | UG |
| 35 | EE 402 | | Robotics | 2-0-2-6 | UG |
| 36 | EE 407 | EE401P | B.Tech. Project EE | 6 credits | UG |
| 37 | EE 410 | | Analog Circuits | 2-0-2-6 | UG |
| 38 | EE 420 | EE301C | Digital Communication and Coding Theory | 2-0-2-6 | UG |
| 39 | EE 422 | EE302T | Power System Protection | 3-0-0-6 | UG |
| 40 | EE 423 | EE402P | B.Tech. Project EE II | 6 credits | UG |
| 41 | EE 424 | | Puzzles, Information and Secrecy | 1-0-0-2 | UG |
| 42 | EE 427 | | Stochastic Process | 3-0-0-6 | UG |
| 43 | EE 432 | EE601T | Information  theory | 3-0-0-6 | UG |
| 44 | EE 433 | EE602T | Next Generation Wireless Systems / Wireless Networks | 3-0-0-6 | UG |
| 45 | EE 435 | | Digital filters and Multirate Systems | 2-0-2-6 | UG |
| 46 | EE 437 | EE303L | Control Systems Design Lab | 0-0-3-3 | UG |
| 47 | EE 439 | | Probability and Random Process | 2-1-0-6 | UG |
| 48 | EE 441 | | Mini Project in Machine Learning | 3 credits | UG |
| 49 | EE 446 | | Batteries for Electric Transportation | 3-0-0-3 | UG |
| 50 | EE 447 | | Introduction to Electric Vehicle Architecture | 3-0-0-3 | UG |
| 51 | EE 601 | EE603T | Analog IC design | 3-0-0-6 | PG |
| 52 | EE 602 | EE614T | Probability Models | 3-0-0-3 | PG |
| 53 | EE 603 | | Electric Drives for EVs - I | 3-0-0-3 | PG |
| 54 | EE 604 | | Electric Drives for EVs - II | 3-0-0-3 | PG |
| 55 | EE 605 | | Probability theory and random process | 3-0-1-6 | PG |
| 56 | EE 606 | | Pattern Recognition and Machine Learning | 3-0-0-6 | PG |
| 57 | EE 607 | EE605T | Power System Dynamics and Control | 2-0-1-6 | PG |
| 58 | EE 608 | EE606T | Wireless Communication | 3-0-0-6 | PG |
| 59 | EE 609 | EE604T | Pattern Recognition and Machine Learning | 3-0-3-9 | PG |
| 60 | EE 610 | EE607T | VLSI Design | 3-0-0-6 | PG |
| 61 | EE 611 | EE601L | Neural networks and deep learning (NNDL) | 0-0-3-3 | PG |

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| | | | Laboratory | | |
| 62 | EE 612 | EE602L | Pattern Recognition and Machine Learning (PRML) Laboratory | 0-0-3-3 | PG |
| 63 | EE 613 | EE501L | Speech Processing Laboratory | 0-0-3-3 | PG |
| 64 | EE 614 | | Data Analysis and Visualization Lab | 0-0-3-3 | PG |
| 65 | EE 620 | | Artificial Neural Networks & Deep Learning | 3-0-0-6 | PG |
| 66 | EE 621 | EE501T | Speech Processing | 3-0-0-6 | PG |
| 67 | EE 622 | EE609T | Multivariable Control Systems | 3-0-0-6 | PG |
| 68 | EE 623 | EE610T | Advanced Power Electronics and Drives | 3-0-0-6 | PG |
| 69 | EE 624 | EE611T | Optimization Theory and Algorithms | 3-0-0-6 | PG |
| 70 | EE 625 | EE612T | Design of Power Converters | 2-0-1-6 | PG |
| 71 | EE 626 | EE613T | VLSI Technology | 3-0-0-6 | PG |
| 72 | EE 627 | | Advanced Power Systems | 3-0-0-6 | PG |
| 73 | EE 628 | | Modeling and Control of Renewable Energy Resources | 3-0-0-6 | PG |
| 74 | EE 629 | EE614T | Probability Models and Applications (PMA | 3-0-0-6 | PG |
| 75 | EE 630 | | Advanced topics in signal processing | 1-0-4-6<br>3-0-0-6 | PG |
| 76 | EE 631 | EE615T | Advanced Electric Drives | 3-0-0-6<br>2-0-2-6 | PG |
| 77 | EE 632 | EE616T | System Design of Electronic Products | 3-0-0-6 | PG |
| 78 | EE 633 | EE617T | Mixed signal VLSI Design | 3-0-0-6 | PG |
| 79 | EE 634 | EE618T | Linear Algebra and its applications | 3-0-0-6 | PG |
| 80 | EE 635 | | Speech Processing | 3-0-3-9 | PG |
| 81 | EE 636 | | Advanced Analog Circuits | 3-0-0-6 | PG |
| 82 | EE 637 | | Physics of Nanoscale devices | 3-0-0-6 | PG |
| 83 | EE 638 | EE619T | Advanced Topics in Control Systems | 3-0-0-6 | PG |
| 84 | EE 639 | | Modern Statistics for Engineers | 3-0-0-6 | PG |
| 85 | EE 640 | EE620T | Game Theory with Control | 3-0-0-6 | PG |
| 86 | EE 641 | | Renewable Energy | 3-0-0-6 | PG |
| 87 | EE 642 | | Microgrid Dynamics and Control | 3-0-0-6 | PG |
| 88 | EE 643 | | Power System Operation and Control | 3-0-0-6 | PG |
| 89 | EE 644 | | Power System II | 3-0-0-6 | PG |
| 90 | EE 645 | EE401T | Electrical Machines II | 3-0-0-6 | PG |
| 91 | EE 646 | | Advanced Topics in Artificial Intelligence | 3-0-0-6 | PG |
| 92 | EE 647 | | Introduction to Machine Learning | 3-0-0-6 | PG |
| 93 | EE 648 | EE621T | Nanoelectronics | 3-0-0-6 | PG |
| 94 | EE 649 | | Neural Networks And Deep Learning (NNDL) (NNDL) | 3-0-3-6 | PG |

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| 95 | EE 650 | | Introduction to Aerial Robots | 2-1-0-6 | PG |
| 96 | EE 651 | | Dynamics and Control of Aerial Robots | 2-1-0-6 | PG |
| 97 | EE 652 | EE622T | Autonomous Navigation | 2-1-0-6 | PG |
| 98 | EE 653 | | Electric Vehicles: Systems and Components | 3-0-0-6 | PG |
| 99 | EE 654 | | Smart Grid | 3-0-0-6 | PG |
| 100 | EE 655 | | Data Science and Visualization Lab | 0-0-3-3 | PG |
| 101 | EE 656 | EE623T | VLSI Test & Testability | 3-0-0-6 | PG |
| 102 | EE 657 | EE601C | Introduction to HIL testing methods | 1-0-1-3 | PG |
| 103 | EE 658 | | Battery Technology | 3-0-0-6 | PG |
| 104 | EE 659 | | Electric Vehicles: Systems and Components | 2-0-2-6 | PG |
| 105 | EE 660 | EE402T | Introduction to Electric Drives | 3-0-0-6 | PG |
| 106 | EE 661 | | EV Charging and Ancillary Services | 3-0-0-6 | PG |
| 107 | EE 662 | | Advanced Methods in HIL Testing of Electric Transportation Systems | 2-0-2-6 | PG |
| 108 | EE 663 | | Pattern Recognition and Machine Learning (PRML) | 3-0-0-6 | PG |
| 109 | EE 664 | | Electric and Hybrid Vehicles | 3-0-0-6 | PG |
| 110 | EE 665 | | Robotics and Automation | 3-0-2-8 | PG |
| 111 | EE 667 | | Stochastic Process and its Applications | 3-0-0-3 | PG |
| 112 | EE 668 | | Mathematics for Data Science I | 3-0-0-3 | PG |
| 113 | EE 669 | | Mathematics for Data Science II | 3-0-0-3 | PG |
| 114 | EE 670 | | Fundamentals of Speech Processing (FSP) | 3-0-0-3 | PG |
| 115 | EE 671 | | Machine Learning of Speech Processing (MLSP) | 1.5-0-0-3 | PG |
| 116 | EE 672 | | Deep Learning of Speech Processing (DLSP) | 1.5-0-0-3 | PG |
| 117 | EE 673 | | Pattern Recognition | 3-0-0-3 | PG |
| 118 | EE 674 | | MACHINE LEARNING (ML) | 1.5-0-0-3 | PG |
| 119 | EE 675 | | ARTIFICIAL NEURAL NETWORKS (ANN) | 3-0-0-3 | PG |
| 120 | EE 676 | | DEEP LEARNING (DL) | 1.5-0-0-3 | PG |
| 121 | EE 677 | | Introduction to Battery Management Systems | 3-0-0-3 | PG |
| 122 | EE 678 | | PWM Techniques | 3-0-0-3 | PG |
| 123 | EE 679 | | Signals, Systems and Controls | 3-0-0-3 | PG |
| 124 | EE 680 | | Digital Signal Processing and Communications | 3-0-0-3 | PG |

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| 125 | EE 681 | | MACHINE LEARNING (ML) | 1.5-0-3-3 | PG |
| 126 | EE 682 | | Computational Techniques and Optimisation | 1.5-0-3-3 | PG |
| 127 | EE 683 | | Embedded Systems | 1.5-0-3-3 | PG |
| 128 | EE 684 | | Design of Power Converters | 1.5-0-3-3 | PG |
| 129 | EE 687 | | Optimization Methods for Wireless Communication and Machine Learning | 3-0-0-6 | PG |
| 130 | EE 688 | EE624T | Physics of Transistors | 3-0-0-6 | PG |
| 131 | EE 689 | EE625T | Semiconductor Radiation Detectors | 3-0-0-6 | PG |
| 132 | EE 701 | EE626T | Power Semiconductor Devices | 3-0-0-6 | PG |
| 133 | EE 702 | | Advanced topics in signal processing | 3-0-0-6 | PG |
| 134 | EE 703 | EE701T | Stochastic Control and Learning for Networked Systems | 3-0-0-6 | PG |
| 135 | EE 704 | | Theory of Machine Learning | 3-0-0-6 | PG |
| 136 | EE 705 | EE801S | Seminar | | |
| 137 | EE 690 | EE627T | Embedded systems Design | 3-0-0-6 | PG |
| 138 | EE 615 | EE603L | Embedded system Lab | 0-0-3-3 | PG |
| 139 | EE 616 | EE604L | VLSI Simulation Lab | 0-0-3-4 | PG |
| 140 | EE 691 | EE602C | Design of Photovoltaic systems | 2-0-2-6 | PG |
| 141 | EE 692 | EE601S | M.Tech Seminar | 0-0-4-4 | PG |
| 142 | EE 617 | EE605L | Power System Simulation Lab | 0-0-3-3 | PG |
| 143 | EE 104 | EE101O | Formal Communications | 1-0-0-2 | UG |
| 144 | EE 239 | EE208T | Control Systems Engineering | 3-0-0-6 | UG |
| 145 | EE 217 | EE203L | Control Systems Engineering Laboratory | 0-0-3-3 | UG |
| 146 | EE 240 | EE209T | Introduction to Modern communication Systems | 3-0-0-6 | UG |
| 147 | EE 320 | EE302C | Fundamentals of Digital Signal Processing | 2-0-2-6 | UG |
| 148 | EE 322 | EE301O | Technical Writing | 1-0-0-2 | UG |
| 149 | EE 694 | | Detection and Estimation Theory | 3-0-0-6 | PG |
| 150 | EE 335 | | Hardware description with VHDL | | UG |
| 151 | EE 334 | EE303T | Sensors and Instrumentation | 3-0-0-6 | UG |
| 152 | EE 709 | EE604C | Advanced Digital System Design | 2-0-2-6 | PG |

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| 153 | EE 336 | EE304T | Electronics system design | 3-0-0-6 | UG |
| 154 | EE 710 | EE631T | Flexible Electronics | 3-0-0-6 | PG |
| 155 | EE 711 | EE632T | RF and Microwave Devices | 3-0-0-6 | PG |
| 156 | EE 712 | | Optical Communication | 3-0-0-6 | PG |
| 157 | EE 713 | | Optical Networks: Principles and Applications | 3-0-0-6 | PG |
| 158 | EE 714 | | Wireless Optical Communications | 3-0-0-6 | PG |
| 159 | EE 715 | EE702T | Modelling and Control of Inverter-based Resources for Grid Integration | 3-0-0-6 | PG |
| 160 | EE 239 | EE208T | Control Systems Engineering | 3-0-0-6 | UG |
| 161 | | EE601T | Information theory | 3-0-0-6 | PG |
| 162 | | EE102L | Digital Systems Laboratory | ----6 | UG |
| 163 | | EE303C | Hardware Descriptive Languages | 2-0-2-6 | UG |
| 164 | | EE304L | Digital Signal Processing Lab | 0-0-4-2 | UG |
| 165 | | EE403T | Digital Image Processing | 3-0-0-6 | PG |
| 166 | | EE603C | Introduction to Cyber-Physical Systems | 2-0-2-6 | PG |
| 167 | | EE608T | Neural Networks And Deep Learning (NNDL) | 3-0-0-6 | |
| 168 | | EE628T | Design of Magnetic Components for Power Electronics | 3-0-0-6 | PG |
| 169 | | EE629T | Power Quality Analysis (PQA) | 3-0-0-6 | PG |
| 170 | | EE630T | Computer vision and digital image processing | 3-0-0-6 | PG |
| 171 | | EE701P | M.Tech. Project - I | 32 | PG |
| 172 | | EE702P | M.Tech. Project - II | 32 | |

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| 1 | **Title of the course**<br>(L-T-P-C) | **Introduction to Electrical Systems and Electronics**<br><br>**(3-0-1-7)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Calculus |
| 3 | **Course content** | **From Physics to Electrical Engineering**<br>(a) Lumped matter discipline<br>(b) Batteries, resistors, current sources and basic laws<br>(c) I-V characteristics and modeling physical systems<br>**Basic Circuit Analysis Methods**<br>(a) KCL and KVL, voltage and current dividers<br>(b) Parallel and serial resistive circuits<br>(c) More complicated circuits<br>(d) Dependent sources, and the node method<br>(e) Superposition principle<br>(f) Thevenin and Norton method of solving linear circuits<br>(g) Circuits involving diode.<br>**Analysis of Non-linear Circuits**<br>(a) Toy example of non-linear circuit and its analysis<br>(b) Incremental analysis<br>(c) Introduction to MOSFET Amplifiers<br>(d) Large and small signal analysis of MOSFETs<br>(e) MOSFET as a switch<br>**Introduction to the Digital World**<br>(a) Voltage level and static discipline<br>(b) Boolean logic and combinational gates<br>(c) MOSFET devices and the S Model<br>(d) MOSFET as a switch; revisited<br>(e) The SR model of MOSFETs<br>(f) Non-linearities: A snapshot<br>**Capacitors and Inductors**<br>(a) Behavior of capacitors, inductors and its linearity<br>(b) Basic RC and RLC circuits<br>(c) Modeling MOSFET anomalies using capacitors<br>(d) RLC circuit and its analysis<br>(e) Sinusoidal steady state analysis<br>(f) Introduction to passive filters<br>**Operational Amplifier Abstraction**<br>(a) Introduction to Operational Amplifier<br>(b) Analysis of Operational amplifier circuits<br>(c) Op-Amp as active filters<br>(d) Introduction to active filter design<br>**Transformers and Motors**<br>(a) AC Power circuit analysis<br>(b) Polyphase circuits<br>(c) Introduction to transformers<br>(d) Introduction to motors |
| 4 | **Texts/References** | **1**. Anant Agarwal and Jefferey H. Lang, "Foundations of Analog and Digital Electronics Circuits," Morgan Kaufmann publishers, 2005<br>**2**. Wlilliam H. Hayt, Jr., Jack E. Kemmerly and Steven M. Durbin, "Engineering Circuit Analysis," Tata McGraw-Hill<br>**3.** Theodore Wildi, "Electrical Machines, Drives and Power Systems," Pearson, 6-th edition.<br>4. V. Del. Toro, "Electrical Engineering Fundamentals," Pearson publications, 2nd edition. |

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| 1 | **Title of the course** (L-T-P-C) | **Introduction to Programming-2** **(3-0-2-4)** |
| 2 | **Pre-requisite courses(s)** | Nil |
| 3 | **Course content** | This is a continuation of the CS101 (first half semester) course. In the first half semester, the students are introduced to basic programming. This course (second half semester) provides an introduction to problem solving with computers using python language. Topics covered will include:<br>Basic python programming: variables, expression and statements, Functions, conditional and recursions, iterations, strings, lists/NumPy and dictionaries.<br>Other topics: Introduction to object oriented programming, classes and objects in python, polymorphisms, introduction to different libraries in python.<br>Applications: Sample problems in engineering, data pre- processing, and plotting tools. |
| 4 | **Texts/References** | **1.** Python Programming: An Introduction to Computer Science, 3rd edition by John M. Zelle, Franklin, Beedle and Associates.<br>**2.** Think Python: How to Think Like a Computer Scientist, 2nd edition, by Allen B. Downey, O'Reilly, 2015. |

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| 1 | **Title of the course** (L-T-P-C) | **Data Analysis** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | -- |
| 3 | **Course content** | The role of statistics. Graphical and numerical methods for describing and summarizing data. Probability. Population distributions. Sampling variability and sampling distributions. Estimation using a single sample. Hypothesis testing a single sample. Comparing two populations or treatments. Simple linear regression and correlation. Case studies. |
| 4 | **Texts/References** | **1.** Introduction to Probability and Statistics for Engineers and Scientists by Sheldon M. Ross, Elsevier, New Delhi, 3rd edition (Indian), 2014.<br>**2.** Probability, Random Variables and Stochastic processes by Papoulis and Pillai, 4th Edition, Tata McGraw Hill, 2002.<br>**3.** An Introduction to Probability Theory and Its Applications, Vol. 1, William Feller, 3rd edition, Wiley International, 1968. |

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| 1 | **Title of the course** (L-T-P-C) | **Digital Systems** **(2-1-0-6)** |
| 2 | **Pre-requisite courses(s)** | None |
| 3 | **Course content** | • Introduction to Digital Systems<br>• Number systems and Logic: Number Systems, Different Codes, Boolean logic, basic gates, truth tables<br>• Introduction to Logic families: TTL, CMOS etc.<br>• Boolean Algebra: Laws of Boolean Algebra, logic minimization using K maps<br>• Combinational Logic Circuits: Adders, Subtractors, Multipliers, MSI components like Comparators, Decoders, Encoders, MUXs, DEMUXs<br>• Sequential circuits: Latches, Flipflops, Analysis of clocked sequential circuits, Registers and Counters (Synchronous and Asynchronous), State Machines<br>• Introduction to Hardware Description Languages<br>• Array based logic elements: Memory, PLA, PLD, FPGA<br>• Special Topics: Asynchronous State machines, Testing and Verification of Digital Systems |
| 4 | **Texts/References** | **1.** J. F. Wakerly: Digital Design, Principles and Practices,4th Edition,Pearson Education, 2005<br>**2.** M. Moris Mano; Digital Design, 4th Edition, Pearson,2009<br>**3.** Ronald J. Tocci; Digital System, Principles and Applications, 10th Edition, Pearson, 2009<br>**4.** H.Taub and D. Schilling; Digital Integrated Electronics, McGraw Hill, 1977<br>**5.** Charles H Roth; Digital Systems Design using VHDL, Thomson Learning, 1998. |

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| 1 | **Title of the course** (L-T-P-C) | **Introduction to Analog Circuits** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Network theory, Electronic Devices |
| 3 | **Course content** | **Part 1: Linear circuits**<br>• Introduction to feedback control – Integral control and proportional control<br>• Linear circuits using Op-amps (amplifiers, arithmetic circuits, filters and oscillators)<br>**Part 2: Need for Non-linearity for amplification**<br>Single stage amplifiers, frequency response, Current mirror circuits, Differential amplifier. |
| 4 | **Texts/References** | **1.** J.V.Wait, L.P.Huelsman and GA Korn, Introduction to Operational Amplifier theory and applications, 2nd edition, McGraw Hill, New York, 1992.<br>**2.** J. Millman and A. Grabel, Microelectronics, 2nd edition, McGraw Hill, 1988.<br>**3.** Ramakant Gayakwad, Op-amps and Linear Integrated Circuit, 4th edition, Pearson, 2000.<br>**4.** P. Horowitz and W. Hill, The Art of Electronics, 2nd edition, Cambridge University Press, 1989.<br>**5.** Behzad Razavi , "Fundamentals of Microelectronics," John Wiley, 2013. |

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| 1 | **Title of the course** (L-T-P-C) | **Network Theory** **(2-1-0-6)** |
| 2 | **Pre-requisite courses(s)** | -- |
| 3 | **Course content** | **Graphs of networks:** current and voltage spaces of graphs and their representations: incidence, cutset and circuit matrices; Tellegen's Theorem.<br>Formal study of methods of analysis such as nodal, modified nodal, cutset, loop analysis for linear networks.<br>Multiport representation for networks with particular emphasis on 2-ports.<br>Time domain analysis of R, L, M, C, controlled sources, networks using state space methods.<br>Introduction to s-domain methods. |
| 4 | **Texts/References** | **1.** Jerome P. Levine, Omar Wing, Classical Circuit Theory, Springer, 2009.<br>**2.** S. Ghosh, Network Theory: Analysis and Synthesis, Prentice Hall of India, 2005.<br>**3.** N Balabanian and T.A. Bickart, Linear Network Theory: Analysis, Properties, Design and Synthesis, Matrix Publishers, Inc. 1981.<br>**4.** L.O. Chua, C.A. Desoer, E.S. Kuh, Linear and Nonlinear Circuits, McGraw - Hill International Edition 1987. |

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| 1 | **Title of the course** (L-T-P-C) | **Introduction to Electrical Machines** **(2-1-0-3)** |
| 2 | **Pre-requisite courses(s)** | Network Theory |
| 3 | **Course content** | Transformer: Magnetic Circuits, principle of transformer action, equivalent circuits, phasor diagram, efficiency, basics of three phase transformer.<br>Synchronous Machines: induced emf and torque in a rotating coil, rotating magnetic field, construction of synchronous Machines, induced emf, phasor diagram, equivalent circuit, OCC- SCC, power angle characteristics, V-curve and inverted V curve.<br>Other topics: introduction to Induction Motor, introduction to DC Machine, Application<br>1. of Electrical Machines and special electrical motors. |
| 4 | **Texts/References** | **1.** P. S. Bimbhra, "Electrical machinery," Khanna Publishers, 7th edition, 1977.<br>**2.** M. G. Say, "The Performance and Design of Alternating Current Machines," CBS, 3rd edition, 2002.<br>**3.** Stephen Chapman, "Electric Machinery Fundamentals," McGraw Hill, 4th edition, 2017.<br>**4.** D.P. Kothari, I.J. Nagrath, "Electric Machines," McGraw Hill, 5th edition, 2017.<br>**5.** A Fitzgerald, Charles Kingsley, and Stephen Umans, "Electric Machinery," McGraw Hill, 6th edition, 2017. |

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| 1 | **Title of the course** (L-T-P-C) | **Introduction to Power Electronics (2-1-0-3)** |
| 2 | **Pre-requisite courses(s)** | Electric circuits, Devices |
| 3 | **Course content** | Introduction to power semiconductor devices, drive circuits, Rectifiers - single and three phase; basics of inverters - single and three phase; PWM generation, DC/DC converters - Buck, Boost and Buck Boost. Basics of magnetic circuits |
| 4 | **Texts/References** | **1.** L. Umanand, ``Power Electronics – essentials and applications," Wiley 2009.<br>**2.** M. H. Rashid " Power Electronics," Pearson. 4th edition, 2017.<br>**3.** Cyril W Lander, "Power Electronics" The McGraw-Hill Companies, 3rd ed, 1993. |

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| 1 | **Title of the course** (L-T-P-C) | **Engineering Electromagnetics** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Basic calculus and first year physics course (PH102). |
| 3 | **Course content** | **1.** Overview of Static Electric and Magnetic Fields, Steady Electric Currents.<br>**2.** Time Varying Electromagnetic Fields, Maxwell's Equations, Boundary Conditions.<br>**3.** Plane Electromagnetic Waves, Propagation in Free Space and in Matter.<br>**4.** Reflection and Refraction of Waves at Conducting and Dielectric Boundary.<br>**5.** Transmission Lines: TEM waves, Transmission Line Equations, Wave Propagation along Finite Transmission Lines, Transients on Lines, The Smith Chart.<br>**6.** Waveguides, Waves in Guided Media, Parallel Plate Waveguide<br>**7.** Rectangular Waveguide, Cavity Resonators.Basic Theory of Antennas and Radiation Characteristics, Elementary Types of Antennas. |
| 4 | **Texts/References** | **1.** D K Cheng, "Fundamentals of Electromagnetics", Addison Wesley, MA 1993.<br>**2.** R K Shevgaonkar, "Electromagnetic Waves", McGraw- Hill Education (India) Pvt Limited, 2005<br>**3.** Hayt, William H., Jr., and John A. Buck, "Engineering Electromagnetics", 7th ed. McGraw-Hill, 2006. |

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| 1 | **Title of the course** (L-T-P-C) | **Signals and Systems** **(2-1-0-6)** |
| 2 | **Pre-requisite courses(s)** | -- |
| 3 | **Course content** | • Continuous-time and Discrete-time signal (and system) classification and properties.<br>• Impulse response, LTI / LSI system and properties; Continuous-time and Discrete-time convolution.<br>• Linear constant coefficient differential (and difference) equations.<br>• Continuous – time Fourier series and Continuous – time Fourier Transform. Their Properties.<br>• Discrete – time Fourier series and Discrete – time Fourier Transform. Their Properties.<br>• Sampling and Aliasing in time and frequency. Discrete Fourier Transform.<br>• Laplace Transform and its Properties. Z-Transform and its Properties. |
| 4 | **Texts/References** | **1.** Signals and Systems, Authors: Alan V. Oppenheim, Alan S. Willsky, Edition: 2, illustrated, Publisher: Pearson, 2013.<br>**2.** Signal Processing and Linear Systems, Author: Bhagawandas P. Lathi, Edition: 2, illustrated, Publisher: Oxford University Press, 2009.<br>**3.** Signals and Systems, Authors: Simon S. Haykin, Barry Van Veen, Edition: 2, illustrated, Publisher: Wiley, 2003. |

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| 1 | **Title of the course** (L-T-P-C) | **Devices and circuits Lab** **(0-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | -- |
| 3 | **Course content** | This lab will reinforce concepts thought in Electronic devices and analog circuits. It will have experiments on Device characterization and circuits design and characterization. The following is the tentative list of experiments for this lab:<br>**1.** LED and Photodiode characterization<br>**2.** BJT biasing and CE amplifier<br>**3.** Solar cell characterization<br>**4.** Diode Temperature characteristics<br>**5.** NMOS characterization and CS amplifier<br>**6.** MOS differential amplifier<br>**7.** basic opamp circuits<br>**8.** Active filters<br>**9.** Multivibrators<br>**10.** Audio amplifiers |
| 4 | **Texts/References** | **1.** J.V.Wait, L.P.Huelsman and GA Korn, Introduction to Operational Amplifier theory and applications, 2nd edition, McGraw Hill, New York, 1992.<br>**2.** J. Millman and A. Grabel, Microelectronics, 2nd edition, McGraw Hill, 1988.<br>**3.** Behzad Razavi, Fundamentals of microelectronics, Wiley Publications<br>**4.** A.S.Sedra and K.C. Smith,Microelectronic Circuits, Saunder's College Publishing, Edition IV, 2017.<br>**5.** Ramakant Gayakwad, Op-amps and Linear Integrated Circuit, 4th edition, Pearson, 2000. |

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|---|---|---|
| 1 | **Title of the course** (L-T-P-C) | **Digital Circuits Laboratory** **(0-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | Digital Systems Theory (EE224) |
| 3 | **Course content** | This purpose of this lab is to complement the Digital Systems Theory Course. The following is the tentative list of experiments for this lab:<br>Experiments with discrete ICs<br>**1.** Introduction of digital ICs<br>**2.** Realizing Boolean expressions<br>**3.** Adder/Subtractor<br>**4.** Shift registers<br>**5.** Synchronous Counters<br>**6.** Asynchronous Counters +<br>**7.** segment display<br>**8.** Finite State Machines (2 weeks) Experiments with CPLDs<br>**9.** Arithmetic and Logic Unit<br>**10.** LCD, Buzzer Interfacing Pipelining |
| 4 | **Texts/References** | **1.** M. Moris Mano; Digital Design, 5th Edition, Pearson, 2009<br>**2.** J.F.Wakerly: Digital Design, Principles and Practices,4th Edition,Pearson Education, 2005<br>**3.** Ronald J. Tocci; Digital System, Principles and Applications, 10th Edition, Pearson, 2009 |

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| | **Title of the course** (L-T-P-C) | **Communications Lab** **(0-0-4-2)** |
| 2 | **Pre-requisite courses(s)** | Introduction to Communication Systems |
| 3 | **Course content** | Practical experiments in-line with the content of "Introduction to Communication Systems" course covering transmission and reception mechanisms corresponding to analog and digital communication.<br>● Introduction to the usage of software defined radios and MATLAB<br>● Analog modulation and demodulation<br>● Digital modulation and demodulation – BPSK and QPSK only |
| 4 | **Texts/References** | **1.** Upamanyu Madhow, ``Introduction to Communication Systems," Cambridge university press, 2008 edition.<br>**2.** Simon Haykin, "An Introduction to Analog and Digital Communication," Wiley India Pvt. Ltd., 2006.<br>**3.** B. P. Lathi and Zhi Ding, ``Modern Digital and Analog Communication Systems," Oxford higher education, 2017. |

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| 1 | **Title of the course** (L-T-P-C) | **Introduction to Probability** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Basic calculus |
| 3 | **Course content** | **Introduction**: Motivation for studying the course, revision of basic math required, connection between probability and length on subsets of the real line, probability-formal definition, events and $\sigma$-algebra, independence of events, and conditional probability, sequence of events, and *Borel-Cantell* Lemma.<br><br>**Random Variables**: Definition of random variables, and types of random variables, CDF, PDF and its properties, random vectors and independence, brief introduction to transformation of random variables, introduction to Gaussian random vectors.<br><br>**Mathematical Expectations**: Importance of averages through examples, definition of expectation, moments and conditional expectation, use of MGF, PGF and characteristic functions, variance and k-th moment, MMSE estimation.<br><br>**Inequalities and Notions of convergence**: Markov, Chebychev, Chernoff and Mcdiarmid inequalities, convergence in probability, mean, and almost sure, law of large numbers and central limit theorem.<br>**A short introduction to Random Process:** Example and formal definition, stationarity, autocorrelation, and cross correlation function, definition of ergodicity. |
| 4 | **Texts/References** | 1. **Robert B. Ash**, ``Basic Probability Theory," Reprint of the John Wiley & Sons, Inc., New York, 1970 edition.<br>2. **Sheldon Ross**, ``A first course in probability," Pearson Education India, 2002.<br>3. **Bruce Hayek**, ``An Exploration of Random Processes for Engineers," Lecture notes, 2012.<br>4. D.P. Bertsekas and J. Tsitisklis, "Introduction to Probability" MIT Lecture notes, 2000 (*link*: https://www.vfu.bg/en/e-Learning/Math-- Bertsekas_Tsitsiklis_Introduction_to_probability.pdf) |

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| 1 | **Title of the course** (L-T-P-C) | **Introductions to Power Systems** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Network Theory, Introduction to Electrical Machines |
| 3 | **Course content** | Introduction: Evolution of Power Systems, Energy Sources Structure of Bulk Power Systems, Power generation concepts, ac and dc transmission concepts, Basic three phase system concepts<br>Transmission lines: Models and performance of transmission lines and cables<br>Insulators: different types, Electric field distribution and insulators<br>Power Flow: modelling of generators, transformers, lines and loads, per Unit Systems, Bus admittance matrix, Gauss Seidel and Newton-Raphson load flow methods<br><br>Introduction to next course: introduction to faults, power system protection, stability, operation, blackout |
| 4 | **Texts/References** | 1. Grainger and Stevenson , "Power System Analysis," 1st edition, McGraw Hill, 2017.<br>2. Bergen and Vittal, "Power System Analysis," 2nd Edison, Pearson 2002.<br>3. O E. Elgerd,"Electrical Energy Systems Theory," 2nd edition, McGraw Hill, 2017.<br>4. Stagg and el-abiad, "Computer methods in Power System Analysis," MedTech, 2019.<br>5. Glover, Sarma and Overbye, "Power System Analysis<br>6. and design," CLIPL, 5th edition, 2012.<br>7. Hadi Saadat, "Power System Analysis," PSA Publishing LLC, 2011.<br>8. B. F. Wollenberg, "Power Generation, operation and control," 2nd edition, Wiley, 2006. Nagrath and Kothari, "Power System. |

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| 1 | **Title of the course** (L-T-P-C) | **Control Systems and Laboratory** **(2-0-2-6)** |
| 2 | **Pre-requisite courses(s)** | -- |
| 3 | **Course content** | ● **Basic concepts:** Notion of feedback, open- and closed-loop systems.<br>● **Modeling and representations of control systems:** Transfer function models of for suitable mechanical, electrical, thermal and pneumatic systems, Ordinary differential equations, Transfer functions, Block diagrams, Signal flow graphs, State-space representations.<br>● **Performance and stability:** Time-domain analysis, Second-order systems, Characteristic-equation and roots, Routh-Hurwitz criteria.<br>● **Basic modes of feedback control:** Proportional, Integral, Derivative.<br>● **Root locus** method of design.<br>● **Frequency-domain techniques:** Root-locus methods, Frequency responses, Bode-plots, Gain- margin and phase-margin, Nyquist plots.<br>● **Compensator design:** Proportional, PI and PID controllers, Lead-lag compensators.<br>● **State-space concepts:** Controllability, Observability, pole placement result, Minimal representations<br>● Laboratory involves set of experiments following the theory component covered in the class |
| 4 | **Texts/References** | **1.** Norman Nise, Control System Engineering, Wiley, $6^{th}$ Edition, 2011<br>**2.** K. Ogata, Modern Control Engineering, Pearson, $5^{th}$ edition, 2010.<br>**3.** Gene franklin et. al., “Feedback Control of Dynamic Systems”, $7^{th}$ Edition, Pearson<br>**4.** B. Kuo, Automatic Control System, Wiley, $9^{th}$ Edition, 2014 |

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| 1 | **Title of the course** (L-T-P-C) | **Data Analysis** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Introduction to Probability |
| 3 | **Course content** | The role of statistics. Graphical and numerical methods for describing and summarizing data. Sampling variability and sampling distributions, Estimation using a single sample, Hypothesis testing using a single sample, Comparing two populations or treatments, Simple linear regression and correlation, and Case studies. |
| 4 | **Texts/References** | Sheldon M. Ross, "Introduction to Probability and Statistics for Engineers and Scientists," Elsevier, New Delhi, 3rd edition (Indian), 1987.<br><br>Papoulis and Pillai, "Probability, Random Variables and Stochastic processes," 4th Edition, Tata McGraw Hill, 1991.<br><br>William Feller , "An Introduction to Probability Theory and Its Applications," Vol. 1, 3rd edition, John Wiley International, 1968. |

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|---|---|---|
| 1 | **Title of the course** (L-T-P-C) | **Electronic Devices** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | EE 102 |
| 3 | **Course content** | • Introduction of Semiconductor Equations: Fermi- **Dirac Distribution, Boltzmann's approximation**<br>• Semiconductor Diodes: Barrier formation in metal- semiconductor junctions, PN homo- and hetero- junctions; CV characteristics and dopant profiling; IV characteristics; Small signal models of diodes; Some Applications of diodes.<br>• Field Effect Devices: JFET/HFET, MIS structures and MOSFET operation; JFET characteristics and small signal models; MOS capacitor CV and concept of accumulation, depletion and inversion; MOSFET characteristics and small signal models.<br>• Bipolar transistors: IV characteristics and Elers-Moll model; small signal models; Charge storage and transient response |
| 4 | **Texts/References** | **1.** D. A. Neamen, Semiconductor Physics and Devices, 4e Edition, McgrawHill, 13th reprint, 2016.<br>**2.** E.S. Yang, Microelectronic Devices, McGraw Hill, Singapore, 1988.<br>**3.** B.G. Streetman, Solid State Electronic Devices, 7th Edition, Pearson, 2016.<br>**4.** J. Millman and A. Grabel, Microelectronics, II edition 34th reprint McGraw Hill, International, 2017.<br>**5.** A.S. Sedra and K.C. Smith, Microelectronic Circuits, Saunder's College Publishing, 1991.<br>**6.** R.T. Howe and C.G. Sodini, Microelectronics : An integrated Approach, Prentice Hall International, 1997. |

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|---|---|---|
| 1 | **Title of the course** (L-T-P-C) | **Control Systems**<br>**(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Linear Algebra (MA 102) |
| 3 | **Course content** | • **Basic concepts:** Notion of feedback, open- and closed-loop systems.<br>• **Modeling and representations of control systems:** Transfer function models of for suitable mechanical, electrical, thermal and pneumatic systems, Ordinary differential equations, Transfer functions, Block diagrams, Signal flow graphs, State-space representations.<br>• **Control hardware and their models:** Potentiometers, synchros, LVDT, DC and AC servo motors, tachogenerators, electro-hydraulic valves, pneumatic actuators.<br>• **Performance and stability:** Time-domain analysis, Second-order systems, Characteristic-equation and roots, Routh-Hurwitz criteria.<br>• **Basic modes of feedback control:** Proportional, Integral, Derivative.<br>• **Root locus** method of design.<br>• **Frequency-domain techniques:** Root-locus methods, Frequency responses, Bode-plots, Gain- margin and phase-margin, Nyquist plots.<br>• **Compensator design:** Proportional, PI and PID controllers, Lead-lag compensators.<br>• **State-space concepts:** Controllability, Observability, pole placement result, Minimal representations. |
| 4 | **Texts/References** | **1** Norman Nise, Control System Engineering, Wiley, 6th Edition, 2011<br>**2** K. Ogata, Modern Control Engineering, Pearson, 5th edition, 2010<br>**3** B. Kuo, Automatic Control System, Wiley, 9th Edition, 2014 |

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|---|---|---|
| 1 | **Title of the course** (L-T-P-C) | **Introduction to Communication Systems** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Exposure to probability, signals and systems |
| 3 | **Course content** | Motivation towards designing Analog and Digital Communication Systems<br>Baseband and passband signals<br>Analog modulation techniques – Amplitude Modulation and Angle Modulation<br>Overview of digital modulation – Signal Constellations, Hypothesis Testing, ML and MAP detection rules, performance analysis of selected digital modulation schemes. |
| 4 | **Texts/References** | **1.** Upamanyu Madhow, ``Introduction to Communication Systems," Cambridge university press, 2008 edition.<br>**2.** Simon Haykin, "An Introduction to Analog and Digital Communication," Wiley India Pvt. Ltd., 2006.<br>**3.** B. P. Lathi and Zhi Ding, ``Modern Digital and Analog Communication Systems," Oxford higher education, 2017. |

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|---|---|---|
| 1 | **Title of the course** (L-T-P-C) | **Electronic Devices and Circuits** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Introduction to Electrical and Electronics Components (EE102) |
| 3 | **Course content** | 1. **Modeling devices:** Static characteristics of ideal two terminals and three terminal devices; Small signal models of non-linear devices.<br>2. **Introduction to semiconductor equations and carrier statistics:** Poisson's and continuity equations, Fermi-Dirac statistics and Boltzmann approximation to the Fermi-Dirac statistics.<br>3. **Semiconductor Diodes:** Barrier formation in metal-semiconductor junctions, PN homo- and hetero- junctions; CV characteristics and dopant profiling; IV characteristics; Small signal models of diodes; Some Applications of diodes.<br>4. **Field Effect Devices:** JFET/HFET, MIS structures and MOSFET operation; JFET characteristics and small signal models; MOS capacitor CV and concept of accumulation, depletion and inversion; MOSFET characteristics and small signal models.<br>5. **Bipolar transistors:** IV characteristics and Elers- Moll model; small signal models; Charge storage and transient response.<br>6. **Discrete transistor amplifiers:** Common emitter and common source amplifiers; Emitter and source followers. |
| 4 | **Texts/References** | 1. D. A. Neamen, Semiconductor Physics and Devices, 4e Edition, McgrawHill, 13$^{th}$ reprint, 2016<br>2. E.S. Yang, Microelectronic Devices, McGraw Hill, Singapore, 1988<br>3. B.G. Streetman, Solid State Electronic Devices, 7$^{th}$ Edition, Pearson, 2016<br>4. J. Millman and A. Grabel, Microelectronics, II edition 34$^{th}$ reprint McGraw Hill, International, 2017.<br>5. A.S. Sedra and K.C. Smith, Microelectronic Circuits, Saunder's College Publishing, 1991<br>6. R.T. Howe and C.G. Sodini, Microelectronics : An integrated Approach, Prentice Hall International, 1997 |

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| 1 | **Title of the course** (L-T-P-C) | **Smart Systems Design Lab** **(1-0-5-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to programming languages (C/C++/MATLAB), ability to rig up basic electrical/electronic circuits |
| 3 | **Course content** | Various applications involving smart systems, such as, networked control systems, distributed decision-making robots, IoT communication system design for smart manufacturing, developing secure IoT protocols, etc. will be considered. Problem statements with respect to the design and development of smart systems for these applicationsare obtained from interested faculty members. Problem statements obtained from students will also be encouraged if found suitable. Students design these systems and develop a working prototype on an embedded platform (Rasberry Pi/Arduino/IoT platform). |
| 4 | **Texts/References** | **1.** Gilchrist, Alasdair, “Industry 4.0: the industrial Internet of things,” Apress, 2016.<br>**2.** Rawat, D. B., C. Brecher, H. Song, and S. Jeschke. "Industrial Internet of Things: Cybermanufacturing Systems." 2017. |

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|---|---|---|
| 1 | **Title of the course** (L-T-P-C) | **Power Systems** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | |
| 3 | **Course content** | Evolution of Power Systems, Energy Sources Structure of Bulk Power Systems Basic three phase system concepts Power System Components: Generators, Loads, Transformers, Transmission Lines etc. Modeling, Performance and Constraints of these components Formulation/Solution of steady state equations for interconnected systems: Balanced and Unbalanced systems. Positive Sequence Network, Per Unit System, Ybus formation Simple example of a load flow solution Introduction to generator swing equations and stability issues, Simple Example of Loss of synchronism Interconnected System Operation and Control: Operational Objectives, Frequency Control, Voltage Control and Power Flow Control: introduction to HVDC transmission and FACTS Economic Issues in Power Systems. Analysis of Faulted Power Systems and Protection: Unbalanced System Analysis using Sequence Components, Equipment Protection Schemes: Over current, Differential and Distance Protection, Relay coordination Preventive Control and Emergency Control System Protection Schemes) Blackouts and Restoration. |
| 4 | **Texts/References** | **1.** J.J. Grainger and W.D. Stevenson, Power System Analysis, McGraw-Hill, New York, 1994<br>**2.** O. I. Elgerd, Electrical Energy System Theory, Tata McGrew Hill, 1995<br>**3.** A.R. Bergen and V. Vittal, Power System Analysis, Pearson Education Inc., 2000<br>**4.** D.P. Kothari and I. J. Nagrath, Modern Power System Analysis, Tata McGrew Hill, New Delhi, 2003. |

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| 1 | **Title of the course** (L-T-P-C) | **Electrical Machines and Power Electronics Laboratory (0-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | Nil |
| 3 | **Course content** | Experiments reinforcing concepts learnt in EE206 |
| 4 | **Texts/References** | |

<table>
<tr><td>1</td><td>Title of the course<br>(L-T-P-C)</td><td>Control Systems lab<br>(0-0-3-3)</td></tr>
<tr><td>2</td><td>Pre-requisite courses(s)</td><td>Exposure to control systems course</td></tr>
<tr><td>3</td><td>Course content</td><td>Experiments related to:<br><br>• Modeling of systems: Obtaining transfer function models of mechanical/electrical/electro-mechanical systems Ordinary<br>• Performance and stability: Time response, steady-state error, stability etc.<br>• Basic modes of feedback control: Proportional, Integral, Derivative.<br>• Root locus method of controller design<br>• Frequency-domain techniques: Frequency responses<br>• Compensatory design using frequency response Course projects related to:<br>• Advanced control concepts<br>• Real life applications of control systems in various fields<br>• Applications of Signal Processing Techniques to Control Systems etc.</td></tr>
<tr><td>4</td><td>Texts/References</td><td>1. Norman Nise, Control System Engineering, Wiley, latest edition<br>2. K. Ogata, Modern Control Engineering, Pearson, latest edition<br>3. B. Kuo, Automatic Control System, Wiley</td></tr>
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| 1 | **Title of the course** (L-T-P-C) | **Electronic Design Laboratory (1-0-4-6)** |
| 2 | **Pre-requisite courses(s)** | All the core courses of Electrical Engineering Department taught till 5th semester |
| 3 | **Course content** | This is project-based course in which students will do embedded systems project applying the concepts of core EE courses. |
| 4 | **Texts/References** | -- |

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| 1 | **Title of the course** (L-T-P-C) | **DSP Lab** **(0-0-4-2)** |
| 2 | **Pre-requisite courses(s)** | DSP |
| 3 | **Course content** | • Overview of DSP kit<br>• generation of waveform<br>• Convolution and correlation<br>• DFT and FFT Design of digital filters |
| 4 | **Texts/References** | **1.** Proakis and Manolokis, "Digital Signal Processing," 4th edition, Prentice Hall, 2006.<br>**2.** S K Mitra, "Digital Signal Processing," McGraw Hill, Inc., 4th edition, 2017.<br>**3.** Alan V Oppenheim, "Digital Signal Processing," Prentice Hall, 1975. |

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| 1 | **Title of the course** (L-T-P-C) | **Microprocessors and microcontrollers lab (0-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | -- |
| 3 | **Course content** | Software experiments using an 8085 Kit to learn its instruction set. Hardware experiments for the use of peripherals like 8251 (USART). Experiments using a development board to learn the instruction set and assembly programming for 8051 family of microcontrollers. Experiments to learn Port IO, control of on chip peripherals such as timers, interfacing with off chip peripherals such as LCD displays, Key boards, Stepper motors and ADC chips. Experiments for the use of other microcontrollers such as PIC using development boards. |
| 4 | **Texts/References** | • R. S. Gaonkar, Microprocessor Architecture: Programming and Applications with the 8085/8080A, Penram International Publishing, 1996.<br>• Kenneth J. Ayala, The 8051 Microcontroller, Penram International Publishing, 1996. |

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|---|---|---|
| 1 | **Title of the course** (L-T-P-C) | **Digital Signal Processing** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Signals and Systems |
| 3 | **Course content** | Review of basic signal processing, and sampling, introduction to DSP, Z transform, DFT, FFT, Implementation of discrete time systems, and Introduction to digital filters. |
| 4 | **Texts/References** | **1.** Proakis and Manolokis, "Digital Signal Processing," 4th edition, Prentice Hall, 2006.<br>**2.** S K Mitra, "Digital Signal Processing," McGraw Hill, Inc., 4th edition, 2017.<br>**3.** Alan V Oppenheim, "Digital Signal Processing," Prentice Hall, 1975. |

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|---|---|---|
| 1 | **Title of the course** (L-T-P-C) | **Introduction to Industry 4.0 and Industrial Internet of Things (3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Basic knowledge in computers and Internet |
| 3 | **Course content** | Introduction: Sensing & actuation, Communication and networking Industry 4.0:Globalization and Emerging Issues, The Fourth Revolution, LEAN Production Systems, Smart and Connected Business Perspective, Smart Factories<br>Industry 4.0: Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management, Augmented Reality and Virtual Reality, Artificial Intelligence Cybersecurity in Industry 4.0<br>IIoT-Introduction, Business Model and Reference Architerture:<br>IIoT- Layers: IIoT Sensing, IIoT Processing, IIoT Communication and Networking<br>Big Data Analytics and Software Defined Networks Security and Fog Computing<br>Application Domains and Case Studies |
| 4 | **Texts/References** | **1.** Gilchrist, Alasdair, "Industry 4.0: the industrial Internet of things," Apress, 2016..<br>**2.** Rawat, D. B., C. Brecher, H. Song, and S. Jeschke. "Industrial Internet of Things: Cybermanufacturing Systems." 2017. |

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|---|---|---|
| 1 | **Title of the course** (L-T-P-C) | **Microprocessors and Microcontrollers (3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | -- |
| 3 | **Course content** | Block diagram view of a general purpose processor; elements of hardware and software architectures; introduction to concepts of data and control paths, registers and memory organization. Instruction set basics and assembly language programming: instruction structure and addressing modes, instruction encoding, and study of 8085A instruction set, hardware architecture and interrupts. Introduction to microcontrollers. 8051 hardware and instruction set architecture, timers/counters, interrupts and serial interface (including multi-processor communication). Interfacing basics using examples of I/O devices: parallel port, serial ports, keypad, display, etc. Introductory discussion on processor performance evaluation and design using a RISC ISA (including concepts of pipelining, pipelining hazards, cache, virtual memory and parallelism). |
| 4 | **Texts/References** | • R.S. Ganorkar, Microprocessor Architecture, Programming, and Applications with the 8085, Penram International Publishing, Fifth Edition, 2011.<br>• J.H. Hennessy, and D.A. Patterson, Computer Architecture: A Quantitative Approch, Morgan Kaufmann Publishers, Fourth Edition, 2006.<br>• Kenneth J. Ayala, The 8051 Microcontroller, Architecture, Programming and Applications, Penram International Publishing, 1996. |

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| 1 | **Title of the course**<br>(L-T-P-C) | **Robotics**<br>**(2-0-2-6)** |
| 2 | **Pre-requisite courses(s)** | Undergraduate Control Systems or Engineering Mechanics |
| 3 | **Course content** | • Introduction<br>• Actuators and Drives: DC motors, dynamics of single axis drive systems, Power Electronics basics etc.<br>• Sensors and control components: Robot control using PWM amplifiers, microcontrollers etc.<br>• Robot Mechanisms: Robot linkages and joints<br>• Planar Kinematics: Planar kinematics of serial link mechanisms, Kinematics of Parallel Link Mechanisms etc.<br>• Differential motion: Properties of Jacobians<br>• Mechanics of Robots: Statics, Duality of differential kinematics and statics, robot dynamics, non-holonomic systems<br>• Inverse kinematics and trajectory generation<br>• Concepts of Control: PID control, Hybrid position-force control, compliance control, torque control etc.<br>• Advanced topics and case studies<br>• Demonstrations and assignments using MATLAB and ARM based experimental set-ups |
| 4 | **Texts/References** | 1. Asada, H., and J. J. Slotine. Robot Analysis and Control. New York, NY: Wiley, 1986.<br>2. John J. Craig Introduction to Robotics: Mechanics andControl, Addison-Wesley Publishing Company, 3rd Edition, 2003.<br>3. M. Spong, M. Vidyasagar, S. Hutchinson, Robot Modeling and Control, Wiley & Sons, 2005.<br>4. R. M. Murray, Z. Li, S. Sastry, A Mathematical Introduction to Robotic Manipulation, CRC press, 1994. |

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| 1 | **Title of the course** (L-T-P-C) | **Analog Circuits** **(2-0-2-6)** |
| 2 | **Pre-requisite courses(s)** | Analog Circuits |
| 3 | **Course content** | • Review of Single stage amplifiers and differential amplifier<br>• Cascode amplifiers<br>• 2 stage amplifiers (opamp) and its stability and compensation Non-idealities of opamps<br>• NMOS output and PMOS output voltage regulators<br>• Current and voltage references<br>• Opamp based circuits<br>1. Howland Current source<br>2. Instrumentation amplifiers<br>3. Logarithmic amplifiers<br>4. Non-linear circuits<br>5. Multivibrators<br>6. A/D and D/A converters, sample and hold circuits<br>• Lab component will contain experiments on Simulation of amplifier and regulator circuits using NGSpice and breadboard based experiments on current sources, log amplifiers and voltage regulators using opamps and discrete transistors. |
| 4 | **Texts/References** | **1.** J.V.Wait, L.P.Huelsman and GA Korn, Introduction to Operational Amplifier theory and applications, $2^{nd}$ edition, McGraw Hill, New York, 1992.<br>**2.** J. Millman and A. Grabel, Microelectronics, $2^{nd}$ edition, McGraw Hill, 1988.<br>**3.** Ramakant Gayakwad, Op-amps and Linear Integrated Circuit, $4^{th}$ edition, Pearson, 2000.<br>**4.** P. Horowitz and W. Hill, The Art of Electronics, $2^{nd}$ edition, Cambridge University Press, 1989. |

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| 1 | **Title of the course** (L-T-P-C) | **Stochastic Process** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Basic calculus |
| 3 | **Course content** | **Background**: Review of probability theory, random variables, limit theorems, and basics of random processes.<br><br>**Application problems**: Statistical signal processing, random graphs and percolation, hypothesis testing.<br><br>**Poisson Processes:** Definition and properties of Poisson process, Combining and splitting of Poisson Process, and non-homogenous Poisson Process, Introduction to Poisson Point Process.<br><br>**Gaussian Process:** Gaussian random vectors and its properties, Conditional PDFs for Gaussian random vectors, Stationarity, Orthonormal expansion, Filtering, and introduction to Circular symmetric Gaussian random variables.<br><br>**Markov Chain:** Communication classes and its properties, stationary distribution and its existence, Poisson processes, Example applications of Markov decision process.<br><br>**Advanced Random Process:** KL expansion, introduction to special random process such as Martingale and Brownian motion. |
| 4 | **Texts/References** | 1. **Robert B. Ash**, ``Basic Probability Theory," Reprint of the John Wiley & Sons, Inc., New York, 1970 edition.<br>2. **Sheldon Ross**, ``A first course in probability," Pearson Education India, 2002.<br>3. **Bruce Hayek**, ``An Exploration of Random Processes for Engineers," Lecture notes<br>4. **Robert G. Gallager**, "Stochastic Processes: Theory For Applications," Cambridge university Press 2013. |

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| 1 | **Title of the course** (L-T-P-C) | **Digital Communication and Coding Theory** **(2-0-2-6)** |
| 2 | **Pre-requisite courses(s)** | Signals and Systems, Introduction to Communication Systems, Introduction to Probability |
| 3 | **Course content** | Digital Modulation - Signal constellations, Nyquist's Sampling Theorem and Criterion for ISI Avoidance, Linear modulation<br>Optimal D*emodul*ation – Review of Hypothesis Testing, ML and MAP decision rules, Signal Space Concepts, Optimal Reception in AWGN and performance analysis of various modulation schemes.<br>Source Coding - Entropy, Shannon's source coding theorem (without proof), Huffman Codes<br>Channel Coding – Mutual information, Shannon's channel coding theorem (without proof), Linear codes, soft decisions and introduction to cyclic codes<br><br>Lab Component:<br><br>Practical experiments in-line with the content of "Digital Communication and Coding Theory"course covering transmission and reception mechanisms corresponding to digital communication.<br>• Digital modulation and demodulation – PSK and QAM<br>• Channel Modelling<br>• Performance analysis of Huffman codingPerformance Analysis of linear and cyclic codes |
| 4 | **Texts/References** | **1.** Upamanyu Madhow, ``Introduction to Communication Systems," Cambridge university press, 2008 edition.<br>**2.** Cover and Thomas, "Elements of Information Theory," Wiley India Pvt. Ltd., 2006. |

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| 1 | **Title of the course** (L-T-P-C) | **Puzzles, Information and Secrecy** **(1-0-0-2)** |
| 2 | **Pre-requisite courses(s)** | Exposure to probability theory |
| 3 | **Course content** | Introduction (one class)<br>Recap of Probability Theory<br>Introduction to the course<br><br>Introduction to Puzzles (1.5 weeks)<br>Puzzle 1: Twelve coins<br>(b) Puzzle 2: Guessing problem<br>Puzzle 3: Hat problems<br>"Entropy" as a solution<br>Introduction to source coding<br>Fundamental theorem of source coding<br>Practical codes based on solutions to puzzles<br>Randomness/Information & its measure (1.5 weeks)<br>Five cards trick<br>Writing on a "dirty paper" (first version)<br>Channel coding theorem<br>(Lower bounds) What performance cannot be achieved?<br><br>Statistics and Secrecy (one week)<br>Statistics and inference<br>Estimation and Fisher Information (special type)<br>Shannon's one-time pad<br>Wyner wiretap channel |
| 4 | **Texts/References** | **1.** Thomas M. Cover and Joy A. Thomas, "Elements of Information Theory." Second edition. John Wiley<br>**2.** Young-Han Kim, "Puzzles. Information and codes" online http://circuitused.edu/-yhk/ece87-aut11/handouts.html |

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| 1 | **Title of the course** (L-T-P-C) | **Information theory** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Basic calculus, Introduction to Probability Theory . |
| 3 | **Course content** | • **Introductio**n: Revision of probability theory, revision of basic digital communications, motivation to information theory through examples from basic statistics and communications.<br>• **Introduction to basic tools and concepts in information theory:** Entropy and mutual information, Chain rules and inequalities, Data processing, Fano's inequality, Asymptotic equipartition property.<br>• **Source coding:** Guessing game, and its connection to Source coding problem, Kraft's inequality, Optimal code length and Huffman code, Shannon-Fano-Elias and arithmetic codes.<br>• **Statistics and information theory:** Hypothesis testing, estimation theory, and its connection to information theory.<br>• **Channel capacity:** Channel coding theorem, joint typicality, Proof of channel coding theorem, Hamming codes and its properties.<br>• **Continuous channel case:** Differential entropy, Gaussian channel, and its capacity, sphere packing argument, High-level introduction to Quantization theory.<br>• **Introduction to Kolmogorov Complexity:** Models of Computation, Kolmogorov Complexity and entropy, Universal Gambling, MDLP. |
| 4 | **Texts/References** | **1.** T. Cover, and J. Thomas, "Elements of Information Theory," Second Edition. Wiley-Interscience, 2006.<br>**2.** David J. C. Mckay, "Information theory, Inference, and Learning Algorithms," Cambridge university press, 2003. |

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| 1 | **Title of the course** (L-T-P-C) | **Next Generation Wireless Systems / Wireless Networks (3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Principles/Fundamentals of Communications |
| 3 | **Course content** | Theory, design techniques, and analytical tools for characterizing next generation wireless systems. Performance analysis of digital communication systems over fading channels, rate and power adaptation, and multi-user diversity techniques; study of the fourth generation (4G) long term evolution (LTE) standard, its air interface, physical and logical channels, and physical layer procedures; introduction to fifth generation (5G) wireless communication and the 5G new radio (NR) standard, survey of non-orthogonal multiple access (NOMA) and the internet-of-things (IoT) related changes in 4G/5G.. |
| 4 | **Texts/References** | **1.** Stefaniz Sesia, Issam Toufik, Matthew Baker, "LTE - The UMTS Long Term Evolution," John Wiley and Sons, 1st ed., 2009.<br>**2.** 3GPP technical specifications available online at http://www.3gpp.org/<br>**3.** David Tse and Pramod Viswanath, "Fundamentals Of Wireless Communication," Cambridge University Press, 2005.<br>**4.** 4. QUEUEING SYSTEMS, VOLUME 1: THEORY by Leonard Kleinrock John Wiley & Sons, Inc., New York, 1975 |

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| 1 | **Title of the course** (L-T-P-C) | **Digital filters and Multirate Systems** **(2-0-2-6)** |
| 2 | **Pre-requisite courses(s)** | Digital signal processing |
| 3 | **Course content** | Review of basic DSP, digital filter design: IIR, FIR filters etc., multi-rate systems: decimator, interpolator, filter bank analysis and design.<br><br>Lab Component:<br>● Sampling rate conversion: Decimator, Interpolator and fractional rates<br>● Applications of DSP in processing speech, audio and biomedical signals Short course project on one of the advanced DSP applications |
| 4 | **Texts/References** | • P P Vaidyanathan, "Multirate Systems and Filter Banks, Prentice Hall Signal Processing Series, 2006.<br>• N J Fliege, "Multirate Digital Signal Processing: Multirate Systems – Filter Banks – Wavelets," John Wiley, 1994.<br>• Proakis and Manolokis, "Digital Signal Processing," $4^{th}$ edition, Prentice Hall, 2006.<br>• S K Mitra, "Digital Signal Processing," McGraw Hill, Inc., $4^{th}$ edition, 2017.<br>• Alan V Oppenheim, "Digital Signal Processing," Prentice Hall, 1975. |

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| 1 | **Title of the course** (L-T-P-C) | **Control Systems Design Lab (0-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | Undergraduate Control Systems |
| 3 | **Course content** | Design experiments that involve the applications of the concepts learnt in Control Systems course using complex systems like Furuta Pendulum, Magnetic Levitator, Temperature Control Loop etc.<br>The topics of emphasis are:<br>1. Modelling<br>2. Analysis of Stability, Transient Response, Steady- State Error<br>3. Controller Design using Root-Locus<br>4. Frequency Domain Analysis<br>5. Controller Design using Frequency Response<br>6. Effects of non-linearities<br>7. Effects of time delays |
| 4 | **Texts/References** | 1. Norman Nise, Control System Engineering, Wiley, 6th edition<br>2. Richard C. Dorf and Robert H. Bishop, “Modern Control Systems”, Pearson India, 12th Edition<br>3. Gene Franklin et. al., “Feedback Control of Dynamic Systems”, 7th Edition, Pearson.<br>4. K. Ogata, Modern Control Engineering, Pearson, 4th edition<br>5. B. Kuo, Automatic Control System, Wiley, 9th Edition |

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| 1 | **Title of the course** (L-T-P-C) | **Probability and Random Process** **(2-1-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to MA 105 (basic calculus) or equivalent |
| 3 | **Course content** | **Introduction:** Motivation for studying the course, revision of basic math required, connection between probability and length on subsets of real line, probability-formal definition, events and $\sigma$-algebra, combinatorial problems, independence of events, and conditional probability, applications of conditional probability in statistics.<br><br>**Random Variables:** Definition of random variables, and types of random variables, CDF, PDF and its properties, joint CDF and PDF, random vectors and independence, brief introduction to transformation of random variables, introduction to Gaussian random vectors.<br><br>**Mathematical Expectation:** Importance of averages through examples, definition of expectation, moments and conditional expectation, use of MGF, PGF and characteristic functions, variance and k-th moment, conditional expectation and its applications in signal processing, correlation.<br><br>**Inequalities and Notions of convergence:** Markov, Chebychev, Chernoff and Mcdiarmid inequalities, convergence in probability, mean, and almost sure and central limit theorem.<br><br>**Application problems:** Statistical signal processing, random graphs and percolation, hypothesis testing.<br><br>**Random Process:** Example and formal definition, stationarity, autocorrelation, and cross correlation function, ergodicity, brief introduction to KL expansion, introduction to Poisson random process and Markov chains.<br><br>**Markov Chain:** Communication classes and its properties, stationary distribution and its existence, example applications of Markov Decision Process (MDP). |
| 4 | **Texts/References** | **1.** Robert B. Ash, "Basic Probability Theory," Reprint of the John Wiley & Sons, Inc., New York, 1970 edition.<br>**2.** Sheldon Ross, "A first course in probability," Pearson Education India, 2002.<br>**3.** Bruce Hayek, "An Exploration of Random Processes for Engineers," Lecture notes. |

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| 1 | **Title of the course** (L-T-P-C) | **Batteries for Electric Transportation** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | |
| 3 | **Course content** | **Overview:** History and evolution of battery technology, Batteries for Electric Vehicle and application specific requirements, battery types, status of EVs and EV batteries around the world; Past, Present and Future<br><br>**Lead Acid Batteries:** Earlier development, Present Challenges, Manufacturing methods, Opportunities<br><br>**Lithium Based Chemistry:** Lithium in context of EVs – overview; Battery design methods, Present Scenario, Opportunities and Challenges<br><br>**Design Issues, Performance and Characterization:** Battery parameters (Voltage, Current, Power, Energy, SOC, SOH, life etc); Primary /Secondary battery systems; Series/Parallel combinations; Design principles Other battery systems for transportation |
| 4 | **Texts/References** | **References:**<br><br>• Warner J. T., **The Handbook of Lithium-Ion Battery Pack Design: Chemistry, Components, Types and Terminology**, Elsevier Science, 2015.<br>• Plett G. L., **Battery Management Systems, Volume I: Battery Modeling**, Artech House, 2015.<br>• Plett G. L., **Battery Management Systems, volume 2**, Artech House, 2015. |

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| 1 | **Title of the course** (L-T-P-C) | **Analog IC design** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Electronic Devices, Analog Electronics |
| 3 | **Course content** | Active and passive CMOS devices, MOS transistors and small signal models, Noise sources, current mirrors, Single stage opamp, cascode amplifier, folded cascode amplifier, 2 stage opamp and compensation, Negative feedback, fully differential amplifiers, Common mode feedback, PLL's. |
| 4 | **Texts/References** | **1)** Jacob Baker, CMOS Circuit Design, Layout, andSimulation, Wiley; 1 edition (2009)<br>**2)** Behzad Razavi, Design of Analog CMOS Integrated Circuits,McGraw Hill Education; Second edition<br>**3)** Hurst, Lewis, Meyer Gray Analysis and Design ofAnalog Integrated Circuits, Wiley; 5 edition |

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| 1 | **Title of the course** (L-T-P-C) | **Probability Models** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | |
| 3 | **Course content** | Introduction to Probability theory: Review of sample space, events, axioms of probability.<br>Random variables, Joint distributions, Notion of independence, and mutually exclusive events<br>Probability Space, limits and sequence of events, and continuity of probability.<br>Conditional probability and conditional expectation, simulating discrete and continuous random variables - accept-reject method, importance sampling.<br>Random vectors and Stochastic processes: Introduction to random vectors, Gaussian vectors, notion of i.i.d random variables |
| 4 | **Texts/References** | Sheldon Ross "Introduction to probability models" 9th Ed., Elsevier AP<br>Sheldon Ross, 'Stochastic process', John Wiley, 2nd Ed., April 1996.<br>David Stirzaker, 'Stochastic process and models', Oxford press. |

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| 1 | **Title of the course** (L-T-P-C) | **Introduction to Electric Vehicle Architecture** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Nil |
| 3 | **Course content** | **Introduction to Electric Vehicles:** EV Technology Roadmap, history and context.<br><br>**EV Technology Building Blocks:** Vehicle Hardware and software components, mechanical and electrical subsystems; structural, battery and drive systems; Supply chain and regulatory complexities.<br><br>**Battery Technology:** Cells, modules and Pack, battery components; battery chemistries, configurations; thermal management, manufacturing tech, Structural components, emerging technologies, BMS, BMU and battery interconnects.<br><br>**Homologation:** Overview, Segments, Battery testing, Vehicle testing<br><br>**Structural Elements:** Design principles, CAD based design, manufacturing processes, stress testing.<br><br>**Powertrains and Electric Drives**: Types of Power Trains, transmission types, design consideration, motor types, technology and specifications; Control systems and hierarchy; CAN system; HMI; Power converters (DC/DC); Isolation and safety<br><br>**Steering, Braking and Auxiliary Systems:** Power Trains, transmission types, design consideration, motor.<br><br>**Charging Systems:** Power Trains, transmission types and its design.<br><br>**Other topics:** Ergonomics from the users' perspective, data collection, telemetry, telematics, commercials, business models and policy issues. |
| 4 | **Texts/References** | **References:**<br><br>**1.** Enge P., Enge N., and Zoepf S., **Electric Vehicle Engineering**, McGraw-Hill Education, 2021.<br>**2.** *Other sources:* Latest application notes, Technical reports and industry publications (will be provided at the beginning of the course). |

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| 1 | **Title of the course** (L-T-P-C) | **Introduction to Electric Vehicle Architecture** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | None; Core for Executive M. Tech |
| 3 | **Course content** | **1.** Fundamentals of Electric Power Technologies; review of sinusoidal steady state systems,. Phasors, three-phase and per-phase quantities; review of mathematical tools (ordinary differential equations, Laplace and Fourier Transforms, space vectors, etc.); fundamentals of magnetics and magnetic circuits<br>**2.** Electric Machines: Transformers, principle of transformer action, equivalent circuits, phasor diagram, efficiency, basics of three phase transformer.<br>**3.** Introduction to Electric Motors and Generators: DC Machines; Induction Machines and Permanent Magnet Machines; steady state average modeling<br>**4.** Basic structure of EV drive system and control architecture |
| 4 | **Texts/References** | **1.** P. S. Bimbhra, "Electrical machinery," Khanna Publishers, 7th edition, 1977.<br>**2.** M. G. Say, "The Performance and Design of Alternating Current Machines," CBS, 3rd ed, 2002.<br>**3.** Stephen Chapman, "Electric Machinery Fundamentals," McGraw Hill, 4th edition, 2017.<br>**4.** D.P. Kothari, I.J. Nagrath, "Electric Machines," McGraw Hill, 5th edition, 2017.<br>**5.** A Fitzgerald, C. Kingsley, and S. Umans, "Electric Machinery," McGraw Hill, 6th ed. 2017.<br>**6.** L. Umanand, ``Power Electronics – essentials and applications," Wiley 2009.<br>**7.** M. H. Rashid "Power Electronics," Pearson. 4th edition, 2017.<br>**8.** Mohan, Robbins, Undeland "Power Electronics: Converters Applications and Design" 3rd Ed.; Wiley, 2007. |

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| 1 | **Title of the course** (L-T-P-C) | **Electric Drives for EVs - II** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Electric Drives for EVs - I |
| 3 | **Course content** | **1.** ntroduction to Fundamentals of Power Electronics: switching circuits; switching power pole; averaging, filtering, ideal switch approximation, DC-DC conversion, DC/AC conversion<br>**2.** Introduction to basic topologies and power electronic circuits. Rectifiers, inverters, power factor control<br>**3.** Power Converters for EVs: Electric Drives, LV and HV loads, regenerative operation; chargers; battery interfaces<br>**4.** Control of Power converters for Electric Drives: overall architecture; digital vs analog control; introduction to advanced control algorithms |
| 4 | **Texts/References** | **1.** S. Raju, N. Mohan, Analysis and Control of Electric Drives: Simulations and Laboratory Implementation, United States, Wiley, 2020.<br>**2.** N. Mohan, Advanced Electric Drives: Analysis, Control, and Modeling Using MATLAB / Simulink, Wiley, 2009<br>**3.** M.G. Say, The Performance and Design of Alternating Current Machines: Transformers, Three-Phase Induction Motors and Synchronous, Machines, India, CBS Publishers & Distributors, 2005<br>**4.** B. K. Bose, Modern Power Electronics and AC Drives, India, Prentice Hall PTR, 2002. |

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| 1 | **Title of the course** (L-T-P-C) | **Probability theory and random process** **(3-0-1-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Calculus (MA 101) |
| 3 | **Course content** | **1. Preliminaries**<br>(a) Sequences and limits<br>(b) Cardinality, sequence of sets<br>(c)Continuity of functions, convex functions, and convex sets<br>**2. Probability Space**<br>(a)) Probability versus length on subsets of R<br>(b)Lebesgue measure and Borel sets (without construction of measures<br>(c) Probability, events and σ-algebra<br>(d)Independence of events, and conditional probability<br>(e)Sequence of events, and Borel-Cantelli Lemma<br>**3. Random Variables**<br>( a)Definition of random variables, and types of random variables<br>(a) CDF, PDF and its properties<br>(b) ) Random vectors and independence<br>(c)Brief introduction to transformation of random variables<br>(d) Introduction to Gaussian random vectors<br>**4. Mathematical Expectation**<br>(a) ) Definition of expectation<br>(b) Convergence theorem involving integrals<br>(c) ) Moments and conditional expectation<br>(d) Use of MGF, PGF and characteristic functions<br>(e) Special topics in probability theory<br>**5. Stochastic Process**<br>(a)) Definition of stochastic process and examples<br>(b) Stationarity of random process<br>(c)Autocorrelation, cross-correlation and its properties<br>**6. Markov Chains**<br>(a) ) Definition and the need for Markov chains<br>(b) Communication classes and its properties<br>(c) ) Stationary distribution and its existence<br>(d) Poisson processes<br>(e) ) Special topics in stochastic process |
| 4 | **Texts/References** | **1.** Robert B. Ash, "Basic Probability Theory," Reprint ofthe John Wiley & Sons, Inc., New York, 1970 edition.<br>**2.** Krishna Jaganathan, "Lecture notes on Probability Foundations for Electrical Engineers," Link: http://www.ee.iitm.ac.in/~krishnaj/ee5110notes.htm.<br>**3.** Andrey Kolmogorov, "Foundations of the theory of probability," Chelsea publishing company, New yourk, 1956.<br>**4.** Terence Tao, "Introduction to Measure Theory,"American Mathematical Society, Vol. 126.<br>**5.** Bruce Hayek, "An Exploration of Random Processes for Engineers," Lecture notes. Link: http://hajek.ece.illinois.edu/Papers/randomprocJuly14.pdf.2<br>**6.** Takis Konstantopoulos, "Introductory lecture notes on Markov Chains and Random Walks,"<br>**7.** Sheldon Ross, "A first course in probability," Pearson Education India, 2008 |

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| 1 | **Title of the course** (L-T-P-C) | **Pattern Recognition and Machine Learning (PRML)** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to basic concepts in calculus and probability |
| 3 | **Course content** | **Overview of** Probability Theory, Linear Algebra, Convex Optimization. **Introduction:** History of pattern recognition & machine learning, distinction in focus of pattern recognition and machine learning. **Regression**: Linear Regression, Multivariate Regression, Logistic Regression. **Clustering:** Partitional Clustering, Hierarchical Clustering, BirchAlgorithm CURE Algorithm, Density-based Clustering **PCA and LDA:** Principal Component Analysis, Linear Discriminant Analysis. **Kernel methods:** Support vector machine **Graphical Models**: Gaussian mixture models and hidden Markov models **Introduction to Bayesian Approach:** Bayesian classification, Bayesian Learning, Bayes Optimal Classifier, Naive Bayes Classifier and BayesianNetwork.. |
| 4 | **Texts/References** | **1.** C. Bishop, “Pattern Recognition and Machine Learning,” Springer, 2006.<br>**2.** S. Theodoridis and K. Koutroumbas, “Pattern Recognition” Second Edn, Elsivier, 2003<br>**3.** B. Yegnanarayana, “Artificial Neural Networks”, PHI, 1999.<br>**4.** Simon Hayking, “Neural Networks and Learning Machines”, Pearson, 1999. |

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| 1 | **Title of the course** (L-T-P-C) | **Power System Dynamics and Control** **(2-0-1-6)** |
| 2 | **Pre-requisite courses(s)** | Power System, Electrical Machines |
| 3 | **Course content** | Modelling of Synchronous Machines, Modelling of Exciters, Small Signal Stability Analysis, Modelling of Turbine and Governors, Simulation of Power System Dynamic Response, Improvement of Stability, Sub-synchronous Oscillations. |
| 4 | **Texts/References** | **1.** Power System Dynamics and Stability: With Synchrophasor Measurement and Power System Toolbox, 2nd Edition<br>**2.** Power System Stability and Control: Prabha Kundur Mc GrawHill<br>**3.** Power System Dynamics and Stability, J Machowski; J Bialek, J Bumby, John Wiley & Sons |

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| 1 | **Title of the course** (L-T-P-C) | **Wireless Communication** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Signals and Systems,Probability (UG level), Principles/Fundamentals of Communications |
| 3 | **Course content** | Review of fundamentals in probability theory, random processes, spectral analysis of deterministic and random signals; review of digital modulation schemes, optimal receiver design under additive white Gaussian noise (AWGN) and error rate performance; orthogonal frequency division multiplexing (OFDM); channel modeling, capacity and diversity techniques in wireless communication; multi-input multi-output (MIMO) systems and space time block codes (STBC); cellular communication systems, multiple-access and interference management. |
| 4 | **Texts/References** | **1)** David Tse and Pramod Viswanath, "Fundamentals Of Wireless Communication," Cambridge University Press, 2005. **2)** Andrea Goldsmith, "Wireless Communications," Cambridge University Press, 2005. |

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| 1 | **Title of the course** (L-T-P-C) | **Pattern Recognition and Machine Learning** **(3-0-3-9)** |
| 2 | **Pre-requisite courses(s)** | Exposure to basic concepts in calculus and probability |
| 3 | **Course content** | **Overview of** Probability Theory, Linear Algebra, Convex Optimization. **Introduction:** History of pattern recognition & machine learning, distinction in focus of pattern recognition and machine learning. **Regression**: Linear Regression, Multivariate Regression, Logistic Regression. **Clustering:** Partitional Clustering, Hierarchical Clustering, Birch Algorithm CURE Algorithm, Density-based Clustering **PCA and LDA:** Principal Component Analysis, Linear Discriminant Analysis. **Kernel methods:** Support vector machine **Graphical Models**: Gaussian mixture models and hidden Markov models **Introduction to Bayesian Approach:** Bayesian classification, Bayesian Learning, Bayes Optimal Classifier, Naive Bayes Classifier and Bayesian Network.. **Lab Component:** Implementation of PRML approaches discussed in various lectures. |
| 4 | **Texts/References** | **1.** C. Bishop, "Pattern Recognition and Machine Learning," Springer, 2006. **2.** S. Theodoridisand K.Koutroumbas, "Pattern Recognition" Second Edn, Elsivier, 2003 **3.** B. Yegnanarayana, "Artificial Neural Networks", PHI, 1999. **4.** Simon Hayking, "Neural Networks and Learning Machines", Pearson, 1999. |

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| 1 | **Title of the course** (L-T-P-C) | **VLSI Design** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to basic concepts in calculus and probability |
| 3 | **Course content** | Review of MOS transistor models, Technology scaling, CMOS logic families including static, dynamic and dual rail logic. Integrated circuit layout; design rules, parasitics. low power design, high performance design, logical effort, Interconnect aware design, clocking techniques.<br><br>VLSI design: data and control path design, floor planning, Design Technology: introduction to hardware description languages(VHDL), logic, circuit and layout verification. |
| 4 | **Texts/References** | **1.** N. Weste and D. M. Harris, "CMOS VLSI Design, A circuits and systems perspective" Pearson, 2010<br>**2.** S. Kang and Y. Leblebici, "CMOS Digital Integrated circuits", Tata McGraw Hill edition, 2003<br>**3.** Jan M. Rabaey, A. Chandrakasan and B. Nikolic, "Digital Integrated circuits" Pearson , 2016 |

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| 1 | **Title of the course** (L-T-P-C) | **Neural Networks And Deep Learning (NNDL) Laboratory (0-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | Currently taking or already taken NNDL theory course |
| 3 | **Course content** | The lab will closely follow the theory course. The idea is to have the students implement the basic algorithms on different topics studied in the NNDL theory course. |
| 4 | **Texts/References** | **1.** B. Yegnanarayana, Artificial Neural Networks, PHI, 1999.<br>**2.** Ian Goodfellow, Yoshua Bengio, and Aaron Courville, Deep Learning, MIT Press, 2016. |

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| 1 | **Title of the course** (L-T-P-C) | **Pattern Recognition and Machine Learning (PRML) Laboratory (0-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | Currently taking or already taken PRML theory course |
| 3 | **Course content** | The lab will closely follow the theory course. The idea is to have the students implement the basic algorithms on different topics studied in the PRML theory course. |
| 4 | **Texts/References** | **1.** C. Bishop, “Pattern Recognition and Machine Learning,” Springer, 2006.<br>**2.** S. Theodoridis and K. Koutroumbas, “Pattern Recognition” Second Edn, Elsivier, 2003<br>**3.** B. Yegnanarayana, “Artificial Neural Networks”, PHI, 1999.<br>**4.** Simon Hayking, “Neural Networks and Learning Machines”, Pearson, 1999. |

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| 1 | **Title of the course** (L-T-P-C) | **Speech Processing Laboratory** **(0-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | Currently taking or already taken Speech Processing theory course |
| 3 | **Course content** | The lab will closely follow the theory course. The idea is to have the students implement the basic algorithms on different topics studied in the speech processing theory course. |
| 4 | **Texts/References** | **1.** L.R. Rabiner and R.W. Schafer, Digital Processing of Speech Signals Pearson Education, Delhi, India, 2004<br>**2.** J. R. Deller, Jr., J. H. L. Hansen and J. G. Proakis, Discrete-Time Processing of Speech Signals, Wiley-IEEE Press, NY, USA, 1999.<br>**3.** D. O'Shaughnessy, Speech Communications: Human and Machine, Second Edition, University Press, 2005.<br>**4.** T. F. Quatieri, "Discrete time processing of speech signals", Pearson Education, 2005.<br>**5.** L. R. Rabiner, B. H. Jhuang and B. Yegnanarayana,"Fundamentals of speech recognition", Pearson Education, 2009. |

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| 1 | **Title of the course** (L-T-P-C) | **Artificial Neural Networks & Deep Learning** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Calculus, Linear Algebra, Probability, Random Processes, Ability to code in Python |
| 3 | **Course content** | **Artificial Neural Networks (ANN):** Background to ANN and PDP models; Basics of ANN including terminology, topology and learning laws. (4 lectures).<br><br>Analysis of Feedforward neural networks (FFNN) including linear associative networks, perceptron network, multilayer perceptron, gradient descent methods and backpropagation learning; (8 lectures) Analysis of Feedback neural networks (FBNN) including Hopfield model, state transition diagram stochastic networks, Boltzmann learning law; (8 lectures) Evolution of ANN architectures - from learning to deep learning: (1 lecture)<br><br>**Deep Learning (DL): Supervised Learning:** Convolutional Neural networks; Recurrent neural networks;LSTMs and BLSTMs<br><br>**Unsupervised Learning:**<br><br>Autoendcoders; Variational autoencoders; Generative adversial networks (GANs) andRepresentation learning and feature extraction |
| 4 | **Texts/References** | **1.** Ian Goodfellow and Yoshua Bengio and Aaron Courville, "Deep Learning," MIT Press<br>**2.** Bishop, C. M. Neural Networks for Pattern Recognition. Oxford University Press. 1995<br>**3.** B Yegnanarayana, "Artificial Neural Networks," PHI.<br>**4.** David E Rumelhart, James L McClelland, and the PDP Research group, Eds, Parallel and Distributed Processing: Explorations in Microstructure of Cognition, Vol.1, Cambridge MA: MIT Press, 1986a<br>**5.** James L McClelland, David E Rumelhart and the PDP Research group, Eds, Parallel and Distributed Processing: Explorations in Microstructure of Cognition, Vol.2, Cambridge MA: MIT Press, 1986b<br>**6.** James L McClelland, David E Rumelhart and the PDP group, Eds, Explorations in Parallel and Distributed Processing: A Handbook of Models, Cambridge MA: MIT Press, 1989<br>**7.** Simon Haykin, Neural Networks and Learning Machines, Pearson Education, 2011 |

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| 1 | **Title of the course** (L-T-P-C) | **Speech Processing** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to probability concepts. |
| 3 | **Course content** | **Introduction:** Speech production and perception, nature of speech;short-term processing: need, approach, time, frequency and time- frequency analysis.<br><br>**Short-term Fourier transform (STFT):** overview of Fourierrepresentation, non-stationary signals, development of STFT, transform and filter-bank views of STFT.<br><br>**Cepstrum analysis:** Basis and development, delta, delta- delta andmel-cepstrum, homomorphic signal processing, real and complex cepstrum.<br><br>**Linear Prediction (LP) analysis:** Basis and development, Levinson-Durbin's method, normalized error, LP spectrum, LP cepstrum, LP residual.<br><br>**Sinusoidal analysis:** Basis and development, phase unwrapping,sinusoidal analysis and synthesis of speech.<br>**Applications:** Speech recognition, speaker recognition, speech synthesis, language and dialect identification and speech coding. |
| 4 | **Texts/References** | 1. L.R. Rabiner and R.W. Schafer, Digital Processing of SpeechSignals Pearson Education, Delhi, India, 2004<br><br>2. J. R. Deller, Jr., J. H. L. Hansen and J. G. Proakis, Discrete-TimeProcessing of Speech Signals, Wiley-IEEE Press, NY, USA, 1999.<br><br>3. D. O'Shaughnessy, Speech Communications: Human andMachine, Second Edition, University Press, 2005.<br><br>4. T. F. Quatieri, "Discrete time processing of speech signals",Pearson Education, 2005.<br>5. L. R. Rabiner, B. H. Jhuang and B. Yegnanarayana, "Fundamentals of speech recognition", Pearson Education, 2009. |

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| 1 | **Title of the course** (L-T-P-C) | **Multivariable Control Systems** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to control systems |
| 3 | **Course content** | **Review of basic mathematics:** Review of differential equations, Fourier and Laplace transform, basic linear algebra: matrices, rank, inverses, decompositions etc., **Review of frequency domain modelling:** revision of frequency domain modelling, transfer functions **Introduction to State Variables:** Motivation for State Variables, Implementation of Differential Equations, Formal Definitions<br><br>**Basic Realization Theory:** Similarity Transformation, Canonical Realizations: Jordan and real canonical forms, Minimal realization **Connections to Transfer Functions:** Characteristic/Minimal Polynomials, matrix exponentials, Markov parameters and other invariants<br><br>**Review of frequency domain analysis:** Recall root locus, stability analysis using Routh-Hurwitz criteria, bode plots, Nyquist plots etc. **Observability, Controllability:** Canonical Realizations, Decomposition of Uncontrollable and Unobservable realizations, State Feedback, Asymptotic Observers, Separation Principle and Pole Placement Theorem **Extensions to MIMO systems:** Transfer matrices, Controllability, Observability and Pole Placement, Controller/Observer forms, Minimality and relations to Controllability and observability, MIMO<br><br>Realization theory |
| 4 | **Texts/References** | **1.** T. Kailath, Linear Systems, Prentice-Hall, New Jersey, 1st edition, (11 February 1980)<br>**2.** Richard Dorf and Robert Bishop, Modern Control Systems, Pearson; 13th edition (5 January 2016)<br>**3.** Karl Johan Aström, Richard M. Murray, Feedback Systems: An Introduction for Scientists and Engineers, Princeton University Press (21 April 2008)<br>**4.** João P. Hespanha, Linear Systems Theory, Princeton University Press (2 October 2009)<br>**5.** Karl Johan Aström, Richard M. Murray, Feedback Systems: An Introduction for Scientists and Engineers, Princeton University Press, 2nd edition (2 March 2021)<br>**6.** João P. Hespanha, Linear Systems Theory, Princeton University Press (2 October 2009), 2nd edition, 13 February 2018 |

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| 1 | **Title of the course** (L-T-P-C) | **Optimization Theory and Algorithms (3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Calculus or equivalent |
| 3 | **Course content** | The following topics will be covered:<br>Quick Review of Linear Algebra and basic calculus. Introduction to convex sets and functions, and its properties. Duality theory, Lagrangian dual and KKT conditions. Algorithms for unconstrained and constrained minimization. Subgradient methods for non-differentiable functions. Important standard classes such as linear and quadratic programming, semidefinite programming etc. Applications of convex programming in electrical engineering. Recognizing and formulating convex optimization problems in practice. Beyond convex optimization. Introduction to functional optimization theory. |
| 4 | **Texts/References** | 1. Stephen Boyd and Lieven Vandenberghe, "Convex Optimization," Cambridge university press.<br>2. David G. Luenberger, "Optimization by Vector Space Methods," Wiley publications. |

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| 1 | **Title of the course** (L-T-P-C) | **Advanced Power Electronics and Drives** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Circuits, semiconductor devices and Electric Machines &power electronics |
| 3 | **Course content** | Basics of semiconductor devices, gate drives for BJT, MOSFET and IGBT, heat sink selection, snubber circuits, non- isolated converters like buck, boost and buck-boost converters, isolated converters like forward, push pull, half bridge, full bridge and fly back, design of magnetics for inductors and transformers, inverters, PWM generation - SPWM, space vector PWM, dq axis theory for 2 and 3 phase applications. Introduction to electric drives, and speed control of electric machines.<br><br>Design examples like, EV Battery chargers, and grid connected PV inverter. |
| 4 | **Texts/References** | **1.** L. Umanand, Power electronics and applications, Wiley India Pvt. Limited, 2009.<br>**2.** Chryssis, G.C., High frequency switching power supplies, Second Edn, McGraw Hill, 1989.<br>**3.** R. W. Erickson, Dragan Maksimovic, Fundamentals of Power Electronics, Springer, 2001.<br>**4**. N.Mohan, Power Electronics: Converter, Applications & Design, John Wiley & Sons, 1989 |

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| 1 | **Title of the course** (L-T-P-C) | **Design of Power Converters** **(2-0-2-6)** |
| 2 | **Pre-requisite courses(s)** | EE222: Introduction to Power Electronics or equivalent as determinedby the instructor or faculty advisor. |
| 3 | **Course content** | Rectifier analysis and design: Analysis and design of buck, boost; Intro to single-phase and 3-phase inverter: Intro to PWM generation and gate-drive basics; Intro to Flyback, Forward, Full Bridge; Switching and conduction loss calculation; Magnetics Design; Basics of Gate Drivers and PWM ICs; Basics of Snubbers. |
| 4 | **Texts/References** | **1.** L Umanand Power Electronics: Essentials & Applications.,, Wiley 2009.<br>**2.** Robert W Erickson and Dragan Maksimovic, Fundamentals of Power Electronics, Springer, 3ed, 2020.<br>**3.** Daniel W Hart, Introduction to Power Electroni Prentice-Hall, 1997.<br>**4.** Mohan, N., et al, Power Electronics, John Wiley, 1989.<br>**5.** Daniel W Hart, Power Electronics, McGraw Hill HigherEducation, 2010<br>**6.** Mohan, N., et al., Power Electronics, John Wiley, 3rd edition,2007 |

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| 1 | **Title of the course** (L-T-P-C) | **VLSI Technology** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Electronic Devices |
| 3 | **Course content** | **1.** Introduction on VLSI Design, Bipolar Junction Transistor Fabrication, MOSFET Fabrication for IC, Crystal Structure of Si, Defects in Crystal Crystal growth techniques – Bridgeman, Czochralski method, Floating-zone method<br>**2.** Epitaxy – Vapour phase Epitaxy, Doping during Epitaxy, Molecular beam Epitaxy<br>**3.** Oxidation – Kinetics of Oxidation, Oxidation rate constants, Dopant Redistribution, Oxide Charges, Oxide Layer Characterization<br>**4.** Doping – Theory of Diffusion, Infinite Source, Actual Doping Profiles, Diffusion Systems, Ion-Implantation Process, Annealing of Damages, Masking during Implantatio<br>**5.** Lithography Etching – Wet Chemical Etching, Dry Etching, Plasma Etching Systems, Etching of Si, Sio2, SiN and other materials, Plasma Deposition Process<br>**6.** Metallization – Problems in Aluminum Metal contacts,<br>**7.** IC BJT – From junction isolation to LOCOS, Problems in LOCOS, Trench isolation, Transistors in ECL Circuits, MOSFET Metal gate vs. Self-aligned Poly-gate, MOSFET II Tailoring of Device Parameters, CMOS Technology, Latch – up in CMOS, BICMOS Technology. |
| 4 | **Texts/References** | **1.** VLSI Technology by S. M. Sze<br>**2.** Silicon VLSI Technology by J.D. Plummer, M. Deal and P.D. Griffin<br>**3.** VLSI Fabrication Principles by S. K. Gandhi |

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| 1 | **Title of the course** (L-T-P-C) | **Advanced Power Systems** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | EE223: Introduction to Power Systems or equivalent as determined by the instructor or faculty advisor. |
| 3 | **Course content** | Symmetrical Components; Fault Analysis in Power Systems; Power System Stability; Power System Transients; Circuit Breakers; Protection ofTransmission Lines, Generators, Transformers; Economic Dispatch; Automatic Generation Control. |
| 4 | **Texts/References** | **1.** Power System Analysis, Bergen & Vittal, 2nd Ed, Pearson, 1999.<br>**2.** Power System Analysis, Hadi Saadat, 2011, ISBN- 10: 0984543864.<br>**3.** Power System Analysis, Grainger & Stevenson, McGraw Hill, 2017, ISBN-10: 9780070585157<br>**4.** Power System Engineering, Nagrath & Kothari, McGraw-Hill, 3rd Ed, 2019, ISBN-10 : 9353165113. |

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| 1 | **Title of the course** (L-T-P-C) | **Modeling and Control of Renewable Energy Resources (3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Power System Analysis, Electrical Machines, Power Electronics |
| 3 | **Course content** | Microgrids and distributed generation; Introduction to renewable energy technologies; electrical systems and generators used in wind energy conversion systems, diesel generators, combined heat cycle plants, inverter based generation, solar PV based systems, fuel cell and aqua- electrolyzer, battery and flywheel based storage system; Voltage and frequency control in a microgrid; Grid connection interface issues. |
| 4 | **Texts/References** | **1)** Anaya-Lara, Jenkins, Ekanayake, Cartwright and Hughes, WIND ENERGY GENERATION Modelling and Control" Wiley, 1st Edison, 2009.<br>**2)** Bevrani, Francois and Ise, Microgrid Dynamics and Control, Wiley; First edition, 2017.<br>**3)** Gilbert M. Masters, Renewable and Efficient Electric Power Systems, Wiley Interscience, 1st Edison, 2004. |

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| 1 | **Title of the course** (L-T-P-C) | **Probability Models and Applications (PMA)** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Data analysis and Introduction to probability (6 credits course that all batches are currently doing as core) |
| 3 | **Course content** | **Introduction to** Probability theory.<br><br>**Review of** sample space, events, axioms of probability, introduction to probability as a measure, Random variables, Notion of independence and mutually exclusive events<br><br>Probability Space, limits and sequence of events, continuity of probability, measurable functions, notions of induced measures, connection with cdf, change of measure, conditional probability and conditional expectation, simulating discrete and continuous random variables - accept-reject method, importance sampling.<br><br>**Random vectors and Stochastic processes:** Introduction to random vectors, Gaussian vectors, notion of i.i.d random variables introduction to elementary stochastic processes like Bernoulli process and Poisson process.<br><br>**Markov Process.** Discrete time and continuous time Markov chains**,** classification of states, notion of stationary distribution.<br><br>Simulating stochastic processes like Gaussian process, Poisson process, Markov chains and Brownian motion.<br><br>Introduction to Markov chain monte carlo methods, Hidden Markov chain and Markov decision process, Introduction to Brownian motion and stationary process.<br><br>**Statistics:** MLE, MAP and Bayesian Estimation, sufficient statistics, Cramer-Rao bound |
| 4 | **Texts/References** | **2.** Sheldon Ross “Introduction to probability models” 9th Ed., Elsevier AP<br>**3.** Sheldon Ross, ‘Stochastic process’, John Wiley, $2^{nd}$ Ed., April 1996.<br>**4.** David Stirzaker, ‘Stochastic process and models’, Oxford press. |

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| 1 | **Title of the course** (L-T-P-C) | **Advanced Topics in Speech Processing** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to probability concepts |
| 3 | **Course content** | Advanced modeling techniques on speech analysis, feature extraction and modeling like deep learning.<br>Advanced topics related to prosody modeling, health information modeling, cognitive speech processing etc. Also latest trends in the speech processing area. |
| 4 | **Texts/References** | **1.** J. R. Deller, Jr., J. H. L. Hansen and J. G. Proakis Discrete-Time Processing of Speech Signals, Wiley-IEEE Press, NY, USA, 1999.<br>**2.** D. O'Shaughnessy, Speech Communications: Human and Machine, Second Edition,University Press, 2005.<br>**3.** L. R. Rabiner, B. H. Jhuang and B. Yegnanarayana, "Fundamentals of speech recognition", Pearson Education, 2009.<br>**4.** J. Benesty, M M Sondhi and Y. Huang, "Springer Handbook of Speech Processing", 2008.<br>**5.** Journals like IEEE Trans on Audio, Speech and Language Processing, Acoustical Society of America, Speech Communication and Interspeech Proceedings. |

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| 1 | **Title of the course** (L-T-P-C) | **Advanced Electric Drives**<br>**(2-0-2-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to basic Power Electronics, Electric Machines, and foundational courses in EE; Instructor consent is required |
| 3 | **Course content** | **1.** Electric Drives Overview: Components, structure; performance, line-side and machine specifications<br>**2.** Rectifiers: Diode and Thyristor rectifiers, multi-pulse rectifiers: 6-pulse, 12- pulse, etc; THD and Power Factor effects<br>**3.** Two-Level Inverters and PWM Techniques<br>Power circuit analysis, Switching states, and Loss models. Sinusoidal PWM, Space- vector PWM, Harmonic Analysis, Over-modulation, Third-harmonic injection, Bus clamping, Selective-harmonic-elimination, current and flux error space-vectors.<br>**4.** Multilevel Inverters: Topologies for multilevel converters: NPC, CHB and FC, MMCs; T-type and I-type; modulation scheme, voltage balancing, PWM techniques for multilevel inverter (level / phase shifted, NLM, sorting, etc)<br>**5.** DC Drives: Structure, power circuit, and control schemes, decoupled control concepts<br>**6.** Induction Motor Modelling: Transformations of abc-α-β-dq quantities, machine modeling in dq-domain, and linearization<br>**7.** Induction Motor Drives: V/f control, vector control; controller design; field-oriented control; direct-torque-control, wound-rotor induction machines (DFIG) |
| 4 | **Texts/References** | References:<br>**1.** S. Raju, N. Mohan, Analysis and Control of Electric Drives: Simulations and Laboratory Implementation, United States, Wiley, 2020.<br>**2.** N. Mohan, Advanced Electric Drives: Analysis, Control, and Modeling Using MATLAB / Simulink, Germany, Wiley, 2009<br>**3.** M.G. Say, The Performance and Design of Alternating Current Machines: Transformers, Three-Phase Induction Motors and Synchronous Machines, India, CBS Publishers & Distributors, 2005<br>**4.** B. K. Bose, Modern Power Electronics and AC Drives, India, Prentice Hall PTR, 2002<br>**5.** B. Wu, High-Power Converters and AC Drives, United Kingdom, Wiley, 2007. |

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| 1 | **Title of the course** (L-T-P-C) | **System Design of Electronic Products** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Strong performance in foundational core courses of a typical EE program as determined by the instructor and/or faculty advisor: Analog and digital design, control systems, communications, and embedded systems / programming. This is a upper undergraduate / graduate level course. B. Tech students would take up this course in 6th or 7th Semester of a typical 8-semester program in preparation for a hardware design project in the final semester. |
| 3 | **Course content** | **Introduction to Systems Design:**Electronic system design workflow, elements of product design; industrial design, design partitioning<br><br>**Analog, Digital and Mixed Signal Design:**Passive components: design, specification and selection, modelling and non-idealities, error budgeting, parasitics, temperature, aging and vibration effects, reliability; D2A and A2D fundamentals, ground planes, and signal integrity, power integrity and power distribution networks, cabling, connectors and bus bars.<br><br>**Noise in Electronic Systems:** Sources, effects and mitigation, fundamentals of EMI/EMC, compliance standards, test processes<br><br>**Electronic Systems Packaging, Prototyping and Production:** Semiconductor packaging, PCB design, manufacture, and assembly, enclosures and interfaces, reliability and MTBF, materials, rapid prototyping, manufacturability, testability, etc.<br><br>**Application Specific Aspects**: Automotive, Industrial, Space and Defense grade and cybersecurity<br><br>**Case Studies, mini-projects and design exercises** |
| 4 | **Texts/References** | **References:**<br><br>**1.** H. W. Ott, Noise Reduction Techniques in Electronic Systems, Singapore: J. Wiley, 1989.<br>**2.** R. Tummala, Fundamentals of Device and Systems Packaging: Technologies and Applications, Second Edition. United States, McGraw-Hill Education, 2019.<br>**3.** L. Umanand, Power Electronics: Essentials & Applications, India. Wiley India Pvt. Limited, 2009.<br>**4.** L. Marks, J. Caterina, Printed Circuit Assembly Design, Ukraine: McGraw-Hill Education, 2000. |

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| 1 | **Title of the course** (L-T-P-C) | **Mixed signal VLSI Design** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | CMOS Analog VLSI Design |
| 3 | **Course content** | **1)** CML logic for high speed mixed signal circuits<br>**2)** Switch design and switched capacitor circuits<br>**3)** Sampling theory and discrete-time signals<br>**4)** Comparators<br>**4)** Basics of data converters<br>**5)** Nyquist rate ADC's: Parallel (single-step converters), algorithmic (multi-step converters) and pipelined ADC'Architectures and design of Nyquist rate ADC's<br>**6)** High resolution data converters (Δ Σ data converters)<br>**7)** Digital to analog converters<br>**8)** Selected topics in mixed-signal VLSI circuits |
| 4 | **Texts/References** | **1)** R.Jacob Baker,H.W.Li, and D.E. Boyce CMOS Circuit Design ,Layout andSimulation, Prentice-Hall of ,1998.<br><br>**2)** R.Jacob Baker, CMOS: Mixed-Signal Circuit Design, Wiley (1 January 2008)<br>**3)** Pavan, Shanthi, Richard Schreier, and Gabor C. Temes. Understandingdelta-sigma data converters. John Wiley & Sons, 2017. |

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| 1 | **Title of the course** (L-T-P-C) | **Linear Algebra and its applications** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Basic calculus. |
| 3 | **Course content** | The following topics will be covered:<br>Vector spaces, linear dependence, basis; Representation of linear transformations with respect to a basis.; Inner product spaces, Hilbert spaces, linear functions; Riesz representation theorem and adjoints.; Orthogonal projections, products of projections, orthogonal direct sums; Unitary and orthogonal transformations, complete orthonormal sets and Parseval's identity; Closed subspaces and the projection theorem for Hilbert spaces.; Polynomials: The algebra of polynomials, matrix polynomials, annihilating polynomials and invariant subspaces, forms, Solution of state equations in linear system theory; Relation between the rational and Jordan forms.; Numerical linear algebra: Direct and iterative methods of solutions of linear equations; Matrices, norms, complete metric spaces and complete normal linear spaces (Banach spaces); Least squares problems (constrained and unconstrained); Eigenvalue problem and SVD. |
| 4 | **Texts/References** | .<br>**2.** K. Hoffman and R. Kunze, Linear Algebra, Prentice-Hall, (1986).<br>**3.** G.H. Golub and C.F. Van Loan, Matrix Computations, Academic, 1983. |

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| 1 | **Title of the course** (L-T-P-C) | **Speech Processing** **(3-0-3-9)** |
| 2 | **Pre-requisite courses(s)** | Exposure to basic concepts in probability |
| 3 | **Course content** | Introduction. Kernelization, Bounded Search Trees, Iterative Compression, Treewidth, Advanced kernelization algorithms. Lower bounds: Fixed-parameter intractability, lower bounds based on ETH, lower bounds for kernelization. Parameterized Algorithms, Kernelization, and Complexity of Graph Modification Problems |
| 4 | **Texts/References** | **Textbook:**<br>(1) Parameterized Algorithms, Marek Cygan, Fedor V. Fomin, Lukasz Kowalik. Daniel Lokshtanov, Daniel Marx, Marcin Pilipczuk, Michal Pilipczuk, and Saket Sourabh. Springer. 2015<br><br>**Reference:**<br>(1) Parameterized Complexity, R. G. Downey, and M. R. Fellows. Springer Science and Business Media. 2012 |

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| 1 | **Title of the course** (L-T-P-C) | **Advanced Analog Circuits**<br>**(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Electronic devices and UG analog circuits |
| 3 | **Course content** | **I.** Review of MOS transistor characteristics and small signal models. CS amplifier, cascade amplifiers, cascode and folded cascode – Design assignment with simulations in cadence. Passive components in CMOS, resistors, capacitors, mismatch and layout techniques to reduce effect of mismatch, current mirrors, voltage references. Differential amplifiers, 2 stage op-amps and miller compensation – Design assignment with simulations in cadence.<br>**II**. Linear, non-linear Circuits using opamps. Oscillator circuits.<br>**III.**Power Electronics: power switching devices: diode, BJT. MOSFET, IGBT; Gate Drive Circuits; Rectifiers<br>- Single and three phase; Introduction to reactive elements - inductors and transformers; Protection Circuits for Semiconductor devices; Linear Regulators and DC/DC Converters. |
| 4 | **Texts/References** | 1. Paul Horowitz, The Art of Electronics 2nd Edition, Cambridge University Press, 2006.<br>2. L. Umanand, Power electronics and applications, Wiley India Pvt. Limited, 2009.<br>3. Chryssis, G.C., High frequency switching power supplies, Second Edn, McGraw Hill, 1989. |

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| 1 | **Title of the course** (L-T-P-C) | **Physics of Nanoscale devices** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Basic Electronics, Electronic Devices |
| 3 | **Course content** | Quantum mechanics, solution of Schrodinger equation, Energy Bands in crystals, generation and recombination, carrier transport, PN junction diodes, MOS capacitors, Nanoscale MOSFETS, MOS electrostatics, MOS characteristics, MOS reliability. |
| 4 | **Texts/References** | **1)** S. M. Sze and K. K. Ng, "***Physics of Semiconductor Devices*** ", 3rd Edition, Wiley-Interscience,<br>**2)** R. F. Pierret, "***Semiconductor Device Fundamentals*** ", Addison-Wesley<br>**3)** Y. Taur and T.H. Ning, *Fundamentals of Modern VLSI Devices,* Cambridge University Press, Cambridge, UK 1998. |

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| 1 | **Title of the course** (L-T-P-C) | **Advanced Topics in Control Systems** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Undergraduate level course on control systems |
| 3 | **Course content** | **Linear Systems:**<br>• **Introduction to State Variables:** Motivation for State Variables, Implementation of Differential Equations, Formal Definitions<br>• **Basic Realization Theory:** Similarity Transformation, Canonical Realizations: Jordan and real canonical forms, Minimal realization<br>• **Connections to Transfer Functions:** Characteristic/Minimal Polynomials, matrix exponentials, Markov parameters and other invariants<br>• **Observability and Controllability:** Duality, Decomposition of Uncontrollable and Unobservable realizations, Popov test, Separation Principle and Pole Placement Theorem, Asymptotic Observers: Full and reduced order, Controllability indices.<br><br>**Optimal Control:**<br>• **Dynamic Programming:** Principle of Optimality, Computation of Optimal Control using Dynamic Programming, Discrete LQR, Hamilton-Jacobi-Bellman Equation, Continuous LQR<br>• **Calculus of Variations:** Constraints and End Point conditions, Necessary Conditions, Indirect methods: TPBVP using Shooting Methods and Collocation<br>• **Constrained Optimal Control:** Pontryagins Minimum Principle, Min Time, Min Energy, Min Fuel Problems, Singular Arcs. |
| 4 | **Texts/References** | **1.** Donald E. Kirk, Optimal Control Theory, Prentice-Hall, New, Jersey, 1970.<br>**2.** Arthur E. Bryson and Yu-Chi Ho, Applied Optimal Control: Optimization, Estimation and Control, Blaisdell Publishing Company, 1969.<br>**3.** T. Kailath, Linear Systems, Prentice-Hall, New Jersey, 1980. |

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| 1 | **Title of the course** (L-T-P-C) | **Modern Statistics for Engineers** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Undergraduate level course on control systems |
| 3 | **Course content** | **<u>Linear Systems</u>:**<br>**1.** Introduction to State Variables: Motivation for State Variables, Implementation of Differential Equations, Formal Definitions<br>**2.** Basic Realization Theory: Similarity Transformation, Canonical Realizations: Jordan and real canonical forms, Minimal realization<br>**3.** Connections to Transfer Functions: Characteristic/Minimal Polynomials, matrix exponentials, Markov parameters and other invariants<br>**4.** Observability and Controllability: Duality, Decomposition of Uncontrollable and Unobservable realizations, Popov test, Separation Principle and Pole Placement Theorem, Asymptotic Observers: Full and reduced order, Controllability indices<br>**<u>Optimal Control:</u>**<br>**1.** Dynamic Programming: Principle of Optimality, Computation of Optimal Control using Dynamic Programming, Discrete LQR, Hamilton-Jacobi-Bellman Equation, Continuous LQR<br>**2.** Calculus of Variations: Constraints and End Point conditions, Necessary Conditions, Indirect methods: TPBVP using Shooting Methods and Collocation<br>**3.** Constrained Optimal Control: Pontryagins Minimum Principle, Min Time, Min Energy, Min Fuel Problems, Singular Arcs |
| 4 | **Texts/References** | Sara Van De Geer, ``Mathematical Statistics," lecture notes.<br>Vincent Poor, ``Introduction to signal detection and estimation," Springer publications |

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| 1 | **Title of the course** (L-T-P-C) | **Game Theory with Control** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to EE 303 or equivalent |
| 3 | **Course content** | • Introduction to game theory<br>• Mathematical tools including convex optimisation and dynamic programming<br>• zero sum games in matrix and extensive form<br>• pure and mixed strategies<br>• minimax theorem<br>• nonzero sum games in normal and extensive form<br>• numerical computation of mixed equilibrium strategies, Nash and Stackelberg equilibria,<br>• potential games, infinite dynamic games, differential games behavioral strategies and informational properties for dynamic games |
| 4 | **Texts/References** | Basar, T. and Olsder, G., “Dynamic Noncooperative Game Theory”, 2nd Edition, Society for Industrial and Applied Mathematics, 1998 |

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| 1 | **Title of the course** (L-T-P-C) | **Renewable Energy** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | None |
| 3 | **Course content** | Fundamentals of energy, energy resources, Thermal power plants, Hydroelectric power plants, nuclear power generation, environmental effects of conventional energy, photovoltaic power generation, wind energy, tidal energy, ocean thermal energy conversion, geothermal energy, energy storage |
| 4 | **Texts/References** | **1.** Gilbert M. Masters , "Renewable and Efficient Electric Power System," Wiley Interscience, 2nd edition, 2004.<br>**2.** Boyle, "Renewable Energy: Power for a Sustainable Future," Oxford University Press, 3rd edition, 2012. |

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| 1 | **Title of the course** (L-T-P-C) | **Microgrid Dynamics and Control** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | exposure to electrical machines, power electronics, power system, renewable energy |
| 3 | **Course content** | Grid connected renewable energy resources, renewable power for control support, Microgrid concepts, structures and operation modes, microgrid dynamics and modeling, Hierarchical Microgrid Control, DC Microgrid Control, Virtual Synchronous Generators: Dynamic Performance and Characteristics, virtual inertia based stability and regulation support, Robust microgrid control and emergency control |
| 4 | **Texts/References** | **1.** Gilbert M. Masters , "Renewable and Efficient Electric Power Systems," Wiley Interscience, 2nd edition, 2004.<br>**2.** Hassan bevrani, Bruno Francois, and Toshifumi Ise, "Microgrid Dynamics and Control," Wiley, Black Well, 1st edition, 2017. |

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| 1 | **Title of the course** (L-T-P-C) | **Power System Operation and Control** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | exposure to electrical machines, power system |
| 3 | **Course content** | Introduction to modern power systems, equipment and stability constraints, reactive power and voltage controls, economic load dispatch and unit commitment, active power and frequency control, line power flow controls, load dispatch center functions, Emergency Controls- Special Protection Schemes. |
| 4 | **Texts/References** | 1. B F Wollenberg, "Power Generation, operation and control," 2nd ,edition, Wiley, 2006.<br>2. Grainger and Stevenson, "Power System Analysis," 1st edition, McGraw Hill Education, 2017.<br>3. Prabha Kundur, "Power System Stability And Control," McGraw Hill ,Education, 1st edition, 2006. |

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| 1 | **Title of the course** (L-T-P-C) | **Power System II** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | exposure to electrical machines, power system half semester courses |
| 3 | **Course content** | Recap: line parameters, three phase power, per unit system, complex power, line diagram, characteristics and performance of lines, load flow. Actual syllabus: power system fault analysis- symmetrical and unsymmetrical faults, power system protection- circuit breakers, line protection, generator protection, transformer protection, power system stability, automatic generation and voltage control |
| 4 | **Texts/References** | 1. Grainger and Stevenson, "Power System Analysis," 1st edition, McGraw Hill Education, 2017.<br>2. Bergen and Vittal, "Power System Analysis," 2nd Edison, Pearson, 2002.<br>3. Hadi Saadat, "Power System Analysis," PSA publishing, 3rd edition, 2011.<br>4. B F Wollenberg, "Power Generation, operation and control," 2nd edition, Wiley, 2006.<br>5. 8. Nagrath and Kothari, "Power System Engineering," 2nd edition, McGraw Hill, 2012. |

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| 1 | **Title of the course** (L-T-P-C) | **Electrical Machines II** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | exposure to electrical machines. |
| 3 | **Course content** | Recap: magnetic circuits, single phase transformer, synchronous generators. Actual syllabus: autotransformer; three phase transformers; Induction machines- construction, working principle, phasor diagram, equivalent circuit, torque-slip characteristics, stability, induction generator and applications; DC Machines-construction, commutator action, emf and torque equations, armature reaction, operating characteristics of Dc generators and motors, speed control of dc motors; special electric motors- stepper motors, variable reluctance motors, brushless dc motors. |
| 4 | **Texts/References** | **1.** P. S. Bimbhra, "Electrical machinery," Khanna Publishers, 7th edition, 1977.<br>**2.** P. S. Bimbhra, "Generalized theory of electrical machines," Khanna Publishers, 6th edition, 2017.<br>**3.** A Fitzgerald, Charles Kingsley, and Stephen Umans, "Electric Machinery," McGraw Hill, 6th edition, 2017.<br>**4.** Stephen Chapman, "Electric Machinery Fundamentals," McGraw Hill, 4th edition, 2017. |

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| 1 | **Title of the course** (L-T-P-C) | **Advanced Topics in Artificial Intelligence** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to a first level course in artificial intelligence or pattern recognition and machine learning or artificial neural networks & deep learning or studied equivalent topics in any other course . |
| 3 | **Course content** | This course will cover selected topics from: advanced pattern recognition, machine learning, neural networks, learning theory, constraint processing, logic programming, probabilistic reasoning. The course will also discuss some practical applications of artificial intelligence like computer vision, speech processing and natural language processing. |
| 4 | **Texts/References** | 1. Ian Goodfellow and Yoshua Bengio and Aaron Courville, "Deep Learning," MIT Press<br>2. Bishop, C. M. Neural Networks for Pattern Recognition. Oxford University Press. 1995<br>3. B Yegnanarayana, "Artificial Neural Networks," PHI.<br>4. Bishop, C. M. Pattern Recognition and Machine Learning. Springer. 2006 |

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| 1 | **Title of the course** (L-T-P-C) | Introduction to Machine Learning<br>**(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Calculus (MA 101) |
| 3 | **Course content** | Recap<br><br>(a) Probability Theory, Linear Algebra, Convex Optimization ,Introduction to statistical decision theory<br>(b) Hypothesis testing<br>(c) Regression, Classification, Bias Variance trade- off ,Regression and PCA<br><br>(a) Linear Regression, Multivariate Regression,<br>(b) Subset Selection, Shrinkage Methods,<br>(c) Principal Component Regression, Partial Least squares<br>(d) Linear Classification, Logistic Regression, Linear Discriminant Analysis<br>Neural Networks<br><br>(a) ) Perceptron, Support Vector Machines<br>(b) Neural Networks - Introduction, Early Models, Perceptron Learning,<br>(c) Backpropagation, Initialization, Training and Validation, Parameter Estimation - MLE, MAP, Bayesian Estimation<br>Decision Trees<br><br>(a) Decision Trees, Regression Trees, Stopping Criterion and Pruning Loss functions, Categorical Attributes, Multiway Splits, Missing Values Decision Trees - Instability Evaluation Measures<br>(b) Bootstrapping and Cross Validation, Class Evaluation Measures, ROC curve, MDL Ensemble Methods - Bagging, Committee Machines and Stacking, Boosting<br>Boosting<br><br>(a) Gradient Boosting, Random Forests, Multi-class Classification Naive Bayes, Bayesian Networks<br>(b) Gaussian Mixture Models, Expectation Maximization |
| 4 | **Texts/References** | 1. Trevor Hastie, Robert Tibshirani, Jerome H. Friedman "The Elements of Statistical Learning," Springer text in statistics.<br><br>2. C. Bishop, "Pattern Recognition and Machine Learning,"<br><br>Springer text in information science and statistics. |

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| 1 | **Title of the course** (L-T-P-C) | **Nanoelectronics** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | -- |
| 3 | **Course content** | **Introduction:** Shrinking of dimensions from micrometers to nanometers, scaling and limitations of scaling of conventional devices.<br><br>**Quantum Nanostructures:** Introduction to quantum wells, quantum wires and quantum dots. Fundamentals of carrier transport in quantum structures.<br><br>**Advanced Electronic Devices:** Single electron transistors, HEMTs, FINFETs, resonant tunneling transistors, optoelectronic and spintronic devices.<br><br>**Nanomanufacturing:** Top-down and Bottom-up approaches of synthesis of nanomaterials. Introduction to different characterization techniques of nanomaterials like FESEM, TEM, XRD, XPS, FTIR.<br><br>**Carbon Nanostructures and Applications:** Carbon nanotubes, graphene, fullerenes, band structures and their applications in sensing, energy storage, nanogeneration and in biomedical domain. |
| 4 | **Texts/References** | 1.Nanoelectronics and Nanosystems: From Transistors to Molecular and Quantum Devices, Karl Goser, Peter Glössekötter, Jan Dienstuhl, Springer, 2004.<br>2. Introduction to Nanotechnology, C.P. Poole Jr., F.J. Owens, Wiley (2003).<br>3. Emerging nanotechnologies for manufacturing by Waqar Ahmed& M.J Jackson William Andrew Publishing, 2009.<br>4. Research papers. |

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| 1 | **Title of the course** (L-T-P-C) | **Neural Networks And Deep Learning (NNDL)**<br>**(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to basic concepts in calculus and probability |
| 3 | **Course content** | **Introduction to Artificial Neural Networks (ANN) and Deep Learning (DL):** Motivation, basics of ANN, overview of PRML, evolution deep learning and different architectures. Applications of ANN vs DL.<br><br>**Feedforward Neural Networks (FFNN):** Working principle, basic architecture, analysis of FFNN for different PRML tasks.<br><br>**Feedback Neural Networks (FBNN):** Working principle, basic architecture, Boltzmann machine, analysis of FFNN for different PRML tasks.<br><br>**Competitive learning Neural Networks (CLNN):** Working principle, basic architecture, analysis of CLNN for different PRML tasks.<br><br>**Deep Learning (DL) Architectures:** Deep FFNN, Convolutional neural networks (CNN), Recurrent neural network (RNN), Longterm shortterm memory (LSTM), Generative adversarial network (GAN), DL architectures with attention mechanism. Some recent DL architectures.<br><br>**Applications of DL:** speech processing, image processing and other tasks. |
| 4 | **Texts/References** | 1. B. Yegnanarayana, Artificial Neural Networks, PHI, 1999.<br>2. Ian Goodfellow, Yoshua Bengio, and Aaron Courville, Deep Learning, MIT Press, 2016. |

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| 1 | **Title of the course** (L-T-P-C) | **Introduction to Aerial Robots** **(2-1-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Engineering mechanics |
| 3 | **Course content** | 1. Types of vehicles (1)<br>2. Applications: DDD (Dull Dirty Dangerous) (1-2) C3.Sub-systems (3)<br>4. Principles of flight of fixed-wing vehicles (8-10) E5. Principles of flight of rotary-wing vehicles (8-10)<br>6. Exposure to policy and regulations related to aerial robots (1) C7. Case studies (3-4) |
| 4 | **Texts/References** | 1. Roland Siegwart, Illah Reza Nourbakhsh and DavideScaramuzza, "Introduction to Autonomous Mobile Robots", Second Edition, MIT Press.<br>2. KenzoNonami, FaridKendoul, Satoshi Suzuki, Wei Wang, Daisuke Nakazawa, "Autonomous Flying Robots: Unmanned Aerial Vehicles and Micro Aerial Vehicles", Springer, 2010.<br>3. Randal W. Beard, Timothy W. McLain, "Small Unmanned Aircraft: Theory and Practice", Princeton University Press, 2012. |

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| 1 | **Title of the course** (L-T-P-C) | **Dynamics and Control of Aerial Robots (2-1-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to control theory |
| 3 | **Course content** | Rigid body dynamics (4), Trim conditions and vehicle primary control, linearization, stability (6), Sensors: accelerometer, rate gyros, pressure sensors, magnetometers, inertial measurement units (IMUs), GNSS (1-2), Arduino based tutorial, Actuators (1), Linear control, controllability, observability (8-10), Levels of autonomy, autopilot architecture and design (1-2) |
| 4 | **Texts/References** | 1.Andrea L'Afflitto, "A Mathematical Perspective on Flight Dynamics and Control" Springer, 2017<br>2. Randal W. Beard, Timothy W. McLain, "Small Unmanned Aircraft: Theory and Practice", Princeton University Press, 2012.<br>3. MatkoOrsag, Christopher Korpela, Paul Oh, Stjepan Bogdan, "Aerial Manipulation", Springer, 2017.<br>4. Duane T. McRuer, Dunstan Graham, Irving Ashkenas, "Aircraft Dynamics and Automatic Control" Princeton University Press, 2014. |

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| 1 | **Title of the course** (L-T-P-C) | **Autonomous Navigation** **(2-1-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Introduction to probability and control theory |
| 3 | **Course content** | Introduction to probability and random processes (3) State estimation: Kalman filter (KF), Extended Kalman filter(EKF) (8-10), Path planning and path following algorithms (8-10), Vision guided navigation (2), Cooperative control (2) |
| 4 | **Texts/References** | **1.** Sebastian Thrun, Wolfram Burgard, and Dieter Fox, Probabilistic robotics, MIT Press, 2006.<br>**2.** Timothy D. Barfoot, "State Estimation for Robotics", Cambridge University Press, 2017<br>**3.** Richard Szelisk, "Computer Vision: Algorithms and Applications", Springer, 2010 |

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| 1 | **Title of the course** (L-T-P-C) | **Electric Vehicles: Systems and Components** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | EE222: Introduction to Power Electronics and EE206: Introduction to Electrical Machines for UG; but for PG students there are no prerequisites. |
| 3 | **Course content** | **Introduction to Electric Vehicles –** discussion on the importance of EV; classification of EVs: e-bike, 2-wheeler, 3-wheeler, and 4- wheelers; light/medium/heavy duty, etc<br><br>**Electric Vehicle Components –** Components of EV, Electric Vehicle Supply Equipment (EVSE), Charging port, connector configuration, Charger, Battery, Drivetrain, BMS, AUX power converters, Electric motors, etc.<br><br>**Electric Vehicle Supply Equipment –** Introduction to EVSE, basic requirements, different types, functional diagram, safety features, and requirements.<br><br>**Electric Vehicle Battery Chargers –** Overview of EV Battery Chargers (onboard and stationary), different types, levels of charging, internal power electronic converters – Rectifiers, PFC, DC/DC converters, Communications, and control aspects.<br><br>**Overview on EV Batteries and Battery Management Systems:** introduction to various electric vehicle batteries, typical energy requirements in EV, battery management systems.<br><br>**Discussion on EV Drivetrain:** Overview of electric motors for EV applications, limitations of existing motors, control of electric motors, and design aspects.<br><br>**Electric Vehicle Control Unit:** discussion on requirements of VCU, inverter topologies and their control strategy, VCU design methodology.<br><br>**AUX Power Converter Unit:** requirements, power converter topologies, discussion on design difficulties for high current low voltage converters. |
| 4 | **Texts/References** | **1.** Ali Emadi, Mehrdad Ehsani, and John M. Miller, "Vehicular Electric Power Systems: Land, Sea, Air, and Space Vehicles (Power Engineering," CRC Press, 1ed, 2003<br><br>**2.** Iqbal Husain, "Electric and Hybrid Vehicles: Design Fundamentals", CRC Press, 2ed, 2010.<br><br>**3.** Who killed the Electric Car, a documentary, 2006.<br><br>**4.** Michael Shnayerson "The Car that Could: The Inside Story of GM's Revolutionary Electric Vehicle", 1996<br><br>**5.** Application Notes of Texas Instruments, Infineon; Curtis Instruments. |

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| 1 | **Title of the course** (L-T-P-C) | **Smart Grid** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | EE223: Introduction to Power Systems or equivalent as determined by the instructor or faculty advisor. |
| 3 | **Course content** | **1.** Synchrophasor & PMU, IEEE standards<br>**2.** State estimation- WLS, Linear, Hybrid<br>**3.** Cyber Security in Smart Grid<br>**4.** Dynamic Security Assessment, Prediction and Control<br>**5.** Wide Area Damping Control<br>**6.** Mode Estimation- Ringdown & Ambient<br>**7.** Dynamic State and Parameter Estimation<br>**8.** Ancillary Services from Renewables, grid forming converter, Virtual Inertia. |
| 4 | **Texts/References** | **1.** Power System Grid Operation Using Synchrophasor Technology, Nuthalapati Sarma, Springer, 2019, ISBN 978-3-319-89378-5.<br>**2.** Phasor Measurement Units and Wide Area Monitoring Systems, Antonello Monti, Carlo Muscas and Ferdinanda Ponci, ISBN: 9780128031407, Academic Press, 2016.<br>**3.** Wide area smart grid architectural model and control: A survey, Renewable and Sustainable Energy Reviews, Vol. 64, pp. 311-328, 2016.<br>**4.** Application of Time-Synchronized Measurements in Power System Transmission Networks, Mladen Kezunovic, Sakis Meliopoulos, Vaithianathan Venkatasubramanian, Vijay Vittal, Springer, 978-3-319-06217-4, Edition 1, 2014.<br>**5.** F. Aminifar et. al. "Synchrophasor Measurement Technology in Power Systems: Panorama and State-of-the-Art," IEEE Access, Vol. 2., No. 1, pp. 1607-1628, 2014. |

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| 1 | **Title of the course** (L-T-P-C) | **Data Science and Visualization Lab** **(0-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | Exposure to basics of probability theory, linear algebra, optimization and computer |
| 3 | **Course content** | **1.** A hands-on introduction to tools for data science and Machine Learning (ML), including Python, NumPy and TensorFlow basics/pytorch. Data visualization using real world data set: Matplotlib, histograms, bar charts, line/scatter plots, pie charts etc. (2 labs)<br>**2.** Sampling from a distribution, hypothesis testing, model parameter estimation. (2 labs)<br>**3.** A hands-on lab for classification and regression with various data sets using Bayesian classifier/ neural networks. (2 labs)<br>**4.** Implementation of Stochastic Gradient Descent (SGD) algorithm and one momentum based algorithm. (1 lab)<br>**5.** Dimensionality reduction and principal component analysis. (1 lab)<br>**6.** Integration of AI engine with web/mobile applications, embedded systems and hardware. (1-2 lab(s)<br>**7. Mini project:** End-to-end development cycle of an AI application (Deployable applications in various areas, such as AI in healthcare and AI in Finance). Students can choose the project but require the instructor's approval. (3 labs). |
| 4 | **Texts/References** | ● Anirudh Koul, Siddha Ganju and Meher Kasam, **Practical Deep Learning for Cloud, Mobile, and Edge**, O'Reilly, 2019.<br><br>● Itay Lieder, Tom Hope, and Yehezkel S. Resheff **Learning TensorFlow: A Guide to Building Deep Learning Systems**, O'Reilly, 2017. |

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| 1 | **Title of the course** (L-T-P-C) | **VLSI Test & Testability** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | EE 224 Digital systems or equivalent |
| 3 | **Course content** | The course describes the theoretical aspects of VLSI Testing and verification. Starting from the basic concepts of verification and testing to advance processor level verification and testing are going to be discussed in this course. In addition, SoC testing strategy will also be addressed.<br><br>The objective of this course is to deal with the study of VLSI design flow, Functional verification, verification flow, Timing verification of the circuit, simulator architecture and operation, assertions, need for electronic testing, fault modeling, test generation for combinational circuits, test generation for sequential circuits, fault simulation, Built- In Self-Test (BIST), Memory testing, In-circuit/On-chip emulation and validation, Design for Testability (DFT), SoC test, fault diagnosis, and Analog/RF test. |
| 4 | **Texts/References** | **1.** William K. Lam, Hardware Design Verification: Simulation and Formal Method-Based Approaches, Prentice Hall (2008).<br>**2.** Michael. L. Bushnell, and Vishwani. D. Agrawal, Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits, Kluwer Academic Publishers, Third Edition, 2004.<br>**3.** B. Wile, John C. Goss and W. Rosner, Comprehensive Functional Verification," Morgan Kaufmann, 2005.<br>**4.** Chris Spear, "System Verilog for Verification," Springer Publications, second edition 2008.<br>**5.** Stuart Sutherland, Simon Davidmann, Peter Flake "System Verilog for Design," Springer Publications, second edition 2006.<br>**6.** M Abromovici, M A Breuer & A. D. Friedman "Digital Systems Testing and Testable Design ", Jaico Publications, Paperback Impression, 2001.<br>7. H. Fujiwara, "Logic Testing and Design for testability," MIT Press, 1985.<br>8. Pallab Dasgupta, "A roadmap for formal property verification," Springer (2006)<br>9. Santanu Chattopadhyay, "Thermal-Aware Testing of Digital VLSI Circuits and Systems," CRC Press, 2018. |

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| 1 | **Title of the course** (L-T-P-C) | **Introduction to HIL testing methods (1-0-1-3)** |
| 2 | **Pre-requisite courses(s)** | None for M. Tech SSM. For others, instructor consent is required . |
| 3 | **Course content** | Introduction to real-time simulation and hardware-in-the-loop systems; structure of HIL platforms; characteristics of discrete systems and simulations; introduction to mathematical and modelling constraints for real-time simulation: sampling, interpolation, parallelization; slow and fast interactions; computability; introduction to solvers: real-time vs non-real-time and faster-than-real-time; CPU vs FPGA based simulation of systems; step-time constraints; multi-core simulation; CPU time constraints; concurrent vs sequential programs for simulation; Rapid Control Prototyping (RCP) Mode; fundamentals of automated testing and verification; interfacing HIL system with DUT: signal constraints; sampling and acquisition; power hardware-in the loop (pHIL) and controller hardware-in the loop (cHIL) modes.<br><br>**Fundamentals of Model-based simulation: discretization; accuracy; simulation step time; convergence, etc.**<br>**1.** Parameterization of Simulation Models, library interfaces; abstractions<br>**2.** Introduction to Real-time toolchains; Automated testing, model profiling<br>**3.** Model parallelization: strong and weak coupling, design partitioning<br>**4.** Simulation of switched systems<br>**5.** FPGA-based solvers<br>**6.** Hardware interfacing: analog and digital I/O |
| 4 | **Texts/References** | References:<br>1. L. Umanand, “Digital Control Series” (Video Lectures)<br>2. A. V. Prokhorov, A. S. Gusev and Y. S. Borovikov, "Hardware-in-the- loop testbed based on hybrid real time simulator," IEEE PES ISGT Europe 2013, 2013, pp. 1-5, doi: 10.1109/ISGTEurope.2013.6695464.<br>3. A. Samiee, N. Tiefnig, J. P. Sahu, M. Wagner, A. Baumgartner and L. Juhász, "Model-Driven-Engineering in Education," 2018 18th International Conference on Mechatronics - Mechatronika (ME), 2018, pp. 1-6.<br>4. Whitepapers from OpalRT, Mathworks, Typhoon, etc |

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| 1 | **Title of the course** (L-T-P-C) | **Battery Technology**<br>**(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | None for M. Tech SSM. For others, instructor consent is required |
| 3 | **Course content** | **Module 1: Battery Chemistry**<br>Electrochemistry, concept of electrochemical energy storage, primary and secondary batteries (Li-Ion, Li-Na, Li-S and Li-air batteries etc.), chemistry behind capacitors and supercapacitors, different energy storage materials and the material characterization.<br><br>**Module 2: Battery Management Systems**<br>Electrical Characteristics of Batteries; measurement and characterization; components of battery-powered electronic/electrical systems; safe-operating-area (SOA), Coulombic and electrical energy efficiency; Lithium-specific considerations; cell modelling and estimation; SOC, DOD; integration of cell/pack/module; Structure and function of BMS; cell balancing: topologies and algorithms; coulomb-counting; second-life batteries; battery/supercapacitor integrated systems<br><br>**Module 3: Thermal Management**<br>Li-ion batteries & hazard levels, EV fire accidents and safety, Battery and heat transfer: methodologies, passive and active air-cooling systems, two phase cooling. |
| 4 | **Texts/References** | **References:**<br>**1.** Electrochemical energy: Advanced materials and technologies, Edited by Zhang (CRC press).<br>**2.** Linden's Handbook of Batteries, 4th Edition.<br>**References:**<br>**1.** "Battery Management Systems for Large Lithium-ion Battery Packs", *Davide Andrea*, Artech House, 2010. ISBN:1608071057<br>**2.** Introduction to Hybrid and Electric Vehicles (NPTEL Online Course), Dr. Praveen Kumar Department of Electronics and Prof. S. Majhi (IIT Guwahati)<br>**3.** "Battery Cell Balancing: What to Balance and How", Barsukov, Y, Texas Instruments (whitepaper) |

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| 1 | **Title of the course** (L-T-P-C) | **Electric Vehicles: Systems and Components**<br>**(2-0-2-6)** |
| 2 | **Pre-requisite courses(s)** | None for M. Tech SSM. For others, instructor consent is required |
| 3 | **Course content** | <u>Each topic is accompanied by hands-on exercises</u><br><br>**Introduction to Electric Vehicles** – Discussion on the importance of EV; classification of EVs: e-bikes, 2 wheelers, 3-wheelers, 4-wheelers; light/medium/heavy duty, etc.<br><br>**Electric Vehicle Components** – Components of EV, Electric Vehicle Supply Equipment (EVSE), Charging ports, connector configurations, Chargers, Battery, Drivetrain, BMS, AUX power converters, Electric motors, etc.<br><br>**Electric Vehicle Supply Equipment** – Introduction to EVSE, basic requirements, different types, functional diagram, safety features, and requirements.<br><br>**Electric Vehicle Battery Chargers** – Overview of EV Battery Chargers (onboard and stationary), different types, levels of charging, internal power electronic converters – Rectifiers, PFC, DC/DC converters, Communications, and control aspects.<br><br>**Overview on EV Batteries and Battery Management Systems:** Introduction to various electric vehicle batteries, typical energy requirements in EV, battery management systems.<br><br>**Discussion of EV Drivetrains:** Overview of electric motors for EV applications, limitations of existing motors, control of electric motors, and design aspects.<br><br>**Electric Vehicle Control Unit:** discussion on requirements of VCU, inverter topologies and their control strategy, VCU design methodology.<br><br>**AUX Power Converter Unit:** requirements, power converter topologies, discussion on design difficulties for high current low voltage converters.<br><br>1. Implementation of Electric Vehicle Supply System - understanding fault trip mechanisms, hand shaking between vehicle and grid, controlling the charging profiles, etc.<br>2. Electric Vehicle battery chargers - understanding various chargers - types, levels, and connectors configurations, different operating modes: CV and CC.<br>3. Basic level implementation of EV chargers - input PFC stage, DC/DC |
| 4 | **Texts/References** | 1. S. Raju, N. Mohan, *Analysis and Control of Electric Drives: Simulations and Laboratory Implementation*, United States, Wiley, 2020.<br>2. Ali Emadi, Mehrdad Ehsani, and John M. Miller, "Vehicular Electric Power Systems: Land, Sea, Air, and Space Vehicles (Power Engineering," CRC Press, 1ed, 2003 |

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| 1 | **Title of the course** (L-T-P-C) | **Pattern Recognition and Machine Learning (PRML)**<br>**(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to basic concepts in calculus and probability |
| 3 | **Course content** | **Overview of** Probability Theory, Linear Algebra, Convex Optimization. **Introduction:** History of pattern recognition & machine learning, distinction in focus of pattern recognition and machine learning.<br>**Regression**: Linear Regression, Multivariate Regression, Logistic Regression.<br>**Clustering:** Partitional Clustering, Hierarchical Clustering, BirchAlgorithm CURE Algorithm, Density-based Clustering<br>**PCA and LDA:** Principal Component Analysis, Linear Discriminant Analysis.<br>**Kernel methods:** Support vector machine<br>**Graphical Models**: Gaussian mixture models and hidden Markov models **Introduction to Bayesian Approach:** Bayesian classification, Bayesian Learning, Bayes Optimal Classifier, Naive Bayes Classifier and BayesianNetwork.. |
| 4 | **Texts/References** | **1.** C. Bishop, "Pattern Recognition and Machine Learning," Springer, 2006.<br>**2.** S. Theodoridis and K. Koutroumbas, "Pattern Recognition" Second Edn, Elsivier, 2003<br>**3.** B. Yegnanarayana, "Artificial Neural Networks", PHI, 1999.<br>**4.** Simon Hayking, "Neural Networks and Learning Machines", Pearson, 1999. |

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| 1 | **Title of the course** (L-T-P-C) | **Introduction to Electric Drives**<br>**(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | None for M. Tech SSM |
| 3 | **Course content** | **1.** **Fundamentals of Electric Power Technologies; review of sinusoidal, phasor, three-phase and per-phase quantities; review of mathematical tools (ordinary differential equations, Laplace and Fourier Transforms, space vectors, etc.)**<br>**2.** Electric Machines: Inductors and Transformers: Magnetic Circuits, principle of transformer action, equivalent circuits, phasor diagram, efficiency, basics of three phase transformer.<br>**3.** Introduction to Electric Motors and Generators: Synchronous Machines: induced emf and torque in a rotating coil, rotating magnetic field, construction of synchronous Machines, induced emf, phasor diagram, equivalent circuit, OCC- SCC, power angle characteristics, V-curve and inverted V curve.<br>**4.** Introduction to Induction Motor, introduction to DC Machine, Applications of Electrical Machines and special electrical motors.<br>**5.** Principles of Power Conversion: AC/DC, Introduction to power semiconductor devices<br>**6.** Rectifiers - single and three phase<br>**7.** Switching Power Pole and PWM<br>**8.** Buck Converter<br>**9.** Basics of inverters - single and three phase<br>**10.** Fundamentals of Isolated Converters |
| 4 | **Texts/References** | **1.** P. S. Bimbhra, “Electrical machinery,” Khanna Publishers, 7th edition, 1977.<br>**2.** M. G. Say, “The Performance and Design of Alternating Current Machines,” CBS, 3rd ed, 2002.<br>**3.** Stephen Chapman, “Electric Machinery Fundamentals,” McGraw Hill, 4th edition, 2017.<br>**4.** D.P. Kothari, I.J. Nagrath, “Electric Machines,” McGraw Hill, 5th edition, 2017.<br>**5.** A Fitzgerald, C. Kingsley, and S. Umans, “Electric Machinery,” McGraw Hill, 6th ed. 2017.<br>**6.** L. Umanand, ``Power Electronics – essentials and applications," Wiley 2009.<br>**7.** M. H. Rashid “Power Electronics,” Pearson. 4th edition, 2017.<br>**8.** Mohan, Robbins, Undeland “Power Electronics: Converters Applications and Design” 3rd Ed.; Wiley, 2007 |

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| 1 | **Title of the course** (L-T-P-C) | **Sensors and Instrumentation**<br><br>**(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Introduction to analog circuits (EE202), Digital system design (EE204), Introduction to Electrical and Electronics Engineering (EE101) |
| 3 | **Course content** | **Module 1:** Understanding basic instrumentation specifications, accuracy, resolution, sensitivity, repeatability, reproducibility, absolute and relative accuracy, systematic and random errors, significant digits, speed etc.<br><br>**Module 2:** Sensors including accelerometers, gyroscopes, electrodes for biomedical signal acquisition, gas sensors etc. Transduction techniques like piezoresistive, piezo electric, capacitive, resistive, etc. Interface circuits for different types of transduction techniques, time domain techniques, charge amplifiers, etc.<br><br>**Module 3:** Electronics measurements and data acquisition, voltmeters, ammeters, ohm meters, bridge circuits, etc. Low level measurement techniques, types of noise,<br>Module 4 : Electronics instruments including function generators, oscilloscopes (real time and sampling oscilloscopes), spectrum analyzers, network analyzers, multi-meters, |

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| 4 | **Texts/References** | ● Low level measurements handbook, 7th Edition, Tektronix handbook ● Electronic Instrumentation, H S Kalsi, McGraw-Hill Education, 2018<br>● A Course in ELECTRICAL AND ELECTRONIC MEASUREMENTS AND INSTRUMENTATION, A K Sawhney, Shree Hari Publications (1 January 2021)<br>● Measurement and Instrumentation: Theory and Application by Alan S. Morris, Academic Press Inc; 2nd edition (7 September 2015).<br>● Sensors and Signal Conditioning, 2nd Edition by Ramón Pallás-Areny, John G. Webster, Wiley India Pvt Ltd; Second edition (28 November 2012). |

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| 1 | **Title of the course** (L-T-P-C) | **EV Charging and Ancillary Services** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Introduction to Power Systems or equivalent as determined by the instructor |
| 3 | **Course content** | **1.** Introduction to Electric Power System Dynamics and Distribution System Power Flow Analysis<br>**2.** Impact of EV Charging on Distribution Systems<br>**3.** Optimal Location of EV Charging Stations<br>**4.** Optimal Scheduling of EV Charging<br>**5.** Ancillary Services from EV- Frequency control, peak shaving, valley filling, congestion management.<br>Communication Technologies for EV Charging Stations |

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| 4 | **Texts/References** | • H. Xiao, Y. Huimei, W. Chen and L. Hongjun, "A survey of influence of electrics vehicle charging on power grid," *2014 9th IEEE Conference on Industrial Electronics and Applications*, 2014, pp. 121-126, doi: 10.1109/ICIEA.2014.6931143.<br>• E. Veldman and R. A. Verzijlbergh, "Distribution Grid Impacts of Smart Electric Vehicle Charging From Different Perspectives," in IEEE Transactions on Smart Grid, vol. 6, no. 1, pp. 333-342, Jan. 2015, doi: 10.1109/TSG.2014.2355494.<br>• O. Beaude, S. Lasaulce, M. Hennebel and I. Mohand-Kaci, "Reducing the Impact of EV Charging Operations on the Distribution Network," in IEEE Transactions on Smart Grid, vol. 7, no. 6, pp. 2666-2679, Nov. 2016, doi: 10.1109/TSG.2015.2489564 R. A. Verzijlbergh, M. O. W. Grond, Z. Lukszo,<br>• J. G. Slootweg and M. D. Ilic "Network Impacts and Cost Savings of Controlled EV Charging," in IEEE Transactions on Smart Grid, vol. 3, no. 3, pp. 1203-1212, Sept. 2012, doi: 10.1109/TSG.2012.2190307<br>• B. Sun, Z. Huang, X. Tan and D. H. K. Tsang, "Optimal Scheduling for Electric Vehicle Charging With Discrete Charging Levels in Distribution Grid," in IEEE Transactions on Smart Grid, vol. 9, no. 2, pp. 624-634, March 2018, doi: 10.1109/TSG.2016.2558585.<br>• N. Leemput, F. Geth, B. Claessens, J. Van Roy, R. Ponnette and J. Driesen, "A case study of coordinated electric vehicle charging for peak shaving on a low voltage grid," 2012 3rd IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe), 2012, pp. 1-7, doi: 10.1109/ISGTEurope.2012.6465656<br>• Haidar and K. M. Muttaqi, "Behavioral Characterization of Electric Vehicle Charging Loads in a Distribution Power Grid Through Modeling of Battery Chargers," in IEEE Transactions on Industry Applications, vol. 52, no. 1, pp. 483-492, Jan.-Feb. 2016, doi: 10.1109/TIA.2015.2483705.<br>• J. C. Mukherjee and A. Gupta, "A Review of Charge Scheduling of Electric Vehicles in Smart Grid," in IEEE Systems Journal, vol. 9, no. 4, pp. 1541-1553, Dec. 2015, doi 10.1109/JSYST.2014.2356559.<br>• C. Jin, J. Tang and P. Ghosh, "Optimizing Electric Vehicle Charging With Energy Storage in the Electricity Market," in IEEE Transactions on Smart Grid, vol. 4, no. 1, pp. 311-320, March 2013, doi: 10.1109/TSG.2012.2218834.<br>• J. Hu, S. You, M. Lind and J. Østergaard, "Coordinated Charging of Electric Vehicles for Congestion Prevention in the Distribution Grid," in IEEE Transactions on Smart Grid, vol. 5, no. 2, pp. 703-711, March 2014, doi: 10.1109/TSG.2013.2279007.<br>• R. Li, Q. Wu and S. S. Oren, "Distribution Locational Marginal Pricing for Optimal Electric Vehicle Charging Management," in IEEE Transactions on Power Systems, vol. 29, no. 1, pp. 203-211 Jan. 2014, doi:10.1109/TPWRS.2013.2278952.<br>• E. Sortomme and M. A. El-Sharkawi, "Optimal Scheduling of Vehicle-to-Grid Energy and Ancillary Services," in IEEE Transactions on Smart Grid, vol. 3, no. 1, pp. 351-359, March 2012, doi: 10.1109/TSG.2011.2164099.<br>• Y. He, B. Venkatesh and L. Guan, "Optimal Scheduling for Charging and Discharging of Electric Vehicles," in<br>• IEEE Transactions on Smart Grid, vol. 3, no. 3, pp. 1095-1105, Sept. 2012, doi: 10.1109/TSG.2011.2173507.<br>• E. Sortomme and M. A. El-Sharkawi, "Optimal Charging Strategies for Unidirectional Vehicle-to-Grid," in IEEE Transactions on Smart Grid, vol. 2, no. 1, pp. 131-138, March 2011, doi: 10.1109/TSG.2010.2090910.<br>• L. Gan, U. Topcu and S. H. Low, "Optimal decentralized protocol for electric vehicle charging," in IEEE Transactions on Power Systems, vol. 28, no. 2, pp. 940-951, May 2013, doi: 10.1109/TPWRS.2012.2210288.<br>• C. Wu, H. Mohsenian-Rad and J. Huang, "Vehicle-to-Aggregator Interaction Game," in IEEE Transactions on Smart Grid, vol. 3, no. 1, pp. 434-442, March 2012, doi: 10.1109/TSG.2011.2166414. |

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| 1 | **Title of the course** (L-T-P-C) | **Electric and Hybrid Vehicles (3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | |
| 3 | **Course content** | Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies.<br>Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, transmission characteristics, mathematical models to describe vehicle performance.<br>Hybrid Electric Drive-trains: Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis.<br>Electric Drive-trains: Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis.<br>Electric Propulsion unit: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives, configuration and control of Permanent Magnet Motor drives, Configuration and control of Switch Reluctance Motor drives, drive system efficiency.<br>Energy Storage: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices.<br>Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Communications, supporting subsystems<br>Energy Management Strategies: Introduction to energy management strategies used in hybrid and electric vehicles, classification of different energy management strategies, comparison of different energy management strategies, implementation issues of energy management strategies.<br>EV Charging: system design, infrastructure requirements, and power system impacts, batteries and their characteristics, chemistries, "MPGe", range anxiety, intro to BMS and battery health<br>Life-cycle Analysis and Costing for EVs, Drive cycles analysis and charging network design |
| 4 | **Texts/References** | **1.** Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.<br>**2.** Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.<br>**3.** James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003. |

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| 1 | **Title of the course** (L-T-P-C) | **Robotics and Automation** **(3-0-2-8)** |
| 2 | **Pre-requisite courses(s)** | |
| 3 | **Course content** | Introduction to Embedded Systems & Robotics Introduction/Review of Circuits<br>Embedded Software Design<br>Power sources and voltage regulation General Purpose Input Output Managing Time<br>Concurrent Multithreading Serial Port Interfacing Motor Interfacing<br>Timers<br>Introduction to Cameras and Visual Servoing;<br>Elements of Mechanical Design of differential drive robot |
| 4 | **Texts/References** | 1. Jonathan W. Valvano, “Embedded Systems: Introduction to Robotics,” ISBN:9781074544300. (2019)<br>2. Andrew Thomson and Jacky Baltes, “Mobile Robot Path Tracking Using visualServoing” http://web.cecs.pdx.edu/~mperkows/CLASS_479/S2006/thomson mobil_robot_path_track_using_visual_servoin.pdf<br>3. Design and Manufacturing I, MIT OCW Lecture Notes. https://ocw.mit.edu/courses/mechanical-engineering/2-007-design-and-manufacturing-i-spring-2009/lecture-notes |

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| 1 | **Title of the course** (L-T-P-C) | **Stochastic Process and its Applications** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Introduction to probability and Data analysis/Probability models. |
| 3 | **Course content** | • Introduction to stochastic processes: Definitions and examples, Bernoulli process and Poisson process. Markov Process, stationary and ergodic process.<br>• Markov Chains: Discrete time and continuous time Markov chains, classification of states, notion of stationary distribution.<br>• Simulating stochastic processes like Gaussian process, Poisson process, Markov chains and Brownian motion.<br>• Introduction to Markov chain monte carlo methods, Hidden Markov chain and Markov decision process.<br>• Statistics: MLE, MAP and Bayesian Estimation, sufficient statistics, and CramerRao lower bound. |
| 4 | **Texts/References** | Sheldon Ross "Introduction to probability models" 9th Ed., Elsevier AP<br>Sheldon Ross, 'Stochastic process', John Wiley, 2nd Ed., April 1996.<br>David Stirzaker, 'Stochastic process and models', Oxford press. |

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| 1 | **Title of the course** (L-T-P-C) | **Mathematics for Data Science I** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Introduction to probability and Data analysis or equivalent, basic calculus. |
| 3 | **Course content** | ● Introduction to Data science and Motivation for the course.<br>● Review of calculus, notion of limits, series and its convergence.<br>● Introduction to Linear Algebra in Data science, the notion of vector space, dimension and rank, algorithms for solving linear equations, importance of norms and notion of convergence, matrix decompositions and its use.<br>● Importance of optimization in data science: Bird's view of Linear Regression, Multivariate Regression, Logistic Regression etc. |
| 4 | **Texts/References** | ● Boyd, Stephen, and Lieven Vandenberghe. Introduction to applied linear algebra: vectors, matrices, and least squares. Cambridge university press, 2018.<br>● Aggarwal, Charu C., Aggarwal, and Lagerstrom-Fife. Linear algebra and optimization for machine *learning*. Springer International Publishing, 2020. |

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| 1 | **Title of the course** (L-T-P-C) | **Fundamentals of Speech Processing (FSP)** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Exposure to calculus and probability |
| 3 | **Course content** | **Introduction** to speech processing area: History, initial electrical mode till latest trends<br><br>**Speech production, perception and cognition** : Study of these mechanisms and important findings for technological development.<br><br>**Nature of speech signal** : Stationary vs non-stationary, voiced/unvoiced/silence classification, vowels and consonants.<br><br>**Speech signal processing** : Time, frequency and cepstral domain processing<br>**Overview of important applications**: Speech recognition, speech synthesis, speaker recognition, language recognition |
| 4 | **Texts/References** | **1.** Rabiner, Jhuang and Yegnanarayana, "Fundamentals of Speech Recognition", Pearson LPE, 2009.<br>**2.** J. R. Deller, Jr., J. H. L. Hansen and J. G. Proakis, "Discrete-Time Processing of Speech Signals", Wiley-IEEE Press, NY, USA, 1999.<br>**3.** Xuedong Huang, Alejandro Acero and Hsiao-Wuen Hon, "Spoken Language Processing: A guide to Theory, Algorithms, and System Development", Prentice Hall, USA, 2001. |

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| 1 | **Title of the course** (L-T-P-C) | **Mathematics for Data Science II** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Introduction to probability and Data analysis or equivalent, basic calculus. Exposure to Mathematics for Data Science I. |
| 3 | **Course content** | ● Convex Optimization: Convex sets, convex functions, cones and other useful geometries.<br>● Different types of optimization problems, Duality theory, KKT conditions, Introduction to linear program, solving constrained optimization problems using the Lagrangian method. Algorithms: Gradient descent methods and its convergence, Improved methods such as Nesterov acceleration, mirror descent/Nestrov dual averaging,<br>● Stochastic gradient descent methods and their convergence, Introduction to Rmsprop, ADAM algorithm etc. |
| 4 | **Texts/References** | ● Boyd, Stephen, and Lieven Vandenberghe. *Introduction to applied linear algebra: vectors, matrices, and least squares*. Cambridge university press, 2018.<br>● Aggarwal, Charu C., Aggarwal, and Lagerstrom-Fife. *Linear algebra and optimization for machine learning*. Springer International Publishing, 2020.<br>● C. Bishop, "Pattern Recognition and Machine Learning," Springer, 2006.<br>● S. Boyd and L. Vandenberghe, "Convex Optimization," Cambridge university press, 2018 (reprint).<br>● Prateek Jain and Purushotam Kar, "Non-Convex Optimization for Machine Learning," Now publisher, 2017. |

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| 1 | **Title of the course** (L-T-P-C) | **Deep Learning of Speech Processing (DLSP)** **(1.5-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | Exposure to calculus and probability |
| 3 | **Course content** | **Introduction** to deep learning<br><br>**Introduction** to MATLAB / Python programming, open source toolkits for speech technology development<br><br>**Overview of machine learning models:** Deep feedword neural networks (DFNN), convolution neural network (CNN), recurrent neural networks (RNNs) and its variations, time delay neural networks (TDNN)<br>**Applications development:** Deep learning based speech recognition, speech synthesis, speaker recognition and language identification. |
| 4 | **Texts/References** | **1.** Rabiner, Jhuang and Yegnanarayana, "Fundamentals of Speech Recognition", Pearson LPE, 2009.<br>**2.** J. R. Deller, Jr., J. H. L. Hansen and J. G. Proakis, "Discrete-Time Processing of Speech Signals", Wiley-IEEE Press, NY, USA, 1999.<br>**3.** Xuedong Huang, Alejandro Acero and Hsiao-Wuen Hon, "Spoken Language Processing: A guide to Theory, Algorithms, and System Development", Prentice Hall, USA, 2001.<br>**4.** Michael Nielsen "Neural Networks and Deep Learning" Open Book.<br>**5.** Ian Goodfellow, Yoshua Bengio and Aaron Courville, "Deep Learning", MIT Press, 2016.<br>**6.** Charu Agarwal, "Neural Networks and Deep Learning", Springer 2018. |

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| 1 | **Title of the course** (L-T-P-C) | **Machine Learning of Speech Processing (MLSP)**<br>**(1.5-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | Exposure to calculus and probability |
| 3 | **Course content** | **Introduction** to machine learning<br>**Introduction** to MATLAB / Python programming<br>**Overview of machine learning models:** Gaussian mixture model (GMM), hidden Markov model (HMM), support vector machine (SVM), Neural Networks (NNs), etc<br>**Applications development:** ML based speech recognition, speech synthesis, speaker recognition and language identification. |
| 4 | **Texts/References** | **1.** Rabiner, Jhuang and Yegnanarayana, "Fundamentals of Speech Recognition", Pearson LPE, 2009.<br>**2.** C. Bishop, "Pattern Recognition and Machine Learning," Springer, 2006.<br>**3.** B. Yegnanarayana, "Artificial Neural Networks", PHI, 1999.<br>**4.** J. R. Deller, Jr., J. H. L. Hansen and J. G. Proakis, "Discrete-Time Processing of Speech Signals", Wiley-IEEE Press, NY, USA, 1999.<br>**5.** Xuedong Huang, Alejandro Acero and Hsiao-Wuen Hon, "Spoken Language Processing: A guide to Theory, Algorithms, and System Development", Prentice Hall, USA, 2001. |

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| 1 | **Title of the course**<br>(L-T-P-C) | **Pattern Recognition**<br>**(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Exposure to calculus and probability |
| 3 | **Course content** | **Introduction** to pattern recognition, pattern vs data, human computer interaction, pattern recognition systems, design cycle, learning and adaptation.<br><br>**Bayesian Decision Theory:** Introduction, theory, classifiers, discriminant functions and decision surfaces, maximum likelihood and Bayesian parameter estimation.<br><br>**Nonparametric Techniques:** Introduction, nearest neighbor estimation, nearest neighbor rule, nearest neighbor classifier.<br><br>**Dimensionality Reduction:** Principal component analysis and Linear discriminant analysis.<br>**Nonparametric Methods:** Introduction, decision trees, CART, other tree |
| 4 | **Texts/References** | **1.** Duda, R.O., Hart, P.E., and Stork, D.G. Pattern Classification. Wiley-Interscience. 2nd Edition. 2001.<br>**2.** Theodoridis, S. and Koutroumbas, K. Pattern Recognition. Edition Academic Press, 2008.<br>**3.** Bishop, C. M. Neural Networks for Pattern Recognition. Oxford University Press. 1995.<br>**4.** Hastie, T., Tibshirani, R. and Friedman, J. The Elements of Statistical Learning. Springer. 2001. |

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| 1 | **Title of the course** (L-T-P-C) | **MACHINE LEARNING (ML)** **(1.5-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | Exposure to basic concepts in calculus and probability |
| 3 | **Course content** | **Introduction to Machine Learning:** What is machine learning? learning approaches: supervised, unsupervised, semi-supervised and reinforcement learning **Regression**: Linear Regression, Multivariate Regression, Logistic Regression.<br>**Clustering:** Partitional Clustering, Hierarchical Clustering, Density-based Clustering<br>**Kernel methods:** Support vector machine<br>**Graphical Models**: Gaussian mixture models and hidden Markov models **Introduction to Bayesian Approach:** Bayesian classification, Bayesian Learning, Bayes Optimal Classifier, and Naive Bayes Classifier. |
| 4 | **Texts/References** | **1.** C. Bishop, "Pattern Recognition and Machine Learning," Springer, 2006.<br>**2.** K. P. Murphy, "Machine Learning: A Probabilistic Perspective", MIT Press, 2012.<br>**3.** "Introduction to Machine Learning" wikipedia guide<br>**4.** M. Nielsen "Mathematics and Applications of Machine Learning", online book. |

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| 1 | **Title of the course** (L-T-P-C) | **ARTIFICIAL NEURAL NETWORKS (ANN)** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Exposure to basic concepts in calculus and probability |
| 3 | **Course content** | Introduction to Artificial Neural Networks (ANN): Motivation, basics of ANN, different architectures. Applications of ANN.<br>Feedforward Neural Networks (FFNN): Working principle, basic architecture, analysis of FFNN for different ML tasks.<br>Feedback Neural Networks (FBNN): Working principle, basic architecture, Boltzmann machine, analysis of FFNN for different ML tasks.<br>Competitive learning Neural Networks (CLNN): Working principle, basic architecture, analysis of CLNN for different ML tasks.<br>Applications of ANN: speech processing, image processing and other tasks. |
| 4 | **Texts/References** | **1**. B. Yegnanarayana, “Artificial Neural Networks”, PHI, 1999.<br>**2.** Simon Haykin, “Neural Networks and Learning Machines”, Pearson Prentice Hall, 2008.<br>**3.** Rumelhart, “Parallel distributed processing : explorations in the microstructure of cognition (Vol. 1 and 2)”, MIT Press, 1986 |

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| 1 | **Title of the course** (L-T-P-C) | **DEEP LEARNING (DL)** **(1.5-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | Exposure to basic concepts in calculus and probability |
| 3 | **Course content** | **Introduction to Deep Learning (DL):** Motivation, evolution of deep learning and different architectures. Applications of DL. **Deep Learning (DL) Architectures:** Deep FFNN, Convolutional neural networks (CNN), Recurrent neural network (RNN), Long Term short term memory (LSTM), Generative adversarial network (GAN), autoencoders, variational autoencoders, DL architectures with attention mechanism. Some recent DL architectures. |
| 4 | **Texts/References** | **1.** Ian Goodfellow Yoshua Bengio Aaron Courville, Deep Learning, MIT Press, 2016. **2.** Charu Agarwal, "Neural Networks and Deep Learning", Springer, 2018. **3.** Michael Nielsen "Neural Networks and Deep Learning" Open Book. |

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| 1 | **Title of the course** (L-T-P-C) | **PWM Techniques** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | **Electric Drives for EVs - I and II** |
| 3 | **Course content** | Basics of PWM, generation of PWM using analog and digital methods (triangle comparison); single and dual slope PWM; leading vs trailing edge PWM; current mode control and hysteresis vs PWM; spectral properties and dithering; three-phase PWM: sine triangle, space-vector, etc; low frequency vs high frequency PWM; space-vector analysis of PWM methods. |
| 4 | **Texts/References** | **1.** L. Umanand, ``Power Electronics – essentials and applications," Wiley 2009.<br>**2.** M. H. Rashid "Power Electronics," Pearson. 4th edition, 2017.<br>**3.** Mohan, Robbins, Undeland "Power Electronics: Converters Applications and Design" 3rd Ed.; Wiley, 2007 |

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| 1 | **Title of the course** (L-T-P-C) | **Introduction to Battery Management Systems (3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | None for EE candidates; all core courses for ME candidates |
| 3 | **Course content** | Introduction to Battery electrochemistry and electrical characteristics, cell types and models, SOC, SOA, SOH estimation, BMS systems; charging algorithms; charge balancing |
| 4 | **Texts/References** | Application notes and technical documentation from vendors |

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| 1 | **Title of the course** (L-T-P-C) | **Signals, Systems and Controls** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | None |
| 3 | **Course content** | Review of basic signal processing techniques; time and frequency domain transformations; inferring time-and frequency domain behaviors of physical systems from mathematical models, ODEs, eigen values.<br>Review of control theory: classical control theory; SISO systems, stability analysis. Linear Algebra for MIMO systems and State Space models; eigenvalue analysis. Modern control methods: Estimation; model-based control; sliding mode control; predictive control. |
| 4 | **Texts/References** | **1.** Signals and systems / Alan V. Oppenheim, Alan S. Willsky, with. S. Hamid Nawab. - 2nd ed. p.<br>**2.** Next Generation Wireless LANs: 802.11n and 802.11ac 2nd Edition, by Eldad Perahia (Author), Robert Stacey (Author)<br>**3.** Relevant IEEE Standards and publications<br>**4.** Modern Control Engineering, Katsuhiko Ogata, Prentice Hall, 2010 ISBN 0136156738 |

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| 1 | **Title of the course** (L-T-P-C) | **Digital Signal Processing and Communications** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Signals, Communications and Controls |
| 3 | **Course content** | • Digital Modulation - Signal constellations, Nyquist's Sampling Theorem and Criterion for ISI Avoidance, Linear modulation Optimal Demodulation – Review of Hypothesis Testing, ML and MAP decision rules, Signal Space Concepts, Optimal Reception in AWGN and performance analysis of various modulation schemes.<br>• DFT and FFT, Digital Filter Design, Analysis and Implementation. |
| 4 | **Texts/References** | **1.** Discrete-time signal processing / Alan V. Oppenheim, Ronald W. Schafer, with John R. Buck. — 2nd ed<br>**2.** Upamanyu Madhow, ``Introduction to Communication Systems," Cambridge university press, 2008 edition. |

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| 1 | **Title of the course** (L-T-P-C) | **Digital Signal Processing and Communications** **(3-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | Signals, Communications and Controls |
| 3 | **Course content** | ● Digital Modulation - Signal constellations, Nyquist's Sampling Theorem and Criterion for ISI Avoidance, Linear modulation Optimal Demodulation – Review of Hypothesis Testing, ML and MAP decision rules, Signal Space Concepts, Optimal Reception in AWGN and performance analysis of various modulation schemes.<br>● DFT and FFT, Digital Filter Design, Analysis and Implementation. |
| 4 | **Texts/References** | **1** Discrete-time signal processing / Alan V. Oppenheim, Ronald W. Schafer, with John R. Buck. — 2nd ed<br>**2** Upamanyu Madhow, ``Introduction to Communication Systems," Cambridge university press, 2008 edition. |

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| 1 | **Title of the course** (L-T-P-C) | **Computational Techniques and Optimisation (1.5-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | Previous exposure to computing systems; strong mathematical background in especially calculus |
| 3 | **Course content** | Introduction to convex functions, types of optimization problems, Linear programming, duality theory and Lagrange formulation of optimization problems, algorithms to solve different optimization problems. Understanding computational systems and computational power, mapping of problem to computational systems, computational performance, introduction to computing platforms, methods to handle large data volumes, parallelisation, etc. |
| 4 | **Texts/References** | **1.** Ian Goodfellow Yoshua Bengio Aaron Courville, Deep Learning, MIT Press, 2016.<br>**2.** Charu Agarwal, "Neural Networks and Deep Learning", Springer, 2018.<br>**3.** Michael Nielsen "Neural Networks and Deep Learning" Open Book. |

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| 1 | **Title of the course** (L-T-P-C) | **Embedded Systems (1.5-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | Previous exposure to computing systems; programming basics necessary |
| 3 | **Course content** | Fundamentals of Embedded and Real-time Systems; Automotive specific performance and computational requirements, real-time constraints, embedded computer architectures, embedded programming fundamentals |
| 4 | **Texts/References** | None. Relevant material will be provided by the ***external instructor*** from datasheets, app notes and manuals. |

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| 1 | **Title of the course** (L-T-P-C) | **Optimization Methods for Wireless Communication and Machine Learning (3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Nil |
| 3 | **Course content** | Introduction to properties of Vectors, Norms, Positive Semi-Definite matrices, Gaussian Random Vectors<br>Introduction to Convex Optimization – Convex sets, Hyperplanes/ Half-spaces, etc<br>**Application**: Power constraints in Wireless Communication Systems<br>Convex/ Concave Functions, Examples, Conditions for Convexity. **Application**: Beamforming in Wireless Systems, Multi-User Wireless, and Cognitive Radio Systems<br>Convex Optimization problems, Linear Programs (interior point method),<br>**Application**: Power allocation in Multi-cell cooperative OFDM<br>QCQP, SOCP Problems, **Application**: Channel shortening for Wireless Equalization, Robust Beamforming in Wireless Systems<br>Duality Principle and KKT Framework for Optimization.<br>**Application**: Optimization for MIMO Systems, OFDM Systems, and MIMO-OFDM systems<br>Optimization for signal estimation, LS, WLS, and Regularization.<br>**Application**: Wireless channel estimation<br>**Application**: Convex optimization for Machine Learning, Principal Component Analysis (PCA), Support Vector Machines<br>**Application**: Cooperative Communication, Optimal Power Allocation for cooperative Communication, Geometric Pro**Optimization Methods for Wireless Communication and Machine Learning** gram, Communication Optimization<br>**Application**: Cooperative Communication, Optimal Power Allocation for cooperative Communication, Geometric Program |
| 4 | **Texts/References** | **References:**<br><br>**1.** Boyd S. and Vandenberghe B., **Convex Optimization**, Cambridge University Press, 2004.<br>**2.** Tse D. and Viswanath P., **Fundamentals of Wireless Communication**, Cambridge University Press, 2005. |

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| 1 | **Title of the course** (L-T-P-C) | **Design of Power Converters (1.5-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | At least one course on Power Electronics at the undergraduate level. Not suitable for candidates with no prior exposure to power electronics. |
| 3 | **Course content** | Introduction to power converter topologies for EV applications, functional and operational constraints, design procedures, introduction to magnetics, thermal and mechanical aspects, packaging |
| 4 | **Texts/References** | None. Relevant material will be provided by the ***external instructor*** from datasheets, app notes and manuals. |

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| 1 | **Title of the course** (L-T-P-C) | **Physics of Transistors** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Not-applicable |
| 3 | **Course content** | Semiconductor Physics Review.<br><br>**The MOS transistor:** MOS Capacitor Fundamentals, Fixed Oxide and Interface Charge Effects, Carrier Transport in MOS capacitor, Basic MOSFET operation, Measurement of MOS transistor parameters, Small Signal Equivalent Circuit, Non-ideal effects, MOSFET scaling and Short channel effects, Advanced MOSFET structures (High-k gate, SOI MOSFET and FinFET), Radiation and Hot-electron effects in transistors, MOSFET reliability, CMOS technology, Charged Coupled Device (CCD).<br><br>**Bipolar transistor:** Basic BJT operation, Minority carrier distribution, Ideal current-voltage characteristics, Non-ideal effects, Base width modulation, High injection, Emitter bandgap narrowing, Current crowding, Nonuniform base doping, Breakdown voltage, Equivalent circuit models, Switching characteristics, Insulated-gate bipolar transistor (IGBT).<br><br>**Heterojunction Transistors:** Heterostructure fundamentals, High electron mobility transistor (HEMT), and Heterojunction bipolar transistor (HBT). |
| 4 | **Texts/References** | **References:**<br><br>1. Tsividis Y. and Mcandrew C., **The MOS Transistor**, New York, Oxford University Press, 2012.<br>2. Taur Y. and Ning T. H., **Fundamentals of Modern VLSI Devices**, 2nd edition, New Delhi, Cambridge University Press, 2009.<br>3. Sze S. M. and Ng K. K., **Physics of Semiconductor Devices**, 3rd edition, New Jersey, John Wiley & Sons, 2007.<br>4. Shur M., **Physics of Semiconductor Devices**, Noida, Pearson, 2019.<br>5. Neamen D. A., **Semiconductor Physics and Technology: Basic Principles**, 4th edition, New York, McGraw Hill, 2012 |

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| 1 | **Title of the course** (L-T-P-C) | **Semiconductor Radiation Detectors** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Not applicable |
| 3 | **Course content** | **Photodetectors:** Optical absorption in Semiconductor, Essential properties of photodetectors, Photoconductor, PiN photodetectors, Schottky Barrier Photodiode, Metal-Semiconductor-Metal (MSM) photodiode, Avalanche Photodiode, State-of-the-art Infra-red (IR) detectors and UV detectors.<br><br>**Radiation Detection:** Interaction of X-rays, gamma-rays, charged particles, and neutrons with semiconductor, Penetration of radiation through Matter, Simplified detector model, Modes of detector operation, Pulse height spectra, Counting curves, Energy resolution, Detection efficiency, Dead time.<br><br>**Detector Physics:** Signal formation and acquisition, Ramo's theorem, Incomplete charge collection due to trapping, Electronic noise, Readout electronics, Energy and radiation-level measurement, Position and energy measurement, Trap characterization in detectors, Radiation induced damage effects in detectors, Application of Silicon, CdZnTe and Diamond detectors.<br><br>**Detector Systems:** Particle trackers, Vertex detectors at Large Hadron Collider, Pixel detectors, Nuclear Instrumentation systems, Astronomical and Medical Imaging detectors. |
| 4 | **Texts/References** | **References:**<br><br>**1.** Bhattacharya P., **Semiconductor Optoelectronic Devices**, 2nd edition, Pearson, 1997.<br>**2.** Knoll G. F., **Radiation Detection and Measurement**, 4th edition, U.S., John Wiley & Sons Inc. 2010.<br>**3**. Lutz G., **Semiconductor Radiation Detectors**, Berlin, Springer, 2007.<br><br>**4**. Spieler H., **Semiconductor Detector Systems**, New York, Oxford University Press, 2005.<br><br>**5**. Tsoulfanidis and Landsberger S., **Measurement and Detection of Radiation**, 4th edition, Bosa Raton, CRC Press, 2015. |

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| 1 | **Title of the course** (L-T-P-C) | **MACHINE LEARNING (ML)** **(1.5-0-3-3)** |
| 2 | **Pre-requisite courses(s)** | Exposure to basic concepts in calculus and probability |
| 3 | **Course content** | Introduction to Machine Learning: What is machine learning? learning approaches: supervised, unsupervised, semi-supervised and reinforcement learning Regression: Linear Regression, Multivariate Regression, Logistic Regression.<br>Clustering: Partitional Clustering, Hierarchical Clustering, Density-based Clustering<br>Kernel methods: Support vector machine<br>Graphical Models: Gaussian mixture models and hidden Markov models Introduction to Bayesian Approach: Bayesian classification, Bayesian Learning, Bayes Optimal Classifier, and Naive Bayes Classifier. |
| 4 | **Texts/References** | **1.** C. Bishop, "Pattern Recognition and Machine Learning," Springer, 2006.<br>**2.** K. P. Murphy, "Machine Learning: A Probabilistic Perspective", MIT Press, 2012.<br>**3.** "Introduction to Machine Learning" wikipedia guide<br>**4.** M. Nielsen "Mathematics and Applications of Machine Learning", online book. |

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| 1 | **Title of the course** (L-T-P-C) | **Power Semiconductor Devices** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Electronic Devices (EE229), Introduction to Power Electronics (EE209) |
| 3 | **Course content** | **Introduction:** Ideal and Typical Power Device Characteristics, Fundamental Material and Carrier Transport Properties, Recombination Life-time, and Breakdown Voltage, Power Electronics Challenges.<br><br>**Diode Rectifiers:** Schottky Rectifiers – Forward Conduction, Reverse Blocking, Device Capacitance, Barrier Height Adjustment, Edge Termination.<br>PiN Rectifiers – Bipolar Current Transport, Switching Performance, Junction-Barrier Schottky (JBS) and Merged pin-Schottky (MPS) Diodes.<br><br>**Power MOSFETs:** Power MOSFET structures such as V-MOSFET, VD-MOSFET and U-MOSFET and their working operation, Blocking Voltage, Specific On-Resistance, and Silicon Power MOSFETs<br>.<br>**Bipolar Power Switching Devices:** Power Bipolar Junction Transistor (BJT), Thyristors and Insulated Gate Bipolar Transistors (IGBTs): Current-Voltage Relationship, Blocking, On-state and Switching characteristics.<br><br>**Wide Bandgap Power Devices:** Introduction to Silicon Carbide (SiC) Power Diodes and MOSFETs, Fundamentals of High-electron Mobility Transistors (HEMTs), Introduction to Gallium Nitride (GaN) - based Power HEMTs, Potential Applications and Challenges. |
| 4 | **Texts/References** | **1.** B. J. Baliga, Fundamentals of Power Semiconductor Devices, 2nd edition, Switzerland, Springer International Publishing AG, 2008.<br>**2.** S. M. Sze, K. K. Ng, Physics of Semiconductor Devices, 3rd edition, New Jersey, John Wiley & Sons Inc., 2007.<br>**3.** Y.C Liang, G. S Samudra, C.-F. Huang, Power Microelectronics: Device and Process Technologies, 2nd edition, Singapore, World Scientific Publishing, 2017.<br>**4.** T. Kimoto, J. A. Cooper, Fundamentals of Silicon Carbide Technology, Singapore, John Wiley & Sons Inc., 2014.<br>**5.** F. Iannuzzo, Modern Power Electronic Devices: Physics, applications, and reliability, UK, The Institution of Engineering and Technology, 2020.<br>**6.** H. Yu, T. Duan, Gallium Nitride Power Devices, Singapore, Pan Stanford Publishing Ptv. Ltd, 2017. |

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| 1 | **Title of the course** (L-T-P-C) | **Advanced topics in signal processing** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Exposure to Signals and systems and/or digital signal processing |
| 3 | **Course content** | Few topics (at least two) out of the following: Multirate systems, time-frequency analysis, detection and estimation, compressive sensing, sparse representation, non-linear signal processing, graph signal processing, deep learning based feature extraction, etc. Some applications like audio processing, financial signal processing, video processing, etc. |
| 4 | **Texts/References** | 1. Mike X. Cohen, "Analyzing Neural Time Series Data: Theory and Practice," The MIT press.<br>2. P. P. Vaidyanathan, "Multirate Systems and Filter Banks," Prentice Hall Signal Processing Series. |

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| 1 | **Title of the course** (L-T-P-C) | **Stochastic Control and Learning for Networked Systems (3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Undergraduate control course, linear algebra, probability |
| 3 | **Course content** | • **Introduction to Nonlinear Systems:** Nonlinear System Dynamics, Lyapunov Stability, Linearization<br>• **Introduction to Optimal Control:** Dynamic Programming, Markov Decision Process, Kalman Filter, Continuous Time Dynamic Programming, Stochastic integration, Introduction to differential games<br>• **Stochastic and Function Approximation:** Stochastic Gradient Descent, Statistical Learning, Linear Regression, Stochastic differential games<br>• **Dynamic Programming and Reinforcement Learning:** Review of Reinforcement learning, Relation between dynamic programming and reinforcement learning, Approximate dynamic programming, stochastic dynamic programming<br>• **Control Structures based on Reinforcement Learning:** Optimal control using synchronous online learning, Synchronous online-learning for zero-sum two player games and multi-player non-zero sum games<br>• **Networked Control System:** Introduction, Characterization and properties of information structures, Stochastic stability, stabilization of Decentralized systems, Agreement in teams and Dynamic Programming Approach under information constraints<br>(**If time permits**): multi-agent reinforcement learning |
| 4 | **Texts/References** | **1.** Hasan Khalil, **Nonlinear Systems**, *Pearson*, 3rd Edition, 2014.<br>**2.** A. E. Bryson, Y. Ho, **Applied Optimal Control: Optimization**, Estimation and Control", *CRC Press*, 2017.<br>**3.** D. Vrabie, K. G. Vamvoudakis, F. L. Lewis, **Optimal Adaptive Control and Differential Games by Reinforcement Learning Principles**, IET, 2013.<br>**4.** Dimitri Bertsekas, **Reinforcement Learning and Optimal Control**, Athena Scientific, 2019.<br>**5.** S. Yuksel, Tamer Basar, **Stochastic Networked Control Systems: Stabilization and Optimization under Information Constraints**, Birkhouser, 2013. |

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| 1 | **Title of the course** (L-T-P-C) | **Theory of Machine Learning**<br>**(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Should have taken probability models and applications or equivalent, exposure to linear algebra, optimization and algorithms. |
| 3 | **Course content** | ● Recap of Probability tools and concentration inequalities, introduction to convex optimization.<br>● Probability Approximately Correct (PAC) model, learning guarantees under finite hypothesis assumption, Infinite hypothesis case: Rademacher complexity, growth function, VC-dimension<br>● Introduction to Perceptron, Support vector machines (SVMs), computing VC dimension and Rademacher complexity for SVM.<br>● Kernel methods: Introduction to Hilbert spaces, Reproducing Kernel Hilbert Spaces (RKHS), kernel algorithm.<br>● On-line learning: Introduction to online setting, prediction with expert advice, halving algorithms, weighted majority and exponential weighted algorithms, bounds and guarantees of these algorithms. |
| 4 | **Texts/References** | **1.** Mehryar Mohri, Afshin Rostamizadeh, and Ameet Talwalkar, **Foundations of Machine Learning**, MIT Press, second edition, 2018.<br>**2.** Yaser S. Abu-Mostafa, Malik Magdon- Ismail, and Hsuan-Tien Lin, **Learning From Data: A short course**, AMLbook.com. |

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| 1 | **Title of the course** (L-T-P-C) | **Formal Communications** **(1.5-0-0-3)** |
| 2 | **Pre-requisite courses(s)** | None |
| 3 | **Course content** | Written communication: Formal Letter writing, Formal email writing, communication etiquette, grammar, comprehension, essay writing, Reading<br>Verbal communication: communication etiquette, comprehension, group discussions, public speaking,<br>Presentations and interpersonal communication, Elevator pitch talks |
| 4 | **Texts/References** | **1.** Wren and Martin "High School English Grammar and Composition"<br>**2.** William strunk Jr. "The elements of style"<br>Sangeeta Sharma and Binod Mishra, "Communication skills for engineersand scientists"<br>**3.** Sangeeta Sharma and Binod Mishra, "Communication skills for engineersand scientists" |

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| 1 | **Title of the course** (L-T-P-C) | **Engineering Electromagnetics** (3-0-0-6) |
| 2 | **Pre-requisite courses(s)** | - |
| 3 | **Course content** | **1.** Review of vector algebra, vector calculus and coordinate systems and transformation<br>**2.** **Electrostatic fields**: Generation of free charge, Coulomb's law, Electric field intensity, Electric flux density, Electric fields in material space, Polarization and bound charges, Gauss' law, Electric potential and its gradient, Boundary or interface conditions, Energy stored in electrostatic fields, Calculation of capacitance, Poisson's equation, Laplace's equation, Uniqueness theorem, and Variable separable method: Solution of Laplace's equation in a bounded structure.<br>**3.** **The steady electric currents**: Conservation of charge, Conductors, Dielectrics, and Lossy Dielectrics, Ohm's law, Current densities: Conduction, Convection, and Displacement currents, Calculation of losses, The Continuity equation and Kirchhoff's current law.<br>**4.** **Magnetostatics**: Magnetic field intensity, Magnetic flux density, The Biot-Savart law, Ampère's law, Magnetic vector potential and its curl, Postulates of magnetostatic fields, Magnetic moments, Magnetic material and their properties, Energy stored in magnetic fields, Calculation of inductance, Magnetic circuits, Boundary conditions, and Forces and torque generated by magnetic fields (Motoring action).<br>**5.** **Time-varying fields**: Faraday's law, Lenz's law, Kirchhoff's voltage law, Motional EMF (Generator action), Induced EMF (Transformer action), Theory of eddy currents, Classical eddy current loss formula, Skin and Proximity effects, Maxwell's equation (point form and integral form), Time-dependent potential functions: Lorentz gauge and Coulomb gauge, and Boundary conditions in electromagnetic fields and the concept of surface currents.<br>**6.** **Electromagnetic waves and propagation**: Plane wave phenomenon and corresponding solution of the electromagnetic wave equation, Electromagnetic spectrum, Concept of transit time delay, The Poynting vector and electromagnetic power density, Propagation of plane wave in materials, and Reflection and transmission of EM waves across a media interface. |
| 4 | **Texts/References** | **1.** N. Ida, "Engineering electromagnetics," Springer-Verlag, New York, 2nd Edition, 2015.<br>**2.** D. J. Griffiths, "Introduction to Electrodynamics," Pearson, 4th Edition, 2015.<br>**3.** M. N. O. Sadiku and S. V. Kulkarni, "Principles of electromagnetics," 6thEdition, Oxford University Press, India, September 2015. |

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| 1 | **Title of the course** (L-T-P-C) | **Control Systems Engineering Laboratory** (0-0-3-3) |
| 2 | **Pre-requisite courses(s)** | Signals & Systems (EE 210) |
| 3 | **Course content** | Experiments based on the contents of the "Control Systems" course.<br>Experiments include modeling of physical systems including DC & Stepper motors, speed & position control of DC & Stepper motors, temperature control, controller design including P, PI, PD and PID controllers. Time permitting, experiments using robotic arms will be introduced. |
| 4 | **Texts/References** | **1.** Norman Nise, Control System Engineering, Wiley, 6th Edition, 2011<br>**2.** K. Ogata, Modern Control Engineering, Pearson, 5th edition, 2010.<br>**3.** Gene Franklin et. al., Feedback Control of Dynamic Systems, 7th Edition, Pearson<br>**4.** B. Kuo, Automatic Control System, Wiley, 9th Edition, 2014 Dorf and Bishop, Modern Control Systems, 8th Edition, Addison Wesley |

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| 1 | **Title of the course** (L-T-P-C) | **Control Systems Engineering**<br>(3-0-0-6) |
| 2 | **Pre-requisite courses(s)** | Signals & Systems (EE 210) |
| 3 | **Course content** | - Basic concepts: Notion of feedback, open- and closed-loopsystems.<br>- Modeling and representations of control systems: Transfer function models for suitable mechanical, electrical, thermal and pneumatic systems, Ordinary differential equations, Transfer functions, Block diagrams, Signal flow graphs, State-space representations.<br>- Performance and stability: Time-domain analysis, Second-order systems, Characteristic equation and roots,Routh-Hurwitz criteria.<br>- Basic modes of feedback control: Proportional, Integral, Derivative.<br>- Root locus method of design.<br>- Frequency-domain techniques: Root-locus methods, Frequency responses, Bode-plots, Gain-margin and phase-margin, Nyquist plots.<br>- Compensator design: Proportional, PI and PID controllers, Lead-lag compensators.<br>- State-space concepts: Controllability, Observability, pole placement result, Minimal representations. |
| 4 | **Texts/References** | 1. Norman Nise, Control System Engineering, Wiley, 6th Edition, 2011.<br>2. K. Ogata, Modern Control Engineering, Pearson, 5th edition, 2010.<br>3. Gene Franklin et. al., Feedback Control of Dynamic Systems, 7th Edition, Pearson.<br>4. B. Kuo, Automatic Control System, Wiley, 9th Edition, 2014<br>Dorf and Bishop, Modern Control Systems, 8th Edition, Addison Wesley. |

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| 1 | **Title of the course** (L-T-P-C) | **Introduction to Modern communication Systems**<br>(2-0-2-6) |
| 2 | **Pre-requisite courses(s)** | Introduction to Probability (EE 221) and Signals & Systems (EE 210) |
| 3 | **Course content** | **Theory:**<br>- Motivation towards designing Analog and Digital Communication Systems<br>- Baseband and passband signals<br>- Analog modulation techniques (Amplitude Modulation and Angle Modulation)<br>- Introduction to Random Processes: Definition, Autocorrelation Functions, Power Spectral Density, Random processes through LTI systems, noise as random processes.<br>- Overview of digital modulation: Signal Constellations, Hypothesis Testing, ML and MAP detection rules, performance analysis of selected digital modulation schemes, and its relevance in 5G and beyond communication systems.<br>**Laboratory:**<br>- Basics of MATLAB: variables, plots, loops, conditional statements<br>- Basic experiments from Signals and Systems: Convolution, LTI systems, power and energy of signals, simulating analog signals on MATLAB<br>- Practical experiments in-line with the course contents covering transmission and reception mechanisms corresponding to analog and digital communication. Introduction to the usage of software defined radios and MATLAB Analog modulation and demodulation<br>- Digital modulation and demodulation – BPSK, QPSK and 16-QAM |
| 4 | **Texts/References** | **(a)** Upamanyu Madhow, "Introduction to Communication Systems," Cambridgeuniversity press, 2008 edition.<br>**(b)** Simon Haykin, "An Introduction to Analogand Digital Communication," Wiley India Pvt. Ltd., 2006.<br>**(c)** B. P. Lathi and Zhi Ding, "Modern Digitaland Analog Communication Systems," Oxford higher education, 2017. |

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| 1 | **Title of the course** (L-T-P-C) | **Fundamentals of Digital Signal Processing** (2-0-2-6) |
| 2 | **Pre-requisite courses(s)** | Signals and Systems (EE 210) |
| 3 | **Course content** | **Lecture:** Review of basic signal processing, and sampling, introduction to DSP, Z transform, DFT, FFT, Implementation of discrete time systems, and Introduction to digital filters.<br><br>**Laboratory:** Overview of DSP kit, generation of waveform, convolution and correlation, DFT and FFT, design of digital filters |
| 4 | **Texts/References** | **1.** Proakis and Manolokis, "Digital Signal Processing," 4thedition, Prentice Hall, 2006.<br>**2.** S K Mitra, "Digital Signal Processing," McGraw Hill, Inc., 4thedition, 2017.<br>**3.** Alan V Oppenheim, "Digital Signal Processing," Prentice Hall,1975. |

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| 1 | **Title of the course** (L-T-P-C) | **Technical Writing** (1.5-0-0-3) |
| 2 | **Pre-requisite courses(s)** | None |
| 3 | **Course content** | LaTeX and plotting tools (Microsoft tools, LaTeXDraw, R, etc.Technical abstract & report writing<br>Professional writing ethics: Plagiarism and citations<br>Technical presentation making: short-duration vs long-duration presentations Technical elevator pitch and poster presentation |
| 4 | **Texts/References** | **1.** A Manual for Writers of Research Papers, Theses, and Dissertations, Kate L Turabian, Ninth Edition, The University of Chicago Press.<br>**2.** Communication Skills for Engineers and Scientists, Sangeeta Sharma and Binod Mishra, Second Edition, PHI Learning.<br>**3.** The elements of style, William Strunk Jr and E White, Fourth Edition, Pearson Education.<br>**4.** New Approach to Research EthicsUsing Guided Dialogue to Strengthen Research Communities, Henriika Mustajoki and Arto Mustajoki, First Edition,Routledge Publications. |

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| 1 | **Title of the course** (L-T-P-C) | **Detection and Estimation Theory**<br>(3-0-0-6) |
| 2 | **Pre-requisite courses(s)** | EE629: Probability Models and Applications |
| 3 | **Course content** | • Structure of statistical reasoning, Introduction to Estimation theory<br>• Quick Pointers to Random variables, vectors, processes, and their relevant statistical description<br>• Estimation: Minimum Variance Unbiased Estimator, Cramer Rao Lower Bound (CRLB) for scalar and vector parameters<br>• Estimation : Maximum Likelihood Estimation (MLE), Maximum A Posteriori Estimation (MAP), Linear Least Squares (LLSE) with examples of Gaussian mixture modeling (GMM) etc.<br>• Detection : Introduction, Neyman Pearson theorem, Binary and Multiple hypothesis testing, Examples<br>• Demonstration of applying above contents to relevant engineering problems |
| 4 | **Texts/References** | 1. H.V. Poor, "An Introduction to Signal Detection and Estimation," Second Edition, Springer, 1998.<br>2. H.L. Van Trees, "Detection, Estimation and Modulation Theory Part I," Second Edition, John Wiley, 1968.<br>3. S.M. Kay, "Fundamentals of Statistical Signal Processing: Detection Theory," First Edition, Prentice Hall, 1998.<br>4. S.M. Kay, "Fundamentals of Statistical Signal Processing: Estimation Theory," First Edition, Prentice Hall, 1998.<br>5. Moulin and Veeravalli, "Statistical Inference for Engineers and Data Scientists", Cambridge university Press, 2019. |

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| 1 | **Title of the course** (L-T-P-C) | **Hardware description with VHDL**<br><br>**(2-0-2-6)** |
| 2 | **Pre-requisite courses(s)** | Digital system design (EE204) |
| 3 | **Course content** | Basic concepts of hardware description languages. Hierarchy, Concurrency, Logic and Delay modelling. Structural, Data-flow and Behavioural styles of hardware description. The architecture of event-driven simulators; Syntax and Semantics of VHDL. Variable and signal types, arrays and attributes. Operators, expressions and signal assignments. Entities, architecture specification and configurations. Component instantiation. Concurrent and sequential constructs. Use of Procedures and functions, Examples of design using VHDL;<br><br>Testbenches and verification : VHDL-2008, Assert statements, Contstrained randomization for random testing, universal verification methologies etc.<br><br>VHDL-AMS: Basics of Analog and mixed mode simulations. Connect rules for AMS simulations, Example designs.<br>Lab component: Example design of digital systems like array multipliers, sequential FSM's, Arithmetic circuits, serial protocol implementations and sub-systems of microprocessors, etc. |
| 4 | **Texts/References** | **1.** The Designer's Guide To VHDL, Peter J. Ashenden, Elsevier; Third edition (1 January 2008), ISBN-13 : 978-8131218556<br>**2.** VHDL: Programming by Example, Douglas Perry, McGraw-Hill Education; 4th edition (1 July 2017), ISBN-13 978-: 0070499447<br>**3.** 1076-2019 - IEEE Standard for VHDL Language Reference Manual, IEEE Language reference manual (available online at https://doi.org/10.1109/IEEESTD.2019.8938196) Dec. 2019<br>**4.** 1076.1-2017 - IEEE Standard VHDL Analog and Mixed Signal Extensions, IEEE Langugage Reference manual (available online at https://doi.org/10.1109/IEEESTD.2018.8267464) Jan. 2018<br>**5.** The System Designer's Guide to VHDL-AMS, Peter J. Ashenden, Morgan Kaufmann Publishers; First Edition (20 September 2004) |

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| 1 | **Title of the course** (L-T-P-C) | **Advanced Digital System Design**<br><br>**(2-0-2-6)** |
| 2 | **Pre-requisite courses(s)** | Digital system design (EE 204) |
| 3 | **Course content** | **Review of Digital Logic Design Fundamentals:** Development and evolution of digital devices, design, and verification tools. Abstraction levels of digital system design. Designing of combinational circuits. Design of sequential circuits- Finite State machine; mealy and Moore machines. Sequential packages.<br>**Overview of PLDs and EDA Software:** Introduction of PLDs, general FPGAs devices, Overview of the hardware platform, Design Development flow, EDA Tools (Integrated software Environment), creation of design project and HDL codes (Verilog or VHDL), test-bench and perform the RTL simulation.<br>**RTL Design with HDLs:** Combinational circuits design and verification, regular sequential circuits and components, Finite state machine (FSM), Finite State Machine with Datapath (FSMD) code development of FSMD- design examples, CPU design, Algorithmic state machine charts (ASM), code conversion of ASM.<br>**Input / Output Modules:**<br>**UART**: Introduction, UART receiving subsystem, Oversampling procedure, Baud rate generator, UART receiver, Interface circuit, UART transmitting subsystem, Overall UART system, Complete UART core, example circuits.<br>**PS2:** Introduction, PS2 receiving subsystem, Device-to-host communication protocol, Design, and code, PS2 keyboard scan code, example circuits.<br>**External SRAM:** Introduction, Specification of SRAM, Architectural Block diagram, Timing parameters, Timing requirement, Design ASMD chart, Timing analysis, HDL implementation, safe and aggressive designs, example circuits.<br>**Customized Hardware and Software:** Special-purpose FSMD, general-purpose microcontroller, embedded microcontrollers.<br>**FPGA Implementation of Digital Circuits**: Constraint file development, synthesis, and implementation of HDL codes. Generation and downloading of the configuration file to a PLD device. |
| 4 | **Texts/References** | ● Mano M. M. and Ciletti M. D., "Digital Design", 6th Ed., Pearson Education, ISBN – 10 9353062012, 2018.<br>● Charles H Roth Jr. , Digital Systems Design Using VHDL, 2nd Ed., CL Engineering; International edition, ISBN - 10. 0534384625, 2008.<br>● Maxfield C. M., "The Design Warrior's Guide to FPGAs – Devices, Tools and Flows", 1st Ed., Newnes (an imprint of Butterworth-Heinemann Ltd ), ISBN 9780750676045, 2005.<br>● Brown S. and Vranesic Z., "Fundamentals of Digital Logic with VHDL Design", 4th Ed., Tata McGraw-Hill Publishing Company Limited, ISBN- 10. 0073529532, 2023.<br>● Pedroni V. A., "Circuit design with VHDL", The MIT Press; 3rd Ed., ISBN-10 0262042649, 2020. |

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| 1 | **Title of the course** (L-T-P-C) | **Electronics system design** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Introduction to analog circuits (EE202), Introduction to Electrical and Electronics Engineering (EE101) |
| 3 | **Course content** | **Module 1:** Review of Linear opamp circuits including amplifiers, filters, integrators, differentiators, current sources etc. Types of opamps and their characteristics including BJT input, JFET input and CMOS input opamps.<br>**Module 2:** Single supply opamp techniques, wide band opamps, oscillators and function generator circuits with opamps including Wein bridge oscillator, quadrature oscillator, Colpitts oscillator, Hartley oscillator, Clapps oscillator, Bubba oscillator etc. Filter designs, Butterworth, Chebyshev filter, higher order filters, practical design constraints. Choosing the right opamp for an application.<br>**Module 3:** Timer circuits, 555 timer, function generator IC's, PWM drivers for motors and displays,<br>**Module 4:** Principles of quantization, sampling rate and quantization noise calculations, Data converter architectures including SAR, integrating, flash and pipelined ADC's and resistive and capacitive DACs. Interfacing of off-the-shelf data converter IC's,<br>**Module 5:** Voltage regulators, line and load regulation, transient behavior. NMOS and NPN output regulators, Low drop out PMOS and PNP output regulators, DC-DC converters. Choosing the right regulator for applications. |
| 4 | **Texts/References** | **1.** Bruce Carter and Ron Mancini, "Op Amps for Everyone", Newnes (an imprint of Butterworth-Heinemann Ltd ); 5th edition, 2017, ISBN-13 : 9780128116487<br>**2.** Ramakant Gayakwad, "Op-Amps and Linear Integrated Circuits", Pearson Education; Fourth edition, 2015, ISBN-13 : 978-9332549913<br>**3.** Operational Amplifiers with Linear Integrated Circuits by William Stanley, Pearson Education; 4th edition (1 January 2004), ISBN-13: 978-8131708453 |

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| 1 | **Title of the course** (L-T-P-C) | **Flexible Electronics** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | NA |
| 3 | **Course content** | Overview of Flexible Electronics Technology. Materials for Flexible and Stretchable Electronics (FSE) Inorganic, Organic and nanomaterials materials. Techniques for Fabrication of FSE: Non-contact and impact printing printable inks, 3D Printing Techniques. Mechanics of Flexible and Stretchable Electronics: Stress and Strain, Flexure rigidity, Bending Radius and Curvature. Flexible Solar Cells: Device Structure and Operational Principle of flexible organic solar cells. Flexible and Stretchable Displays and Thin-Film Transistors (TFTs) Flexible and Stretchable Sensors and actuators: Architectural Strategies for Flexible and Stretchable Sensors Fabrication of Flexible Actuators. Artificial skin and its applications: Mechanical Properties of Skin, Biomimetic Skin Sensations, Applications of Artificial Skin. |
| 4 | **Texts/References** | **1.** William S. Wong and Alberto Salleo- Flexible Electronics: Materials and Application –Springer, 2009, Edition 1. ISBN: 978-1-4419-4494-8<br>**2.** M. M. Hussain and Nazek El-Atab Handbook of Flexible and Stretchable Electronics, CRC Press, 2020, Edition 1. ISBN: 978-1032337692 |

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| 1 | **Title of the course** (L-T-P-C) | **RF and Microwave Devices** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Not applicable |
| 3 | **Course content** | **Diodes:** Point-contact diode, Schottky multipliers & Varactors, Step recovery diode, Transferred electron effect, Gunn diode, Avalanche Transit Devices IMPATT and TRAPATT, Tunnel diode, Resonant tunneling diode.<br>**RF MOSFET**: Basics of RF CMOS, LDMOS – device physics, transport, breakdown, On resistance, snapback, LDMOS - layout & design, bond pad manifold, frequency aspects, concept of RESURF.<br>**MESFET:** Physics and transport, I-V, load line, transconductance, Intro to JFOM, GaAs MESFET, and SiC MESFET.<br>**HFET:** Heterostructure physics, modulation doping & formation of 2DEG, breakdown, gain, traps, dispersion, GaAs pseudomorphic HEMT (pHEMT), Basics of III-nitrides and polarization, GaN HEMT - benefits of WBG, various aspects of GaN RF HEMT such as substrate, processing, multi-finger devices, dispersion & virtual gate, leakage, trapping effect, self-heating effect.<br>**HBT:** Working of HBT, Early Effect, Kirk Effect, Gain, Common Emitter & Common Base mode, Small-signal model, SiGe HBT and GaAs HBT.<br>**Microwave concepts for devices**: S-parameters & 2-port analysis, concept of impedance, Introduction to Smith chart, de-embedding parasitics, derivation of cut-off frequencies and MAG/MSG, Transmission lines & waveguides, concept of impedance matching, Basics of RF device packaging and thermal management Introduction to RF power amplifier (RFPA), and Monolithic Microwave Integrated Circuit (MMIC). |
| 4 | **Texts/References** | **1.** S. Yngvesson, Microwave Semiconductor Devices, Springer, 1991.<br>**2.** M. Golio, RF and Microwave Semiconductor Device Handbook, CRC Press, 2003.<br>**3.** I. J. Bahl, Fundamentals of RF and Microwave Transistor Amplifiers, John Wiley & Sons Inc., 2009.<br>**4.** S. M. Sze, K. K. Ng, Physics of Semiconductor Devices, 3rd edition, John Wiley & Sons Inc., 2007. S. Y. Liao, Microwave Devices and Circuits, 3rd edition, Pearson, 2012.<br>**5.** J. Walker, Handbook of RF and Microwave Power Amplifiers, Cambridge University Press, 2012. |

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| 1 | **Title of the course** (L-T-P-C) | **Optical Communication** **( 3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | EE 210: Signals and Systems, EE 221: Introduction to Probability,<br>EE 309: Introduction to Communication System |
| 3 | **Course content** | **Introduction to Optical Communication**<br>● Overview of optical communication systems<br>● Historical development and milestones<br>● Advantages and limitations of optical communication<br>**Optical Fibers**<br>● Basics of optical fibers<br>● Fiber types and materials<br>● Fiber fabrication techniques<br>● Fiber optic cables and connectors<br>**Light Sources and Detectors**<br>● Light sources: LEDs and lasers<br>● Detector types: photodiodes, avalanche photodiodes<br>● Optical amplifiers: EDFA, Raman amplifiers<br>**Modulation Techniques**<br>● Direct modulation<br>● External modulation: Mach-Zehnder modulator<br>● Coherent modulation: Phase shift keying (PSK), Quadrature amplitude modulation (QAM)<br>**Multiplexing in Optical Communication**<br>● Time division multiplexing (TDM)<br>● Wavelength division multiplexing (WDM)<br>● Space division multiplexing (SDM)<br>**Transmission Impairments**<br>● Attenuation and dispersion<br>● Nonlinear effects: self-phase modulation, four-wave mixing<br>● Polarization effects<br>**Optical Communication System Design**<br>● Link budget analysis<br>● Receiver sensitivity and system performance<br>● System design considerations: power budget, signal-to-noise ratio (SNR), bit error rate (BER)<br>**Advanced Topics and Emerging Trends**<br>● Coherent detection and digital signal processing<br>● Optical networking: SDN, ROADM<br>● Free-space optical communication<br>● Quantum communication and cryptography |
| 4 | **Texts/References** | **1**. Optical Communication Systems by John Gowar, Springer - 2nd Edition (2022)<br>**2**. Fiber-Optic Communication Systems by Govind P. Agrawal, Wiley - 5th Edition (2021)<br>**3**. Optical Fiber Communications: Principles and Practice by John M. Senior and M.Y. Jamro, Pearson - 4th Edition (2020)<br>**4.** Optical Fiber Communications by Gerd Keiser, McGraw-Hill Education - 5th Edition (2013)<br>**5.** Optical Fiber Communication by John M. Senior, Prentice Hall - 3rd Edition (2008) |

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| 1 | **Title of the course** (L-T-P-C) | **Optical Networks: Principles and Applications**<br>**(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Optical Communication |
| 3 | **Course content** | **Introduction to Optical Networks**<br>• Overview of optical network evolution<br>• Basics of network architectures: SONET/SDH, WDM, DWDM<br>•Optical network components: switches, routers, transceivers Wavelength Division Multiplexing (WDM) Networks<br>• Principles of WDM and DWDM<br>• Network topologies and configurations<br>• Optical amplifiers and dispersion compensation<br>**Reconfigurable Optical Add-Drop Multiplexing (ROADM) Networks**<br>• Introduction to ROADM architectures<br>• Flex-grid and fixed-grid ROADMs<br>• Control plane protocols: GMPLS, RSVP-TE<br>**Routing and Wavelength Assignment (RWA)**<br>• RWA algorithms: static vs. dynamic<br>• Dynamic routing protocols: Dijkstra, shortest path<br>• Load balancing and congestion management<br>**Optical Network Security**<br>• Threats to optical networks: eavesdropping, interception • Encryption and authentication techniques<br>• Key management and secure key exchange protocols<br>**Optical Network Design, Performance Evaluation and Optimization**<br>• Optical Network Design<br>• Network performance metrics: throughput, latency, availability • Performance Modeling and simulation techniques<br>• Optimization approaches: traffic engineering, resource allocation Emerging Trends in Optical Networking<br>• Software-Defined Networking (SDN) for optical networks • Network Function Virtualization (NFV)<br>• Quantum communication and quantum networking |
| 4 | **Texts/References** | **1.** Fiber-Optic Communication Systems by Govind P. Agrawal, Wiley - 5th Edition (2021)<br>**2.** Optical Communications: Advanced Systems and Devices for Next Generation Networks edited by Alberto Paradisi, Rafael Carvalho Figueiredo, and Andrea Chiuchiarelli, Springer - 1st Edition (2022).<br>**3.** Optical WDM Networks: Principles and Practice edited by Krishna M. Sivalingam and Suresh Subramaniam, Springer - 1st Edition (2020).<br>**4**. Optical Networks: A Practical Perspective by Rajiv Ramaswami and Kumar N. Sivarajan, Morgan Kaufmann - 3rd Edition (2009) |

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| 1 | **Title of the course** (L-T-P-C) | **Wireless Optical Communications** **(3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | Optical Communication |
| 3 | **Course content** | **Introduction to Wireless Optical Communications**<br>• Overview of wireless optical communication systems<br>• Comparison with other wireless communication technologies • Applications and challenges in wireless optical communication **Optical Wireless Channel Modeling**<br>• Atmospheric channel modeling<br>• Indoor and outdoor channel characteristics<br>• Scattering and absorption effects<br>**Modulation and Coding Techniques**<br>• Pulse Position Modulation (PPM)<br>• On-Off Keying (OOK)<br>• Coding schemes: FEC, Turbo codes, LDPC codes<br>**Multiple Access Schemes**<br>• Time Division Multiple Access (TDMA)<br>• Frequency Division Multiple Access (FDMA)<br>• Code Division Multiple Access (CDMA)<br>**Link Optimization in Wireless Optical Communication**<br>• Link budget analysis<br>• Receiver design and sensitivity<br>• Diversity techniques: spatial diversity, polarization diversity **Network Architectures and Protocols**<br>• Point-to-point and point-to-multipoint systems<br>• Hybrid optical wireless and RF systems<br>• MAC protocols for wireless optical networks<br>**Emerging Trends and Applications**<br>• Li-Fi (Light Fidelity) technology<br>• Underwater optical wireless communication<br>• Space-based optical communication<br>**Advanced Topics and Project**<br>• Advanced modulation and coding techniques<br>• Research project |
| 4 | **Texts/References** | **1.** Advanced Optical and Wireless Communications Systems by Ivan B. Djordjevic, Springer - 1st Edition (2023)<br>**2.** Optical Wireless Communications: An Emerging Technology by Zabih Ghassemlooy, Anthony Boucouvalas, and Eszter Udvary, Springer - 1st Edition (2022)<br>**3.** Optical Wireless Communications: System and Channel Modelling with MATLAB by Z. Ghassemlooy, W. Popoola, and S. Rajbhandari, CRC Press - 2nd Edition (2019)<br>**4.** Principles of LED Light Communications: Towards Networked Li-Fi by P. S. Chowdhury and S. Ghosh, Cambridge University Press - 1st Edition (2018) |

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| 1 | **Title of the course** (L-T-P-C) | **Modelling and Control of Inverter-based Resources for Grid Integration (3-0-0-6)** |
| 2 | **Pre-requisite courses(s)** | • Intro to Power Systems (EE 223)<br>• Intro to Power Electronics (EE 209)<br>• Control Systems and Laboratory (EE 226) |
| 3 | **Course content** | A. **Modelling of Inverter-based Resources (IBRs)**<br>- Introduction to renewable energy and distributed energy technologies. - Modelling of Solar PV Systems: PV cell, I-V characteristics, MPPT, PV based systems,<br>- Modelling of Wind Energy Systems: Wind energy, conversion systems power in wind, maximum efficiency, efficiency vs turbine speed, Type 1-4 wind energy conversion systems, modelling of type 3 and type 4. - Modelling of battery energy storage systems. Estimation of SoC. - Modelling of Hydrogen Electrolyzer Systems: Electro-chemical model, Modeling of DC DC buck converter and AC DC rectifier.<br>**B. Control of Inverter-based Resources (IBRs)**<br>- Introduction: Basic Control Principles in Power Electronics: Analog and Digital Control Design, Design and Control of Voltage Source Converters (both single-phase and three-phase) With LCL-Filters.<br>- Grid Synchronization of Inverters: Single-phase synchronizations, Three phase synchronizations, Phase-locked Loop (PLL), Frequency-locked Loops (FLLs), Open-loop synchronization.<br>- Control in Various Reference Frames: Natural reference (abc-) frame, Stationary reference frame (αβ-), Synchronous reference (dq-) frame, Overview of linear controllers (P, PI, PD, PID, PR, Repetitive etc.).<br>- Control of Grid-Following Inverters: Outer Power and DC voltage control, Inner current control. Inertia Emulation Techniques,<br>- Control of Grid-Forming Inverters: Droop control, Virtual Synchronous Machine (VSM) control, Power Synchronization Control (PSC), Synchronverter, dispatchable Virtual Oscillator Control (dVOC), Cross Forming Control, Inner Voltage and Current Control, Over-current issues and mitigation techniques - Direct, Indirect and Hybrid Methods.<br>- Grid Ancillary Services by Inverters: Concept of Grid Supporting Inverters, Active and Reactive Power Control, Voltage and Frequency control, Fault Ride Through (LVRT and HVRT), Frequency Ride Through, Anti Islanding Detection, Power Quality Analysis, Knowledge about IEEE 1547, IEEE 2800-2022 and Indian Grid Codes. |

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| 4 | **Texts/References** | 1) Anaya-Lara, Jenkins, Ekanayake, Cartwright and Hughes, "Wind Energy Generation Modelling and Control" 1st Edison, Wiley, 2009. 2) Gilbert M. Masters, "Renewable and Efficient Electric Power Systems", 1st Edison, Wiley Interscience, 2004.<br>3) Frede Blaabjerg, "Control of Power Electronic Converters and Systems," in Academic Press, - (Volume 1 and 2), 1st Edition, 2018, - (Volume 3), 1st Edition, 2021.<br>4) Nilanjan Chaudhuri, Balarko Chaudhuri, Rajat Majumder, and Amirnaser Yazdani, "Multi-terminal Direct-Current Grids: Modeling, Analysis, and Control", 1st Edition, 2014.<br>5) Amirnaser Yazdani, "Voltage-Sourced Converters in Power Systems: Modeling, Control, and Applications", in Wiley-IEEE Press, 1st Edition, 2010. 6) IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBR) Interconnecting with Associated Transmission Electric Power Systems," IEEE Standard 2800-2022, 2022.<br>7) "IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces-- Amendment 1: To Provide More Flexibility for Adoption of Abnormal Operating Performance Category III," in IEEE Std 1547a-2020 (Amendment to IEEE Std 1547-2018), vol., no., pp.1-16, 15 April 2020.<br>8) https://cercind.gov.in/2022/draft_reg/Draft-IEGC-07062022.pdf |

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| 1 | **Title of the course** (L-T-P-C) | **Information theory**<br>**3-0-0-6** |
| 2 | **Pre-requisite courses(s)** | Introduction to Probability (EE221) |
| 3 | **Course content** | • Introduction: Revision of probability theory, revision of basic digital communications, motivation to information theory.<br>• Statistics and information theory: Hypothesis testing, estimation theory, and its connection to information theory. Motivation to entropy, KL divergence etc.<br>• Introduction to basic tools and concepts in information theory: Entropy and mutual information, Chain rules and inequalities, Data processing, Fano's inequality, Asymptotic equipartition property, Entropy rate<br>• Source coding: Source coding and Kraft inequality, Optimal code length and roof code, Huffman codes, Shannon-Fano-Elias and arithmetic codes, Maximum entropy<br>• Channel capacity: Channel coding theorem, joint typicality, Proof of channel coding theorem, Hamming codes and its properties.<br>• Continuous channel case: Differential entropy, Gaussian channel, Parallel Gaussian channel and water-filling, High-level introduction to rate distortion theory.<br>• Inequalities: Lower bounds on mutual information, entropy power inequality etc.<br>• Applications of Information theory: Lower bounds for minimax problems using Assouad, Le Cam and Fano, applications in linear regression problems, other applications of information theory in Machine Learning (ML). |
| 4 | **Texts/References** | • T. Cover, and J. Thomas, “Elements of Information Theory,” Second Edition, Wiley-Interscience, 2006. ISBN: 9780471241959.<br>• Mackay, D. J. C. "Information Theory, “Inference and Learning Algorithms,” Cambridge: Cambridge U, " 2004.<br>• Robert B. Ash, “Information theory,” Courier corporation, 2012. |