Course Structure

of

M.Tech.(ECE)

with specialization in

1. Communication Engineering

&

2. Microelectronics

Electronics and Communication Engineering Department

Indian Institute of Information Technology Allahabad

(Session 2022-23 onwards)

M.Tech.(ECE)

with specialization in

Communication Engineering

Curriculum Structure (L-T-P)

Semester I:

Course Name	**Core/Elective**	**Code**	**Credit**	**L-T-P**	**Pre Requisites**
Applied Mathematics	Core	Hard	4	3-1-0	Nil
Advanced Digital Communication	Core	Hard	4	3-1-0	Nil
Statistical Signal Analysis	Core	Hard	4	3-1-0	Nil
Radiating Systems	Core	Hard	4	3-1-0	Nil
Introduction to Machine Learning	Core	Hard	4	3-0-1	Nil
Total			20		

Semester II:

Course Name	**Core/Elective**	**Code**	**Credit**	**L-T-P**	**Pre Requisites**
*Minor Module on 1. Wireless Communication 2. RF/Microwave 3. Signal Processing *Later on more modules may be added and some of these may be dropped by DPGC*	Elective	Soft	8		Nil
Hands-on with Experimental Tool on Minor Module	Elective	Soft	4	0-2-2	Nil
Independent Study	Elective	Soft	4	0-2-2	Nil
Total			**16**		

**The Faculty member(s) who are offering a minor module may suitably divide 8 credits into multiple courses/lab/workshop/project with customized LTP components as per their teaching plan.*
** Maximum/Minimum number of seats in different modules will be decided by DPGC every year before the beginning of 2nd semester*

Semester III:

Course Name	**Core/Elective**	**Code**	**Credit**	**L-T-P**	**Pre Requisites**
**Major Module on 1. Wireless Communication 2. RF/Microwave 3. Signal Processing *Later on more modules may be added and some of these may be dropped by DPGC*	Elective	Soft	12		Minor module in respective major area
Minor Project	Core	Soft	4	0-1-3	Nil
Total			**16**		

***The Faculty member(s) who are offering a major module may suitably divide 12 credits into multiple courses/lab/workshop/project with customized LTP components as per their teaching plan.*

Semester IV:

Course Name	**Core/Elective**	**Code**	**Credit**	**L-T-P**	**Pre Requisites**
Thesis	Core	Hard	12	0-0-12	**Mini Project**
Total			12		

Semester-1

Course Name	Core/Elective	Code	Credit	L-T-P	Pre Requisites
Applied Mathematics	Core	Hard	4	3-1-0	Nil
Advanced Digital Communication	Core	Hard	4	3-1-0	Nil
Statistical Signal Analysis	Core	Hard	4	3-1-0	Nil
Radiating Systems	Core	Hard	4	3-1-0	Nil
Introduction to Machine Learning	Core	Hard	4	3-0-1	Nil
Total			20		

Name of the Course: *Applied Mathematics*

1. **LTP structure of the course:** 3-1-0
2. **Objective of the course:** The primary goal of this course is to introduce students to the mathematical ideas that form the basis for linear algebra, properties of matrices and linear optimization.
3. **Outcome of the course**: Students will be able to exploit the knowledge of various mathematical topics and wide range of engineering applications.
4. **Course Plan**:

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	**Introduction to Vector Spaces** Fields, Systems of Linear Equations, Matrices and Elementary Row Operations, Vector spaces, Subspaces, Linear Independence, Basis and Dimension, Linear Transformation, Isomorphism, Linear Functionals, Polynomials
	Unit 2	**Introduction to Matrix Theory** Matrix notations, Inverse, Transpose, Column Space, Nullspace, Subspaces of matrices, Inner products, projection, Norm of vectors and matrics, Gram-Schmidt Orthogonalization, Determinant, Eigen value, Eigen Vectors, Positive definite matrices, Semidefinite, Singular value decomposition,
Component 2	Unit 3	**Linear Programming** Linear inequalities, Linear programming, Simplex method, theory of duality, Network model, Min max Theorem
	Unit 4	**Matrix methods** Least square problem, Four ways to solve least square problem, Computation with large matrices, low rank matrices, Connection to communication and signal processing (Least mean square filters, Gradient descent for least square problem)

5. **Texts book:**

1. Kenneth Hauffman and Ray Kunze, *Linear Algebra*, Second edition, Prentice hall publication, 2015.
2. Gilbert Strang, *Linear Algebra and its applications*; Cengage Learning India publication, 2005.
3. Dimitri Bertsimas and John Tsitsiklis, *Introduction to Linear Optimization*, Athena Scientific, 1997.
4. Gilbert Strang , *Linear Algebra and Learning from Data*, Wellesley-Cambridge Press, 2018.

6. **References:**

1. H D Sherali, M S Bazara and J Jarvis, *Linear Programming and Network Flows*, 2nd edition, Wiley, 2008.
2. Paul Halmos, *Finite Dimensional Vector Spaces*,Ingram short title, 2012.
3. Simon Haykin and B. Widrow, *Least Mean Square and Adaptive Filters*, Wiley-Interscience, 2003.

Name of the Course: ***Advanced Digital Communication***

1. **LTP structure of the course:** 3-1-0
2. **Objective of the course:** To provide students with an understanding of design and performance analysis techniques for digital communication systems.
3. **Outcome of the course:** Students will be able to apply mathematical modelling to problems in wireless digital communications and explain how this is used to analyse and synthesize methods and algorithms within the field.
4. **Course Plan:**

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	**Introduction to Digital Communications** Review of Digital communication, Passband Pulse and Quadrature-Amplitude Modulation, Pulse code modulation (PCM), Delta Modulation, Intersymbol interference and pulse shaping, Optimum Detection, Probability of error analysis
	Unit 2	**Introduction to Digital Modulation Techniques** Line Coding, Review of Digital modulation techniques, Multiplexing and multiple access techniques, Adaptive Modulation and Coding, Spread spectrum modulation, Probability of error analysis of digital modulation techniques
Component 2	Unit 3	**Source Coding** Mathematical models for information sources, Entropy and mutual information, Lossless data compression, Coding for discrete sources, Huffman coding, Run-length coding, Lempel-Ziv algorithm, Lossy data compression, Rate distortion functions
	Unit 4	**Advanced Channel Coding** Review of Linear Block codes and Convolutional codes, LDPC codes, Turbo codes, Serially concatenated codes, bit-interleaved coded modulation, Polar codes

6. Text Books:

1. J. G. Proakis, *Digital Communications*, fourth edition, McGraw–Hill, 2001.
2. A. B. Carlson et. al., *Communication Systems: An Introduction to Signals and Noise in Electrical Communication*, 4th Edition, McGraw Hill International, 2002.

7. References:

1. R. G. Gallager, *Principles of Digital Communication*, Cambridge University Press, 2008.
2. S. Haykin, *Communication Systems*, John Wiley & Sons, 2001.

Name of the Course: *Statistical Signal Analysis*

1. **LTP structure of the course:** 3-1-0
2. **Objective of the course:** The primary goal of this course is to introduce students to the mathematical ideas that form the basis for modern statistically-based analysis of signals and systems.
3. **Outcome of the course:** Students will be able to exploit the knowledge of various mathematical models in wide range of engineering applications.
4. **Course Plan:**

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	**Introduction to Random Signals and Random Variable Theory** Review of random signals, Transformation (function) of random variables, Moment generating function, Characteristic function, Conditional expectation, Sequences of random variables, Law of large numbers, Central limit theorem, Jointly Gaussian random vectors, Covariance matrices, Principal component analysis
	Unit 2	**Introduction to Random Processes and Random Vectors** Wide-sense stationary processes, Ergodicity, Moments, Autocorrelation and autocovariance functions, Spectral representation of random signals, Poisson process, Gaussian processes, Wiener process, White noise, MA, AR, ARMA models, Overview of Markov Chains
Component 2	Unit 3	**Hypothesis Testing and Detection** Bayes Rule, Likelihood ratios, Sufficient statistics, Minimax Rule, Composite Hypothesis Testing, Neyman-Pearson test, Receiver operating characteristics
	Unit 4	**Parameter Estimation** Maximum likelihood estimation, Maximum a posteriori probability estimation, Minimum mean-square estimation, Linear least square estimation, Cramer Rao lower bound, Kalman filtering

6. Text Books:

1. A. Papoulis, *Probability, Random Variables and Stochastic Processes*, 2nd Ed., McGraw Hill, 1983.
2. H. L. Van Trees, *Detection, Estimation and Modulation Theory (Part I)*, John Wiley & Sons, 2001.

7. References:

1. A. Larson and B.O. Schubert, *Stochastic Processes, Vol. I and II*, Holden-Day, 1979.
2. S. M. Kay, *Fundamentals of Statistical Signal Processing - Estimation Theory (Vol. 1)*, Prentice-Hall, Inc., 1993, ISBN: 978-0133457117.

Name of the Course: *Radiating Systems*

1. **LTP structure of the course:**3-1-0
2. **Objective of the course:** To learn about the basics of radiating elements.
3. **Outcome of the course:** Students will learn about basic of electromagnetic and antenna theory
4. **Course Plan:**

Component	Unit	Topics for Coverage
Component 1	Unit-1	**Introduction To Electromagnetic Theory** Review of Maxwell's Equation and boundary conditions, Wave propagation, Normal and Oblique incidence of plane wave at conducting and dielectric media
	Unit-2	**Introduction to Antenna Theory** Antenna Basics, Antenna Parameters, Radiation pattern, near- and far-field regions, Reciprocity, Polarization, input impedance, Efficiency, Friis transmission equation, Dipole Antenna, Circular loop Antenna, Radiation from sectoral and pyramidal Horns
Component 2	Unit-3	**Antenna Arrays** Two-Element Array, N-Element Linear Array: Uniform Amplitude and Spacing, Design Procedure, Synthesis of antenna arrays, Analysis of uniformly spaced arrays with uniform and non-uniform excitation amplitudes, etc.
	Unit-4	**Metamaterials** Composite Right/Left Handed (CRLH) transmission line metamaterials, CRLH metamaterial by an equivalent homogeneous CRLH TL, L-C network implementation and its physical realization.

5. **Texts Books:**

   1. Balanis, Constantine A., *Advanced Engineering Electromagnetics*, Wiley India Pvt. Ltd., Reprint 2008.
   2. C A Balanis, *Antenna Theory and Design*.3rd Ed., John Wiley & Sons. 2005

6. **References:**

   1. A. R. Harish, and M. Sachidananda., *Antennas and wave propagation*. Oxford University Press, USA, 2007.
   2. Caloz, C. and Itoh, T., "*Electromagnetic Metamaterial*s: Transmission Line Theory and Microwave Applications", Wiley IEEE Press 2005.

Name of the Course: *Introduction to Machine Learning*

1. **LTP structure of the course:** 3-0-1
2. **Objective of the course:** To make students familiar with techniques for analysis and modeling of speech both from signal processing and machine learning aspects coving number of applications.
3. **Outcome of the course:** Machine learning is an exciting topic about designing machines that can learn from examples. The course covers the necessary theory, principles and algorithms for machine learning. The methods are based on statistics and probability.

4. **Course Plan:**

Component	Unit	Topics for Coverage
Component 1	Unit 1	**Introduction to Machine Learning** Basic ML concepts and examples, Basic Probability Notations, Bayesian Inference, Basic concepts of statistics, probability and calculus.
	Unit 2	**Supervised Machine Learning** **Regression** (Linear Regression, Ridge regression, Regression Trees, Non-linear regression, Bayesian Linear regression, polynomial regression, Lasso regression, Gradient decent) **Classification** (Random forest, Decision Trees, Logistic Regression, Naïve Bayes classifier, multi-class classification)Maximum Likelihood estimation, Regularization/MAP, Soft/Hard Margin SVM, SVM Duality
Component 2	Unit 3	**Unsupervised Machine Learning** **Clustering** (K-means clustering (Soft/Hard), KNN (k-nearest neighbors), Hierarchical clustering, Anomaly detection, Neural networks, Principal Component Analysis, Independent Component Analysis, A-priori algorithm, Posteriori Algorithm, Singular value decomposition) **Association** (Hidden Markov Model, Gaussian Mixture Model, Gaussian Mixture Model-Universal Background Model, Joint Factor Analysis, i-vector, i-vector/PLDA methods)
	Unit 4	**Reinforcement Machine Learning** Reinforcement Learning overview, The learning Task, Q-Learning, Nondeterministic Q-Learning, Temporal Difference-Learning, RL-General formulation, Multi-armed Bandits, Markov Decision Process and Deep Reinforcement Learning

6.Text Books and References:

1. *Pattern Recognition and Machine Learning* by Bishop, Springer, 2006.
2. *Machine Learning: A Probabilistic Perspective by Kevin P. Murphy*, MIT Press, 2012
3. *The Elements of Statistical Learning*, 2nd edition by Hastie, Tibshirani and Friedman, Springer-Verlag, 2008.
4. *Bayesian Reasoning and Machine Learning* by David Barber, Cambridge University Press, 2012.
5. *Information Theory, Inference, and Learning Algorithms* by David Mackay, Cambridge University Press, 2003.
6. *Richard Sutton and Andrew Barto, Reinforcement Learning: An Introduction,* Second Edition, MIT Press, 2018.

Semester-2

Course Name	Core/Elective	Code	Credit	L-T-P	Pre Requisites
*Minor Module on 1. Wireless Communication 2. RF/Microwave 3. Signal Processing *Later on more modules may be added and some of these may be dropped*	Elective	Soft	8		Nil
Hands-on with Experimental Tool on Minor Module	Elective	Soft	4	0-2-2	Nil
Independent Study	Elective	Soft	4	0-2-2	Nil
Total			**16**		

**The Faculty member(s) who are offering a minor module may suitably divide 8 credits into multiple courses/lab/workshop/project with customized LTP components as per their teaching plan.*

Minor Module
on
Wireless Communications

Module Part Name	Core/Elective	Code	Credit	L-T-P	Pre Requisites
Part-I: Introduction to Cellular Networks Wireless Channels Diversity in Wireless Communications	Elective	Soft	5	3-1-1	Basic knowledge in the following fields is desired 1. Digital Communications 2. Probability and Statistics
Part-II: Communication Networks	Elective	Soft	2	1-1-0	Nil
Part-III: Machine Learning for Wireless Communications	Elective	Soft	1	0-1-0	Basic Knowledge of Machine Learning
Hands-on with Experimental Tool on Wireless Communication	Elective	Soft	4	0-2-2	Nil

-More Electives may be added as per the requirement of the Module

Note:

a) The result of each part will be separately prepared as per the applicable ordinance and should be displayed as follows:

Title of the module:
Part-I GPI= xxx
Part-II GPI=xxx
Part-III GPI=xxx

b) C1, C2 and C3 for each part of the module should be separately evaluated as per CCLCAA ordinance i.e., after completing the 50% syllabus of the respective PART, the C1 score should be submitted. Later on, the C2 score should be submitted after completion of the 100% syllabus, and then C3 should be conducted as a summative assessment. Therefore, the score submission dates for the C1, C2 & C3 of all the courses of various modules may be different than the other regular subjects.

PART-I (5 Credits) (L=3, T=1, P=1) Total Contact Hours (as per 18 weeks of semester) = 126 Hours		
Topics for Coverage	**Contact Hours**	**Pre-Requisite**
Introduction to Cellular Networks Evolution of mobile radio communication, Cellular communication, Overview of first generation (1G) system, 2G system, 3G system, 4G system, 5G system, Cellular system design fundamentals: frequency reuse concept, channel assignment, co-channel interference, adjacent channel interference, system capacity, cell splitting, sectoring, etc. Cellular System Architectures: GSM system, Multiple access techniques of cellular networks: frequency division multiple access (FDMA), time division multiple access (TDMA), code division multiple access (CDMA), space division multiple access (SDMA), Orthogonal frequency division multiplexing (OFDM), LTE architecture, 5G architecture	18 Hrs. Lecture 12 Hrs. Tutorial 10 Hrs. Lab	Basic knowledge in the following fields is desired 1. Digital Communications 2. Probability and Statistics
Wireless Channels Physical modeling for wireless channels: free space fixed transmitting and receive antennas, free space moving antenna, reflecting wall fixed antenna, reflecting wall moving antenna, power decay with distance and shadowing, two-ray model, etc., Link budget design using path-loss model, Outdoor and indoor propagation models, Small scale multipath propagation, Delay spread, Coherence bandwidth, Doppler spread & Coherence time, Flat fading, Frequency selective fading, Fast fading, Slow fading Fading Channel Modeling and Performance Analysis: Modeling of flat fading channels: multipath fading, log-normal fading, and composite multipath &shadowing, Modeling of frequency selective fading channels, Overview of wireless systems performance measures: instantaneous and average signal-to-noise ratios (SNRs), outage probability, average bit error rate, ergodic capacity, Expressions for evaluating error probability performance under Gaussian-Q function, Marcum-Q function, Incomplete Gamma function for various fading channels, Channel estimation	20 Hrs. Lecture 14 Hrs. Tutorial 16 Hrs. Lab	
Diversity in Wireless Communications Diversity concept, Non-coherent and coherent reception, Time diversity, Repetition coding, Frequency diversity, Receiver diversity (SC, EGC and MRC), Multiple receive antenna system model and its error performance analysis, Transmit diversity, Channel estimation for multi-antenna system, Diversity order analysis	16 Hrs. Lecture 10 Hrs. Tutorial 10 Hrs. Lab	

Texts/References:

1. J. Goldsmith, *Wireless Communications*, Cambridge University Press, 2005.
2. D. Tse and P. Viswanath, *Fundamentals of Wireless Communications*, Cambridge University Press, 2005.
3. T. S. Rappaport, *Wireless Communications*, Prentice Hall, 1996.
4. T. Cover and J. Thomas, *Elements of Information Theory*, John Wiley & Sons, 1991.
5. M. K. Simon and M. S. Alouini, *Digital Communications over Fading Channels*, John Wiley & Sons, 2000.

PART-II (2 Credits)
(L=1, T=1, P=0)
Total Contact Hours (as per 18 weeks of semester) = 54 Hours

Topics for Coverage	Contact Hours	Pre-Requisite
Communication Networks Introduction to computer networks and layered architecture, Packet switching and Fast packet switching, Circuit Switching, Point to Point Protocols and links (ARQ retransmission strategies, Selective repeat ARQ), Framing, Data link control protocol-HDLC, SDLC, LAPD, Multi-access communication and multiple access protocols, ALOHA, slotted ALOHA, CSMA, CSMA/CD, Ethernet, Wireless LANs, Internetworking issues (Bridges, Routers and Switched networks), Network layer design issues, Routing, Congestion Control algorithms, Quality of Service, Overview of transport layer	18 Hrs. Lecture 36 Hrs. Tutorial	NIL

Texts/References:

1. Alberto Leon-Garcia and Indra Widjaja, "*Communication Networks: Fundamental Concepts and Key Architectures*", McGraw-Hill,2004.
2. R. G. Gallager and D. Bertsekas, *Data Networks*, Prentice Hall of India, 1992.
3. W Stallings, *Data and Computer Communications*, Prentice Hall of India, 1997.

PART-III (1 Credit)
(L=0, T=1, P=0)
Total Contact Hours (as per 18 weeks of semester) = 36 Hours

Topics for Coverage	Contact Hours	Pre-Requisite
Machine Learning for Wireless Communications Machine learning for physical layer design, Supervised Learning and its applications in wireless systems, Applications in modulation classification, Adaptive modulation and coding (AMC) mechanisms for wireless systems: classical AMC, using support vector machines, using k-nearest neighbors, using k-means, using reinforcement learning	36 Hrs. Tutorial	Basic Knowledge of Machine Learning

Texts/References:

1. Fa-L. Luo, *Machine Learning for Future Wireless Communications*, Wiley, 2020.
2. Online Resources

Name of the Course: *Hands-On with Experimental Tool on Wireless Communication*

1. **LTP structure of the course:** 0-2-2
2. **Objective of the course:** To provide students with an understanding of various software and tools used in wireless communication systems.
3. **Outcome of the course:** Students will be able to simulate, test, and verify various mathematical models in wireless communications systems.
4. **Course Plan:**

Component	**Unit**	**Topics for Coverage**	**Chapter No. (Optional)**
Component 1	Unit 1	Hands-on Training on MATLAB Programming	
	Unit 2	Hands-on Training on MATHEMATICA Programming	
Component 2	Unit 3	Hands-on Training on Software Defined Radio	
	Unit 4	Hands-on Training on NetSim and OptiWave Software	

6. Text Books/ References:

1. Introduction to MATLAB, manual by MATLAB.
2. Introduction to OptiWave, Tutorial and manual by OptiWave.
3. Introduction to NetSim, Tutorial and manual by NetSim.
4. Manual on Software Defined Radio
5. B. F. Torrence and E. A. Torrence, “The Students’s Introduction to MATHEMATICA; and the Wolfram Language,” 3rd Edition, Wolfram.

Minor Module
on
RF & Microwave

Module Part Name	**Core/Elective**	**Code**	**Credit**	**L-T-P**	**Pre Requisites**
Part-I: Advanced Antenna Theory	Elective	Soft	2	2-0-0	Basic Knowledge of Electromagnetics
Part-II: Microwave Theory and Technique	Elective	Soft	3	2-1-0	Basic Knowledge of Electromagnetics
Part-III: Radar Signal Processing	Elective	Soft	3	2-1-0	NIL
Hands-on with Experimental Tool on RF & Microwave	Elective	Soft	4	0-2-2	Nil

-More Electives may be added as per the requirement of the Module

Note:

a) The result of each part will be separately prepared as per the applicable ordinance and should be displayed as follows:

Title of the module:

Part-I GPI= xxx

Part-II GPI=xxx

Part-III GPI=xxx

b) C1, C2 and C3 for each part of the module should be separately evaluated as per CCLCAA ordinance i.e., after completing the 50% syllabus of the respective PART, the C1 score should be submitted. Later on, the C2 score should be submitted after completion of the 100% syllabus, and then C3 should be conducted as a summative assessment. Therefore, the score submission dates for the C1, C2 & C3 of all the courses of various modules may be different than the other regular subjects.

PART-I (2 Credits) (L=2, T=0, P=0) Total Contact Hours (as per 18 weeks of semester) = 36 Hours		
Topics for Coverage	**Contact Hours**	**Pre-Requisite**
Advanced Antenna Theory Duality theorem, Uniqueness theorem, Image theory, Reciprocity theorem, Surface and Volume equivalence theorem etc, Basics of microstrip line, Feeding method of patch antenna, Fringing effect, rectangular and circular patch antenna, Dielectric resonator Antenna	36 Hrs. Theory	Basic Knowledge of Electromagnetics

Texts/References:

1. Balanis, Constantine A., Advanced Engineering Electromagnetics,Wiley India Pvt. Ltd., Reprint 2008.
2. C A Balanis, Antenna Theory and Design.3rd Ed., John Wiley & Sons. 2005.
3. Garg, R., Bhartia, P., Bahl, I. and Ittipiboon, A., “Microstrip Antenna Design Handbook”, Artech House. 2001.

<table>
<tr><th colspan="3">PART-II (3 Credits)
(L=2, T=1, P=0)
Total Contact Hours (as per 18 weeks of semester) = 72 Hours</th></tr>
<tr><th>Topics for Coverage</th><th>Contact Hours</th><th>Pre-Requisite</th></tr>
<tr><td>Microwave Theory and Technique

Wave propagation in transmission line, Terminated transmission line, Input impedance of Transmission line, Wave Propagation in waveguide, Smith Chart, Single and double stub matching, Quarter-wave Transformer, Theory of Small Reflection, Binomial and Chebyshev multisection matching, Tapered line, Scattering and Transmission (ABCD) Parameters, Mixed-mode scattering Parameters, SIW basics, Transition of SIW with other technology</td><td>36 Hrs. Theory

36 Hrs. Tutorial</td><td>Basic Knowledge of Electromagnetics</td></tr>
<tr><td colspan="3">Texts/References:

1. D.M. Pozar, Microwave Engineering.3rd Ed., John Wiley & Sons. 2004.
2. R.E. Collin, Foundations for Microwave Engineering. 2nd Ed., John Wiley & Sons. 2000.</td></tr>
</table>

PART-III (3 Credits)

(L=2, T=1, P=0)

Total Contact Hours (as per 18 weeks of semester) = 72 Hours

Topics for Coverage	Contact Hours	Pre-Requisite
Radar Signal Processing Introduction to radar systems, History and applications of radar, Basic radar function, Radar classifications, elements of pulsed radar, The radar equation, A preview of basic radar signal processing, Pulse Radar, CW radar, Directional Properties of Radar Measurement, Resolution, Imaging Radar, Introduction to Synthetic Aperture Radar, Range Resolution, Azimuth Resolution, Introduction to SAR Polarimetric, Generation and Propagation of Polarized Waves, Geometry of Polarized Waves, Representation of Partially Polarized Waves, Polarization Descriptors: Poincare Sphere, Jones Vector, Stokes Vector, Electromagnetic vector scattering operators: Scattering Matrix, Coherency and Covariance Matrices, Muller and Kennaugh Matrices, Change of Polarization Basis, Canonical Scattering Mechanisms	36 Hrs. Theory 36 Hrs. Tutorial	NIL

Texts/References:

1. Mark A. Richards, “Fundamentals of Radar Signal Processing”, McGraw Hill Education Edition, 2005.
2. Harold Mott, “Remote Sensing with Polarimetric Radar”, IEEE Press/Wiley Interscience, 2007.
3. S. R. Cloude, “Polarisation: Application in Remote Sensing”, Oxford university Press, 2010.
4. J.-S. Lee, E. Pottier, “Polarimetric Radar Imaging: From Basics to Application”, CRC Press, 2009.

Name of the Course: *Hands-on with Experimental Tool on RF & Microwave*

1. **LTP structure of the course:** 0-2-2
2. **Objective of the course:** To make students familiar with different simulation tools of RF/Microwave
3. **Outcome of the course:** Students will be able to learn the different RF & Microwave Tools
4. **Course Plan:**

Component	Unit	Topics for Coverage	Chapter No.(Optional)
Component 1	Unit-1	Hands-on Training on ADS (Advanced Design System)	
	Unit-2	Hands-on Training on HFSS (High Frequency Structure Simulator)	
Component 2	Unit-3	Hands-on Training on CST (Computer Simulation Technology)	
	Unit-4	Antenna and RF circuit design using HFSS/ADS/CST and its fabrication and measurement	

6. *Texts/References*:

1. Introduction to ADS, manual by ADS.
2. Introduction to HFSS, manual by HFSS.
3. Introduction to CST, manual by CST.

Minor Module
on
Signal Processing

Module Part Name	Core/Elective	Code	Credit	L-T-P	Pre Requisites
Part-I: Introduction to Digital Signal Processing Digital Filters Design	Elective	Soft	4	2-1-1	Basic knowledge of Signal and System, Digital Signal Processing
Part-II: Speech Processing	Elective	Soft	2	2-0-0	Basic knowledge of Signal and System, Digital Signal Processing
Part-III: Digital Image Processing	Elective	Soft	2	2-0-0	Basic knowledge of Signal and System, Digital Signal Processing
Hands-on with Experimental Tool on Signal Processing	Elective	Soft	4	0-2-2	Nil

-More Electives may be added as per the requirement of the Module

Note:

a) The result of each part will be separately prepared as per the applicable ordinance and should be displayed as follows:

Title of the module:

Part-I GPI= xxx

Part-II GPI=xxx

Part-III GPI=xxx

b) C1, C2 and C3 for each part of the module should be separately evaluated as per CCLCAA ordinance i.e., after completing the 50% syllabus of the respective PART, the C1 score should be submitted. Later on, the C2 score should be submitted after completion of the 100% syllabus, and then C3 should be conducted as a summative assessment. Therefore, the score submission dates for the C1, C2 & C3 of all the courses of various modules may be different than the other regular subjects.

PART-I (4 Credits)

(L=2, T=1, P=1)

Total Contact Hours (as per 18 weeks of semester) = 108 Hours

Topics for Coverage	Contact Hours	Pre-Requisite
Introduction to Digital Signal Processing Discrete-time signals and systems, Linear shift invariant systems, stability and causality, frequency domain representation of discrete time signals and systems, Fourier Series, DFT, DCT and Haar; Properties of DFS, DFT, FFT structures, DIT and DIF, Linear Convolution using DFT, frequency domain sampling, Relationships of DFT to other transforms, Inverse FFT	18 Hrs. Lecture 18 Hrs. Tutorial 18 Hrs. Lab	Basic knowledge of Signal and System, Digital Signal Processing
Digital Filters Design Structures for FIR systems, Structures for IIR systems, Basic FIR/IIR filter structures, Cascade and Lattice structures, Parallel All pass structures of IIR transfer functions, Symmetric and Anti symmetric FIR filters, FIR Digital filters by Windows, IIR filter design by Approximation of Derivatives, impulse, invariance, bilinear transformation, characteristics using Analog, filters (Butterworth and Chebyshev), Frequency transformation, Comparison of IIR and FIR filters). STFT	18 Hrs. Lecture 18 Hrs. Tutorial 18 Hrs. Lab	

Texts/References

1. A.V. Oppenheim, R. W. Schaffer, “Discrete Time Signal Processing”, Prentice Hall India, New Delhi.
2. John G. Proakis, Dimitris K Manolakis. "Digital Signal Processing: Principles, Algorithms and Applications." Fourth Edition (2006).
3. Oppenheim, Alan V., and A.S. Willsky “Signals and Systems”, Prentice Hall, 1982.
4. Dag Stranneby, William Walker. “Digital Signal Processing and Applications” Second Edition, Publishers, 2004.

PART-II (2 Credits)

(L=2, T=0, P=0)

Total Contact Hours (as per 18 weeks of semester) = 36 Hours

Topics for Coverage	Contact Hours	Pre-Requisite
Speech Processing Anatomy; Physiology of Speech Organs, The process of Speech Production, Acoustic Phonetics, Articulatory Phonetics, The Acoustic Theory of Speech Production-effect of losses in vocal tract, effect of radiation at lips, Digital models for speech signals, Acoustic Theory of Speech Production, Speech Perception Speech production model, Source-system model, speech perception and acoustic-phonetic characteristics, Sound Propagation in the Vocal Tract using LPC, PLP and MFCC coefficients, Time Domain Methods in Speech Processing, Speech Representations Based on STFT Analysis-synthesis Methods, Speech Coding Methods Model-Based Approaches. Linear Predictive Coding, pitch estimation, speech enhancement and prosodic speech modification	36 Hrs. Lecture	Basic knowledge of Signal and System, Digital Signal Processing

Texts/References:

1. Furui.S., "*Digital Speech Processing, Synthesis and Recognition*", CRC Press, Second Edition, 2004.
2. Spanias, A., Painter, T. and Venkatraman, A., "*Audio Signal Processing and Coding*", John Wiley & Sons, 2007
3. L. R. Rabiner, B. H. Juang, B. Yegnanarayana, "*Fundamental of Speech Recognition*", Pearson Education Inc., New Delhi, India, 2009.
4. Rabiner, L.R. and Schafer, R.W., "*Digital Processing of Speech Signals*" Prentice Hall, New Delhi, (2006).

PART-III (2 Credits)

(L=2, T=0, P=0)

Total Contact Hours (as per 18 weeks of semester) = 36 Hours

Topics for Coverage	Contact Hours	Pre-Requisite
Digital Image Processing Fundamentals of Image Processing, Spatial Domain: Basic relationship between pixels- Basic Gray level Transformations – Histogram Processing – Smoothing spatial filters- Sharpening spatial filters. Frequency Domain: Smoothing frequency domain filters- sharpening frequency domain filters Holomorphic filtering. Detection of discontinuities – Edge linking and Boundary detection- Thresholding Edge based segmentation-Region based Segmentation- matching-Advanced optimal border and surface detection- Use of motion in segmentation. Image Morphology – Boundary descriptors- Regional descriptors.	36 Hrs. Lecture	Basic knowledge in the following fields is desired 1. Signal and Systems 2. Digital Signal Processing

Texts/References:

1. Rafael C.Gonzalez& Richard E.Woods – Digital Image Processing – Pearson Education- 2/e – 2004.
2. Anil.K.Jain – Fundamentals of Digital Image Processing- Pearson Education-2003.
3. William K. Pratt – Digital Image Processing – John Wiley & Sons-2/e, 2004

Name of the Course: *Hands-on with Experimental Tool on Signal Processing*

1. **LTP structure of the course**: 0-2-2
2. **Objective of the course:** To provide students with an understanding of MATLAB software and its use in speech signal and image processing.
3. **Outcome of the course:** Students will be able to implement and simulate various models in signal processing.
4. **Course Plan:**

Component	**Unit**	**Topics for Coverage**	**Chapter No. (Optional)**
Component 1	Unit 1	Basics of MATLAB Programming in Image processing,Importing, Inspecting, and displaying images, Converting between image types, Exporting images Basics of MATLAB Programming in Speech Signal Processing, feature extraction, modeling and classification for Isolated Digit Recognition, Speaker Recognition and etc	
	Unit 2	Hands-on Training on python (openCV and Numpy) Hands-on Training on Python (Numpy, Librosa, Pickle, Keras, Tensorflow)	
Component 2	Unit 3	Hands-on Training on python openCV and Numpy Hands-on Training on Python Using ML Algorithms	
	Unit 4	Hands-on Training on Python, MATLAB and Shell Scripts	

5. **Text Books/ References:**

1. Introduction to MATLAB, manual by MATLAB.
2. Gonzalez, Rafael C. *Digital image processing*. Pearson education india, 2009.
3. Rafael C.. Gonzalez, Richard E.. Woods, and Steven L..Eddins. *Digital image processing using Matlab*®. McGraw Hill Education., 2010.
4. Paul Hill "Audio and Speech Processing With MATLAB" Routledge Taylor and Francis Group,2019
5. Ian Vince McLoughlin "Speech and Audio Processing" A MATLAB Based Approach, Cambridge University Press, 2016.

Semester-3

Course Name	**Core/Elective**	**Code**	**Credit**	**L-T-P**	**Pre Requisites**
**Major Module on 1. Wireless Communication 2. RF/Microwave 3. Signal Processing *Later on more modules may be added and some of these may be dropped*	Elective	Soft	12		Minor module in respective specialization
Minor Project	Core	Soft	4	0-1-3	Nil
Total			16		

***The Faculty member(s) who are offering a major module may suitably divide 12 credits into multiple courses/lab/workshop/project with customized LTP components as per their teaching plan.*

Major Module
on
Wireless Communications

Module Part Name	Core/Elective	Code	Credit	L-T-P	Pre Requisites
Part-I: MIMO Communications 5G and Beyond Wireless Technologies	Elective	Soft	5	4-1-0	Minor Module in Wireless Communications
Part-II: Security in Wireless Communications	Elective	Soft	2	1-1-0	Minor Module in Wireless Communications
Part-III: Internet of Things (IoT)	Elective	Soft	3	1-1-1	Minor Module in Wireless Communications
Part-IV: Optical Wireless Communications	Elective	Soft	2	1-1-0	Minor Module in Wireless Communications
Total			12		

-More Electives may be added as per the requirement of the Module

Note:

a) The result of each part will be separately prepared as per the applicable ordinance and should be displayed as follows:

Title of the module:

Part-I GPI= xxx

Part-II GPI=xxx

Part-III GPI=xxx

b) C1, C2 and C3 for each part of the module should be separately evaluated as per CCLCAA ordinance i.e., after completing the 50% syllabus of the respective PART, the C1 score should be submitted. Later on, the C2 score should be submitted after completion of the 100% syllabus, and then C3 should be conducted as a summative assessment. Therefore, the score submission dates for the C1, C2 & C3 of all the courses of various modules may be different than the other regular subjects.

PART-I (5 Credits)

(L=4, T=1, P=0)

Total Contact Hours (as per 18 weeks of semester) = 108 Hours

Topics for Coverage	Contact Hours	Pre-Requisite
MIMO Communications Introduction to MIMO wireless communications, Analytical MIMO channel models: Uncorrelated, fully correlated, keyhole MIMO fading models, Singular value decomposition of MIMO channels, MIMO capacity, Uniform power allocation, Optimal MIMO power allocation, asymptotic MIMO capacity, Near optimal power allocation, Ergodic capacity and outage probability analysis of MIMO channels over fading channels, Space-time codes, MIMO detector: Linear detector (ZF, MMSE), Non-linear Detector (ML, V-BLAST), MIMO Beamforming, Transmit Antenna Selection, Spatial Modulation	40 Hrs. Lecture 20 Hrs. Tutorial	Minor Module in Wireless Communications
5G and Beyond Wireless Technologies Cooperative relaying communications, Large-Scale MIMO systems, Cognitive radio networks, Device-to-Device (D2D) Communications, Wireless energy harvesting, Simultaneous wireless information and powertransfer (SWIPT), Ambient backscatter communications (AmBC), Reconfigurable intelligent surface (RIS), Non-orthogonal multiple access (NOMA), Millimeter wave communications, Terahertz (THz) relaying systems, Applications of Machine learning, deep learning and reinforcement learning approaches in 5G and beyond wireless communications	32 Hrs. Lecture 16 Hrs. Tutorial	

Texts/References:

1. D. Tse and P. Viswanath, *Fundamentals of Wireless Communications*, Cambridge Uni. Press, 2005.
2. N. Costa and S. Haykin, *Multiple-input multiple-output channel models*, John Wiley & Sons, 2010.
3. A. Chokhalingam and B. S. Rajan, *Large MIMO systems*, Cambridge University Press, 2014.
4. Research articles and other Online Resources

PART-II (2 Credits)

(L=1, T=1, P=0)

Total Contact Hours (as per 18 weeks of semester) = 54 Hours

Topics for Coverage	Contact Hours	Pre-Requisite
Security in Wireless Communications Basics of cryptographic systems, symmetric and public key cryptography, Encryption and Decryption techniques, cryptography techniques for certificates, authentication etc., Privacy issues, Attacks and countermeasures Physical layer security (PLS): information-theoretic secrecy, secret communication over noisy channels, secret-key generation from noisy channels, information theoretic models for key generation, PLS performance of wireless communications against eavesdropping and jamming, Cooperative relaying communications for PLS, Overview of other physical layer security approaches: Channel approaches, Code approaches, Power approaches	18 Hrs. Lecture 36 Hrs. Tutorial	Minor Module in Wireless Communications

Texts/References:

1. Yulong Zou, Jia Zhu,*Physical-Layer Security for Cooperative Relay Networks*, Springer 2016.
2. W. Stallings, *Cryptography and Network Security: Principles and Practice,* Pearson Education, 7th edition, 2016.
3. Research articles and other Online Resources

PART-III (3 Credits) **(L=1, T=1, P=1)** **Total Contact Hours (as per 18 weeks of semester) = 90 Hours**		
Topics for Coverage	**Contact Hours**	**Pre-Requisite**
Internet of Things (IoT) Introduction to IoT, IoT Network architecture and communication protocols, The "Things" in IoT: Sensor, actuators and other components, Basis of wireless sensor networks, IP and Non-IP based IoT WPAN, Application protocols for IoT, Tiny OS for IoT, Introduction to IoT data and analytics, Data Acquisition in IoT, IoT Applications: Smart Cities, Smart Transportation, Public Safety	18 Hrs. Lecture 36 Hrs. Tutorial 36 Hrs. Lab	Minor Module in Wireless Communications

Texts/References:

1. Perry Lea, *Internet of Things for Architects: Architecting IoT solutions by implementing sensors, communication infrastructure, edge computing, analytics, and security*, Packt Publishing.
2. D. Hanes, G. Salgueiro, P. Grossetete, R. Barton, J. Henry, *IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things*, Cisco Press.
3. Research articles and other Online Resources

PART-IV (2 Credits)

(L=1, T=1, P=0)

Total Contact Hours (as per 18 weeks of semester) = 54 Hours

Topics for Coverage	Contact Hours	Pre-Requisite
Optical Wireless Communications Overview of optical fibre communication, Optical sources (LED, Laser), Photodetectors, Photodetection techniques, Overview of optical wireless communications (OWC), OWC and Radio comparison, Link configuration, Channel modeling: Indoor & Outdoor OWC channels, Modulation techniques, System performance analysis (Indoor and Outdoor), Free space optics (FSO) link performance under the effect of atmospheric turbulence, Visible light communication (VLC)	18 Hrs. Lecture 36Hrs. Tutorial	Minor Module in Wireless Communications

Texts/References:

1. G. Keiser, *Optical Fibre Communications*, McGraw Hill, 5^{th} Edition, 2017.
2. Z. Ghassemlooy, W. Popoola, S. Rajbhandari, *Optical Wireless Communications: System and Channel Modelling with MATLAB*, Taylor and Francis, 2012.
3. Research articles and other Online Resources

Major Module
on
RF & Microwave

Module Part Name	Core/Elective	Code	Credit	L-T-P	Pre Requisites
Part-I: Microwave Circuits	Elective	Soft	4	2-1-1	Minor Module in RF & Microwave
Part-II: Remote Sensing with Advanced SAR Polarimetry Concepts	Elective	Soft	4	3-1-0	Minor Module in RF & Microwave
Part-III: Smart Antennas	Elective	Soft	4	3-1-0	Minor Module in RF & Microwave
Total			12		

-More Electives may be added as per the requirement of the Module

Note:

a) The result of each part will be separately prepared as per the applicable ordinance and should be displayed as follows:

Title of the module:

Part-I GPI= xxx

Part-II GPI=xxx

Part-III GPI=xxx

b) C1, C2 and C3 for each part of the module should be separately evaluated as per CCLCAA ordinance i.e., after completing the 50% syllabus of the respective PART, the C1 score should be submitted. Later on, the C2 score should be submitted after completion of the 100% syllabus, and then C3 should be conducted as a summative assessment. Therefore, the score submission dates for the C1, C2 & C3 of all the courses of various modules may be different than the other regular subjects.

PART-I (4 Credits) (L=2, T=1, P=1) Total Contact Hours (as per 18 weeks of semester) = 108 Hours		
Topics for Coverage	**Contact Hours**	**Pre-Requisite**
Microwave Circuits T Junction power divider, Wilkinson and Gysel Power divider, 90° and 180° Couplers, Balanced microwave power divider and coupler, SIW based power divider and coupler, Filter: Periodic structures, Filter design by the Image Parameter method, Filter design by the Insertion Loss method, Filter transformations,Richards' and Kuroda Identities, Microstrip implementation of filters, Spoof Surface Plasmon Polariton (SSPP) based filters; Noise in microwave circuits, Noise Figure, Non-linear distortion, Dynamic Range, Diode switches, Microwave Amplifier, Mixer and Oscillators	36 Hrs. Theory 36 Hrs. Tutorial 36 Hr. Lab	Minor Module in RF & Microwave

Texts/References:

1. D.M. Pozar, Microwave and RF Design of Wireless System. 2nd Ed., John Wiley & Sons. 2001.
2. Jia-Sheng Hong and M. J. Lancaster, Microstrip Filters for RF/Microwave Applications 2nd Ed., John Wiley & Sons. 2001.
3. Roberto Sorrentino and Giovanni Bianchi, "Mirowave and RF Engineering" John Wiley & Sons 2010.
4. Ludwig, R. and Bretchko, P., "RF Circuit Design", Pearson Education 2000.

PART-II (4 Credits)

(L=3, T=1, P=0)

Total Contact Hours (as per 18 weeks of semester) = 90 Hours

Topics for Coverage	Contact Hours	Pre-Requisite
Remote Sensing with Advanced SAR Polarimetry Concepts Electromagnetic Radiation and its Interaction with Matter, Atmospheric Effects and Corrections, Characteristics of Remote Sensors and Platforms: Optical, Infrared and Microwave Sensor Systems, Recent Trends in Active Remote Sensing Techniques: Lasers and Radars, Data Formats, Visual Interpretation, Microwave Remote Sensing, Wave and Scattering Polarimetry, PolSAR data interpretation and preprocessing, PolSAR Speckle Statistics, PoSAR Speckle Filtering, Pol-InSAR scattering descriptors, Introduction to Target Decomposition Theorems, Scattering Models in Microwave Remote Sensing, Coherent Decomposition Theorems: Pauli Decomposition, Krogager Decomposition, Cameron Decomposition, Polar Decomposition, Incoherent Decomposition theorems: Eigenvector-based decomposition, Model-based Decomposition, Polarimetric SAR applications: Polarimetric Signature Analysis, Polarimetric Orientation Angle Estimation and Application, Land-use and Urban Applications, Change Detection and Monitoring, Lunar Surface Characterization, Weather Forecasting Systems	54 Hrs. Theory 36 Hrs. Tutorial	Minor Module in RF & Microwave

Texts/References:

1. Rees, W.G., "Physical Principles of Remote Sensing", Cambridge University Press, 2001.
2. Iain H. Woodhouse, "Introduction to Microwave Remote Sensing", CRC Press, 2006.
3. Yoshio Yamaguchi, "Polarimetric SAR Imaging: Theory and Applications", CRC Press, 2020.
4. C. Elachi, Jakob J. van Zyl, "Introduction to the Physics and Techniques of Remote Sensing", John Wiley and Sons, 2021.
5. Jakob J. van Zyl, "Synthetic Aperture Radar Polarimetry: 2", (JPL Space Science and Technology Series), 2011.

<table>
<tr><th colspan="3">PART-III (4 Credits)
(L=3, T=1, P=0)
Total Contact Hours (as per 18 weeks of semester) = 90 Hours</th></tr>
<tr><th>Topics for Coverage</th><th>Contact Hours</th><th>Pre-Requisite</th></tr>
<tr><td>Smart Antennas

Introduction and Fundamentals. What is a Smart Antenna, Need of smart antenna system, Overview of smart antenna System, Functions of smart antenna, Type of smart Antennas: switched beam system, adaptive system, Fixed Weight Beam forming Basics, Maximum signal-to-interference ratio, Maximum likelihood, Minimum Variance. Adaptive Beam forming, Least mean squares, Recursive least squares, Constant modulus, Least squares constant modulus, Conjugate gradient method, The Architecture of Smart Antenna Systems</td><td>54 Hrs. Theory

36 Hrs. Tutorial</td><td>Minor Module in RF & Microwave</td></tr>
<tr><td colspan="3">Texts/References:

1. Smart Antennas, T. K. Sarkar, Michael C. Wicks, M. Salazar-Palma, Robert J. Bonneau, John Wiley & Sons, 2005.
2. Introduction to Smart Antennas, Constantine A. Balanis, Panayiotis I. Ioannides, Morgan & Claypool Publishers, 2007.</td></tr>
</table>

Major Module
on
Signal Processing

Module Part Name	Core/Elective	Code	Credit	L-T-P	Pre Requisites
Part-I: Multirate and Wavelet Signal Processing	Elective	Soft	4	3-0-1	Minor Module in Signal Processing
Part-II: Biomedical Signal Processing	Elective	Soft	4	3-0-1	Minor Module in Signal Processing
Part-III: Advanced Speech Information Processing	Elective	Soft	4	3-0-1	Minor Module in Signal Processing
Total			12		

-More Electives may be added as per the requirement of the Module

Note:

a) The result of each part will be separately prepared as per the applicable ordinance and should be displayed as follows:

Title of the module:
Part-I GPI= xxx
Part-II GPI=xxx
Part-III GPI=xxx

b) C1, C2 and C3 for each part of the module should be separately evaluated as per CCLCAA ordinance i.e., after completing the 50% syllabus of the respective PART, the C1 score should be submitted. Later on, the C2 score should be submitted after completion of the 100% syllabus, and then C3 should be conducted as a summative assessment. Therefore, the score submission dates for the C1, C2 & C3 of all the courses of various modules may be different than the other regular subjects.

PART-I (4 Credits) (L=3, T=0, P=1) Total Contact Hours (as per 18 weeks of semester) = 90 Hours		
Topics for Coverage	**Contact Hours**	**Pre-Requisite**
Multirate and Wavelet Signal Processing Introduction, Basic multirate operations, Polyphase representation, Mulstage implementation, filter banks, Multiresolution analysis (MRA), Maximally decimated FB, QMF bank, Tree structured filter banks, Alias-free QMF, properties induced by paraunitariness, Two channel FIR paraunitary QMF banks, QMF lattice, M – channel FIR paraunitary filter banks, Transform coding. Haar filter bank, Conjugate Quadrature Filter banks (CQF) and their design, Cosine Modulated Filter Banks: Introduction, Lattice structure for linear phase FIR PR banks, Formal synthesis of linear phase FIR PR QMF lattice. Pseudo QMF banks, Design of the pseudo QMF bank, Efficient polyphase structure, Cosine modulated perfect reconstruction system Wavelet Transform; Discrete-time orthogonal wavelets, Continuous-time orthogonal and bi-orthogonal wavelets, Piecewise constant approximation, Haar wavelet, Daubechies wavelets, spline wavelets, dyadic wavelets, Wavelet packet transform, Case studies and present status	54 Hrs. Theory 36 Hrs. Lab	Minor Module in Signal Processing

Texts/References:

1. D. Tse and P. Viswanath, *Fundamentals of Wireless Communications*, Cambridge Uni. Press, 2005.
2. N. Costa and S. Haykin, *Multiple-input multiple-output channel models,* John Wiley & Sons, 2010.
3. A. Chokhalingam and B. S. Rajan, *Large MIMO systems*, Cambridge University Press, 2014.
4. Research articles and other Online Resources

PART-II (4 Credits)

(L=3, T=0, P=1)

Total Contact Hours (as per 18 weeks of semester) = 90 Hours

Topics for Coverage	Contact Hours	Pre-Requisite
Biomedical Signal Processing EEG, Neuron potential, Resting potential, Nernst equation, Sources of brain potentials, Component waves, EEG recording electrodes, 10-20 electrode system, Electrocardiograph, ECG lead system and recording, Vector cardiography, Echo-cardiograph, Electroretinogram, Electroocculogram, Generation of cochlear potentials and nature, Evoked responses, Auditory nerves, Bioelectric Signals Analysis: Noise and interference in bioelectric signals, Sources of noise, Grounding & shielding, Filter design for Biosignal processing, Frequency domain analysis, STFT, WT, Linear decomposition methods, machine learning algorithms for biomedical aaplications Noise in medical images, Smoothing and sharpening, Spatial domain methods, Frequency domain methods, Image restoration, Segmentation, representation, Description and recognition, Diagnostic X-rays, CAT, MRI, Thermography, Ultrasonography, Medical use of Isotopes, Endoscopy, Case studies and present status	54 Hrs. Theory 36 Hrs. Lab	Minor Module in Signal Processing

Texts/References:

1. Eugene N. Bruce, "*Biomedical Signal Processing and Signal Modeling*", JohnWiley& Sons, 2006.
2. John L. Semmlow, "*Biosignal and Biomedical Image Processing: MATLAB BasedApplications*", CRC press, 2008.
3. Rangaraj M. Rangayyan, "*Biomedical Signal Analysis*", John Wiley & Sons, 2002
4. Amine Nait-Ali, "*Advanced Biosignal Processing*", Springer, 2009.
5. Rafael C. Gonzalez, Richard E. Woods,"*Digital Image Processing*", Pearson Education, Inc., Second Edition, 2004.

<table>
<tr><th colspan="3">PART-III (4 Credits)
(L=3, T=0, P=1)
Total Contact Hours (as per 18 weeks of semester) = 90 Hours</th></tr>
<tr><th>Topics for Coverage</th><th>Contact Hours</th><th>Pre-Requisite</th></tr>
<tr><td>Advanced Speech Information Processing

Basic pattern recognition approaches, parametric representation of speech, Isolated Digit Recognition System, HMM for speech recognition, Viterbi algorithm, Baum-welch parameter re-estimation, implementation issues in Training and Testing using HMMs, Speaker Recognition (Principles of speech recognition, spectral distance measures, DTW, HMM, GMM, GMM-UBM, i-vector/PLDA)

Deep Learning: Review of Multi-layer Perceptron's, Back propagation Algorithms, Stochastic Gradient Descent, Loss and Activation functions, Regularization strategies, Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), Long Short-Term Memory Units (LSTM), Auto encoders; Reinforcement Learning, Applications and Case Studies and present status</td><td>54 Hrs. Theory

36 Hrs. Lab</td><td>Minor Module in Signal Processing</td></tr>
<tr><td colspan="3">Texts/References:

1. Ben Gold, Nelson Morgan and Dan Ellis, "Speech and Audio Signal Processing", Wiley Edition, Singapore, 2004.
2. J. Benesty, M. M. Sondhi and Y. Huang, "Springer Handbook on Speech Processing", Springer Publishers, 2008.
3. L. R. Rabiner and B. H. Juang, "Fundamentals of Speech Recognition", Pearson Education, New Delhi, 2003.
4. I. Goodfellow, Y. Bengio , A. Courville, Deep Learning, MIT Press, 2017
5. Kamath, Uday, Liu, John and Whitaker, Jimmy, "Deep Learning for NLP and Speech Recognition", Springer Publishers, 2019.
6. Daniel Jurafsky and James H Martin, "Speech and Language Processing- An Introduction to Natural Language Processing, Computational Linguistics and Speech Recognition", Pearson Education.</td></tr>
</table>

Semester-4

Course Name	Core/Elective	Code	Credit	L-T-P	Pre Requisites
Thesis	Core	Hard	12	0-0-12	**Mini Project**
Total			**12**		

M.Tech.(ECE)

with specialization in

Microelectronics

Curriculum Structure (L-T-P)

Semester I:

Course Name	**Core/Elective**	**Code**	**Credit**	**L-T-P**	**Pre Requisites**
Embedded Systems Design	Core	Hard	4	3-1-0	Nil
Reconfigurable Computing Systems	Core	Hard	4	2-1-1	Nil
Digital System Design	Core	Hard	4	2-1-1	Nil
VLSI Technology	Core	Hard	4	3-0-1	Nil
Solid State Devices	Core	Hard	4	3-1-0	Nil
Total			20		

Semester II:

Course Name	**Core/Elective**	**Code**	**Credit**	**L-T-P**	**Pre Requisites**
*Minor Module on 1. VLSI Design 2. Device Fabrication Technology 3. Computational Nanoelectronics *Later on more modules may be added and some of these may be dropped by DPGC*	Elective	Soft	8		Nil
Hands-on with Experimental Tool on Minor Module	Elective	Soft	4	0-2-2	Nil
Independent Study	Elective	Soft	4	0-2-2	Nil
Total			16		

**The Faculty member(s) who are offering a minor module may suitably divide 8 credits into multiple courses/lab/workshop/project with customized LTP components as per their teaching plan.*

** Maximum/Minimum number of seats in different modules will be decided by DPGC every year before the beginning of 2nd semester*

Semester III:

Course Name	**Core/Elective**	**Code**	**Credit**	**L-T-P**	**Pre Requisites**
**Major Module on 1. VLSI Design 2. Device Fabrication Technology 3. Computational Nanoelectronics *Later on more modules may be added and some of these may be dropped by DPGC*	Elective	Soft	12		Minor module in respective major area
Mini Project	Core	Soft	4	0-1-3	Nil
Total			16		

***The Faculty member(s) who are offering a major module may suitably divide 12 credits into multiple courses/lab/workshop/project with customized LTP components as per their teaching plan.*

Semester IV:

Course Name	**Core/Elective**	**Code**	**Credit**	**L-T-P**	**Pre Requisites**
Thesis	Core	Hard	12	0-2-12	Mini Project
Total			12		

Semester-1

Course Name	Core/Elective	Code	Credit	L-T-P	Pre Requisites
Embedded Systems Design	Core	Hard	4	3-1-0	Nil
Reconfigurable Computing Systems	Core	Hard	4	2-1-1	Nil
Digital System Design	Core	Hard	4	2-1-1	Nil
VLSI Technology	Core	Hard	4	3-0-1	Nil
Solid State Devices	Core	Hard	4	3-1-0	Nil
Total			**20**		

Name of the Course: *Embedded System Design*

1. **LTP structure of the course:** 3–1–0
2. **Objective of the course:** To make students familiar with the fundamentals of embedded system Design and techniques.
3. **Outcome of the course:** Students will be able to model and design the processor, memory, and controllers for the system applications.
4. **Course Plan:**

Component	Unit	Topics for Coverage
Component 1	Unit 1	Evolution of processors for embedded application; High performance computing and low power computing; Moore's law and Amdahl's law; Brief overview of performance estimation; Performance gap in microprocessor and memory; Introduction of Cache hierarchy in processors; Memory elements and hierarchy (SRAM, DRAM, Flash, Hard Disk).Techniques for hardware Performance improvement; Design Process of embedded system; Hardware/Software Interface.
	Unit 2	Performance and efficiency of ARM architecture (ARM 7, ARM 9, ARM 11). Thumb and ARM Instruction set and Programming; Data processing, Data transfer, and Control flow instructions. Data Level Parallelism and Thread level parallelism, Memory Interfacing,, I/O interfacing, Interface IP: AMBA, DDR, Ethernet, USB, Analog IP: Data Converter and PLL, Embedded Memory IP; Serial Communication and Parallel Communication.
Component 2	Unit 3	Sensors and actuators, Interfacing to sensors and actuators, Constraints in design, Reaction constraints and execution constraints, Heterogeneity, Constructivity; Execution and Interaction Semantics, Composition of state machines, Hierarchical state machines.
	Unit 4	Real Time Operating systems, Scheduling, Memory and I/O management, Bus I/O and networking considerations, System verification, Testing of embedded systems.

Reference Books

1. Heath, Steve, Embedded systems design., Newnes, 2002.
2. Hennessy, John L., and David A. Patterson. Computer architecture: a quantitative approach. Elsevier, 2012.
3. Wolf, Wayne. FPGA-based system design. Pearson Education, 2004.

Name of the Course: *Reconfigurable Computing*

1. **LTP structure of the course:** 2–1–1
2. **Objective of the course:** To make students familiar with the fundamentals of reconfigurable hardware architectures, design techniques, and applications.
3. **Outcome of the course:** Students will be able to synthesize reconfigurable hardware architecture and applications.
4. **Course Plan:**

Component	Unit	Topics for Coverage
Component 1	Unit 1	General Purpose, Domain Specific, Application Specific & Reconfigurable Computing, Programmable Logic ROM, PLA, PAL, PLD, programming and applications
	Unit 2	FPGA Architecture, Configuration: SRAM Based-FPGAs, Permanently Programmed FPGAs, Programmable I/O, Circuit Design & Architecture of FPGA Fabrics, Case Studies (Xilinx/Altera/Vertex etc).
Component 2	Unit 3	Logic Design Process, Design Integration, FPGA Design Flow, Implementation Approaches, Run Time Reconfiguration (RTR), systolic array, Super systolic array, Logic Synthesis
	Unit 4	Multi-Context FPGAs, Introduction to Partial Reconfiguration, FPGA partitioning, floor planning, placement, physical design flow, global routing,circuit extraction – DRC

Reference Materials and Books

1. Wolf Wayne, “FPGA Based System Design”, Pearson Education India, 2004.
2. Design manuals of Altera, Xilinx and Actel. (From the web).
3. P. K. Chan& S. Mourad, Digital Design using Field Programmable Gate Array, Prentice Hall
5. K. Hwang: Advanced Computer Architecture; McGraw-Hill, 1993.
6. R. Hartenstein, H. Grünbacher (Editors): The Roadmap to Reconfigurable computing - Proc. FPL2000.
7. D. Cherepacha and D. Lewis: A Datapath Oriented Architecture for FPGAs; Proc. FPGA‘94

Name of the Course: *Digital System Design*

1. **LTP structure of the course:** 2–1–1
2. **Objective of the course:** To make students familiar with the fundamentals of Digital circuit and system Design.
3. **Outcome of the course:** Students will be able to design the digital integrated circuits and systems and estimate the performance.
4. **Course Plan:**

Component	Unit	Topics for Coverage
Component 1	Unit 1	**Introduction:** MOSFETs, CMOS process design kit, Static Characteristics: Introduction, Resistive-Load Inverters, Inverters with n-Type MOSFET Load, CMOS Inverter. Dynamic characteristics and interconnect effect: Introduction, Delay-Time Definitions, Calculation of Delay-Times, Inverter Design with Delay Constraints, Estimation of Interconnect Parasitic, Calculation of Interconnect Delay, Switching Power Dissipation of CMOS Inverters.
	Unit 2	**Combinational and Sequential Circuits:** MOS Logic Circuits with Depletion nMOS Loads, CMOS Logic Circuits, Complex Logic Circuits, CMOS Transmission Gates (Pass Gates), Behavior of Bistable Elements, SR Latch Circuits, Clocked Latch and Flip-Flop Circuits, CMOS D-Latch and Edge-Triggered FlipFlop.
Component 2	Unit 3	**Dynamic Logic Circuits:** Introduction, Basic Principles of Pass Transistor Circuits, Dynamic CMOS Circuit Techniques like Precharge-Evaluation logic, NORA, ZIPPER, Stick Diagrams, Physical Design Rules; Layout Designing; Euler's Rule for VLSI Physical Design.
	Unit 4	**Clock Generation, Distribution, and Timing Analysis**: Simple clock generation circuits, Clock Distribution schemes, Input and Output Interface circuits: Set up time, hold time, clock skew, slack, calculation of set up time and hold time violation, clock frequency, propagation delay, metastability, Standard designs of Dynamic Random Access Memory (DRAM), Static Random Access Memory (SRAM) and Non-volatile Memory, Flash Memory.

Reference Books:

1. Uyemura, John P. "Introduction to VLSI circuits and systems." (2002).
2. Rabaey, Jan M., Anantha P. Chandrakasan, and Borivoje Nikolic. Digital integrated circuits. Vol. 2. Englewood Cliffs: Prentice hall, 2002.
3. Kang, Sung-Mo, and Yusuf Leblebici. CMOS digital integrated circuits. Tata McGraw-Hill Education, 2003

Name of the Course: *VLSI Technology*

1. **LTP structure of the course:** 3-0-1
2. **Objective of the course:** The subject provides an in-depth knowledge of how a semiconductor device is prepared right from the substrate preparation to device fabrication.
3. **Outcome of the course:** After completion of this course, the students will be able to understand the technology and basic principles underlying the fabrication process of semiconductor devices.
4. **Prerequisites**: The basic knowledge of semiconductor device physics.
5. **Course Plan:**

Component	Unit	Topics for Coverage
Component 1	Unit 1	Crystal growth, and wafer preparation: crystal structures, wafer fabrication, crystal defects, gettering
	Unit 2	Thermal Oxidation: Oxidation kinetics, impurity redistribution during oxidation, oxide charges, nitridation of Silicon
Component 2	Unit 3	Lithography: photolithography steps, photoresists, wet and dry etching, introduction to E-beam, X-ray and ion-Beam lithography
	Unit 4	Basic diffusion process, equations, and profiles; Ion Implantation and implant range, Ion stopping and ion channeling interconnects, modern CVD and PVD techniques and systems, refractory metals, Modern CMOS processes

Textbook:

1. J. D. Plummer, M. D. and P. D. Griffin, Silicon VLSI Technology: Fundamentals, Practice, and Modeling, Pearson Education.

References:

1. S. M. Sze, VLSI Technology, McGraw Hill Education, Second Edition.
2. G. S. May and S M Sze, Fundamentals of Semiconductor Fabrication, John Wiley & Sons,
3. S. K. Gandhi, VLSI Fabrication Principles: Silicon and Gallium Arsenide, John Wiley & Sons, Second Edition.

Name of the Course: *Solid State Devices*

1. **LTP structure of the course**: 3-1-0
2. **Objective of the course**: To acquire the basic concepts of electronic devices
3. **Outcome of the course**: The student is expected to apply the concepts developed from this course in their MTech thesis/research in the field of Microelectronics.
4. **Course Plan:**

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	**Basic Semiconductor Physics:** Quantum mechanical concepts and atomic states, band structure, charge carriers, diffusion of carriers, BTE, etc.
	Unit 2	**Junctions:** p-n junctions, Schottky barrier junctions, heterojunctions, ohmic contacts, introduction to photonic devices
Component 2	Unit 3	**Bipolar Junction Transistors:** principle of operation,I-V characteristics, Ebers-Moll Model, Gummel-Poon model, small signal amplifier
	Unit 4	**Field Effect Transistors:** MOS Capacitor, MOSFET, principle of operation,I-V characteristics, short channel and non-ideal effects in MOSFETs

Text Book:

1. Michael Shur, *Physics of Semiconductor Devices*, PHI, 1995.
2. Ben G. Streetman, Solid State Electronic Devices, PHI, 4th Edition.

References:

1. S. Sedra and K. C. Smith, Microelectronic Circuits, Oxford Univ. Press, 5th Edition.

Semester-2

Course Name	Core/Elective	Code	Credit	L-T-P	Pre Requisites
*Minor Module on 1. VLSI Design 2. Device Fabrication Technology 3. Computational Nanoelectronics *Later on more modules may be added and some of these may be dropped*	Elective	Soft	8		Nil
Hands-on with Experimental Tool on Minor Module	Elective	Soft	4	0-2-2	Nil
Independent Study	Elective	Soft	4	0-2-2	Nil
Total			16		

**The Faculty member(s) who are offering a minor module may suitably divide 8 credits into multiple courses/lab/workshop/project with customized LTP components as per their teaching plan.*

Minor Module
on
VLSI Design

Course Name	Core/Elective	Code	Credit	L-T-P	Pre Requisites
Analog Integrated Circuit Design	Elective	Soft	2	2-0-0	NIL
Hardware Design Methodology	Elective	Soft	2	2-0-0	NIL
Testing and Verification	Elective	Soft	4	3-0-1	NIL
Advanced Computer Architecture	Elective	Soft	2	2-0-0	NIL
Total			8*		
* Student has to complete total 8 credit out of the course work -More Electives may be added as per the requirement of the Module					
Hands-on with Experimental Tool on VLSI Design	Elective	Soft	4	0-2-2	Nil

Name of the Course: *Analog Integrated Circuit Design*

1. **LTP structure of the course:** 2-0-0
2. **Objective of the course:** To make students familiar with the fundamentals of Analog circuit Design.
3. **Outcome of the course:** Students will be able to design the Analog integrated circuits and systems and estimate the performance.
4. **Course Plan:**

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Review of integrated circuits Device characteristics & models.
	Unit 2	CS, CG and CD amplifier, Differential amplifier, Current mirror, active loads, Output Stages, Frequency response of CS, CG and CD amplifier.
Component 2	Unit 3	Multistage amplifiers, Frequency Response of amplifiers, feedback techniques, Frequency Response & Stability of Feedback Amplifiers.
	Unit 4	OPAMP in amplifiers and filters etc, Noise, non-linearity, mismatch, MOS vs Bipolar OPAMP

Books:

1. Gray, Paul R., and Robert G. Meyer. Analysis and design of analog integrated circuits. John Wiley & Sons, Inc., 1990.
2. Razavi, Behzad. Design of analog CMOS integrated circuits. 2005.

Name of the Course: *<u>Hardware Design Methodology</u>*

1. **LTP structure of the course:** 2–0-0
2. **Objective of the course:** To make students familiar with the fundamentals of Hardware Design and Methodology.
3. **Outcome of the course:** Students will be able to apply speed, power and area optimization methods while designing digital and analog ICs and also shall be able to know and distinguish frontend and backend design.
4. **Course Plan:**

Component	**Unit**	**Topics for Coverage**
Component-1	Unit 1	Number Representation, computer arithmetic, Representing Signed Numbers, Redundant & Residue Number Systems
	Unit 2	Addition/Subtraction, Addition and Counting, Adders, Variation bib Fast Adders, Multi operand Addition.
Component-2	Unit 3	Basic Multiplication Schemes, High-Radix Multipliers, Tree and Array Multipliers, Variations in Multipliers, Real Arithmetic
	Unit 4	Function Evaluation, Square-Rooting Methods, The CORDIC Algorithms Variations in Function Evaluation, High-Throughput AND Low pOwer Arithmetic

Textbooks:

1. CMOS VLSI Design A circuit and systems perspective by Neil H.E. Weste and David M. Harris.
2. Computer Arithmetic By BehroozParhami , Oxford 2020.
3. N. Zainalabedin. Verilog digital system design, McGraw-Hill, 1999.
4. Digital Integrated Circuits: A Design Perspective, J. M. Rabaey, PHI, 2nd edition.
5. W. Wayne. FPGA-based system design, Pearson education, 2004
6. Computer Arithmetic Algorithms, 2nd Edition by Israel Koren

References:

1. Logical Effort, Designing Fast CMOS Circuits, Ivan Sutherland, Bob Sproull, David Harris. Morgan Kaufmann, 1999.
2. W. Wayne. FPGA-based system design, Pearson education, 2004

Name of the Course: *Testing and Verification*

1. **LTP structure of the course**: 3-0-1
2. **Objective of the course**: To let the first year M. Tech. students exposed to Testing and to demonstrate their application on real time system.
3. 4. **Outcome of the course**: The students will learn how to handle Verification Students will be exposed to Testing and explore many areas of Testing & Verification
4. Course Plan: As per the below format only

Component	Unit	Topics for Coverage
Component 1	Unit 1	Basics of testing and fault modelling: Introduction- Principle of testing - types of testing - DC and AC parametric tests - fault modelling
	Unit 2	Testing and testability of combinational &sequential circuits, algorithms, Boundary scan, Memory, IDDQ
Component 2	Unit 3	Testing : Testable memory design - test algorithms for RAMs, IDDQ testing - testing methods - limitations
	Unit 4	Built-in self-test: Test pattern generation (BIST) - Output response analysis – BIST architectures.

Text Book:

1. M.L. Bushnell and V.D. Agrawal, "Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits", Kluwar Academic Publishers.

References:-

1. P. K. Lala, "Digital Circuit Testing and Testability", Academic Press.
2. N.K. Jha and S.G. Gupta, "Testing of Digital Systems", Cambridge University Press.
3. N. Zainalabedin, "Digital System Test and Testable Design: Using HDL Models and Architectures", Springer.

Name of the Course: *<u>Advanced Computer Architecture</u>*

1. **LTP structure of the course:** 2–0–0
2. **Objective of the course:** To make students familiar with fundamentals of Computer Architecture.
3. **Outcome of the course:** Students will be able to analyze and improve the performance of CPU, memory and controllers.
4. **Course Plan:**

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Instruction set architecture; single-cycle, FSM, and pipelined processor microarchitecture; resolving structural, data, control, and name hazards; and analyzing processor performance.
	Unit 2	Memory technology; direct-mapped vs. associative caches; write-through vs write-back caches; memory protection, translation, and virtualization; FSM and pipelined cache microarchitecture; analyzing memory performance; and integrating processors and memories.
Component 2	Unit 3	Superscalar execution, out-of-order execution, register renaming, memory disambiguation, branch prediction, speculative execution; multithreaded, VLIW, and SIMD processors.
	Unit 4	Advanced cache microarchitecture; memory synchronization, consistency, and coherence.

Reference Books

1. Harris, Sarah L., and David Harris. Digital design and computer architecture: arm edition. Morgan Kaufmann, 2015.
2. Hennessy, John L., and David A. Patterson. Computer architecture: a quantitative approach. Elsevier, 2011.

Name of the Course: *Hands-on with Experimental Tool on VLSI Design*

1. **LTP structure of the course:** 0–2–2
2. **Objective of the course:** To make students familiar with the methods and techniques used in EDA Tools for simulations .
3. **Outcome of the course:** Students will be able to design and simulate digital and analog design using EDA Tools.
4. **Course Plan:**

Component	Unit	Topics for Coverage
Component 1	Unit 1	Digital design using Verilog
	Unit 2	Implementation of Digital system using FPGA Kits
Component 2	Unit 3	Basic Analog design using Spice Simulation
	Unit 4	Analog design using Spice Simulation

Text Book/ References: -

1. **Muller, Richard S., et al. "Device electronics for integrated circuits." (1986): 54.**
2. **Allen and Holberg - CMOS *Analog Circuit Design*.**

Minor Module
on
Device Fabrication Technology

Course Name	Core/Elective	Code	Credit	L-T-P	Pre Requisites
Testing and Verification	Elective	Soft	4	3-1-0	NIL
Advanced Lithography	Elective	Soft	4	3-1-0	NIL
Physics of Nanoscale Devices	Elective	Soft	4	3-1-0	NIL
Total			**8**		
-More Electives may be added as per the requirement of the Module					
Hands-on with Experimental Tool on Device Fabrication Technology	Elective	Soft	4	0-2-2	Nil

Name of the Course: *Testing and Verification*

1. **LTP structure of the course**: 3-1-0
2. **Objective of the course**: To let the first year M. Tech. students exposed to Testing and to demonstrate their application on real time system.
3. 4. **Outcome of the course**: The students will learn how to handle Verification Students will be exposed to Testing and explore many areas of Testing & Verification
4. Course Plan: As per the below format only

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Basics of testing and fault modeling: Introduction- Principle of testing - types of testing - DC and AC parametric tests - fault modeling
	Unit 2	Testing and testability of combinational &sequential circuits,algorithms, Boundary scan, Memory, IDDQ
Component 2	Unit 3	Testing : Testable memory design - test algorithms for RAMs, IDDQ testing - testing methods - limitations
	Unit 4	Built-in self-test: Test pattern generation (BIST) - Output response analysis – BIST architectures.

Text Book:

1. M.L. Bushnell and V.D. Agrawal, "Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits", Kluwar Academic Publishers.

References: -

1. P. K. Lala, "Digital Circuit Testing and Testability", Academic Press.
2. N.K. Jha and S.G. Gupta, "Testing of Digital Systems", Cambridge University Press.
3. N. Zainalabedin, "Digital System Test and Testable Design: Using HDL Models and Architectures", Springer.

Name of the Course: *Advanced Lithography*

1. **LTP structure of the course**: 3-1-0
2. **Objective of the course**: To let the students learn the advanced lithography techniques being used in the modern VLSI technology.
3. **Outcome of the course**: The students will be able to understand the basic and advanced lithography methods which will help them to pursue in the research and development the VLSI domain.
4. Course Plan:

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Overview of nanofabrication, Lithographies, Thin film deposition techniques. Etching techniques. High resolution photon-based lithography. Electron beam lithography. (4h)
	Unit 2	Resists and developers, resolution limits, contrast, sensitivity, etching selectivity. Nano-patterning by focused ion beam. Ion source, ion optics, instrumentation.
Component 2	Unit 3	Nanoimprint lithography (NIL). Nano-patterning by scanning probes. AFM-based, local oxidation and dip-pen lithography. STM-based, manipulation of atoms and exposure of resist.
	Unit 4	Soft lithography. Micro-contact printing of chemical patterns, capabilities and resolution limits. Nano-transfer printing. Nano-patterning by self-assembly, Anodized aluminum oxide,

Text Book:

1. Nanofabrication: principles, capabilities and limits, by Zheng Cui

References:

1. Silicon VLSI Technology: Fundamentals, Practice, and Modeling by James D. Plummer,Michael,laeD (noitidE dn2) nosraeP ,niffirG .D reteP

Name of the Course: *Physics of Nanoscale Devices*

1. **LTP structure of the course:** 3–1–0
2. **Objective of the course:** To develop the fundamental concepts underlying the operation of nanoscale devices
3. **Outcome of the course:** The student is expected to apply in the concepts developed in their research activities.
4. **Course Plan:**

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	**Basic concepts:** Ballistic and diffusive conductance, Drude formula, angular averaging
	Unit 2	**Energy Band model:** E-k relation, counting States, DOS number of modes, conductivity vs. Electron Density quantum capacitance
Component 2	Unit 3	Quasi-Fermi Levels (QFL's), current from QFLs, Landauer Formulas, Boltzmann Equation
	Unit 4	**Heat and Energy:** Seebeck Coefficient, heat current, one-level device, second law, entropy, fuel Value of Information

Text Book:

1. S. Datta, "Lessons from Nanoelectronics: A New Perspective on Transport", World Scientific, 2012.

References:

1. Research papers related to the topics.

Name of the Course: ***<u>Hands on Experience on Device Fabrication Technology</u>***

1. **LTP structure of the course:** 0–2–2
2. **Objective of the course:** To make students familiar with the methods and techniques used in EDA Tools for simulations and fabrication for semiconductor devices.
3. **Outcome of the course:** Students will be able to design and simulate devices and circuits using EDA Tools.
4. **Course Plan:**

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Understating of the simulation tool Quantum ATK/Setfos – Fluxim/Comsol/Sentaurus TCAD
	Unit 2	Basic structure design using simulation tool
Component 2	Unit 3	Preliminary processes of device fabrication
	Unit 4	Fabrication and characterization

References:

1. Research papers related to the topics.

Minor Module
on
Computational Nanoelectronics

Course Name	**Core/Elective**	**Code**	**Credit**	**L-T-P**	**Pre-Requisites**
Quantum Mechanics	Elective	Soft	4	3-1-0	Electronic Devices
Semiconductor Optoelectronics	Elective	Soft	4	3-1-0	Electronic Devices
Physics of Nanoscale Devices	Elective	Soft	4	3-1-0	Electronic Devices
Total			8*		
* Student has to complete total 8 credit out of the course work -More Electives may be added as per the requirement of the Module					
Hands-on with Experimental Tool on Computational Nanoelectronics	Elective	Soft	4	0-2-2	Nil

Name of the Course: *Quantum Mechanics*

1. **LTP structure of the course**: 3-1-0
2. **Objective of the course**: To let the first year M. Tech. students exposed to Quantum Mechanics.
3. **Outcome of the course**: The student is expected to apply in the concepts developed in their research activities.
4. Course Plan: As per the below format only

Component	Unit	Topics for Coverage
Component 1	Unit 1	Basic postulates of quantum mechanics, Stern-Gerlach experiment and spin, Kets, Bras and operators, Wave functions.
	Unit 2	Schrodinger equation, Schrodinger and Heisenberg picture, Simple Harmonic Oscillator, Hydrogen Atom
Component 2	Unit 3	Symmetries, conservation laws and degeneracy's, Continuous and discrete symmetries
	Unit 4	Theory of angular momentum, Addition of angular momentum, Bell's inequality, Tensor operators. Identical particles.

Text Books/References: -

1. Introduction to Quantum Mechanics by D. J. Griffiths.
2. Modern Quantum Mechanics by J. J. Sakurai.
3. Principles of Quantum Mechanics by R. Shankar.

Name of the Course: *Semiconductor Optoelectronics*

1. **LTP structure of the course**: 3-1-0
2. **Objective of the course**: To let the first year M.Tech. students exposed to Optoelectronic Devices.
3. **Outcome of the course**: The students will learn how to fundamentals of optoelectronic devices.
4. Course Plan: As per the below format only

Component	Unit	Topics for Coverage
Component 1	Unit 1	Energy bands in solids, the E-k diagram, Density of states, Heterostructures and Quantum Wells.
	Unit 2	Interaction of photons with electrons and holes, Rates of emission and absorption, Condition for amplification by stimulated emission
Component 2	Unit 3	Semiconductor Photon Sources: Electroluminescence. DFB-, DBR- and vertical-cavity surface-emitting lasers (VCSEL).
	Unit 4	Semiconductor Photodetectors:Types of photodetectors, Photoconductors, Single junction under illumination

Text Book/References:

1. S. Lien Chuang, Physics of photonic devices. Vol. 80.John Wiley & Sons, 2012.
2. P. Bhattacharya, Semiconductor Optoelectronic Devices, 2nd Edition
3. J. Piprek, Semiconductor Optoelectronic Devices: Introduction to Physics and Simulation, Academic press, 2003

Name of the Course: ***<u>Physics of Nanoscale Devices</u>***

1. **LTP structure of the course:** 3–1–0
2. **Objective of the course:** To develop the fundamental concepts underlying the operation of nanoscale devices
3. **Outcome of the course:** The student is expected to apply in the concepts developed in their research activities.
4. **Course Plan:**

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	**Basic concepts:** Ballistic and diffusive conductance, Drude formula, angular averaging
	Unit 2	**Energy Band model:** E-k relation, counting States, DOS number of modes, conductivity vs. Electron Density quantum capacitance
Component 2	Unit 3	Quasi-Fermi Levels (QFL's), current from QFLs, Landauer Formulas, Boltzmann Equation
	Unit 4	**Heat and Energy:** Seebeck Coefficient, heat current, one-level device, second law, entropy, fuel Value of Information

Text Book:

1. S. Datta, "Lessons from Nanoelectronics: A New Perspective on Transport", World Scientific, 2012.

References:

1. Research papers related to the topics.

Name of the Course: *Hand on Experience on Simulation of Materials and Devices*

1. **LTP structure of the course: 0–2–2**
2. **Objective of the course: To make students familiar with the methods and techniques used in EDA Tools for simulations of nano materials and nano devices.**
3. **Outcome of the course: Students will be able to simulate materials and devices using EDA Tools.**
4. **Course Plan:**

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Electronics structure simulation using Quantum ESPRESSO, Synopsys - QuantumATK
	Unit 2	Study of thermoelectric properties using Quantum ESPRESSO, Synopsys - QuantumATK
Component 2	Unit 3	0D Device simulation using Synopsys - QuantumATK
	Unit 4	1D/2D Device simulation using Synopsys - QuantumATK

References:

1. Lee, J.G., 2016. Computational materials science: an introduction. CRC press.
2. Smidstrup, S., Markussen, T., Vancraeyveld, P., Wellendorff, J., Schneider, J., Gunst, T., Verstichel, B., Stradi, D., Khomyakov, P.A., Vej-Hansen, U.G. and Lee, M.E., 2019. QuantumATK: an integrated platform of electronic and atomic-scale modelling tools. Journal of Physics: Condensed Matter, 32(1), p.015901.

Semester-3

Course Name	Core/Elective	Code	Credit	L-T-P	Pre-Requisites
**Major Module on 1. VLSI Design 2. Device Fabrication Technology 3. Computational Nanoelectronics *Later on more modules may be added and some of these may be dropped*	Elective	Soft	12		Minor module in respective major area
Mini Project	Core	Soft	4	0-1-3	Nil
Total			**16**		

***The Faculty member(s) who are offering a major module may suitably divide 12 credits into multiple courses/lab/workshop/project with customized LTP components as per their teaching plan.*

Major Module
on
VLSI Design

Course Name	**Core/Elective**	**Code**	**Credit**	**L-T-P**	**Pre-Requisites**
Low Power System Design	Elective	Soft	4	3-1-0	**NIL**
RF Integrated Circuit Design	Elective	Soft	4	3-1-0	**NIL**
Mixed Signal IC Design	Elective	Soft	4	3-0-1	**NIL**
Memory Architecture	Elective	Soft	4	3-1-0	**NIL**
Embedded System Security	Elective	Soft	4	3-1-0	**NIL**
Total			12*		

* Student has to complete total 12 credit out of the course work

-More Electives may be added as per the requirement of the Module

Name of the Course: *Low Power System Design*

1. **LTP structure of the course:** 3–1–0
2. **Objective of the course:** To make students familiar with fundamentals of low power system Design and techniques.
3. **Outcome of the course:** Students will be able to model and design low power design techniques in CMOS Digital and Analog subsystems.
4. **Course Plan:**

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	**Introduction:** Basics of MOSFETs and CMOS technology, CMOS combinational and sequential circuits, Logic families, standard cell libraries for logic synthesis. **Sources of Power dissipation:** Power and Energy, Dynamic power dissipation (short circuit, switching, glitching), static power dissipation, degrees of freedom.
	Unit 2	**Supply Voltage Scaling:** Device feature size scaling, Multi-Vdd Circuits, Architectural level approaches: Parallelism, Pipelining, Voltage scaling using high-level transformations, Dynamic voltage scaling, Power Management, Hardware Software Tradeoff, Bus Encoding, Architectural optimization, Clock Gating, Logic styles.
Component 2	Unit 3	**Leakage Power minimization Approaches:** Variable-threshold-voltage CMOS (VTCMOS) approach, Multi-threshold-voltage CMOS (MTCMOS) approach, Power gating, Transistor stacking, Dual-Vt assignment approach (DTCMOS).**Miscellaneous Topics:** Adiabatic Switching Circuits, Battery-aware Synthesis, Variation tolerant design, CAD tools for low power synthesis. Battery driven circuits
	Unit 4	**Scaled Analog CMOS Design:** Sub-threshold region of operation, Scaled V_{DD} and voltage swing consideration, Low-voltage current mirrors, VDD_{min}, Fundamentals of Sub-threshold Circuit design, Self-cascode, Low power OPAMPS and MOS only-BGRs.

Reference Books

1. Sung Mo Kang, Yusuf Leblebici, CMOS Digital Integrated Circuits, Tata Mcgrag Hill.
2. CMOS Analog Circuit Design, Phillip E. Allen, Douglas R. Holberg, 2nd edition, Oxford University Press
3. Neil H. E. Weste and K. Eshraghian, Principles of CMOS VLSI Design, 2nd Edition, Addison Wesley.
4. Bellamour, and M. I. Elmasri, Low Power VLSI CMOS Circuit Design, Kluwer Academic Press, 1995.
5. Anantha P. Chandrakasan and Robert W. Brodersen, Low Power Digital CMOS Design, Kluwer Academic Publishers, 1995.
6. Kaushik Roy and Sharat C. Prasad, Low-Power CMOS VLSI Design, Wiley-Interscience, 2000.

Name of the Course: ***Radio Frequency Integrated Circuits***

1. **LTP structure of the course:** 3–1–0
2. **Objective of the course:** To make students familiar with fundamentals and design of RF integrated circuits.
3. **Outcome of the course:** Students will be able to design cascaded systems used for transceiver applications in various frequency bands that can be used for cellular, Bluetooth, WiFi, IoT applications.
4. **Course Plan:**

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	CMOS and BiCMOS Technology, RF systems (Transmitter and Receiver Architecture), Basic radio architectures, Process design kit, Passive and active components, Thermal Noise and Flicker Noise, Noise figure.
	Unit 2	High frequency amplifiers, Low noise amplifiers, Power Amplifiers.
Component 2	Unit 3	Up conversion and down conversion mixer design, PLL, Voltage controlled oscillator, Phase detector, charge pump, phase lock loop.
	Unit 4	High speed OP-AMP, OTA, negative feedback, active inductor, first order and second order low pass, high pass, band pass and band reject filter design.

Books:

1. Lee, Thomas H. The design of CMOS radio-frequency integrated circuits. Cambridge university press, 2004.
2. Razavi, Behzad, and RazaviBehzad. RF microelectronics. Vol. 1. New Jersey: Prentice Hall, 1998.

Name of the Course: *Mixed Signal IC Design*

1. **LTP structure of the course:** 3–0–1
2. **Objective of the course:** To make students familiar with Mixed signal Integrated Circuits.
3. **Outcome of the course:** Students will be able to performance optimization for mixed signal ICs followed by chips.
4. **Course Plan:**

Component	Unit	Topics for Coverage
Component 1	Unit 1	Review of Current and Voltage Sources, Current Mirrors, Voltage References and CMOS op-amps
	Unit 2	Noise in MOS Circuits, Introduction to Data Conversion Circuits
Component 2	Unit 3	Data Conversion Circuits, Basic Requirements, Different A/D and D/A circuits, design & working
	Unit 4	Clock Generation for Mixed Signal System ICs , PLL, SC circuits

Text Book/ References: -

1. Allen and Holberg - CMOS *Analog Circuit Design*.

Name of the Course: ***Memory Architecture***

1. LTP structure of the course: 3-1-0
2. Objective of the course: To let the M. Tech. students exposed about Memory Architecture.
3. Outcome of the course: Students will be able to understand Memory Architecture for embedded System
4. Course Plan: As per the below format only

Component	Unit	Topics for Coverage
Component-1	Unit 1	Introduction, Evolution of memory technologies. Static Random Access Memories (SRAM), Advanced SRAMs (Vmin, Leakage, Reliability, New device concepts), High performance multi-ported SRAMs, Register files, Multi-ported SRAMs.
	Unit 2	Content Addressable memories (CAM)- Binary CAMs, Ternary CAMs, Dynamic Random Access Memory (DRAM) – basics and peripheral circuit design, DRAM stacking, Embedded DRAM (eDRAM): 1T1C, and gain-cell eDRAMs
Component-2	Unit 3	Embedded Non-Volatile Memories (eNVM): Read-Only-Memory (ROM), Programmable ROM (PROM), Resistive RAM: Device technologies (OxRAM, CBRAM, 2D) and Circuits
	Unit 4	Magnetic RAM: Bitcells (STT, SOT, VCMA) and Circuits, Special purpose memories: NV-SRAMs, NOR FLASH: Device and circuits, NAND FLASH: devices, circuits and array architectures.

Reference Books:

1. Xie, Yuan, ed. *Emerging Memory Technologies: Design, Architecture, and Applications*. Springer Science & Business Media, 2013.
2. Handy, Jim. *The cache memory book*. Morgan Kaufmann, 1998.

Name of the Course: *Embedded System Security*

1. LTP structure of the course: 3-1-0
2. Objective of the course: This course is intended to be the text for a course in Embedded System Security where it introduces to various encryption and decryption techniques. It is partitioned into four parts starting from the basics of Encryption, Preliminary mathematics needed, Symmetric Ciphers and Hashes and Asymmetric Ciphers. Various encryption algorithms of both symmetric and asymmetric types like DES, AES, SHA, RSA and Diffie-Hellman are being discussed and will be implemented.
3. Outcome of the course:To provide an overall understanding of various security techniques. The student will understand how an encryption and decryption algorithm is designed and the mathematics behind it. Besides this, the course will develop an understanding of the various encryption techniques like DES, AES, SHA, RSA, and Diffie-Hellman.
4. Course Plan: As per the below format only

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Basics of Public key and Private key, Encryption & Decryption, Classical Ciphers and their working, Security Goals and Notions.
	Unit 2	Essential Number Theory and Discrete Math, Information Security, Computational Security,
Component 2	Unit 3	DES, P-Box S-Box design. Cryptographic Hashes: SHA
	Unit 4	Asymmetric Ciphers: RSA, Diffie-Hellman. Applications: Key Exchange

Text Book:

1. Modern Cryptography: Applied Mathematics for Encryption and Information Security. Chuck Easttom.McGraw-Hill Education, 2016.
2. The mathematics of encryption: An Elementary Introduction. Cozzens, Margaret, and Steven J. Miller. Vol. 29. American Mathematical Soc., 2013

References:

1. Algebraic Aspects of the Advanced Encryption Standard.Cid, Carlos, Sean Murphy, and Matthew Robshaw. Springer Science & Business Media, 2006.

3. Serious Cryptography: A Practical Introduction to Modern Encryption. Jean-Philippe Aumasson. No Starch Press.

Major Module
on
Device Fabrication Technology

Course Name	**Core/Elective**	**Code**	**Credit**	**L-T-P**	**Pre-Requisites**
Microelectromechanical Systems (MEMS)	Elective	Soft	4	3-1-0	NIL
Modeling and Simulation of VLSI Devices	Elective	Soft	4	2-1-1	NIL
Thin Film Science & Technology	Elective	Soft	4	3-1-0	VLSI Technology
Total			12		

-More Electives may be added as per the requirement of the Module

Name of the Course: ***Microelectromechanical Systems (MEMS)***

1. **LTP structure of the course**: 3-1-0
2. **Objective of the course**: The course is aimed at teaching the basics and advancements micro and nano-electromechanical system with technology and design part on the prime focus.
3. **Outcome of the course**: The students will be able to understand the principles and technologies behind micro and the nano-electromechanical system being used in the modern era.
4. **Course Plan**:

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Introduction, Surface micromachining, Transport inPolySi, Basic Electrical &Mechanical concepts: Transduction Methods Magnetic Sensing & actuation
	Unit 2	Bulk micromachining; Bonding, Comparison of bulk and Surface micromachining: LIGA; SU-8; Mouldingprocesses, Basic Electrical &Mechanical concepts: Electrostatic/Thermal/Piezoresistive
Component 2	Unit 3	Stiction process, Pull-in parallel plate capacitor Pressure Sensor: piezo-resisitivity, Diffused Si, Poly, porous Si, Beams, Accelerometer,
	Unit 4	RF MEMS, Optical MEMS, Micro-fluidics, Chemical & Bio MEMS, Packaging & testing Nanoelectromechanical systems (NEMS), MEMSbased nanotechnology , NEMS physics

Text Book:

1. Foundations of MEMS, Chang Liu,Illinois ECE series, Pearson International edition
2. An Introduction to microsystem Engineering, N.Maluf, Artech House,2000

References:

1. Fundamentals of Microfabrication, M. Madau,2ndedition, CRC Press,2002
2. RF MEMS Theory, Design& Technology, G.M.Rebeiz, John –Willey,2003

Name of the Course: ***Modeling and Simulation of VLSI Devices***

1. **LTP structure of the course:** 2-1-1
2. **Objective of the course:** The subject provides an in-depth knowledge of modelling and simulation of state-of-art VLSI devices
3. **Outcome of the course:** After completion of this course, the students will be able to understand the technology and basic principles underlying modelling and simulation of VLSI devices.
4. **Prerequisites**: The basic knowledge of semiconductor device physics.
5. **Course Plan:**

Component	Unit	Topics for Coverage
Component 1	Unit 1	Review of Semiconductor Fundamentals, **Modeling and Simulation of Carrier Transport:** Carrier-Scattering (impurity, phonon, carrier-carrier, remote/interface), Boltzmann Transport Equation, Monte Carlo, Hydrodynamic, Drift-diffusion.
	Unit 2	**Short Channel MOSFET Devices:** Scaling effects, Channel velocity limitations (saturation velocity, interface scattering, mobility models), Hot carrier effects Quantum mechanical effects.
Component 2	Unit 3	**Modeling of CMOS Devices:**Scaling relationships, Threshold voltage control, On/Off currents, Channel doping profiles, Implanted channel, buried channel, retrograde wells, S/D extension, HALO/LATID structures, Circuit and switching behavior.
	Unit 4	**Advanced Device Technology:**SOI, SiGe, strained Si, Alternative oxide/gate materials, Alternative geometries (raised source/drain, dual gate, vertical, FinFET), Tunnel FETs, Memory Devices (DRAM, Flash).

Practices Components: -

1. Introduction to TCAD Device Simulators (4 hours)
2. Hands-on training sessions on TCAD Device Simulators: Silvaco (ATLAS), and Synopsys (Sentaurus) TCAD. (10 Hours)

Text books:

1. "Semiconductor Physics and Devices" by Donald Neamen (TMH Publications)
2. ``Advanced MOS Devices" by Schroder
3. `Operation and Modeling of the MOS Transistor" by Tsividis\

Reference Books:

1. "Fundamentals of Carrier Transport," by Mark Lundstrom, 2000.
2. ``Device Electronics for Integrated Circuits" by Muller and Kamins
3. "3D TCAD Simulation for CMOS Nanoeletronic Devices" by Yung-Chun Wu Yi-RueiJhan

Name of the Course: ***<u>Thin-Film Science and Technology</u>***

1. **LTP structure of the course**: 3-1-0
2. **Objective of the course**: The course is aimed at teaching the basics of thin film science and technology, which is one of the important form of materials preparation covering the necessary basics from thermodynamics, electrodynamics, quantum mechanics, and solid state physics relevant to thin film science.
3. **Outcome of the course**: The students are expected to have a broad understanding of the status of thin film technology.
4. **Course Plan:**

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Introduction to thin films – Physics and Engineering Perspective, Materials Science basics. Vacuum Technology: Film growth and Phenomenology: Symmetry, surfaces and interfaces,
	Unit 2	Thin film Deposition Methods: Physical and Chemical deposition methods, Plasma based deposition methods.Characterization of films:– Methods and mechanisms.
Component 2	Unit 3	Thin film properties: Thermodynamic and transport properties of thin films (Mechanical, Electrical, Thermal, Magnetic, Optical etc.)
	Unit 4	Applications of Thin films: Electronic, optical, mechanical, thermal, and energy applications of thin film technology. Emergent research activities in thin film science and technology

Text Book:

1. Thin-film deposition: principles and practice. Smith, Donald Leonard. Vol. 108. New York: McGraw-hill, 1995. ISBN: 978-0070585027

References:

1. Materials science of thin films, Ohring, Milton. Academic press, 2001. ISBN: 978- 01252497517.

Major Module
on
Computational Nanoelectronics

Course Name	**Core/Elective**	**Code**	**Credit**	**L-T-P**	**Pre Requisites**
High Speed devices	Elective	Soft	4	3-1-0	Electronic Devices
Nanoscale Device Modeling	Elective	Soft	4	3-1-0	Electronic Devices
Emerging Nanoelectronic Devices	Elective	Soft	4	2-1-1	Electronic Devices
Total			**12**		

-More Electives may be added as per the requirement of the Module

Name of the Course: ***<u>High Speed Devices</u>***

1. **LTP structure of the course**: 3-1-0
2. **Objective of the course**: To let the first year M.Tech. students exposed to high speed devices.
3. **Outcome of the course**: The students will learn how to fundamentals of high speed devices.
4. **Course Plan:** As per the below format only

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Quantum Physics, Schrodinger's equation and problems, Kronig-Penny model, carrier density, scatterings, mobility.
	Unit 2	MB statistics, Extensive doping, generation-recombination, diffusion and continuity equation
Component 2	Unit 3	PN junction diodes, diffusion capacitance, varactor diode, PIN diode Schottky diode.
	Unit 4	Semiconductor Heterojunction, BJT, 1st order model of BJT, Heterojunction FET

Text Book:

1. S.M Sze, High Speed Semiconductor Devices, John Wiley, 1990.
2. C Y Chang and Francis Kai, GaAs High-Speed Devices: Physics, Technology and Circuit Applications,John Wiley, 1994

Name of the Course: *Nanoscale Device Modeling*

1. **LTP structure of the course:** 3–1–0
2. **Objective of the course:** To make students aware of underlying concepts of nanoscale transistors.
3. **Outcome of the course:** The student is expected to apply the physical concepts in modeling of any nanoscaled device.
4. **Course Plan:**

Component	Unit	Topics for Coverage
Component 1	Unit 1	**Basic concepts:** DOS, semiclassical and quantum transport, scattering
	Unit 2	1D, 2D MOS electrostatistics, I-V characteristics, ultimate limits of CMOS technology
Component 2	Unit 3	**Ballistic nanotransistor:** Natori's theory and beyond Natori's model, nondegenerate, degenerate characteristics
	Unit 4	Scattering theory of MOSFET: scattering physics, transmission coefficient under high and low bias

Text Book:

1. M. Lundstrom, J. Guo, "NANOSCALE TRANSISTORS: Device Physics, modeling and Simulation", Springer, 2006.

References:

1. M. Lundstrom, "Fundamentals of Carrier Transport", Cambridge University Press, 2000.
2. Research papers related to the topics.

Name of the Course: ***Emerging Nano-Electronic Devices.***

1. **LTP structure of the course**: 2-1-1.
2. **Objective of the course**: To let the M.Tech. students exposed to principles of various emerging nano-devices for beyond the silicon technology.
3. **Outcome of the course**: The students are expected to apply in the learned concepts in their research activities.
4. Course Plan: As per the below format only

Component	**Unit**	**Topics for Coverage**
Component 1	Unit 1	Introduction to nano-science, nano-technology and nano-electronics, 0D, 1D, 2D Materials, Technology nodes, Technology Roadmap, band theory and broadening, quantum capacitance, basics of Spintronics.
	Unit 2	Single Electron Transistors: Basics, Coulomb Blockade, Charging Energy, Operating principle, Applications: Switching Element and Sensor.
Component 2	Unit 3	Carbon Electronics: Graphene, Carbon Nanotube, Chirality, GNR FETs, CNT FETs, Sensors and Interconnects.
	Unit 4	Tunnel FETs: basics and operation, Molecular Rectifiers, Memristors.

Text Books/References:-

1. Advanced technologies for next generation Integrated Circuits. Edited by Ashok Srivastava and Saraju Mohanty. IET Publishers.
2. Quantum Transport: Atom to transistor. Supriyo Datta, Cambridge Publishers.
3. Emerging Nano-electronic devices. An Chen et al. Wiley Publishers.
4. Carbon based electronics. Ashok Srivastava et al. Pan Stanford Publishing.
5. Relevant research papers.

Semester-4

Course Name	Core/Elective	Code	Credit	L-T-P	Pre-Requisites
Thesis	Core	Hard	12	0-0-12	Mini Project
Total			**12**		