MODEL CURRICULUM

of

Engineering & Technology PG Courses

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

Specialisation in:
Internet of Things (IoT)
&
Sensor System

ALL INDIA COUNCIL FOR TECHNICAL EDUCATION

M. Tech. (Electronics & Telecommunication) Specialization: IoT and Sensor System

Semester I

Sr. No.	Course Code		Scheme of Studies			Credits
			L	T	P	
1	M-EC101	Introduction to IoT	3	0	0	3
2	M-EC102	Principles of Sensors and Signal Conditioning	3	0	0	3
3	M-ECElv101	Program Elective - I	3	0	0	3
4	M-ECElv102	Program Elective - II	3	0	0	3
5	M-ECEL101	Advanced Embedded System Lab	0	0	4	2
6	M-ECEL102	Sensors' Lab	0	0	4	2
7	M-ECER101	Research Methodology and IPR	2	0	0	2
8	M-ECA 101	Audit course 1	2	0	0	0

Semester II

Sr. No.	Course Code	Course Name	Scheme of studies per week			Credits
			L	T	P	
1	M-EC201	Microcontrollers for IoT Prototyping	3	0	0	3
2	M-EC202	Signal Processing and Data Analysis	3	0	0	3
3	M-ECElv201	Program Elective – III	3	0	0	3
4	M-ECElv201	Program Elective – IV	3	0	0	3
5	MECEL201	IoT and application Lab	0	0	4	2
6	MECEL202	Signal Processing and ML Lab	0	0	4	2
7	MECEP201	Mini Project	2	0	0	2
8	MECA201	Audit course 2	2	0	0	0

Semester III

Sr. No.	Course Code	Course Name Credits	Scheme of Studies Periods Per Week			
				L	**T**	**P**
1.	M-ECElv301	**Elective – V**	**3**	**0**	**0**	**03**
2.	M-OECElv301	Open Elective – 1	3	0	0	03
3.	M-ECED301	Dissertation Phase – I	0	0	20	10

Semester IV

Sr. No.	Course Code		Scheme of Studies Periods Per Week			
		Course Name Credits	**L**	**T**	**P**	
1.	MECED302	Dissertation Phase – II	0	0	32	16

Program Elective Subjects:

1. **Advanced Wireless Communication**
2. **RF and Microwave Sensors**
3. **Biomedical Sensors**
4. **Deep learning - An approach to AI**
5. **Automatic Sensors and In-vehicle Networking**
6. **Fiber Optics Sensors and Photonics**
7. **Data Science**
8. **Advance Machine Learning**
9. **Advance Semiconductor devices**
10. **Smart Sensors and IOT**
11. **Advance Statistical Methods**
12. **Semiconductor Manufacturing**
13. **Artificial Intelligence**
14. **Chemical and Environmental Sensors**
15. **Machine Learning for Communication Systems**
16. **Python Programming**
17. **Audio Processing**

List of Core Subjects:

1. **Introduction to IoT**
2. **Principle of Sensors and Signal Conditioning**
3. **Microcontrollers for IoT prototyping**
4. **Signal Processing and Data Analysis**
5. **Data Communication and Networking**
6. **Wireless Sensor Network and IoT**

Audit courses:

1. **English for Research Paper Writing**
2. **Pedagogy Studies**
3. **Value Education**
4. **Constitution of India**
5. **Software Tools and Application**

List of Laboratory:

1. **Sensors and Application Lab**
2. **Advanced Embedded System Lab**
3. **IoT Application Lab**
4. **Signal Processing and ML Lab**

Open Elective Course:-

Course Title	Hrs. /Week L: T: P	Credits
1. Optimization Techniques 2. Real Time Operating Systems 3. Robotics 4. Microwave Devices and Circuits 5. Electrical Machine 6. Satellite Communication 7. IC Technology 8. Advanced Control system 10. Reverse Engineering. 11. Yoga and Sports science. 12. Cyber Security. 13. Material Science. 14. Microelectronics 15. Human Values and professional ethics. 16. Operation research 17. Big data analytics 18. Electric Vehicles 19. Renewable Energy 20. Information and communication technology (ICT) 22. Software Engineering. 23. VLSI 24. Pattern Recognition 25. Integrated optics and photonic system 26. Radar Engineering 27. Mixed Signal Circuit Design 28. Low Power VLSI Design 29. Secure Communication 30. Machine Learning 31. Object Oriented Programming (C++) 33. Deep Learning 34. Smart Farming 35. Concurrent Engineering 36. Communication System and Sensor 37. Military Electronics System Engineering.	3:0:0 (ALL SUBJECTS)	3

Course Syllabus

Course Code	Course Title	L	T	P	C
M-EC101	**Introduction to IoT**	**3**	**0**	**0**	**3**

Course Contents:

Module 1 : **8 hours**

IoT Introduction and Fundamentals: Deciphering the term IoT Applications where IoT can be deployed Benefits/Challenges of deploying an IoT, IoT components: Digital Signal Processing, Data transmission, Choice of channel (wired/wireless), back-end data analysis. Understanding packaging and power constraints for IoT implementation.

Module 2: **9 hours**

Signals, Sensors, Actuators, Interfaces : Introduction to sensors & transducers, Introduction to electrodes & biosensors, Static and dynamic characteristics of sensors, Different types of sensors, Selection criteria's for sensors / transducers, Signal conditioning modules of IoT system , Energy and power considerations, Introduction to actuators, Different types of actuators, Interfacing challenges, Modules of data acquisition system, Wireless sensor node structure, positioning topologies for IoT infrastructure.

Module 3: **8 hours**

Communication and Networking in IoT, Modern networking: Review of Communication Networks, Challenges in Networking of IoT Nodes, range, bandwidth Machine-to-Machine (M2M) and IoT Technology Fundamentals, Medium Access Control (MAC) Protocols for M2M Communications Standards for the IoT Basics of 5G Cellular Networks and 5G IoT Communications, Low-Power Wide Area networks (LPWAN)Wireless communication for IoT: channel models, power budgets, data rates.Networking and communication aspects: IPv6, 6LoWPAN, COAP, MQTT, Operating Systems need and requirements for IoT.

Module 4: **10 hours**

Cloud computing, IoT Data analytics and Security and IoT Applications: Introduction to the Cloud Computing, History of cloud computing, Cloud service options, Cloud Deployment models, Business concerns in the cloud, Hypervisors, Comparison of Cloud providers, Cloud and Fog Ecosystem for IoT Review of architecture OLAP and OLTP, NoSQL databases, Row and column Oriented databases, Introduction to Columnar DBMS CStore , Run :Length and Bit vector Encoding, IoT Data Analytics. Cryptographic algorithms, Analysis of Light weight Cryptographic solutions IoT security, Key exchange using Elliptical Curve Cryptography, Comparative analysis of Cryptographic Library for IoT. IoT applications like Home Automation, Precision Agriculture, Smart vehicles, Smart Grid, Industry 5.0.

Text/Reference Books

1. Arshdeep Bahga and Vijay Madisetti , "Internet of Things, a hands on approach" , Universities Press (India) Pvt. Ltd. 2017.
1. Rajkumar Buyya, Amir Vahid Dastjerdi, "Internet of Things Principles and Paradigms"Copyright © 2016 Elsevier Inc.
3. William Stallings, " Foundations of Modern Networking: SDN, NFV, QoE, IoT, and Cloud" Publisher: Addison-Wesley 2015

Course Code	Course Title	L	T	P	C
M-EC102	**Principles of Sensors and Signal Conditioning**	**3**	**0**	**0**	**3**

Module: 1

Sensor fundamentals and characteristics **2 hours**

Sensor Classification, Performance and Types, Error Analysis characteristics

Module: 2

Optical Sources and Detectors and Intensity Polarization and InterferometricSensors **5 hours**

Electronic and Optical properties of semiconductor as sensors, LED, Semiconductor lasers,Fiber optic sensors, Thermal detectors, Photo multipliers, photoconductive detectors, Photo diodes, Avalanche photodiodes, CCDs.

Intensity sensor, Microbending concept, Interferometers, Mach Zehnder, Michelson, Fabry-Perot and Sagnac, Phase sensor: Phase detection, Polarization maintaining fibers.

Module:3

Strain, Force, Torque and Pressure sensors **5 hours**

Strain gages, strain gage beam force sensor, piezoelectric force sensor, load cell, torque sensor, Piezo-resistive and capacitive pressure sensor, optoelectronic pressure sensors, vacuum sensors. Design of signal conditioning circuits for strain gauges, piezo, capacitance and optoelectronics Sensors

Module:4

Position, Direction, Displacement and Level sensors **4 hours**

Potentiometric and capacitive sensors, Inductive and magnetic sensor, LVDT, RVDT, eddy current, transverse inductive, Hall effect, magneto resistive, magnetostrictive sensors. Fiber optic liquid level sensing, Fabry Perot sensor, ultrasonic sensor, capacitive liquid level sensor. Signal condition circuits for reactive and self generating sensors.

Module:5

Velocity and Acceleration sensors and Flow, Temperature and Acoustic sensors 5 **hours**

Electromagnetic velocity sensor, Doppler with sound, light, Accelerometer characteristics,capacitive, piezo-resistive, piezoelectric accelerometer, thermal accelerometer, rotor, monolithic and optical gyroscopes.

Module:6

Flow sensors: pressure gradient technique, thermal transport, ultrasonic, electromagnetic andLaser anemometer. microflow sensor, coriolis mass flow and drag flow sensor. Temperature sensors-thermoresistive, thermoelectric, semiconductor and optical. Piezoelectric temperaturesensor. Acoustic sensors- microphones-resistive, capacitive, piezoelectric, fiber optic, solid state -electrect microphone.

Text Book(s)

1. Jacob Fraden, "Hand Book of Modern Sensors: physics, Designs and Applications", 2015, 3rd edition, Springer, New York.
2. Jon. S. Wilson, "Sensor Technology Hand Book", 2011, 1st edition, Elsevier, Netherland.

Reference Books

1. GerdKeiser,"Optical Fiber Communications", 2017, 5th edition, McGraw-Hill Science, Delhi.
2. John G Webster, "Measurement, Instrumentation and sensor Handbook", 2017, 2nd edition, CRC Press, Florida.
3. Eric Udd and W.B. Spillman, "Fiber optic sensors: An introduction for engineers and scientists", 2013, 2nd edition, Wiley, New Jersey.
4. Bahaa E. A. Saleh and Malvin Carl Teich, "Fundamentals of photonics", 2012, 1st edition, John Wiley, New York.

Course Code	Course Title	L	T	P	C
M-EC201	**Microcontrollers for IoT Prototyping**	**3**	**0**	**0**	**3**

Module:1 MSP430 microcontrollers: 6 hours

Architecture of the MSP430, Memory, Addressing modes, Reflections on the CPU instruction set.Clock system, Exceptions: Interrupts and resets. Functions and subroutines, Mixing C and assembly language, Interrupts, Interrupt service routines, Issues associated with interrupts, Low-power modes of operation.

Module:2 ARM Cortex MX microcontroller 6 hours

ARM Cortex M4: Assembly language basics, Thumb-2 Technology, ARM Instruction set, CortexM4 architecture, advantages, peripherals, instruction set, floating point operations, Advanced Cortex MX Microcontroller, core, architecture, on-chip wi-fi.

Module:3 : Display and Communication modules 4 hours

GPIO, LCD display, graphical display, relays, Peripheral programming SPI, I2C, UART, Zigbee controller.

Module:4 : Sensors interfacing 4 hours

Sensors interfacing techniques- Port Programming, ADC, SPI thermometer, I2C thermometer, PWM generation and demodulation, DTH11, single wire thermometer, Frequency counters.

Module:5: Microcontrollers for IoT 2 hours

ESP8266,NodeMCU,TI-CC3200,Access point and station point mode, HTTP, MQTT, transmission and receiving, Intel-Gallileo boards.

Module:6 Single board computers **4 hours**

Raspberry pi board, porting Raspbian, sensor interface examples, Python programming for cloud access, sensor systems using Arduino boards

Module:7 : Cloud interfacing **2 hours**

Interfacing and data logging with cloud: Thing speak, Things board, Blync platform.

Text Book(s)

1. John H. Davies, "MSP430 Microcontroller Basics", 2011, 2nd ed., Newnes publishing, New York.
2. Jacob Fraden, "Hand Book of Modern Sensors: physics, Designs and Applications", 2014, 4th ed., Springer, New York.

Reference Book(s)

1. Sergey Y. Yurish,"Digital Sensors and Sensor Systems: Practical Design", 2011, 1st ed., IFSA publishing, New York.
2. Jonathan W Valvano, "Introduction to ARM Cortex –M3 Microcontrollers", 2012, 5th ed.,Create Space publishing, New York.
3. Muhammad Ali Mazidi, Shujen Chen, SarmadNaimi, SepehrNaimi, "TI ARM Peripherals Programming and Interfacing: Using C Language", 2015, 2nd ed., Mazidi and Naimi publishing, New York.

Course Code	Course Title	L	T	P	C
M-EC202	Signal Processing and Data Analysis	3	0	0	3

Syllabus

Module:1 **2 hours**

Random Processes, Gaussian Process- Multi variate Gausssian Process, Stationary process, Autocorrelation, Auto Covariance, Ergodicity, White noise, Power Spectrum, Filtering of Random Process. ARMA, AR, MA Models.

Module:2 **3 hours**

Wiener filter, Linear prediction, Kalman Filter. FFT, DCT, filter banks, Wavelet, Wavelet Packets, Cepstrum. Univariate, Multivariate and nonstationary time series analysis. Bayesian decision, Linear discrimination,Principal Component analysis, SVD, Independent Component Analysis.

Module:3 **2 hours**

Supervised learning, generative algorithms, Support Vector machines, Unsupervised learning, K means clustering, Neural network (SOM, ART), Expectation maximization.

Module:4 **3 hours**

Introduction to Big data analytics, visualization and data exploration, basic and intermediate analysis, linear and logistic regression, decision tree.

Program Elective Subjects:

Course Code	Course Title	L	T	P	C
M-ECElv	**Advanced Wireless Communication**	**3**	**0**	**0**	**3**

Module-1 **3 hours**

Basics of single-user System, Diversity System, Multiple-Input-Multiple-Output (MIMO) communications – Channel models, outage capacity, ergodic capacity – Diversity techniques: time, frequency, space and diversity combiners – Precoding for spatial multiplexing, optimum, linear and nonlinear receivers – Space-time coding and MIMO decoding

Module-2 **3 hours**

Fading Channels, Different Fading Models, Advanced Fading Models, Design of a mathematical fading model, Introduction to Mathematica Soft., Basic of Communication and Signal Processing MATLAB Tool Box, Random variables and Channel Design, Design and analysis of Wireless Communication Channels in fading environment.

Module-3 **4 hours**

The 5G architecture: Introduction, NFV and SDN, Basics about RAN architecture, High-level requirements for the 5G architecture, Functional architecture and 5G flexibility, Functional split criteria, Functional split alternatives, Functional optimization for specific applications, Integration of LTE and new air interface to fulfil 5G Requirements, Enhanced Multi-RAT coordination features, Physical architecture and 5G deployment.

Module-4 **4 hours**

Emerging techniques and applications in 5G – Recent advances in MIMO: massive MIMO and millimeter wave MIMO – Internet of Things (IoT) networks and Low Power Wide Area Network (LPWAN) technologies (Lora, SigFox, LTE-M, EC-GSM-IoT, NB-IoT) – Other topics: Caching, Device-to-device (D2D) communications, Massive IoT, Ultra-Reliable Low-Latency Communication (URLLC), Green and energy efficient communications, Mobile Cloud/Edge/Fog computing and C-RAN architectures.

Text Book/Reference Book:

- D. Tse and P. Viswanath, “Fundamentals of wireless communication”, 2005.
- R. W. Heath Jr. and A. Lozano, “Foundations of MIMO Communication”, 2018.
- T.L. Marzetta, E.G. Larsson, H. Yang, H.Q. Ngo, “Fundamentals of Massive MIMO”, 2016.
- 5G Mobile and Wireless Communications Technology Afif Osseiran, Jose F. Monserrat, Patrick Marsch, Cambridge University Press, Second Edition 2011
- 5G NR: The Next Generation Wireless Access Technology, Erik Dahlman, Stefan Parkvall, Johan Sko¨ld, Elsevier First Edition 2016

Course Code	Course Title	L	T	P	C
M-ECElv	**RF and Microwave Sensors**	**3**	**0**	**0**	**3**

Module:1 **3 hours**

RF Sensors : Microwave Antenna-Introduction, types of Antenna, fundamental parameters of antennas,radiation mechanism, Fresnel and Fraunhofer regions. Antenna for communication and Antenna for sensing, radiometer and radar

Module:2 : **4 hours**

Antenna for personal area communication: Concepts of Printed Antennas, Broadband Microstrip Patch Antennas, Antennas for WearableDevices, Design Requirements, Modeling and Characterization of Wearable Antennas, WBAN Radio Channel Characterization and Effect of Wearable Antennas, Domains of Operation, Sourceson the Human Body, Compact Wearable Antenna for different applications.

Module:3 : **2 hours**

Radar: Introduction to RADAR, RADAR range equation, MTI and pulse Doppler RADAR, Tracking**,** RADAR, SAR pulse RADAR, CW RADAR

Module:4 : **3 hours**

Applications of Radar: Automotive, remote sensing, agriculture, medicine, detection of buried objects, NDT, defense factors affecting the performance of RADAR, RADAR transmitters, Receivers,

Module:5 : **2 hours**

Radiometers: Radiative transfer theory, SMMR, Types of radiometers - and Bolometers, Applications in automotive, agriculture, medicine, weather forecasting

Module:6: **3 hours**

Microwave power Sensors: Diode Sensors: Diode detector principles, dynamic range average power sensors, signal waveform effects on the measurement uncertainty of diode sensors. Thermocouple Sensors: Principles ofThermocouple sensor, power meters for thermocouple sensors.

Module:7 : **2 hours**

RFID Sensors: Introduction, Components of RFID systems, hardware and software components, RFID standards, RFID applications.

Text Book(s):

1. Finkenzeuer Klaus, “RFID Handbook”, 2011, 3rd edition, John Wiley and Sons, New Jersey.
2. Constantine A. Balanis, “Antenna Theory Analysis and Design”, 2016, 4th edition, John Wiley and Sons, New Jersey.

Reference Books

1. B. Hoffman - Wellenhof, H.Lichtenegger and J.Collins, "GPS: Theory and Practice ", 5th edition, Springer, New York, 2012.

2. Lillesand & Kiefer, "Remote Sensing and Image Interpretation", 2011, 6th edition, John Wiley and Sons, New Jersey.

Course Code	Course Title	L	T	P	C
M-ECElv	**Biomedical Sensors**	**2**	**0**	**2**	**3**

Module:1 : Biopotential Electrodes **3 hours**

Origin of bio potential and its propagation. Electrode-electrolyte interface, electrode–skin interface, half-cell potential, impedance, polarization effects of electrode – nonpolarizable electrodes. Types of electrodes - surface, needle and micro electrodes and their equivalent circuits.
Recording problems - measurement with two electrodes.

Module:2 : EEG, EMG & ECG **3 hours**

Bio signal characteristics – frequency and amplitude ranges. ECG – Einthoven's triangle, standard 12 lead system. EEG – 10-20 electrode system, unipolar, bipolar and average mode. EMG– unipolar and bipolar mode. EEG- procedure, signal artefacts, signal analysis, evoked potential,
EMG- procedure and signal analysis, Nerve conduction study

Module:3 : Bio Amplifiers **3 hours**

Need for bio-amplifier - single ended bio-amplifier, differential bio-amplifier – right leg driven ECG amplifier. Band pass filtering, isolation amplifiers – transformer and optical isolation - isolated DC amplifier and AC carrier amplifier. Chopper amplifier. Power line interference

Module:4 : Physical Sensors in Biomedicine **4 hours**

Temperature measurement: core temperature,-surface temperature- invasive. Blood flow measurement: skin blood- hot film anemometer- Doppler sonography- electromagnetic sensor - blood pressure measurement: noninvasive- hemodynamic invasive. Spirometry- sensors for pressure pulses and movement- ocular pressure sensor- acoustic sensors in hearing aid, in blood flow measurement, sensors for bio-magnetism, tactile sensors for artificial limbs, sensors in
ophthalmoscopy, artificial retina.

Module:5 : Sensors for Chemical Quantities in Biomedicine **2 hours**

Blood gas and pH sensor, electrochemical sensor, transcutaneous, optical fiber sensor, mass spectrometer, optical oximetry, pulseoximetry, earoximetry.

Module:6: Detectors in Radiology **2 hours**

X ray imaging with sensors, detectors in nuclear radiology, magnetic field sensors for imaging, magnetic resonance imaging.

Module:7 : Sound in Medicine **2 hours**

Interaction of Ultrasound with matter; Cavitations, Reflection, Transmission- Scanning systems – Artefacts- Ultrasound- Doppler-Double Doppler shift-Clinical Applications

Text Book(s)

1. J. G. Webster, J. G. Webster ,"Medical Instrumentation; Application and Design", John Wiley & Sons, Inc., New York, 4th Edition, 2015

Reference Books:

1. Khandpur R.S, "Handbook of Biomedical Instrumentation", Tata McGraw-Hill, New Delhi, 3rd edition ,2014.
2. John Enderle, Joseph Bronzino, "Introduction to Biomedical Engineering", Academic Press, 3rd Edition, 2011.
3. Myer Kutz, "Biomedical Engineering and Design Handbook, Volume 1: Volume I: Biomedical Engineering Fundamentals", McGraw Hill Publisher, USA, 2nd Edition 2009.

Course Code	Course Title	L	T	P	C
M-ECElv	**Deep learning - An approach to AI**	**3**	**0**	**0**	**3**

Module:1 **3 hours**

Foundations of Machine Learning-I : Supervised and unsupervised learning, parametric vs non-parametric models, parametric models forclassification and regression- Linear Regression, Logistic Regression, Naïve Bayes classifier, simple non-parametric classifier-K-nearest neighbour,support vector machines.

Module:2 **3 hours**

Foundations of Machine Learning-II : Clustering- distance based- K-means, density based, association rule mining, validation techniques-cross validations, feature selection and dimensionality reduction, principal component analysis-Eigen values, Eigen vectors, Orthogonality- challenges motivating deep learning

Module:3 **4 hours**

Neural Networks for Classification and Regression : ANN as a technique for regression and classification, structure of an artificial neuron, activation functions- linear activation, sigmoid andsoftmax. Feedforward neural networks- shallow model- single layer perceptron,multi-layer perceptron as complex decision classifier- learning XOR-Gradient based learning, Backpropagation algorithm, risk minimization, loss function, regularization, heuristics
for faster training and avoiding local minima.

Module:4 **4 hours**

Deep Feed Forward Neural Networks : Feed forward neural networks- deep model- output units and hidden units, training deep models- hyper parameters and validation sets-cross validation, capacity, overfitting and under fitting, bias vs variance trade off, cross validation - vanishing gradient problem, new optimization methods (adagrad, adadelta, rmsprop, adam), regularization methods (dropout, batch normalization, dataset augmentation), early stopping.

Module:5 **5 hours**

Convolutional Neural Networks : Convolution operation- kernel and feature map, sparse connectivity, equivariance through parameter sharing, pooling function for invariant representation, convolution and pooling as strong prior, convolution with stride, effect of zero padding, single-channel and multi-channel data types used in ConvNet, variants of basic convolution- locally connected, tiled ConvNet-spatial separable anddepthwise separable convolutions, fully connected layers, ConvNet architecture-layer patterns, layer sizing parameters,case studies- LeNet, AlexNet

Module:6 **2 hours**

Recurrent Neural Networks : Sequence learning with neural nets, unrolling the recurrence, training RNN- Backpropagation throughtime (BPTT), vanishing gradient problem, Gated recurrent unit (GRU), Long short term memory (LSTM), Bidirectional LSTMs, bidirectional RNNs

Module:7 **2 hours**

Deep Learning Tools and Applications : Tools:TensorFlow, Keras, PyTorch, Caffe, Theano, MXNet. Applications: Object detection with RCNN - YOLO, SSD. Speech recognition with RNN.

Course Code	Course Title	L	T	P	C
M-ECElv	**Automatic Sensors and In-vehicle Networking**	**3**	**0**	**0**	**3**

Module:1 **3 hours**

Introduction to Automotive Engineering, Automotive Management systems : Power-train, Combustion Engines, Transmission, Differential Gear, Braking Systems, Introduction to Modern Automotive Systems and need for electronics in Automobiles,Application areas of electronics in the automobiles, Possibilities and challenges in the automotive industry, Enabling technologies and Industry trends.

Module:2 **2 hours**

Power train Sensors : λ sensors, exhaust temperature sensor, NOx sensor, PM sensor, fuel quality sensor, level sensor, torque sensor, speed sensor, mass flow sensor, manifold pressure sensor.

Module:3 **3 hours**

Sensors for Chassis management : Wheel speed sensors/direction sensors, steering position sensor (multi turn), acceleration sensor (inertia measurement), brake pneumatic pressure sensor, ABS sensor, electronic stability sensor.

Module:4 **4 hours**

Sensors for vehiclebody management, Sensors for automotive vehicle convenience and security systems : Gas sensors (CO_2), Temperature/humidity sensor, air bag sensor, key less entering sensor, radar sensors. Tire pressure monitoring systems, Two wheeler and Four wheeler security systems, parking guide systems, anti-lock braking system, future safety technologies, Vehicle diagnostics and health monitoring, Safety and Reliability, Traction Control, Vehicle dynamics control, Accelerators and tilt sensors for sensing skidding and anti-collision, Anti-collision techniques using ultrasonic Doppler sensors

Module:5 : **3 hours**

Air Bag and Seat Belt Pre tensioner Systems : Principal Sensor Functions, Distributed Front Air Bag sensing systems, Single-Point Sensing systems, Side-Impact Sensing, and Future Occupant Protection systems.

Module:6 : **2 hours**

Passenger Convenience Systems: Electromechanical Seat, Seat Belt Height, Steering Wheel, and Mirror Adjustments, Central Locking Systems, Tire Pressure Control Systems, Electromechanical Window Drives, etc.

Module:7 **3 hours**

Modern Trends and Technical Solutions : Enabling Connectivity by Networking:-In vehicle communication standards (CAN & LIN), Telematic solutions, Portable or embedded connectivity-Endorsing Dependability in Drive-by- wire systems:- Terminology and concepts , Why by-wire, FLEXRAY, Requirements on cost and dependability, Drive-by-wire case studies- prototype development-future of In vehicle communication.

Text Book(s)

1. Automotive Electrics, Automotive Electronics: Systems & Components, 2014, 5th Edition, BOSCH.
2. John Turner, Automotive Sensors, 2010, 1st Edition, Momentum Press, New York.

Reference Books

1. Automotive Sensors Handbook, 8th Edition, 2011, BOSCH.
2. Jiri Marek, Hans-Peter Trah, Yasutoshi Suzuki, IwaoYokomori, Sensors for Automotive Technology, 2010, 4th Edition, Wiley, New York.
3. Ernest O. Doebelin, "Measurement Systems – Application and Design", 2017, 6th Edition, McGraw-Hill, New Delhi.

Course Code	Course Title	L	T	P	C
M-ECElv	**Fiber Optics Sensors and Photonics**	**3**	**0**	**0**	**3**

Module:1 **3 hours**

Theory of Optical Waveguides

Wave theory of optical waveguides, formation of guided modes, Slab waveguide, Rectangular waveguide, Radiation fields from waveguide, Effective index method, Marcatili's method, Beam propagation method. Basic characteristic of Optical Fiber Waveguides, Acceptance angle, Numerical
aperture, skewrays- Electromagnetic Modes in Cylindrical Waveguides.

Module:2 **3 hours**

Active and Passive Optical Components : Electro-optic and acousto optic wave guide devices, directional couplers, optical switch, phase and amplitude
modulators,filtersetc,Yjunction,powersplitters,arrayedwaveguidedevices,fiberpigtailing, end-fiber prism coupling, FBG and fabrication of FBG,Tapered couplers.

Module:3 **4 hours**

Intensity and Polarization Sensors : Intensity sensor: Transmissive concept –Reflective concept-Micro bending concept–Transmission and Reflection with other optic effect-Interferometers –Mach Zehnder-Michelson-Fabry-Perot and Sagnac– Phase sensor: Phase detection-Polarization maintaining fibers. Displacement and temperature sensors: reflective and Micro bending Technology- Applications of displacement and temperature sensors.

Module:4 **4 hours**

Interferometric Sensors : Pressure sensors: Transmissive concepts, Microbending –Intrinsic concepts–Interferometric concepts,

Applications. Flow sensors: Turbine flowmeters- Differential pressure flowsensors –Laser Doppler velocity sensors-Applications- Sagnac Interferometer for rotation sensing. Magnetic and electric field sensors: Intensity and phase modulation types– applications.

Module:5 **3 hours**

Polymer based waveguide in sensing : Polymer based waveguide, materials, properties, fabrication process of polymer based waveguide,
Polymer based optical components - Passive, Active polymer devices, Ring Resonator, structure, theory, Filter using Ring Resonator-application in sensing

Module:6 **2 hours**

Fiber based Chemical Senors : Fiber based Chemical Sensing, Absorption, Fluorescence, Chemi-luminescence, Vibrational, Spectroscopic, SPR.

Module:7 **2 hours**

Fiber based Bio-Senors : Fiber based Bio-molecules sensing: High Index, SPR, Hollow core fiber probes, Label Free bio-molecules.

Text Book(s):

1. David A. Krohn, Trevor W. MacDougall, Alexis Mendez, "Fiber Optic Sensors: Fundamentals and Applications" SPIE Press, 4th ed. 2015. ISBN: 1628411805
2. Eric Udd , William B. Spillman Jr., "Fiber Optic Sensors: An Introduction for Engineers and Scientists", Wiley, 2nd Ed., 2011. ISBN: 0470126841

Reference Book(s)

1. Zujie Fang & et. al., "Fundamentals of Optical Fiber Sensors" Wiley, 1st Ed., 2012.ISBN: 0470575409
2. Shizhuo Yin, Paul B. Ruffin, and Francis T.S. Yu, "Fiber Optic Sensors",CRC Press, 2 Ed, 2017. ASIN: B078JN75QW.
3. F.Baldini&et.al.,“Optical Chemical Sensors”, NATO Science Series II: Mathematics, Physics and Chemistry, Springer, 2008. ISBN: 1402046103

Course Code	Course Title	L	T	P	C
M-ECElv	**Data Science**	**3**	**0**	**0**	**3**

Module 1: [7 Lectures] **3 hours**

Introduction to Data Science, Different Sectors using Data science, Purpose and Components of Python in Data Science.

Module 2: [7 Lectures] 3 hours

Data Analytics Process, Knowledge Check, Exploratory Data Analysis (EDA), EDA-Quantitative technique, EDA- Graphical Technique, Data Analytics Conclusion and Predictions.

Module 3: [11 Lectures] 3 hours

Feature Generation and Feature Selection (Extracting Meaning from Data)- Motivating application: user (customer) retention- Feature Generation (brainstorming, role of domain expertise, and place for imagination)- Feature Selection algorithms.

Module 4: [10 Lectures] 2 hours

Data Visualization- Basic principles, ideas and tools for data visualization, Examples of inspiring (industry) projects- Exercise: create your own visualization of a complex dataset.

Module 5: [7 Lectures] 2 hours

Applications of Data Science, Data Science and Ethical Issues- Discussions on privacy, security, ethics- A look back at Data Science- Next-generation data scientists.

Text Books/References:

1. Data Sciences & Analytics, V.K. Jain, Khanna Publishing House.
2. Business Analytics: The Science of Data - Driven Decision Making, U Dinesh Kumar, John Wiley & Sons.
3. Introducing Data Science: Big Data, Machine Learning, and More, Using Python Tools, Davy Cielen, John Wiley & Sons.
4. Joel Grus, Data Science from Scratch, Shroff Publisher/O'Reilly Publisher Media
5. Annalyn Ng, Kenneth Soo, Numsense! Data Science for the Layman, Shroff Publisher Publisher
6. Cathy O'Neil and Rachel Schutt. Doing Data Science, Straight Talk from The Frontline. O'Reilly Publisher.
7. Jure Leskovek, Anand Rajaraman and Jeffrey Ullman. Mining of Massive Datasets. v2.1, Cambridge University Press.
8. Jake VanderPlas, Python Data Science Handbook, Shroff Publisher/O'Reilly Publisher Media.
9. Philipp Janert, Data Analysis with Open Source Tools, Shroff Publisher/O'Reilly Publisher Media.

Course Code	Course Title	L	T	P	C
M-ECElv	**Advance Machine Learning**	**3**	**0**	**0**	**3**

Module-1 **4 hours**

Review on basics of ML: (i) Motivation and role of machine learning in computer science and problem solving (ii) Representation (features), linear transformations, Appreciate linear transformations and matrix vector operations in the context of data and representation. (iii) Problem formulations (classification and regression). (iv) Appreciate the probability distributions in the context of data, Prior probabilities and Bayes Rule. (v) Introduce paradigms of Learning (primarily supervised and unsupervised. Also a brief overview of others)

Module-2 **4 hours**

Fundamentals of ML: (i) PCA and Dimensionality Reduction, (ii) Nearest Neighbours and KNN. (iii) Linear Regression (iv) Decision Tree Classifiers (iv) Notion of Generalization and concern of Overfitting (v) Notion of Training, Validation and Testing; Connect to generalisation and overfitting. Selected Algorithms: (i) Ensembling and RF (ii) Linear SVM, (iii) K Means, (iv) Logistic Regression (v) Naive Bayes

Module-3 **4 hours**

Neural Network Learning: (i) Role of Loss Functions and Optimization, (ii) Gradient Descent and Perceptron/Delta Learning, (iii) MLP, (iv) Backpropagation (v) MLP for Classification and Regression, (vi) Regularisation, Early Stopping (vii) Introduction to Deep Learning (viii) CNN, Key Concepts from ML: Kernels (with SVM), Bayesian Methods, Generative Methods, HMM, EM, PAC learning, Deep Learning Architectures: Popular CNN Architectures, RNNs, GANS and Generative Models. Advanced ML and Neural Networks, Advances in Back propagation and Optimization for Neural Networks Adversarial Learning.

Suggested text books/ Reference Books:

1. Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong, Mathematics for Machine Learning, Cambridge University Press (23 April 2020)
2. Tom M. Mitchell- Machine Learning - McGraw Hill Education, International Edition
3. Aurélien Géron Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, O'Reilly Media, Inc. 2nd Edition
4. Ian Goodfellow, Yoshoua Bengio, and Aaron Courville Deep Learning MIT Press Ltd, Illustrated edition
5. Christopher M. Bishop Pattern Recognition and Machine Learning - Springer, 2nd edition
6. Trevor Hastie, Robert Tibshirani, and Jerome Friedman - The Elements of Statistical Learning: Data Mining, Inference, and Prediction - Springer, 2nd edition

Course Code	Course Title	L	T	P	C
M-ECElv	**Advance Semiconductor devices**	**3**	**0**	**0**	**3**

Module-1 **2 hours**

Review of Fundamentals of Semiconductors: Semiconductor Materials and their properties Carrier Transport in Semiconductors Excess Carriers in Semiconductor

Module-2 **3 hours**

Junctions and Interfaces: Description of p-n junction, Action, The Abrupt Junction, Example of an Abrupt Junction, The linearly graded Junction. The Ideal Diode Model, Real Diodes, Temperature Dependence of I-V Characteristics, High Level Injection Effects, Example of Diodes. Description of Breakdown Mechanism, Zener and Avalanche Breakdown in p-n Junction

Module-3 **2 hours**

Majority Carrier Diodes: The Tunnel Diode, The Backward Diode, The Schottkey Barrier Diode, Ohmic Contacts Heterojunctions.

Module-4 **3 hours**

Microwave Diodes and: The Varactor Diode, The p-i-n Diode, The IMPATT Diode, TRAPATT Diode, The BARITT Diode, Transferred Electron Devices

Optoelectronic Devices: The Solar Cell, Photo detectors, Light Emitting Diodes, Semiconductor Lasers.

Module-5 **3 hours**

Metal Semiconductor Field Effect Transistors: Basic Types of MESFETs, Models for I-V Characteristics of Short – Channel MESFETs, High Frequency Performance, MESFETs Structures.

MOS Transistors and Charge Coupled Devices: **3 hours**

Basic Structures and the Operating Principle, I-V Characteristics, Short- Channel Effects, MOSFET Structures, Charge Coupled Devices.

Text Book:

M.S. Tyagi, "Introduction To Semiconductor Materials And Devices", John Willy-India Pvt. Ltd.

Reference Books:

1. S. M. Sze, "Physics of Semiconductor Devices", 2nd Edition, John Willy-India Pvt. Ltd. B. G. Streetman and S. Banerjee, "Solid state electronics devices", 5th Edition, PHI.

Course Code	Course Title	L	T	P	C
M-ECElv	**Smart Sensors and IOT**	**3**	**0**	**0**	**3**

Module 1: **2 hours**

Environmental Parameters Measurement and Monitoring: Why measurement and monitoring are important, effects of adverse parameters for the living being for IOT

Module 2 **3 hours**

Sensors: Working Principles: Different types; Selection of Sensors for Practical Applications Introduction of Different Types of Sensors such as Capacitive, Resistive, Surface Acoustic Wave for Temperature, Pressure, Humidity, Toxic Gas etc

Module 3: **3 hours**

Important Characteristics of Sensors: Determination of the Characteristics Fractional order element: Constant Phase Impedance for sensing applications such as humidity, water quality, milk quality Impedance Spectroscopy: Equivalent circuit of Sensors and Modelling of Sensors Importance and Adoption of Smart Sensors

Module 4: **3 hours**

Architecture of Smart Sensors: Important components, their features Fabrication of Sensor and Smart Sensor: Electrode fabrication: Screen printing, Photolithography, Electroplating Sensing film deposition: Physical and chemical Vapor, Anodization, Sol-gel

Module 5: **3 hours**

Interface Electronic Circuit for Smart Sensors and Challenges for Interfacing the Smart Sensor,

Usefulness of Silicon Technology in Smart Sensor And Future scope of research in smart sensor

Module 6: **2 hours**
Recent trends in smart sensor for day to day life, evolving sensors and their architecture.

References:
1. Yasuura, H., Kyung, C.-M., Liu, Y., Lin, Y.-L., Smart Sensors at the IoT Frontier, Springer International Publishing
2. Kyung, C.-M., Yasuura, H., Liu, Y., Lin, Y.-L., Smart Sensors and Systems, Springer International Publishing

Course Code	Course Title	L	T	P	C
M-ECElv	**Advance Statistical Methods**	**3**	**0**	**0**	**3**

Module 1: **3 hours**
Statistics: Population, Sample, Sampling, Estimators and Estimates, Maximum Likelihood , Confidence Intervals

Project-1
Application of Confidence intervals as a tool in decision making

Module 2: **3 hours**
Hypothesis Testing: Null and the alternative hypothesis, Rejection region and significance level, Chi-Square Test

Project-2
Hypothesis Testing in Quality Management

Module 3: **2 hours**
Regression: Multiple Regression and Logistic Regression

Practice-1
Multiple Regression Analysis in Python

Practice-2
Logistic Regression using Python

Module 4: **4 hours**
Analysis of Variance(ANOVA): F- Distribution, One way ANOVA, Two Way ANOVA

Practice-3
One way ANOVA using Python

Practice-4
Two way ANOVA using Python

Project-3
The utility of multivariate statistical techniques in hydro geochemical studies

Module 5: **3 hours**
Covariance: (ANCOVA): Analysis of Covariance (ANCOVA), Bivariate Pearson Correlation, Alternative Correlation Coefficients

Practice-5
Python Analysis of covariance (ANCOVA)

Project-4
Application of Analysis of covariance (ANCOVA) in psychological research

Module 6: **3 hours**
Multivariate analysis of variance (MANOVA): One-way MANOVA, Two-way MANOVA

Project-5
Comparison of MANOVA to ANOVA Using an Example

Module 7: **3 hours**
Time Series Analysis: Introducing Time Series Analysis, Components of Time Series Analysis, Multivariate Time Series Analysis

Practice-6
Time Series Analysis using Python

Project-6
A Report on Applications of Time Series Analysis in Census Analysis

Text Books:
1. Statistical Methods By S.P. Gupta (31st Edition) ; Publisher: Sultan Chand & Sons
2. Mathematical Statistics by S.C. Gupta & V.K. Kapur (10th Edition); Publisher: Sultan Chand & Sons.

Reference Books:
Understanding And Using Advanced Statistics by Jeremy Foster Emma Barkus Christian Yavorsky, SAGE Publications

Course Code	Course Title	L	T	P	C
M-ECElv	**Semiconductor Manufacturing**	**3**	**0**	**0**	**3**

Module 1: **6 hours**

Introduction/ Invention of the Transistor/ Emergence of Silicon Valley/ Moore's Law. Modern CMOS

Technology . Crystal Growth and Wafer Engineering

Module 2: **10 hours**

Semiconductor Manufacturing, Gettering and Wafer Cleaning . Lithography and Pattern Transfer . Thermal Oxidation and the Si/ SiO2 Interface Rapid Thermal Processing.

Module 3: **10 hours**

Chapter 7: Dopant Diffusion Chapter 8: Ion Implantation Chapter 9: Thin Film Deposition and Epitaxy [Atomic Layer Deposition (ALD) of high-k dielectrics] Chapter 10: Etching Chapter 11: Back-end Technology Chapter 12: Statistical Process Control and Process Monitoring in Semiconductor Fabrication. (10 Hrs.)

Text/ Reference Books:

1. Silicon VLSI Technology: Fundamentals, Practice and Modeling by James D. Plummer, Michael D. Deal and Peter B. Griffin (Prentice Hall Electronics and VLSI Series) , 2009

Additional Reading:

1. The Science and Engineering of Microelectronic Fabrication by Stephen A. Campbell (Oxford University Press), 2001
2. Semiconductor Manufacturing and Process Control by Gary S. May and Costas J. Spanos (IEEE, Wiley-Interscience), 2006
4. Integrated Circuit Manufacturability – The Art of Process and Design Integration, edited by Jose Pineda de Gyvez and Dhiraj K. Pradhan (IEEE Press), 1998
5. VLSI Technology by S. M. Sze (McGraw Hill), 2017

Course Code	Course Title	L	T	P	C
M-ECElv	**Chemical and Environmental Sensors**	**3**	**0**	**0**	**3**

Module 1 - Introduction to biosensor architecture Types of sensors; components and design; ideal requirements **2 hours**

Module 2 - Probe attachment Types of probe – antibodies, nucleic acids, enzymes, receptors; criteria for device surface attachment, introduction to the non-specific adsorption problem **3 hours**

Module 3 - Methods for probe attachment to surfaces Adsorption; chemisorption v physisorption; polymer trapping; covalent attachment; film deposition techniques; molecular imprinted polymers and biomimicry. **3 hours**

Module 4 - Surface characterization Probe information required; general characteristics of surface analysis, X-ray photoelectron spectroscopy; secondary ion mass spectrometry; Auger spectroscopy; probe techniques such atomic force microscopy **2 hours**

Module 5 - Electrochemical sensors Types of device – potentiometric, amperometric, voltammetric; ion selective electrodes; physics of field effect transistor technology - ISFETS, IMMUNOFETS; history and design of the glucose electrode; nucleic acid –based electrochemical sensing **3 hours**

Module 6 - Acoustic wave devices The phenomenon of piezoelectricity; operation of devices in air; bulk acoustic wave devices as chemical sensors; the Sauerbrey response equation; propagation of acoustic waves in fluids; other devices – surface acoustic wave, shear horizontal wave, surface transverse wave **3 hours**

Module 7 - Optical and electromagnetic radiation-based devices Sources of radiation for sensors; laser technology; optical components; fiber optic-based systems for sensing; intrinsic versus extrinsic sensing mechanisms; evanescent wave technology; the phenomenon of surface plasmon resonance; design of the SPR experiment for bio-sensing; other types such interferometry. **3 hours**

TEXT BOOKS

- F. G. Banica, KJ 8056 : Kompendium/Lecture Notes.
- B. R. Fggins, Chemical sensors and biosensors, Wiley, New York, 2002.
- G. Ramsay (Ed.), Commercial biosensors: applications to clinical, bioprocess, and environmental samples, Wiley, New York 1998.

Course Code	Course Title	L	T	P	C
M-ECElv	**Machine Learning for Communication Systems**	**3**	**0**	**0**	**3**

Module 1: **6 hours**

Introduction to mixture models and EM, K-means clustering, mixture of Gaussians - Maximum likelihood and EM for Gaussian mixtures - Neural networks - network training - local quadratic approximation - use of gradient information - gradient descent optimization; error back propagation - Bayesian neural networks - Support vector machines-SVM formulation with two variables - Lagrangian dual - L1 SVM with soft margin (linear Kernel) - L2 norm linear SVM - Non-linear SVM and Kernel trick - SVM formulation of non-linear Kernels with soft margin (L1 norm, and L2 norm) - Introduction to support vector regression - one class SVM

Module 2: **6 hours**

The Jacobian matrix - Hessian matrix and diagonal approximation - Regularization in neural networks - mixture density neural networks - Introduction to deep learning neural networks - Theoretical advantages of deep architectures - Neural networks for deep architectures - Deep generative architectures - Convolution neural networks (CNN) - Auto encoders - Restricted Boltzmann machines - Variants of RBMs and auto encoders.

Module 3: **4 hours**

Applications in communication systems – Signal Detection – Channel Encoding and Decoding – Channel estimation, Prediction and Compression – End – to – End communication – Resource

allocation

TEXT BOOKS / REFERENCES:

1. Christopher Bishop, *Pattern Recognition and Machine Learning*, First Edition, Springer,2016.
2. K. P. Soman, R. Loganathan, and V. Ajay, *Machine Learning with SVM and Kernel Methods*, First Edition, PHI Learning Private Ltd., New Delhi, 2011.
3. Yoshua Bengio, *Learning Deep Architectures for AI, Foundations and Trends in Machine Learning*, First Edition, Now Publishers Inc, 2009.
4. https://www.comsoc.org/publications/best-readings/machine-learning-communications

Course Code	Course Title	L	T	P	C
M-ECElv	**Python Programming**	**3**	**0**	**0**	**3**

Module 1: **6 hours**

Introduction to Python Programming: Python Introduction, Installing and setting Python environment in Windows and Linux, basics of Python interpreter, Execution of python program, Editor for Python code, syntax, variable, Data types. Flow control if else, for, while, range() function, continue, pass, break. Strings: Sequence operations, String Methods.

Module 2 - : **4 hours**

Lists: Basic Operations, List slices,list methods, list and strings **Dictionaries:** looping and dictionaries, dictionaries & lists. **Tuples and Files:**reading and writing Functions: Definition, Call, Arguments ,Input output file handling.

Module 3 - : **4 hours**

Object Oriented Programming features in Python: Classes, Objects, Inheritance, Errors and xceptions: try, except and else statements, Exception Objects, Regular expressions.

Module 4 - : **6 hours**

Numpy and Matplotlib :Array operations, Numpy Side Effects, 2D Numpy Arrays , Numpy Basic Statistics. Matplotlib: Introduction, Simple plots, Line API, Legend API, Figures, Subplots.
Pandas: Look Ups, Selections and Indexing, Filling Methods, Series operation,
Handling NaN values, Mapping, Data Frames, Reading Files, Plotting, Joins,
Correlation, Histograms, Rolling calculation.

Text Books:

1. Allen B Downey, ―Think PYTHON‖, O_Rielly, ISBN: 13:978-93-5023-863-9, 4th Indian Reprint 2015
2. Peng, Roger D and Elizabeth Matsui, ―The Art of Data Science." A Guide for Anyone Who Works with
Data. Skybrude Consulting 200 (2015): 162

Reference Books:

1. Zed A. Shaw,Learn Python the Hard Way

Course Code	Course Title	L	T	P	C
M-ECElv	**Audio Processing**	**3**	**0**	**0**	**3**

Audio Processing

Course Contents:

Module 1 - **6 hours**

Audio Signal Characteristics, Production model, Hearing and Auditory model, Acoustic characteristic of speech, Speech production models, Linear Separable equivalent circuit model, Vocal Tract and Vocal Cord Model

Module 2 - **4 hours**

Audio signal acquisition, Representation and Modelling, Enhancement of audio signals**:** Spectral Subtraction, Weiner based filtering, Neural nets

Module 3 - **6 hours**

Audio/ Speech Analysis and Synthesis Systems**:** Digitization, Sampling, Quantization and coding, Spectral Analysis, Spectral structure of speech, Autocorrelation and Short Time Fourier transform, Window function, Sound Spectrogram, Mel frequency Cepstral Coefficients, Filter bank and Zero Crossing Analysis, Analysis –by-Synthesis, Pitch Extraction**.**, Linear Predictive Coding Analysis**.**

Module 4 - **4 hours**

Psychoacoustics, Multi-microphone audio processing**:** Room acoustics, Array beamforming**.** Acoustic sound source localization and tracking

Module 5 - **6 hours**

Applications**:** Principles of Automatic Speech Recognition **(**ASR**)**,Theory and implementation of Hidden Markov Model **(**HMM**)** for ASR, Speaker Recognition, Evolution of Speech APIs, Natural Language Processing, Sound source separation models**.**

Text/References:

1. Sen, Soumya, Dutta, Anjan Dey, Nilanjan, Audio Processing and Speech Recognition,1st edition, 2019, Springer
2. Gold, B**.**; Morgan, N**.**; Ellis, D**.** Speech and audio signal processing**:** processing and perception of speech and music**.** 2nd rev**.** ed**.** Wiley-Blackwell, 2011**.**
3. Bali & Bali, Audio Video Systems, Khanna Book Publishing**.**
4. Sadaoki Furui, **"**Digital Speech Processing, Synthesis and Recognition**"** 2/e**.**

5. Rabiner and Schafer, **"**Digital Processing of Speech Signals**"**, Pearson Education

Course Outcomes:

At the end of this course, the students should be able to

1. Understand different characteristics of Audio signals**.**

2. Analyze different speech analysis and synthesis systems**.**

3. Write an algorithm for automatic speech recognition system

4. Design models and algorithms for audio and speech processing applications**.**