DEPARTMENT OF

ELECTRONICS AND COMMUNICATION ENGINEERING

Scheme of Instruction

and

Syllabus of

M.E. (E C E)
VLSI & Embedded Systems

Full Time & PTPG

2022-23

UNIVERSITY COLLEGE OF ENGINEERING
(Autonomous)
Osmania University
Hyderabad – 500 007, TS, INDIA

INSTITUTE

<u>**Vision**</u>

The Vision of the institute is to generate and disseminate knowledge through harmonious blending of science, engineering and technology. To serve the society by developing a modern technology in student's heightened intellectual, cultural, ethical and humane sensitivities, fostering a scientific temper and promoting professional and technological expertise.

<u>**Mission**</u>

- To achieve excellence in Teaching and Research
- To generate, disseminate and preserve knowledge
- To enable empowerment through knowledge and information
- Advancement of knowledge in Engineering, Science and Technology
- Promote learning in free thinking and innovative environment
- Cultivate skills, attitudes to promote knowledge creation
- Rendering socially relevant technical services to the community
- To impart new skills of technology development
- To inculcate entrepreneurial talents and technology appreciation programmes
- Technology transfer and incubation

DEPARTMENT

<u>**Vision**</u>

- To be in the forefront of advances in Electronics and Communication Engineering education and research to guide and motivate young engineers to face future technological challenges.

<u>**Mission**</u>

- To inculcate analysis and design for innovative problems in the field of Electronics and Communication Engineering with the help of state of art curricula.
- To impart practical training to face real life case studies and inter-disciplinary simple solutions to complex problems.
- To make engineering education an enjoyable learning experience through challenging tutorials, mini-projects, assignments and laboratory exercises.
- To build project team spirit for professional working environment with high ethical values
- To develop overall character that will care for the society and concerned for the nation through extra-curricular activities.

Programme Educational Objectives (PEO):

PEO1: Employability in the diversified sectors of core industry, public sector or multinational corporations, in the domain of Semiconductor Technology, ASIC Design and Verification, Embedded Systems- Hardware and Software Development.

PEO2: Ability to pursue higher education in technologies related to VLSI and Embedded Systems at institutes of repute and high standard leading to contributions to technology.

PEO3: Attitude of lifelong learning and skills of effective inter-person communication resulting in leading diverse teams, with ethical and social behavior

PEO4: To equip the students with laboratory training leading to solving real life practical Problems and project analysis of Digital systems through case-studies, seminars, Miniprojects, internships and main projects.

PEO5: Design and conduct experiments, analyze and interpret data, imbibe programming skills for development of simulation experiments.

Programme Outcomes (PO):

PO1: Apply the knowledge of science, mathematics, and engineering principles for developing problem solving attitude.

PO2: Identify, formulate and solve engineering problems in the broad areas like System Design using VLSI and Embedded Platforms and tools, Semiconductor Technologies, Applications in Signal Processing, Machine Vision and Communication Networks.

PO3: Use different software tools in the domain of VLSI and Embedded Systems Design, Analysis and Verification such as Design entry, Synthesis, Functional and Timing Simulation, Floor planning, Place and route, Layout editors, RTL schematic, Platform specific EDA sets, MATLAB.

PO4: Design and conduct experiments, analyze and interpret data, imbibe programming skills for development of simulation experiments

PO5: Use different software tools in the domains of VLSI and embedded systems for Analysis and Verification.

DEPARTMENT OF ELECTONICS & COMMUNICATION ENGINEERING
M. E. ECE (VLSI and EMBEDDED SYSTEMS) Scheme and Syllabus

S.No.	Type of Course	Course Code	Course Name	Contact hours per week		Scheme of Evaluation		Credits
				L	P	CIE	SEE	
			SEMESTER-I					
1.	Core-I	EC401	Principles of VLSI system design	3	-	40	60	3
2.	Core-II	EC402	Microcontrollers for Embedded Systems Design	3	-	40	60	3
3.	Core-III	EC403	VLSI Design Verification and Testing	3	-	40	60	3
4.	Programme Elective-I	EC411	VLSI Testing	3	-	40	60	3
		EC412	Pattern Recognition					
		EC413	IOT and Applications					
5.	Programme Elective-II	EC421	System on Chip Design	3	-	40	60	3
		EC422	Wireless and Mobile Communications					
		EC423	Remote Sensing – Ground Stations					
6.	Programme Elective-III	EC431	VLSI Signal Processing	3	-	40	60	3
		EC432	Optimization Techniques					
		EC433	Advanced Communication and Computer Networks					
7.	Laboratory-I	EC461	VLSI Design verification Laboratory	0	2	50	-	1
8.		EC471	Seminar	0	2	50	-	1
			TOTAL	**18**	**4**	**340**	**360**	**20**
			SEMESTER-II					
1.	Core-IV	EC404	Analog and Mixed signal IC Design	3	-	40	60	3
2.	Core-V	EC405	VLSI physical Design	3	-	40	60	3
3.	Core-VI	EC406	Scripting Languages	3	-	40	60	3
4.	Programme Elective-IV	EC441	Wireless sensor networks	3	-	40	60	3
		EC442	Real Time Operating Systems					
		EC443	DSP Processors and Architectures					
5.	Programme Elective-V	EC451	CPLD and FPGA Architectures	3	-	40	60	3
		EC452	Unmanned Aerial Vehicle Systems					
		EC453	Low Power VLSI Design					

6.	Open Elective	OE941BM	Medical Assistive Devices	3	-	40	60	3
		OE942BM	Medical Imaging Techniques					
		OE941CE	Green Building Technology					
		OE942CE	Cost Management of Engineering Projects					
		OE941CS	Business Analytics					
		OE941EE	Waste To Energy					
		OE942EE	Power Plant Control and Instrumentation					
		OE941EC	Elements of Embedded Systems					
		OE941ME	Operation Research					
		OE942ME	Composite Materials					
		OE943ME	Industrial Safety					
		OE941LA	Intellectual Property Rights					
7.		EC472	Mini Project	-	4	50	-	2
8.	Laboratory-II	EC462	Embedded System Design Lab	-	2	50	-	1
9.	Laboratory-III	EC463	CMOS VLSI Design Lab	-	2	50	-	1
			TOTAL	**18**	**8**	**390**	**360**	**22**
			SEMESTER-III					
1.	Audit Course-I	AC030EC	Research Methodology	2	-	40	60	0
2.	Audit Course-II	AC031	English for Research Paper Writing	2	-	40	60	0
		AC032	Disaster Mitigation and Management					
		AC033	Sanskrit for technical Knowledge					
		AC034	Value Education					
		AC035	Stress Management by Yoga					
		AC036	Personality Development through Life Enlightenment Skills					
		AC037	Constitution of India					
		AC038	Pedagogy Studies					
		AC039	E-Waste Management					
3.	Dissertation-I	EC181	Dissertation Phase-I	-	20	100		10
			TOTAL	**4**	**20**	**180**	**120**	**10**
			SEMESTER-IV					
1.	Dissertation-II	EC482	Dissertation Phase-II	-	32	100	100	16
			GRAND TOTAL	**40**	**64**	**1010**	**940**	**68**

Note:
i.   Dissertation-II has two parts, CIE - I and CIE – II, at the end of 8th week and 16th week respectively for evaluation of 50 marks each.
ii. Audit Courses will be offered in ONLINE mode and SEE will be conducted in Computer Based Test Mode.

EC401	**PRINCIPLES OF VLSI SYSTEM DESIGN**						
	Core-I						
Pre-requisites	Digital System Design	**L**		**T**	**P**		**C**
		3		**-**	**-**		**3**
Evaluation	**SEE**	60 Marks		**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To Understand the VLSI design flow
2	To understand different CMOS logic families and their circuit layout.
3	To understand various VLSI design methodologies.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Explain the different levels of abstraction and issues with the technology
CO-2	Analuse static and Dynamic circuits performances
CO-3	Design strategies and full custom design
CO-4	Design of sub systems
CO-5	Work and exploring case studies of CMOS Systems

	PO1	PO2	PO3	PO4	PO5
CO1					
CO2					
CO3					
CO4					
CO5					

Correlation rating: Low / Medium / High: 1 / 2 / 3 respectively.

UNIT–I
Introduction to VLSI System design hierarchical design-design abstraction-different levels of abstraction and domains. Computer aided design VLSI design flow-technology implications and economics, issues connected with technology defect densities yield and die size, components of chips cost.

UNIT–II
Static and dynamic CMOS circuits, circuit characterizations and performance estimation: Resistance, Capacitance and Inductance- delay estimations power dissipation static and dynamic, design margining-reliability issues.

UNIT–III
CMOS design methods: Structured design strategies-Hierarchy, regularity modularity, chip design options: Programmable logic, logic structures, gate arrays. Sea-of gate and gate array design standard cell-based designs-standard cell libraries design reuse-fullcustom mark design.

UNIT-IV
CMOS sub system design: Adders and Subtractors fast adders like carry bypass carry select and carry look ahead adders Multipliers, array and fast multipliers- Parity Generators- Zero-One Detectors- Binary Counters- Multiplexers- shifters-memory elements.

UNIT – V
CMOS System case study: Core of RISC Micro Controller ALU address architectures, Instruction sets pipelining major blocks of the processor and 6-Bit Flash A/D converter-high speed comparators and thermometer code converter.

SUGGESTED READING:

1	Weste Kamran Eshraghian, Principles of CMOS VLSI design- asystems perspective by NEILHE, Pearson Education Series, Asia, 2002
2	Wolf, Modern VLSI Design, Pearson Education Series, 2002..
3	Jean M. Rabey, "Digital Integrated Circuits", Prentice Hall India, 2003.

EC402		MICROCONTROLLERS FOR EMBEDDED SYSTEM DESIGN			
		Core-II			
Pre-requisites	Microprocessors and Microcontrollers	**L**	**T**	**P**	**C**
		3	**-**	**-**	**3**
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Detailed overview of important concepts of Embedded system.
2	Analyze PIC microcontroller, its features and programming.
3	Describe ARM Microcontroller architectural details and instruction set
4	Understand ARM Memory management.
5	Learn the techniques to develop an embedded system and case studies

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Define an embedded system with an overview of important concepts and trends in the design process along with the challenges faced in the embedded systems design
CO-2	Understand the architecture of PIC 18 Microcontroller, its features and programming.
CO-3	Understand ARM Design Philosophy, architectural details, instruction set and ARM Memory Management.
CO-4	Analyze and compare the utility and effectiveness of various debugging tools and techniques
CO-5	Understand Embedded Software development Tools and design a real time based embedded system in the area of communication, automotive, etc.

	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1					
CO2					
CO3					
CO4					
CO5					

Correlation rating: Low / Medium / High: 1 / 2 / 3 respectively.

UNIT–I
Introduction to Embedded Systems: Overview of Embedded System Architecture, Challenges & Trends of Embedded Systems, Hardware Architecture, Software Architecture. Application areas of Embedded Systems and Categories of Embedded Systems. Embedded System Design and Co-Design issues and Design Cycle Process.

UNIT–II

PIC 18: Family Overview, Architecture, Instruction Set, Addressing modes. Timers, interrupts of PIC 18, Capture/Compare and PWM modes of PIC 18

UNIT–III

ARM Architecture: ARM Design Philosophy, Registers, Program Status Register, Instruction Pipeline, Interrupts and Vector Table, Architecture Revision, ARM Processor Families. Instruction Set: Data Processing Instructions, Addressing Modes, Branch, Load, Store Instructions, PSR Instructions, Conditional Instructions.

UNIT-IV

ARM Thumb Instruction Set: Register Usage, Other Branch Instructions, Data Processing Instruction Single-Register and Multi Register Load-Store Instructions, Stack, Software Interrupt Instructions. Exception and interrupt handling.

ARM Memory Management: Cache Architecture, Polices, Flushing and Caches, MMU, Page Tables, Translation Access Permissions, Context Switch.

UNIT – V

Embedded Software Development Tools: Host and Target Machines, Linkers/Locators for Embedded Software, Getting Embedded Software into the Target System. Debugging Techniques.

SUGGESTED READING:

1	Raj Kamal, *Embedded Systems – Architecture, Programming and Design*, 2nd Edition, TMH, 2008
2	Andrew N. Sloss, Dominic Symes, Chris Wright, *ARM Systems Developer's Guides – Designing & Optimizing System Software*, Elsevier, 2008
3	Mazidi, MCKinlay and Danny Causey, *PIC Microcontrollers and Embedded Systems*, Pearson Education, 2007
4	David.E.Simon, *An Embedded Software Primer,* 1st Edition, Pearson Education, 1999
5	Jonathan W. Valvano, *Embedded Microcomputer Systems, Real Time Interfacing*, Thomas Learning, 1999.

EC403			**VLSI DESIGN VERIFICATION AND TESTING**			
			Core-III			
Pre-requisites		-	**L**	**T**	**P**	**C**
			3	**-**	**-**	**3**
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To Develop Structural, Dataflow and Behavioral Modeling of Verilog HDL.
2	To Know Basics of System Verilog
3	To Familiarize with Object Oriented Programming
4	To Explore Randomization and Threads in System Verilog
5	To Know Test Coverage in System Verilog

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	To Realize and Verify Combinational and Sequential Circuits in Verilog HDL
CO-2	To Construct User Defined Data Types in System Verilog
CO-3	To Create Object Oriented Programming Environment
CO-4	To Demonstrate Randomization and Coverage Concepts of System Verilog
CO-5	To Propose Efficient Testable Digital Systems in System Verilog

	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1					
CO2					
CO3					
CO4					
CO5					

Correlation rating: Low / Medium / High: 1 / 2 / 3 respectively.

UNIT–I Introduction to Verilog
Verilog Basics: Modules and Ports, Data Flow, Behavioral and structural Modeling, Tasks and Functions, Logic Synthesis, Timing Delays.   **Static timing analysis**: Setup time & hold time violations and clock skew, Test bench creation, Significance of Verification and Verilog for verification.

UNIT–II Introduction to System Verilog
System Verilog Basics: Advantages over Verilog, Verification process. **Data Types**: Built-in data types, Fixed and dynamic Arrays, Queues, Associative Arrays and Enumerated data types **Statements and Functions**: Procedural statements, Tasks and Functions, Time values, Test bench and DUT

UNIT–III Introduction to Object Oriented Programming (OOP)
OOP: Object Oriented Programming significance and advantages, classes, objects, object handles, methods, Static and Global Variables, using one class inside another class, Dynamic objects, Copying objects, Public Vs Local and Building a test bench. Inheritance, Overriding, Data Hiding and Encapsulation, Abstract Classes and Virtual Methods. Scope Resolution Operator, Classes Extern Methods, type def classes.

UNIT-IV Verification using System Verilog
Randomization: Significance of Randomization, randomization in system Verilog, Constraint randomization, Random number generation, constraint tips and techniques. **Threads:** Threads, Inter process communication, Events, Semaphores and Mailboxes virtual methods

UNIT – V Advanced System Verilog
Callbacks, Parameterized Classes, Static and Singleton Classes **Coverage**: Introduction to Coverage, Coverage Types, Functional Coverage Strategies and cover group. **Universal Verification Methodology**: Case study using Universal Verification Machine (UVM)

SUGGESTED READING:

1	Ming-Bo Lin., *Digital System Designs and Practices Using Verilog HDL and FPGAs*, Wiley India, 2008.
2	Samir Palnitkar, *Verilog HDL: A Guide to Digital Design and Synthesis*, Pearson Education, 2005.
3	Christ Spear and Greg Tumbush, *System Verilog for Verification*, 3rd ed., Springer, 2012.

EC411			VLSI TESTING			
			Program Elective - I			
Pre-requisites		-	**L**	**T**	**P**	**C**
			3	**-**	**-**	**3**
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To model the circuits at different levels of abstraction and to develop logical fault
2	To understand classical test generation algorithms for combinational and sequential
3	To learn scan based testing approaches for digital circuits
4	To understand BIST architectures and ATP generation
5	To learn diagnosing circuits at logic and system levels

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Develop logic and fault models for digital circuits.
CO-2	Realize test patterns for the CUT.
CO-3	Understand scan based design and DFT concepts.
CO-4	Understand various generic and specific BIST architectures.
CO-5	Understand fault diagnosis and apply.

	PO1	PO2	PO3	PO4	PO5
CO1					
CO2					
CO3					
CO4					
CO5					

Correlation rating: Low / Medium / High: 1 / 2 / 3 respectively.

UNIT–I BASICS OF TESTING AND FAULT MODELLING
Introduction to Testing –Functional modeling at various levels of abstraction, Logic Simulation - Types of simulation - Delay models –Element evaluation – Hazard detection - Gate level Event-driven simulation.   Faults in digital circuits - Modeling of faults - Logical Fault Models –Fault detection– Fault equivalent and Fault location - Fault dominance-Fault simulation for Combinational circuits-Fault sampling

UNIT–II TEST GENERATION FOR COMBINATIONAL AND SEQUENTIAL CIRCUITS
Test generation for combinational logic circuits –one dimensional path sensitization- Boolean difference-PODEM, Testable combinational logic circuit design –Reed-Muller expansion technique- Three level OR-AND-OR design,   Test generation for sequential circuits –testing sequential circuits as iterative combinational circuits- State table verification.

UNIT–III DESIGN FOR TESTABILITY
Design for Testability –Testability, Ad-hoc design for testability techniques, Generic scan based design – Full serial integrated scan-Isolated serial scan-non serial scan, Classical scan designs, System level DFT approaches.

UNIT-IV BIST and ATPG
Built-In Self Test–BIST concepts, Test pattern generation for BIST- Exhaustive-Pseudo exhaustive –Pseudo random testing, BIST Architectures-Generic OFF line- Specific BIST architectures.

UNIT – V FAULT DIAGNOSIS
Logic Level Diagnosis –Fault dictionary, Guided probe testing, Diagnosis by UUT reduction, Fault Diagnosis for Combinational Circuits, System Level Diagnosis-simple model- generalizations of PMC model.

SUGGESTED READING:

1	M. Abramovici, M.A. Breuer and A.D. Friedman, "Digital Systems testing and Testable Design", Jaico Publishing House, 2002.
2	Parag. K. Lala, "Fault tolerant and fault testable hardware design",BS Publications, 2002.
3	M.L. Bushnell and V.D. Agrawal, "Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits", Kluwer Academic Publishers, 2002.

EC412			PATTERN RECOGNITION			
			Program Elective - I			
Pre-requisites		-	**L**	**T**	**P**	**C**
			3	**-**	**-**	**3**
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Understand basic concepts in pattern recognition
2	Gain knowledge about state-of-the-art algorithms used in pattern recognition research
3	Understand pattern recognition theories, such as Bayes classifier, linear discriminant analysis.
4	Apply pattern recognition techniques in practical problems.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Explain and compare a variety of pattern classification, structural pattern recognition, and pattern classifier combination techniques.
CO-2	Understand machine learning concepts and range of problems that can be handled by machine learning.
CO-3	Design neural network and SVM for classification.
CO-4	Describe and model data to solve problems in regression and classification
CO-5	Apply pattern recognition techniques to real-world problems such as document analysis and recognition.

	PO1	PO2	PO3	PO4	PO5
CO1					
CO2					
CO3					
CO4					
CO5					

UNIT–I
Overview of Pattern classification and regression
What is Pattern recognition; Applications and Examples. Overview of Pattern Classifiers Clustering vs. Classification; Supervised vs. unsupervised. The Bayes Classifier for minimizing Risk Estimating Bayes Error; Minimax and Neymann-Pearson classifiers

UNIT–II
Implementing Bayes Classifier; Estimation of Class Conditional Densities Maximum Likelihood estimation of different densities Bayesian estimation of parameters of density functions, MAP estimates Bayesian Estimation examples; the exponential family of densities and ML estimates Sufficient Statistics; Recursive formulation of ML and Bayesian estimates. Mixture Densities and EM Algorithm Mixture Densities, ML estimation and EM algorithm Convergence of EM algorithm; Convergence of EM algorithm; overview of Nonparametric density estimation Nonparametric estimation, Parzen nearest neighbor methods

UNIT–III
Linear models for classification and regression Linear Discriminant Functions; Perceptron --Learning Algorithm and convergence proof Linear Least Squares Regression; LMS algorithm AdaLinE and LMS algorithm; General non liner least-squares regression Logistic Regression; Statistics of least squares method; Regularized Least Squares Fisher Linear Discriminant Linear Discriminant functions for multi-class case;multi-class logistic regression

UNIT-IV
Artificial Neural Networks for Classification and regression Overview of Artificial Neural Networks Multilayer Feed Forward Neural networks with Sigmoidal activation functions; Backpropagation Algorithm; Representational abilities of feedforward networks Feedforward networks for Classification and Regression; Back propagation in Practice Radial Basis Function Networks; Gaussian RBF networks Learning Weights in RBF networks; K-means clustering algorithm

UNIT – V
Support Vector Machines and Kernel based methods Support Vector Machines -- Introduction,obtaining the optimal hyperplane SVM formulation with slack variables; nonlinearSVM classifiers Kernel Functions for nonlinear SVMs; Mercer and positive definite Kernels Support Vector Regression and ε-insensitive Loss function, examples of SVM learning Overview of SMO and other algorithms for SVM; ν-SVM and ν-SVR; SVM as a risk minimizer Positive Definite Kernels; RKHS; RepresenterTheorem Bagging and Boosting; ClassifierEnsembles; AdaBoost

SUGGESTED READING:

1	R. Duda, et al., *Pattern Classification*, John Wiley & Sons, 2001.
2	T. Hastie, et al.,*The Elements of Statistical Learning*, Spinger, 2009.
3	C. Bishop, *Pattern Recognition and Machine Learning*, Springer, 2006.

EC413	IOT and Applications				
	Program Elective - I				
Pre-requisites	-	**L**	**T**	**P**	**C**
		3	**-**	**-**	**3**
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To understand the concepts of Internet of Things and able to build IoT applications
2	To learn the programming and use of Arduino and Raspberry Pi boards.
3	To know about data handling and analytics in SDN.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Known basic protocols in sensor networks.
CO-2	Program and configure Arduino boards for various designs.
CO-3	Python programming and interfacing for Raspberry Pi.
CO-4	Design IoT applications in different domains.

	PO1	PO2	PO3	PO4	PO5
CO1					
CO2					
CO3					
CO4					
CO5					

Correlation rating: Low / Medium / High: 1 / 2 / 3 respectively.

UNIT–I
Introduction to Internet of Things, Characteristics of IoT, Physical design of IoT, Functional blocks of IoT, Sensing, Actuation, Basics of Networking, Communication Protocols, Sensor Networks.

UNIT–II
Machine-to-Machine Communications, Difference between IoT and M2M, Interoperability in IoT, Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino

UNIT–III
Introduction to Python programming, Introduction to Raspberry Pi, Interfacing Raspberry Pi with basic peripherals, Implementation of IoT with Raspberry Pi

UNIT-IV
Implementation of IoT with Raspberry Pi, Introduction to Software defined Network (SDN), SDN for IoT, Data Handling and Analytics.

UNIT – V
Cloud Computing, Sensor-Cloud, Smart Cities and Smart Homes, Connected Vehicles, Smart Grid, Industrial IoT, Case Study: Agriculture, Healthcare, Activity Monitoring

SUGGESTED READING:

1	"The Internet 'of Things: Enabling Technologies, Platforms, and Use Cases", by PethuruRaj and Anupama C. Raman (CRC Press).
2	"Make sensors": Terokarvinen, kemo, karvinen and villeyvaltokari, 1st edition, maker media, 2014.
3	"Internet of Things: A Hands-on Approach", by ArshdeepBahga and Vijay Madisetti
4	Vijay Madisetti,
5	ArshdeepBahga, "Internet of Things: A Hands-On Approach"
6	WaltenegusDargie, ChristianPoellabauer, "Fundamentals of Wireless Sensor Networks: Theory and Practice"

EC421	**SYSTEM-ON-CHIP DESIGN**				
	Program Elective - II				
Pre-requisites	Analog Communications, Digital Communications	**L**	**T**	**P**	**C**
		3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks

Course Objectives:
.
1. To understand the concepts of System on Chip Design methodology for Logic and Analog Cores.
2. To understand the concepts of System on Chip Design Validation
3. To understand the concepts of SOC Testing.

Course Outcomes:
1. Upon successful completion of this course student should be able to: understand about SoC DesignMethodology.
2. Ability to understandthe design of different embeddedmemories
3. Validation and Testing Concepts can beunderstood.
4. Investigate new techniques for future systems.

Course Outcome	PO-1	PO-2	PO-3	PO-4	PO-5
CO-1	2		1	2	
CO-2	1		1	2	
CO-3	1		2	2	
CO-4	1		1		
CO-5	2		2	2	

Unit-I
Introduction- System tradeoffs and evolution of ASIC Technology- System on chip concepts and methodology – SoC design issues -SoC challenges and components.

UNIT-II
Design Methodological For Logic Cores- SoC Design Flow – On-chip buses –Design process for hard cores – Soft and firm cores – Core and SoC design examples.

UNIT-III
Design Methodology for Memory and Analog Cores- Embedded memories –Simulation modes Specification of analog circuits – A to D converter –Phase locked loops –High I/O.

UNIT-IV
Design Validation- Core level validation –Test benches –SoC design validation – Co simulation – hardware/ Software co-verification. Case Study: Validation and test of systems on chip.

UNIT-V
SoC Testing- SoC Test Issues –Cores with boundary scan –Test methodology for design reuse– Testing of microprocessor cores – Built in self-method –testing of embedded memories.

Suggested Reading:

1. RochitRajsunah,System-on-a-chip:DesignandTest,ArtechHouse,2007.
2. PrakashRaslinkar, Peter Paterson &Leena Singh, System-on-a-chip verification: Methodology and Techniques, Kluwer Academic Publishers,2000.
3. M.Keating, D.Flynn, R.Aitken, A, GibbonsShi, Low Power Methodology Manual for System-on- Chip Design Series: Integrated Circuits and Systems, Springer,2007.

EC422	WIRELESS AND MOBILE COMMUNICATIONS				
Program Elective - II					
Pre-requisites	Analog Communications, Digital Communications	**L**	**T**	**P**	**C**
		3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks

Course Objectives : This course aims at	
1.	An overview of key wireless technologies: Various generations of mobile communications for voice and data, 5G networks.
2.	Wireless system design fundamentals: channel assignment, handoffs, interference, frequency reuse, capacity planning, large-scale fading, and Outdoor, Indoor propagation models.
3.	Path loss, small-scale fading, multipath, reflection, diffraction, scattering and Various statistical models for small-scale fading study.
4.	Various Diversity techniques, Equalizers used in communication receivers.
5.	Multiple Access techniques and their applications in wireless networks.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Develop design models for cellular systems.
CO-2	Analyze the various Large-scale fading effects in designing propagation models for Mobile communications in Outdoor environments.
CO-3	Analyze the various types of Small-scale fading, measurement techniques, Parameters of multi-path radio and Statistical models.
CO-4	Understand Various Diversity techniques and Equalizers used in communication receivers.
CO-5	Develop the design models for various Multiple access techniques and understand their spectral efficiencies.

Course outcome	PO-1	PO-2	PO-3	PO-4	PO-5
CO-1	2		1	2	
CO-2	1		1	2	
CO-3	1		2	2	
CO-4	1		1		
CO-5	2		2	2	

Correlation rating: Low / Medium / High: 1 / 2 / 3 respectively.

UNIT – I
Evolution of Mobile Radio Communications: Examples of Wireless Communication Systems, Overview of 1G,2G, 2.5G, 3G, 4G and 5G Cellular networks.   **The Cellular Concept**: Introduction, Frequency Reuse, Channel Assignment Strategies, Handoff Strategies, Interference and System Capacity, Improving Coverage and Capacity in cellular systems.

UNIT – II
Introduction to Radio wave propagation: Free-space propagation model, Relating Power to Electric Field, The three basic propagation mechanisms- Reflection, Ground Reflection (Two Ray) model, Diffraction, Scattering. **Outdoor propagation models**: Longley-Rice model, Okumura model, Hata model, PCS Extension to Hata model, Walfisch and Bertoni Model, Wideband PCS Microcell model. **Indoor propagation models**: Partition losses (same floor), Partition losses between floors, Log-distance path loss model, Ericsson multiple breakpoint model, Attenuation factor model, Signal penetration into buildings.

UNIT – III
Small scale multipath propagation: Factors influencing small scale fading, Doppler shift, Small scale multipath Measurements-Direct RF Pulse System, Spread Spectrum Sliding correlator Channel Sounding, Frequency Domain Channels Sounding, Parameters of Mobile multipath channels, Types of Small Scale Fading, Statistical models for multipath Fading Channels-Clarke's model for flat fading, spectral shape due to Doppler, Level Crossings and Fading Statistics, Two-ray Rayleigh Fading model..

UNIT – IV
Equalization: Introduction, Fundamentals of Equalization, Training a Generic Adaptive Equalizer, Equalizers in a communication Receiver, Linear Equalizers, Non linear Equalization-Decision Feedback Equalization (DFE), Maximum Likelihood Sequence Estimation (MLSE) Equalizer, Algorithms for adaptive equalization. **Diversity Techniques**: Practical Space Diversity Considerations, Selection Diversity, Scanning Diversity, Maximal Ratio Combining, Equal Gain Combining, Polarization Diversity, Frequency Diversity, Time Diversity, RAKE Receiver.

UNIT –V
Multiple Access techniques: FDMA, TDMA, Spread Spectrum Multiple Access- FHMA and CDMA, SDMA, Spectral efficiency analysis for Multiple Access Technologies: FDMA, TDMA and CDMA Comparison of these technologies based on their signal separation techniques, advantages, disadvantages and application areas.

Suggested Reading:

1	Theodore, S.Rappaport , Wireless Communications, Principles and Practice, 2nd Ed.,2002,PHI.
2	Andrea Goldsmith, Wireless Communications, 2005, Cambridge University Press
3	Kaveh pah Laven and P.Krishna Murthy, Principles of Wireless networks, 2002,PE.
4	P.Nicopolitidis, M.S.Obaidat, G.I.Papadimitriou, A.S.Pomportsis, Wireless Networks, 2003,John Wiley & Sons Pte Ltd.
5	Ashok Raj, Wireless Communication, First Edition, 2014, Khanna Publishers

EC423		REMOTE SENSING – GROUND STATIONS					
		Program Elective - II					
Pre-requisites		-	**L**	**T**	**P**		**C**
			3	**-**	**-**		**3**
Evaluation	**SEE**	60 Marks	**CIE**			40 Marks	

Course Objectives :
The course is taught with the objectives of enabling the student to:

1	To explain and make the students to understand the basic concepts of Remote sensing platforms and various satellite sensor technologies.
2	To understand the different types of satellites and various application in the present scenario
3	To understand the satellite ground station technology
4	To understand the RF systems , servo systems , Base sand systems
5	To demonstrate the satellite data quality evaluation and implement the quality assurance aspects

Course Outcomes :
On completion of this course, the student will be able to :

CO-1	Able to understand remote sensing and various applications
CO-2	Acquires knowledge related to design and development of RF systems , servo systems , Frame synchronizers etc
CO-3	Perform system verification and validation of satellite data quality parameters
CO-4	Understands environmental tests and EMI /EMC test standards related to various systems of ground station
CO-5	Can design and develop electronic hardware for components in the data reception chain

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	3	3	2	1	3
CO-2	3	3	3	2	2	3
CO-3	3	3	3	2	2	3
CO-4	3	3	3	2	1	3
CO-5	3	3	3	2	2	3

UNIT – I
Physics and principle of Remote Sensing: Electro Magnetic Spectrum, Different remote sensing platforms, Satellite sensors, active sensors and passive sensors, Introduction to space segment , ground segment and user segment, Space technology etc.

UNIT – II
Satellite orbital dynamics, satellite path and row concepts, reference schemes, Sun synchrounous satellites, geostationary satellites, Difference between Geo,MEO and LEO orbits and its requirements, Onboard satellite data conversion and modulation. Signal transmission and EIRP, satellite band L,S,X,Ku,Ka . Allocation of bands , Geostationary satellites constellations, IRNSS satellite , GPS constellations, Types and characteristics of different platforms –RESOURCESAT, OCEANSAT, LANDSAT, IRS, INSAT, TERRA, AQUA,NPP etc.

UNIT – III
Noise survey for ground station, Link margin calculations, Ground station requirements for LEO ,MEO, GEO. Types os antenna mounts, Cassegranian configuration, Prime focus, astronomical mounts, Antenna systems for planetary missions, cross polarisation, isolation, Pointing and tracking accuracy, Auto tracking mechanism, Different tracking mechanisms step track, monopulse track etc, Antenna servo controller, Figure of merit of antenna systems, Front end electronics, Different RF feed systems, RF Downconverters , upconverters, Modulators, Configuration matrix, Demodulators, Frame synchronisers, Data acquisition systems.

UNIT – IV
Satellite Data receive chain verification and validation, testing of End-end satellite receive chain for high data rate satellites, Servo control systems tests for performance evaluation, Satellite time importance, TCG, Interfacing of ECL,LVDS,TTL signals. Coding mechanisms, phase keying mechanisms and advantages, High speed fiber links for data transfers, RAID controllers and data acquisition systems.

UNIT –V
Quality assurance of ground station systems, KPI monitoring of RF signal parameters, Eb/N0, C/No, IF level. Improving signal to noise, RF performance tuning and signal level monitoring, Servo parameters tuning, tracking gradients, BER verification of satellite data receive chain, IS 9000 environmental test standards for systems/sub systems qualification. CISPR-22 ,IEC 61000 standards for EMI/EMC tests qualification for ground station systems. Overview of ISO 9001:2015 standard.

Suggested Reading:

1	Bruce Elbert "The satellite communication Ground segment and earth station hadbook", Artech house- 2014, 2nd edition.
2	Louis J.Ippolito, Jr "Satellite Communications Systems Engineering" Wiley- 1st Edition, 2008.
3	William F. Egan "Practical RF System Design (IEEE Press) Hardcover", Wiley-IEEE Press, 1st edition 2003
4	Warren L.Stutzman, Gary A.thiele " Antenna theory and design" Wiley , 2012 3rd edition
5	Bureau of Indian standards BIS" Basic Environmental testing procedures for electronic and electrical items, Part 32, " BIS , 2006
6	https://kanchiuniv.ac.in/coursematerials/Notes_Satellite_Commn_Dr_Umapathy_ECE.pdf
7	Clayton R. Paul," Introduction to Electromagnetic Compatibility" Wiley-2010, 2nd edition

EC431	VLSI SIGNAL PROCESSING				
	Program Elective - III				
Pre-requisites	-	**L**	**T**	**P**	**C**
		3	**-**	**-**	**3**
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To enable the students to learn about the concept of pipelining and parallel processing
2	To make the students to understand the analysis of VLSI system with high speed and ~~low power by using students with knowledge of Systolic Design for Space~~
3	To make the students to understand the concept of Power Reduction and Estimation techniques in VLSI signal processing

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Explain parallel and pipelining processing techniques
CO-2	Identify applications for unfolding algorithm
CO-3	Analyse Systolic Design for Space Representations containing Delays
CO-4	Explain Cook-Toom Algorithm, Fast Convolution algorithm by Inspection method
CO-5	Analyze Power Reduction techniques and Power Estimation techniques.

	PO1	PO2	PO3	PO4	PO5
CO1					
CO2					
CO3					
CO4					
CO5					

Correlation rating: Low / Medium / High: 1 / 2 / 3 respectively.

UNIT–I
Introduction to DSP: Typical DSP algorithms, DSP algorithms benefits, Representation of DSPalgorithms. Pipelining and Parallel Processing: Introduction, Pipelining of FIR Digital filters,Parallel Processing, Pipelining and Parallel Processing for Low Power, Retiming: Introduction– Definitions and Properties – Solving System of Inequalities – Retiming Techniques.

UNIT–II
Folding and Unfolding, Folding: Introduction -Folding Transform - Register minimization Techniques – Register minimization in folded architectures – folding of multirate systems, Unfolding: Introduction – An Algorithm for Unfolding – Properties of Unfolding – critical Path, Unfolding and Retiming – Applications of Unfolding.

UNIT–III
Systolic Architecture Design: Introduction – Systolic Array Design Methodology – FIR Systolic Arrays – Selection of Scheduling Vector – Matrix Multiplication and 2D Systolic Array Design – Systolic Design for Space Representations contain Delays.

UNIT-IV
Fast Convolution: Introduction – Cook-Toom Algorithm – Winogard algorithm – Iterated Convolution – Cyclic Convolution – Design of Fast Convolution algorithm by Inspection.

UNIT – V
Low Power Design: Scaling Vs Power Consumption–Power Analysis, Power Reduction techniques – Power Estimation Approaches, Programmable DSP: Evaluation of Programmable Digital Signal Processors, DSP Processors for Mobile and Wireless Communications, Processors for Multimedia Signal Processing.

SUGGESTED READING:

1	Keshab K. Parthi, *"VLSI Digital Signal Processing- System Design and Implementation"*, 1998, Wiley Inter Science.
2	Kung S. Y, H. J. While House, T. Kailath, *"VLSI and Modern Signal processing"*,1985, Prentice Hall.
3	Jose E. France, Yannis Tsividis, *"Design of Analog – Digital VLSI Circuits for Telecommunications and Signal Processing",*1994, Prentice Hall.
4	Medisetti V. K,*"VLSI Digital Signal Processing",*IEEE Press (NY), USA, 1995.

EC432			OPTIMIZATION TECHNIQUES			
			Program Elective – III			
Pre-requisites		-	**L**	**T**	**P**	**C**
			3	**-**	**-**	**3**
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To introduce various optimization techniques i.e classical, linear
2	Constrained and unconstrained optimization techniques for solving and optimizing
3	To explain the concept of Dynamic programming and its applications to project implementation

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Explain the need of optimization of engineering systems
CO-2	Understand optimization of electrical and electronics engineering problems
CO-3	Apply classical optimization techniques, linear programming, simplex algorithm, transportation problem
CO-4	Apply unconstrained optimization and constrained non-linear programming and dynamic
CO-5	Formulate optimization problems.

	PO1	PO2	PO3	PO4	PO5
CO1					
CO2					
CO3					
CO4					
CO5					

Correlation rating: Low / Medium / High: 1 / 2 / 3 respectively.

UNIT–I
Use of optimization methods. Introduction to classical optimization techniques, motivation to the simplex method, simplex algorithm, sensitivity analysis.

UNIT–II
Search methods - Unrestricted search, exhaustive search, Fibonocci method, Golden sectionmethod, Direct search method, Random search methods, Univariate method, simplex method,Pattern search method.

UNIT–III

Descent methods, Gradient of function, steepest decent method, conjugate gradient method.Characteristics of constrained problem, Direct methods, The complex method, cutting plane method.

UNIT-IV

Review of a global optimization techniques such as Monte Carlo method, Simulatedannealing and Tunneling algorithm.

UNIT – V

Generic algorithm - Selection process, Crossover, Mutation, Schema theorem, comparison between binary and floating-point implementation.

SUGGESTED READING:

1	SS Rao, *"Optimization techniques"*, PHI, 1989
2	ZhigmiewMichelewicz, *"Genetic algorithms + data structures = Evaluation programs"*,SpringerVerlog - 1992.
3	Merrium C. W., *"Optimization theory and the design of feedback control systems"*, McGraw Hill, 1964.
4	Weldo D.J., *"Optimum seeking method",* PHI, 1964.

EC433	ADVANCED COMMUNICATION AND COMPUTER NETWORKS						
Program Elective - III							
Pre-requisites	-		**L**	**T**	**P**		**C**
			3	**-**	**-**		**3**
Evaluation	**SEE**	60 Marks	**CIE**			40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Overview of communication computer networks, internet, and foundation of basics
2	Study of Routing and Congestion control at the network layer.
3	Learn Protocols in Network layer and multicast routing in internetworking and also analyze of protocols Transport layer, and Application Layer.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Understand advanced concepts in Communication Networking.
CO-2	Design and develop protocols for Communication Networks.
CO-3	Understand the mechanisms in Quality of Service in networking.
CO-4	Optimise the Network Design.
CO-5	Analyse protocols multicast routing in internetworking.

	PO1	PO2	PO3	PO4	PO5
CO1					
CO2					
CO3					
CO4					
CO5					

Correlation rating: Low / Medium / High: 1 / 2 / 3 respectively.

UNIT–I
Data Communications concepts: Data Communications Model Communication Tasks, Networks and Networking configurations and Internet. Foundation of Networking Protocols: 5-layer TCP/IP Model, 7-Layer OSI Model, Internet Protocols and Addressing.

UNIT–II
Data Link Control protocol: Flow Control, Sliding Window Flow Control, Error control, CRC, ARQ Protocols, Data Link Control, Bit stuffing, HDLC Operation.
Local Area Networks: LAN Architecture. Topologies, Choice of Topology, Ring and Star Usage, MAC and LLC, Generic MAC Frame Format, Multiple Access Protocols, LAN Addresses and ARP, Ethernet, Hubs, Bridges and Switches.

UNIT–III
Switching and multiplexing: Circuit Switching networks and Packet Switching: Packet Switching Principles, Datagram and Virtual Circuit switching, Wide Area Routing: Path Selection Algorithms - Dijkstra‟s Algorithm, Bellman-Ford Algorithm, Packet Flooding and Deflection Routing Algorithm.

UNIT-IV
Network layer: Congestion Control at the Network Layer, Internet Protocol: Internetworking, IPv4, IPv6, Transition from IPv4 to IPv6 Multi cast Routing and Protocols: Basic Definitions and Techniques, Internet Group Management Protocol (IGMP).

UNIT – V
Transport and End-to-End Protocols: User Data gram Protocol (UDP), Transmission Control Protocol (TCP), TCP Congestion Control. With effect from Application Layer: The Web and HTTP, File Transfer: FTP, Electronic Mail in the Internet, Domain Name System (DNS).

SUGGESTED READING:

1	William Stallings, "Data and Computer Communications", Eigth Edition, Pearson Prentice Hall, 2007.
2	Behrouz A. Forouzan, "Data Communications and Networking", Fourth Edition, Tata Mc Graw Hill, 2007.
3	Douglas E. Comer, "Internetworking with TCP/IP", Pearson Education, 6th Edition. 4 Prakash and C.gupta "Data communications and computer networks" second Edition, Pearson, PHI learning, 2014

EC461	VLSI DESIGN VERIFICATION LAB				
Pre-requisites	-	**L**	**T**	**P**	**C**
		-	-	2	1
Evaluation	SEE	-	**CIE**	50 Marks	

1. Access the class properties and methods by creating objects.

2. Use class constructor to initialize the class properties while creating the object for a class.

3. Demonstrate the working of Static class properties and methods

4. Use the concept of Inheritance to extend the functionality of an existing class.

5. Demonstrate the process of overriding class members:

6. Write a program to demonstrate the use of local and protected keywords.

7. Use rand and randc to generate a random stimulus.

8. Write a program to demonstrate how threads work using fork-join.

9. Write a program to demonstrate the function of semaphore

10. Write a program to demonstrate the function of mailbox

EC471		SEMINAR			
Pre-requisites		-	**L**	**T**	**P**	**C**

Pre-requisites		-	**L**	**T**	**P**	**C**
			-	-	2	1
Evaluation	**SEE**	-	**CIE**	50 Marks		

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Identify appropriate topic of relevance.
2	Update literature on technical articles of selected topic and develop comprehension.
3	Prepare a technical report.
4	Deliver presentation on specified technical topic.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Review literature on technical articles and develop comprehension.
CO-2	Recognize appropriate topic of relevance
CO-3	Prepare review repot of literature studied
CO-4	Write a technical report.
CO-5	Give presentation on specified technical topic

At least two faculty members will be associated with the seminar presentation to evaluate and award marks.

SEMESTER-II

EC404			ANALOG AND MIXED SIGNAL IC DESIGN				
			CORE – IV				
Pre-requisites		-	**L**	**T**	**P**	**C**	
			3	**-**	**-**	**3**	
Evaluation	**SEE**	60 Marks	**CIE**			40 Marks	

Course Objectives

The objectives of this course are to
1. Familiarize the students with basic building blocks of Analog & Mixed signal IC design and their modelling.
2. Train the students to analyze and design basic building blocks of Analog and Mixed Signal IC Design.
3. Impart skills for analyzing different responsesof various Amplifiers and Op-Amp, etc.

Course Outcomes

At the end of the course student will be able to
1) Choose appropriate model of MOSFET as per the given circuit/application/condition.
2) Choose, Analyze and Design various amplifiers & current Mirrors for a given application / specification
3) Analyze the effect of frequency and noise on various building blocks of analog IC Design.
4) Analyze and Design complex analog circuits like comparator, OP-Amp and Band Gap references, etc.
5) Choose, Analyze and Design various switched capacitor and mixed signal circuits.

	PO1	PO2	PO3	PO4	PO5
CO1					
CO2					
CO3					
CO4					
CO5					

UNIT I

Building Blocks of Analog Circuits:
MOS Transistor – Nanometer Transistor and its model – body effect, Channel Length Modulation and short channel effects – velocity saturation, sub-threshold conduction, threshold voltage control, drain induced barrier lowering, gate induced drain leakage, Complete MOS Transistor Model and large and small signal models of BJTs and MOSFETs, Process Corners.
Current Mirrors andSingle Stage Amplifiers – Simple CMOS current mirror, common source amplifier, source follower, common gate amplifier, cascode amplifiers. Source de-generated current mirrors, cascode current mirror, cascode gain stage.

UNIT II

Differential Signaling and Advanced Current Mirrors
Differential Amplifier:
Single ended vs differential operation, basic differential pair, basic differential pair - quantitative analysis, Common mode response, Differential amplifier with MOS loads, Differential pairs with current mirror loads (i.e., active load), large signal analysis, small signal analysis, common mode properties.

Advanced current Mirrors – Wilson current mirror, Enhanced output-impedance current mirror and gain boosting and wide swing current mirror with enhanced output impedance.
Single stage Op-amp – Folded-cascode op-amp, current mirror op-amp.

UNIT-III:

FrequencyResponse & Noise of Amplifiers, Reference Generation
Frequency Response of Amplifiers:
Miller effect, association of poles with nodes, Frequency Response: common source stage, source follower, common gate stage, differential pair.
Noise: Noise, Statistical characteristics of noise, noise spectrum, types of noise: thermal noise, flicker noise, representation of noise in circuit, Noise in common source amplifier.
Biasing and References – Analog IC biasing, establishing constant trans-conductance and band-gap reference – Positive and negative temperature coefficient basics and circuits.

UNIT-IV

Op-Amp &Comparators:
Basic two-stage MOS Operational amplifier, characteristic parameters, compensation, design and analysis of two-stage MOS Op-Amp with given specifications. Stability and frequency compensation of Op-Amps, fully differential Op-Amp and common mode feedback circuits.
Comparators: Op-Amp Based Comparators, Charge Injection Errors – Latched Comparators

UNIT – V

Mixed Signal Circuits
Switched capacitor circuits: Basic building blocks; basic operation and analysis, inverting and non-inverting integrators, signal flow diagrams, first order filter.
Sample and hold circuits - Performance requirements, MOS sample and hold basics, clock feed through problems, S/H using transmission gates, high input impedance S/H circuits, improved S/H circuits from the point of slewing time, clock feed through cancellations.
Data Converters – Review of Nyquist-Rate A/D and D/A converters, Oversampling converters – Over sampling without noise shaping and with noise shaping.
Phase locked loops –simple PLL, charge pump PLL and dynamics of PLL.

Suggested Reading

1. Tony Chan Carusone, David Johns and Ken Martin, Analog Integrated Circuit Design, 2nd edition, John Wiley & sons. 2013.
2. Behzad Razavi, Design of Analog CMOS Integrated Circuits, McGraw Hill Companies, 2013.
3. Philip E. Allen and Douglas R. Holberg, CMOS Analog Circuit Design,2nd edition, Oxford University Press, 2010.

EC405			VLSI PHYSICAL DESIGN			
			CORE – V			
Pre-requisites		-	**L**	**T**	**P**	**C**
			3	**-**	**-**	**3**
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:

1. Draw the structure of passive active components
2. Know the concepts of physical design and understand the layouts and stick diagrams of complex circuits
3. Understand the system level physical design and floor planning and hands-on experience on CAD tools

Outcomes: *At the end of this course, students will be able to:*
1. Understand the basic theory of BJT MOS transistors
2. Understand the basic concepts of physical design, layouts of BJT, MOS transistors and interconnect issues
3. Students are able to slove the performance issues in circuit layout
4. Able to analyze physical design problems and employ for partitioning, floor planning, placement and routing
5. Students are able to analyze circuits using both analytical and CAD tools

	PO1	PO2	PO3	PO4	PO5
CO1					
CO2					
CO3					
CO4					
CO5					

UNIT – I
Scope of physical design, Components of VLSI, Various layers of VLSI, Typical structures of BJTS, MOSFETS, Resistors, capacitors, inductors, interconnects, brief review of technology, cost and performance analysis.

UNIT – II
Basic concepts of Physical Design, layout of basic structures wells, FET, BJT, resistors, capacitors, contacts, vias and wires (Interconnects). Mask overlays for different structures.Parasitics, latch up and its prevention. Device matching and common centroid techniques foranalog circuits.

UNIT – III
Design rules, fabrication errors, alignment sequence and alignment inaccuracies, processvariations and process deltas, drawn and actual dimensions and their effect on design rules–scalable design rules. Scalable CMOS (SCMOS) design rules, layout design, and stick diagrams, Hierarchical stick diagrams.

UNIT – IV

Cell concepts, cell-based layout design, Weinberger image array, physical design of logic gates –NOT, NAND and NOR – design hierarchies. System level physical design, large scale physical design, inter connect delay modelling, floor planning, routing and clock distribution.

UNIT – V

CAD Tools: Layout editors, Design rule checkers, circuit extractors, Hierarchical circuit extractors, Automatic layout tools, modelling and extraction of circuit parameters from physical layout. Input-Output Interfacing: Power Supply, Bonding pad, Pad Ring, Input structures, Digital output structures, Low Voltage Differential swing, Power clamp, Core/Pad Limitation, Signal Propagation between Integrated Circuits

References:
1. John P. Uyemura, "Introduction to VLSI Circuits and Systems", John Wiley & sons, Inc.2012.
2. Wayne Wolf, "Modern VLSI Design (System-on-Chip)", Pearson Education, 3rd Edition 2005.
3. R. Jacob Baker; Harry W.Li., David E. Boyce, "CMOS Circuit Design, Layout and Simulation", IEEE Press, Prentice Hall of India.
4. Etienne Sicard Sonia Delmas Bendhia "Advanced CMOS Cell Design" Tata McGraw Hill First Edition 2007.
5. Preas, M. Lorenzatti, "Physical Design and Automation of VLSI Systems", the Benjamin Cummins Publishers, (1998).

EC406			**SCRIPTING LANGUAGES**				
			Core-VI				
Pre-requisites		-	**L**	**T**	**P**		**C**
			3	**-**	**-**		**3**
Evaluation	**SEE**	60 Marks	**CIE**			40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To Know Linux Operating System and work with Simple commands.
2	To learn PERL Scripting language.
3	To learn Python Scripting language.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Use Linux operating system based work stations.
CO-2	Understand PERL scripting language and its basics.
CO-3	Describe Regular expressions and Data structures of PERL
CO-4	Understand Python scripting language and its basics
CO-5	Describe Files, Lists and Strings concept in Python.

	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1					
CO2					
CO3					
CO4					
CO5					

Correlation rating: Low / Medium / High: 1 / 2 / 3 respectively.

UNIT–I
Linux Basics: Introduction to Linux, File System of the Linux, General usage of Linux kernel & basic commands, Permissions for file, directory and users, searching a file & directory, zipping and unzipping concepts, Overview of scripting languages.

UNIT–II
PERL Scripting Language: PERL basics, file handles, operators, control structures, regular expressions, built in data types, operators, statements and declarations- simple, compound, loop statements, global and scoped declarations. Lists, Arrays and Hashes.

UNIT–III
Pattern Matching in PERL - Regular expression, Pattern matching operators, character classes. PERL Subroutines, Semantics, Prototypes, References, Data Structures- arrays of arrays, hashes of arrays. PERL Debugger, Programs using PERL.

UNIT-IV
Python Scripting Language: Variables in Python, Performing Calculations (Operators, Type conversions, Expressions), Decision Structures and Boolean Logic, Comparing Strings, Logical Operators, Boolean Variables. Repetition Structures: Introduction, while loop, for loop, Input Validation Loops, Nested Loops. Functions: Introduction, Defining and Calling a Void Function, Designing a Program to Use Functions, Local Variables, Passing Arguments to Functions, Global Variables and Global Constants, Value-Returning Functions.

UNIT – V
Lists and Tuples: Sequences, Introduction to Lists, List slicing, Finding Items in Lists with the in Operator, List Methods and Useful Built-in Functions, Copying Lists, Processing Lists, Two-Dimensional Lists, Tuples. File and Exceptions: Introduction to File Input and Output, Using Loops to Process Files, Processing Records, Exceptions. Strings: Basic String Operations, String Slicing, Testing, Searching, and Manipulating Strings

SUGGESTED READING:

1	Larry Wall, Tom Christiansen, John Orwant, "*Programming PERL*", Oreilly publications, 3rd ed.
2	Tony Gaddis, *Starting out with Python*, Pearson College Division, 3rd Edition, 2014.
3	Reema Thareja, "Python programming using problem solving approach", Oxford University Press.

EC441			**WIRELESS SENSOR NETWORKS**			
			Program Elective - IV			
Pre-requisites	-		**L**	**T**	**P**	**C**
			3	**-**	**-**	**3**
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

COURSE OUTCOMES

On completion of the course, students will be able to

1. Design wireless sensor network system for different applications under consideration.
2. Understand the architecture details of different sensors network scenarios and select right type of sensor for various applications.
3. Understand radio standards and communication protocols at physical layer and MAC layer to be used for wireless sensor network-based systems.
4. Understand radio standards and communication protocols at Network layer to be used for wireless sensor network-based systems.
5. Use operating systems and programming languages for wireless sensor nodes, performance of wireless sensor networks systems and platforms.

	PO1	PO2	PO3	PO4	PO5
CO1					
CO2					
CO3					
CO4					
CO5					

UNIT – I
Introduction and overview of sensor network architecture and its applications, Challenges for WSNs, WSN comparison with Mobile Ad Hoc Networks, Single Sensor node architecture with hardware components and operating systems.
UNIT – II
Network Architecture: Sensor Network scenarios, Optimization goals, Design principles for WSNs, Service interfaces of WSNs and Gateway concepts
UNIT – III
Physical layer and MAC protocols: Physical layer and Transceiver design considerations in WSNs, MAC protocols for WSNs, Low duty cycle protocols and wakeup concepts, Contention based and Scheduled based protocols, IEEE 802.15.4 MAC protocol
UNIT – IV
Routing Protocols for WSNs: Gossiping and agent based unicast forwarding, Energy efficient unicast, Broadcast and multicast, Geographic routing and Mobile nodes
UNIT – V
Sensor Network programming: Challenges in Sensor network Programming, Node centric programming, nesC language, tinyGALS, thread based model, Macro programming, Dynamic programming, Sensor network simulators and environment

References:

1. H. Karl and A. Willig, *"Protocols and Architectures for Wireless Sensor Networks"*, John Wiley & Sons, India, 2012

2. Kazem Sohrbay, Daniel Minoli, Taieb Znati, " Wireless Sensor Networks Technology,Protocols and Applications", Wiley Publications, 2007

3. Waltenegus Dargie, Christian Poellabauer, " Fundamentals of WSNs, Theory and Practice", Wiley series on Wireless Communications and Mobile Computing, 2010

4. C. S. Raghavendra, K. M. Sivalingam, and T. Znati, Editors, *"Wireless Sensor Networks",* Springer Verlag, 1st Indian reprint, 2010.

5. YingshuLi, MyT. Thai, Weili Wu, *"Wireless sensor Network and Applications"*, Springer series on signals and communication technology, 2008.

EC442	REAL TIME OPERATING SYSTEMS				
	Program Elective - IV				
Pre-requisites	-	**L**	**T**	**P**	**C**
		3	**-**	**-**	**3**
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To learn basics of Operating Systems.
2	To get acquainted with UNIX and POSIX
3	To get familiarized with RTOS concepts
4	To get acquainted with various commercial RTOS

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Understand the fundamental structure of Operating System.
CO-2	Compare between Hard and Soft Real time systems and analyze real time scheduling algorithms.
CO-3	Analyze the concept of Real Time Kernel and implementation of Inter Process Communication.
CO-4	Analyze the features of VxWorks and compare the commercially available RTOS's
CO-5	Explore the features of UNIX operating system and differentiate between UNIX and POSIX.

	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1					
CO2					
CO3					
CO4					
CO5					

Correlation rating: Low / Medium / High: 1 / 2 / 3 respectively.

UNIT–I
Brief Review of Unix Operating Systems (Unix Kernel – File system, Concepts of – Process, Concurrent Execution & Interrupts. Process Management – forks & execution. Programming with system calls, Process Scheduling. Shell programming and filters). Portable Operating System Interface (POSIX) – IEEE Standard 1003.13 & POSIX real time profile. POSIX versus traditional Unix signals, overheads and timing predictability.

UNIT–II
Hard versus Soft Real-time systems – examples, Jobs & Processors, Hard and Soft timing constraints, Hard Real-time systems, Soft Real-time systems. Classical Uni-processor Scheduling Algorithms – RMS, Preemptive EDF, Allowing for Preemptive and Exclusion Condition.

UNIT–III
Concept of Embedded Operating Systems, Differences between Traditional OS and RTOS. Real time System Concepts, RTOS Kernel & Issues in Multitasking – Task Assignment, Task Priorities, Scheduling, Inter task Communication & Synchronization – Definition of Context Switching, Foreground ISRs and Background Tasks. Critical Section – Reentrant Functions, Inter process Communication (IPC) – IPC through Semaphores, Mutex, Mailboxes, Message Queues or Pipes and Event Flags.

UNIT-IV
VxWorks – POSIX Real Time Extensions, timeout features, Task Creation, Semaphores (Binary, Counting), Mutex, Mailbox, Message Queues, Memory Management – Virtual to Physical Address Mapping. Comparison of RTOS – VxWorks, µC/OS-II and RT Linux for Embedded Applications.

UNIT – V
Debugging Tools and Cross Development Environment – Software Logic Analyzers, ICEs. Comparison of RTOS – VxWorks, µC/OS-II and RT Linux for Embedded Applications.

SUGGESTED READING:

1	Jane W.S.Liu, *Real Time Systems*, Pearson Education, Asia, 2001.
2	Wind River Systems, *VxWorks Programmers Guide*, Wind River Systems Inc.1997.
3	Shibu K.V., *Introduction to embedded systems*, MC Graw-Hill Inc., 1997.
4	Tanenbaum, *Modern Operating Systems*, 3rd edition, Pearson Edition, 2007.
5	Jean.J.Labrosse, *MicroC/OS-II*, The CMP Books.
6	C.M.Krishna and G.Shin, *Real Time System*, McGraw Hill International Editions, 1997

EC443	DSP PROCESSORS AND ARCHITECTURES				
	Program Elective - IV				
Pre-requisites	-	**L**	**T**	**P**	**C**
		3	**-**	**-**	**3**
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To give an exposure to the various fixed point DSP architectures
2	To give an exposure to floating-point DSP architectures
3	To develop applications using these processors.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Identify and formalize architectural level characterization of DSP hardware
CO-2	Design and implement signal processing modules in DSPs
CO-3	Ability to design, programming (assembly and C), and testing code using Code Composer Studio environment
CO-4	Deployment of DSP hardware for Control, Audio and Video Signal processing Applications
CO-5	Understanding of major areas and challenges in DSP based embedded systems.

	PO1	PO2	PO3	PO4	PO5
CO1					
CO2					
CO3					
CO4					
CO5					

Correlation rating: Low / Medium / High: 1 / 2 / 3 respectively.

UNIT–I
Introduction to Digital Signal Processing: Introduction, A Digital signal-processing system, The sampling process, Discrete time sequences. Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT), Linear time-invariant systems, Digital filters, Decimation and interpolation. Computational Accuracy in DSP Implementations: Number formats for signals and coefficients in DSP systems, Dynamic Range and Precision, Sources of error in DSP implementations, A/D Conversion errors, DSP Computational errors, D/A Conversion Errors, Compensating filter.

UNIT–II
Architectures for Programmable DSP Devices: Basic Architectural features, DSP Computational Building Blocks, Bus Architecture and Memory, Data Addressing Capabilities, Address Generation UNIT, Programmability and Program Execution, Speed Issues, Features for External interfacing.

UNIT–III
Programmable Digital Signal Processors: Commercial Digital signal-processing Devices, Data Addressing modes of TMS320C54XX DSPs, Data Addressing modes of TMS320C54XX Processors, Memory space of TMS320C54XX Processors, Program Control, TMS320C54XX instructions and Programming, On-Chip Peripherals, Interrupts of TMS320C54XX processors, Pipeline operation of TMS320C54XX Processors.

UNIT-IV
Analog Devices Family of DSP Devices: Analog Devices Family of DSP Devices – ALU and MAC block diagram, Shifter Instruction, Base Architecture of ADSP 2100, ADSP2181 high performance Processor. Introduction to Blackfin Processor - The Blackfin Processor, Introduction to Micro Signal Architecture, Overview of Hardware Processing Units and Register files, Address Arithmetic Unit, Control Unit, Bus Architecture and Memory, Basic Peripherals.

UNIT – V
Interfacing Memory and I/O Peripherals to Programmable DSP Devices: Memory space organization, External bus interfacing signals, Memory interface, Parallel I/O interface, Programmed I/O, Interrupts and I/O, Direct memory access (DMA).

SUGGESTED READING:

1	A Practical Approach to Digital Signal Processing - K Padmanabhan, R. Vijayarajeswaran, Ananthi. S, New Age International, 2006/2009
2	Embedded Signal Processing with the Micro Signal Architecture Publisher: Woon-Seng Gan, Sen M. Kuo, Wiley-IEEE Press, 2007
3	Digital Signal Processors, Architecture, Programming and Applications – B. Venkataramani and M. Bhaskar, 2002, TMH.
4	DSP Processor Fundamentals, Architectures & Features – Lapsley et al. 2000, S. Chand & Co.
5	Digital Signal Processing Applications Using the ADSP-2100 Family by The Applications Engineering Staff of Analog Devices, DSP Division, Edited by Amy Mar, PHI

EC451			CPLD and FPGA Architectures			
			Program Elective - V			
Pre-requisites		-	**L**	**T**	**P**	**C**
			3	**-**	**-**	**3**
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:
1. Understand the basic operation of Programmable gate arrays
2. Learn the architecture of various types of FPGAs/CPLD and design a digital circuit and implement it on an FPGA,
3. Implement the programming techniques used in FPGA design and Verification

Course Outcomes: By the end of this course, students will be able to:

1. Evaluation of PLDs
2. Familiarity architecture of various types of FPGAs/CPLD.
3. Design a digital circuit and implement it using reconfigurable logic.
4. Design and develop IP cores and Prototypes in FPGA design.
5. Apply simulators and verify develop FPGA designs.

	PO1	PO2	PO3	PO4	PO5
CO1					
CO2					
CO3					
CO4					
CO5					

UNIT – I

Programmable Logic Devices: Revision of basic Digital systems, PROM, PLA, PAL, Architecture of PAL's applications, programming technologies, programmable logic design methods and tools.

UNIT – II

CPLD's: complex programmable logic devices: logic block, I/O block, interconnect matrix, logic blocks and features of altera flex logic 10000 series CPLD"s , max 7000 series CPLD"s, AT & T– ORCA"s (Optimized Reconfigurable Cell Array), cypres flash 370 device technology, lattice plsi"s architectures.

UNIT – III

FPGAs: Field Programmable Gate Arrays: Logic blocks, routing architecture, Logic cells and features of commercially available FPGA"s- XILINX XC4000, SPARTAN II, virtexII FPGA"s, XILINX, Altera"s FPGA, ACETEL Act1, Act2, Act3 FPGAS , AMD FPGA.

UNIT – IV

Synthesis process: Placement: objectives, placement algorithms: Mincut-Based placement, iterative improvement Placement, simulated annealing. Routing: objectives, segmented channel routing, Maze routing, Routability estimation, Net delays, Computing signal delay in RC tree networks.

UNIT – V

FPGA implementation steps: simulation process, verification: introduction, logic simulation, design validation, timing verification. Testing concepts: failures, mechanisms and faults, fault coverage, ATPG methods, programmability failures, Case studies: programmable counter, ALU, Barrel shifter.

References:
1. P.K. Chan & S. Mourad, "Digital Design Using Field Programmable Gate Array", Pearson Education 2009
2. S. Trimberger, Edr.,"Field Programmable Gate Array Technology", Kluwer Academic Publications, 1994.
3. J. Old Field, R. Dorf, "Field Programmable Gate Arrays", John Wiley & Sons, Newyork, 1995.
4. S. Brown, R. Francis, J. Rose, Z.Vransic, "Field Programmable Gate array", Kluwer Publn, 1992 5 Manuals from Xilinx, Altera, AMD, Actel.

EC452	UNMANNED AERIAL VEHICLE SYSTEMS				
	Program Elective - V				
Pre-requisites	-	**L**	**T**	**P**	**C**
		3	**-**	**-**	**3**
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	To explain and make the students to understand the basic concepts of UAV/DRONE systems and its applications.
2	To understand the different hardware configurations for UAV.
3	To understand the designing, integration and testing of UAV.
4	To understand the GCS Software & applications.
5	To demonstrate the flight configurations and Practical implementation.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Able to identify different hardware for UAV.
CO-2	Prepare preliminary design requirements for an unmanned aerial vehicle.
CO-3	Perform system testing for unmanned aerial vehicles.
CO-4	Integrate various systems of unmanned aerial vehicle.
CO-5	Design micro aerial vehicle systems by considering practical limitations. Understanding of GCS Software & Practical implementation.

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	3	3	2	1	3
CO-2	3	3	3	2	2	3
CO-3	3	3	3	2	2	3
CO-4	3	3	3	2	1	3
CO-5	3	3	3	2	2	3

UNIT – I
Introduction to Unmanned Aerial Vehicle Systems -- evolution of UAV – classification – models and prototypes – System Composition-applications.

UNIT – II
Introduction to Design and Selection of the System- Aerodynamics and Airframe Configurations- Characteristics of Aircraft Types- Regulations of DGCA- Fixed Wing Operations and Aerodynamics - Drone Piloting-Weather and Meteorology- ATC Procedures & Radio Telephony.

UNIT – III
Basic Components of Drone - Different Types of Drones- Assembling of Drone, Artificial Intelligence in Drone -Drone Mapping.

UNIT – IV
Theory of Flight-Three Axes of Fight-Take –Off - Landing – Hover- Turning- Forwards and Sideway-Aerodynamic of Drone.

UNIT –V
Waypoints Navigation-Introduction to Ground Control software (GCS) - System Ground Testing- System In-flight Testing of Mini and Micro UAVs- Case study on the usage of UAV/DRONE.

Suggested Reading:

1	Paul G Fahlstrom, Thomas J Gleason, "Introduction to UAV Systems", UAV Systems, Inc, 1998.
2	Reg Austin "Unmanned Aircraft Systems UAV design, development and deployment", Wiley, 2010.
3	Dr. Armand J. Chaput, "Design of Unmanned Air Vehicle Systems", Lockheed Martin Aeronautics Company, 2001.
4	Kimon P. Valavanis, "Advances in Unmanned Aerial Vehicles: State of the Art and the Road to Autonomy", Springer, 2007.
5	Robert C. Nelson, Flight Stability and Automatic Control, McGraw-Hill, Inc, 1998.

EC453			**LOW POWER VLSI DESIGN**			
			Program Elective - V			
Pre-requisites		-	**L**	**T**	**P**	**C**
			3	**-**	**-**	**3**
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To study the sources of power dissipation and low power design techniques with voltage
2	To study various low power arithmetic units and the design of low power multipliers
3	To study about low power memory technologies

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Understand various power components
CO-2	Understand and design low power memories
CO-3	Understand and use mathematical models for power analysis in CMOS circuits
CO-4	Design low power architectures
CO-5	Understand and design multipliers

	PO1	**PO2**	**PO3**	**PO4**	**PO5**
CO1					
CO2					
CO3					
CO4					
CO5					

Correlation rating: Low / Medium / High: 1 / 2 / 3 respectively.

UNIT–I
Fundamentals: Need for Low Power Circuit Design, Sources of Power Dissipation – Switching Power Dissipation, Short Circuit Power Dissipation, Leakage Power Dissipation, Glitching Power Dissipation, Short Channel Effects –Drain Induced Barrier Lowering and Punch Through, Surface Scattering, Velocity Saturation, Impact Ionization, Hot Electron Effect.

UNIT–II
*Low-Power Design Approaches***:** Low-Power Design through Voltage Scaling – VTCMOS circuits, MTCMOS circuits, Architectural Level Approach –Pipelining and Parallel Processing Approaches. Switched Capacitance, Minimization Approaches: System Level Measures and Circuit Level Measures.

UNIT–III
*Low-Voltage Low-Power Adders***:** Introduction, Standard Adder Cells, CMOS Adder Architectures – Ripple Carry Adders, Carry Look-Ahead Adders, Carry Select Adders, Carry Save Adders, Low-Voltage Low-Power Design Techniques–Trends of Technology and Power Supply Voltage, Low-Voltage Low-Power Logic Styles.

UNIT-IV
Low-Voltage Low-Power Multipliers: Introduction, Overview of Multiplication, Types of Multiplier Architectures, Braun Multiplier, Baugh-Wooley Multiplier, Booth Multiplier and Introduction to Wallace Tree Multiplier.

UNIT – V
*Low-Voltage Low-Power Memories***:** Basics of ROM, Low-Power ROM Technology, Future Trend and Development of ROMs, Basics of SRAM, Memory Cell, Pre-charge and Equalization Circuit, Low-Power SRAM Technologies, Basics of DRAM, Self-Refresh Circuit, Future Trend and Development of DRAM.

SUGGESTED READING:

1	Sung-Mo Kang, Yusuf Leblebici, *"CMOS Digital Integrated Circuits – Analysis and Design"*, TMH, 2011.
2	Ming-BO Lin, "*Introduction to VLSI Systems: A Logic, Circuit and System Perspective",* CRC Press, 2011
3	AnanthaChandrakasan, *"Low Power CMOS Design*", IEEE Press/Wiley International, 1998
4	Kaushik Roy, Sharat C. Prasad, *"Low Power CMOS VLSI Circuit Design*", John Wiley & Sons,2000.
5	Gary K. Yeap, "*Practical Low Power Digital VLSI Design*", Kluwer Academic Press, 2002.

OE 941 BM			MEDICAL ASSISTIVE DEVICES			
(OPEN ELECTIVE)						
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To extend knowledge of the amputee, of lost and remaining functions affecting locomotion, and to collect information on the best possible medical treatment.
2	To improve fitting techniques and practices, including training, so that existing devices might be used with greater comfort and function.
3	To develop improved lower-extremity devices

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Apply fundamental knowledge of engineering in rehabilitation
CO-2	Apply analytical skills to assess and evaluate the need of the end-user
CO-3	Develop self-learning initiatives and integrate learned knowledge for problem solving
CO-4	Understand the basics of robotics and apply their principles in developing prosthetics
CO-5	Apply the knowledge of computers in solving rehabilitation problems

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
Introduction to Rehabilitation Engineering, Measurement and analysis of human movement, Disability associated with aging in the workplace and their solutions, clinical practice of rehabilitation engineering.

Unit – II
Assistive Technology, Seating Biomechanics and systems. Wheeled Mobility: Categories of Wheelchairs. Wheelchair Structure and Component Design. Ergonomics of Wheel chair propulsion. Power Wheelchair Electrical Systems. Control. Personal Transportation. Auxiliary devices and systems.

Unit – III
Sensory augmentation and substitution: Visual system: Visual augmentation. Tactual vision substitution, Auditory vision substitution; Auditory system: Auditory augmentation. Cochlear implantation, Visual auditory substitution, Tactual auditory substitution, Tactual system: Tactual augmentation. Tactual substitution. Measurement tools and processes: fundamental principles, structure, function; performance and behavior. Subjective and objective measurement methods.

Unit – IV
Rehabilitation Robotics, Major Limb Prosthetic Devices, Orthotic Devices, Types of orthotics and prosthetics, Intelligent prosthetic Knee, Prosthetic Hand, Controlled orthotics and prosthetics FES system, Restoration of Hand function, Restoration of standing and walking, Myo-electric Hand.

Unit – V
Augmentative and Alternative communication technology, Computer applications in Rehabilitation Engineering, telecommunications, and Web Accessibility.

Suggested Reading:

1	Robinson C.J., *Rehabilitation Engineering*, CRC Press, 1995.
2	Ballabio E., et al., *Rehabilitation Technology*, IOS Press, 1993.
3	Rory A Cooper, Hisaichi Ohnabe, Douglas A. Hobson, *Series in medical physis and biomedical engineering: An introduction to rehabilitation engineering*, Taylor and Francis Group, London, 2007.
4	Joseph D. Bronzino *The biomedical engineering handbook -biomedical engineering fundamentals*, 3rdEd., CRC Press, Taylor & Francis Group, London, 2006.

OE 942 BM	MEDICAL IMAGING TECHNIQUES					
	(OPEN ELECTIVE)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To familiarize the students with various medical imaging modalities.
2	To make learners understand the principles, detectors and operating procedures of X-ray, CT, MRI, ultrasound, PET and SPECT.
3	To make the students learn the advantages, disadvantages and hazards of various medical imaging equipment.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Interpret the working principle and operating procedure and applications of X-ray equipment.
CO-2	Understand the image reconstruction techniques and applications of CT.
CO-3	Summarize the image acquisition and reconstruction techniques in MRI.
CO-4	Comprehend the working principle, modes and medical applications of ultrasound imaging.
CO-5	Examine the operation and applications of PET, SPECT and radio nuclide instrumentation.

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
X ray Imaging: Electromagnetic spectrum, Production of X-rays, X-ray tubes- Stationary and Rotating Anode types, Block diagram of an X-Ray Machine, Collimators and Grids, Timing and Exposure controls. X-Ray Image visualization-Films, Fluorescent screens, Image Intensifiers.   Dental X-Ray machines, Portable and mobile X-Ray units, Mammographic X-Ray equipment,   Digital Radiography and flat panel detectors.   Radiation safety, ALARA principle, Dose units and dose limits, Radiation dosimeters and detectors.

Unit – II
Computed Tomography: Basic principles, CT number scale, CT Generations. Major sub systems- Scanning system, processing unit, viewing unit, storage unit. Need and Principle of sectional imaging, 2D image reconstruction techniques - Iteration and Fourier methods. Applications of CT - Angio, Osteo, Dental, Perfusion (Body & Neuro), Virtual Endoscopy, Coronary Angiography.

Unit – III
Magnetic Resonance Imaging: Principles of NMR imaging systems, Image reconstruction techniques-Relaxation processes, imaging/ pulse sequences. Sub systems of an NMR imaging system, NMR detection system, types of coils, biological effects and advantages of NMR imaging.   Functional MRI - The BOLD effect, intra and extra vascular field offsets, source of $T2^*$ effects, Creating BOLD contrast sequence optimization sources and dependences of physiological noise in fMRI.

Unit – IV
Ultrasound Imaging: - Principles of image formation -Imaging principles and instrumentation of A-mode, B-Mode, Gating Mode, Transmission mode and M-mode.   Basics of multi-element linear array scanners, Digital scan conversion.   Doppler Ultrasound and Colour Doppler imaging, Image artifacts, Biological effects, Ultrasound applications in diagnosis, therapy and surgery.

Unit – V
Nuclear Medicine–Radioisotopes in medical diagnosis, Basic instrumentation- Radiation detectors, Pulse height analyzer, Rectilinear scanner, Gamma camera.   Emission Computed Tomography (ECT), Principle and instrumentation of Single Photon Emission Computed Tomography(SPECT) and Positron Emission Tomography (PET). Comparison of SPECT, PET and combined PET/ X-ray CT.

Suggested Reading:

1	Khandpur R.S., *Handbook of Biomedical Instrumentation*, Tata McGraw Hill, 2016.
2	S Webb, "*The Physics of Medical Imaging*", Adam Highler, Bristol Published by CRC Press, 1988.
3	A C Kak, "*Principle of Computed Tomography*", IEEE Press New York, 1988.
4	Hykes, Heorick, Starchman, *Ultrasound physics and Instrumentation* MOSBY year book, 2nd Ed. 1992.
5	Stewart C. Bushong, *Magnetic Resonance Imaging- physical and biological principles*, MOSBY, 2nd Ed., 1995.

OE 941 CE			GREEN BUILDING TECHNOLOGY			
			(OPEN ELECTIVE)			
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Exposure to the green building technologies and their significance.
2	Understand the judicial use of energy and its management.
3	Educate about the Sun-earth relationship and its effect on climate.
4	Enhance awareness of end-use energy requirements in the society.
5	Develop suitable technologies for energy management

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand the fundamentals of energy use and energy processes in building.
CO-2	Identify the energy requirement and its management.
CO-3	Know the Sun-earth relationship vis-a-vis its effect on climate.
CO-4	Be acquainted with the end-use energy requirements.
CO-5	Be familiar with the audit procedures of energy

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	3	3	2	1	2
CO-2	3	2	3	2	1	1
CO-3	3	2	3	2	1	2
CO-4	3	2	3	2	1	2
CO-5	3	2	3	2	1	1

Unit – I
Overview of the significance of energy use and energy processes in building - Indoor activities and environmental control - Internal and external factors on energy use and the attributes of the factors - Characteristics of energy use and its management - Macro aspect of energy use in dwellings and its implications.

Unit – II
Indoor environmental requirement and management - Thermal comfort - Ventilation and air quality – Air-conditioning requirement - Visual perception - Illumination requirement - Auditory requirement.

Unit – III
Climate, solar radiation and their influences - Sun-earth relationship and the energy balance on the earth's surface - Climate, wind, solar radiation, and temperature - Sun shading and solar radiation on surfaces - Energy impact on the shape and orientation of buildings.

Unit – IV
End-use, energy utilization and requirements - Lighting and day lighting - End-use energy requirements - Status of energy use in buildings Estimation of energy use in a building. Heat gain and thermal performance of building envelope - Steady and non-steady heat transfer through the glazed window and the wall - Standards for thermal performance of building envelope - Evaluation of the overall thermal transfer.

Unit – V
Nuclear Medicine–Radioisotopes in medical diagnosis, Basic instrumentation- Radiation Energy management options - Energy audit and energy targeting - Technological options for energy management.

Suggested Reading:

1	Bryant Edwards (2005): Natural Hazards, Cambridge University Press, U.K.
2	Carter, W. Nick, (1991): Disaster Management, Asian Development Bank, Manila.
3	Sahni, Pardeep et.al. (eds.) (2002), Disaster Mitigation Experiences and Reflections, Prentice Hall of India, New Delhi.
4	Bryant Edwards (2005): Natural Hazards, Cambridge University Press, U.K.

OE 942 CE	COST MANAGEMENT OF ENGINEERING PROJECTS					
	(OPEN ELECTIVE)					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Introduce the concepts of cost management
2	Fundamentals of cost overruns
3	Introduce the concepts of Quantitative techniques for cost management Linear Programming, PERT/CPM.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understanding of strategic cost management process, control of cost and decision making based on the cost of the project.
CO-2	Ability to appreciative detailed engineering activities of the project and execution of projects
CO-3	Preparation of project report and network diagram
CO-4	Able to plan Cost Behavior , Profit Planning , Enterprise Resource Planning, Total Quality Management.
CO-5	Applications of various quantitative techniques for cost management

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
Introduction and Overview of the Strategic Cost Management Process-Cost concepts in decision-making; relevant cost, Differential cost, Incremental cost and Opportunity cost. Objectives of a Costing System- Inventory valuation- Creation of a Database for operational control; Provision of data for Decision-Making.

Unit – II
Project: meaning, Different types, why to manage, cost overruns centres, various stages of project execution: conception to commissioning- Project execution as conglomeration of technical and non- technical activities- Detailed Engineering activities.

Unit – III
Pre project execution main clearances and documents Project team: Role of each member. Importance Project site: Data required with significance. Project contracts. Types and contents. Project execution Project cost control. Bar charts and Network diagram. Project commissioning: mechanical and process.

Unit – IV
Cost Behavior and Profit Planning Marginal Costing; Distinction between Marginal Costing and Absorption Costing; Break-even Analysis, Cost-Volume-Profit Analysis. Various decision-making problems- Standard Costing and Variance Analysis. Pricing strategies: Pareto Analysis. Target costing, Life Cycle Costing. Costing of service sector- Just-in-time approach, Material Requirement Planning, Enterprise Resource Planning, Total Quality Management and Theory of constraints- Activity-Based Cost Management, Bench Marking; Balanced Score Card and Value-Chain Analysis. Budgetary Control; Flexible Budgets- Performance budgets- Zero-based budgets. Measurement of Divisional profitability pricing decisions including transfer pricing.

Unit – V
Quantitative techniques for cost management, Linear Programming, PERT/CPM,- Transportation problems, Assignment problems, Simulation, Learning Curve Theory.

Suggested Reading:

1	Cost Accounting A Managerial Emphasis, Prentice Hall of India, New Delhi
2	Charles T. Horngren and George Foster, Advanced Management Accounting
3	Robert S Kaplan Anthony A. Alkinson, Management & Cost Accounting
4	Ashish K. Bhattacharya, Principles & Practices of Cost Accounting A. H. Wheeler publisher
5	N.D. Vohra, Quantitative Techniques in Management, Tata McGraw Hill Book Co. Ltd.

OE 941 CS			BUSINESS ANALYTICS			
			(OPEN ELECTIVE)			
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Understanding the basic concepts of business analytics and applications
2	Study various business analytics methods including predictive, prescriptive and prescriptive analytics
3	Prepare the students to model business data using various data mining, decision making methods

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	To understand the basic concepts of business analytics
CO-2	Identify the application of business analytics and use tools to analyze business data
CO-3	Become familiar with various metrics, measures used in business analytics
CO-4	Illustrate various descriptive, predictive and prescriptive methods and techniques
CO-5	Model the business data using various business analytical methods and techniques

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
Introduction to Business Analytics: Introduction to Business Analytics, need and science of data driven (DD) decision making, Descriptive, predictive, prescriptive analytics and techniques, Big data analytics, Web and Social media analytics, Machine Learning algorithms, framework for decision making, challenges in DD decision making and future.

Unit – II
Descriptive Analytics: Introduction, data types and scales, types of measurement scales, population and samples, measures of central tendency, percentile, decile and quadrille, measures of variation, measures of shape-skewness, data visualization.

Unit – III
Forecasting Techniques: Introduction, time-series data and components, forecasting accuracy, moving average method, single exponential smoothing, Holt's method, Holt-Winter model, Croston's forecasting method, regression model for forecasting, Auto regression models, auto-regressive moving process, ARIMA, Theil's coefficient

Unit – IV
Decision Trees: CHAID, Classification and Regression tree, splitting criteria, Ensemble and method and random forest. **Clustering**: Distance and similarity measures used in clustering, Clustering algorithms, K-Means and Hierarchical algorithms, **Prescriptive Analytics**-Linear Programming(LP) and LP model building.

Unit – V
Six Sigma: Introduction, introduction, origin, 3-Sigma Vs Six-Sigma process, cost of poor quality, sigma score, industry applications, six sigma measures, DPMO, yield, sigma score, DMAIC methodology, Six Sigma toolbox.

Suggested Reading:

1	U Dinesh Kumar, "Data Analytics", Wiley Publications, 1st Edition, 2017
2	Marc J. Schniederjans, Dara G. Schniederjans, Christopher M. Starkey, "Business analytics Principles, Concepts, and Applications with SAS", Associate Publishers, 2015
3	S. Christian Albright, Wayne L. Winston, "Business Analytics - Data Analysis and Decision Making", 5th Edition, Cengage, 2015

Web Resources:

1	https://onlinecourses.nptel.ac.in/noc18-mg11/preview
2	https://nptel.ac.in/courses/110105089/

OE 941 EC	ELEMENTS OF EMBEDDED SYSTEMS				
(OPEN ELECTIVE)					
Pre-requisites		**L**	**T**	**P**	**C**
		3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**	40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Understanding various Embedded Design strategies
2	Designing Micro controller based Embedded Systems
3	Designing FPGA Based Embedded Systems

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand Embedded Design Strategies and architecture of Arduino Board
CO-2	Program using various onboard components of Arduino
CO-3	Design real time interfacing with Arduino
CO-4	Understand Design Flow of FPGA, programming FPGA using Verilog HDL
CO-5	Implement combinational and sequential circuits using verilog HDL

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
Embedded Systems Design Strategies: Micro Controller, DSP, FPGA, Introduction to Arduino (Micro controller Board), Components of Arduino, Architecture and Pin Configuration of ATMega328, Ports of ATMega328.

Unit – II
Interfacing: Interfacing Switches, LEDs, Analog to Digital Converter, Digital to Analog Converter, Interfacing and Programming I2C, SPI

Unit – III
Real Time Programming: Interfacing Key Pad, 7-segment display, LCD, Interfacing Sensors, Interfacing Stepper Motor**,** USB programming

Unit – IV
FPGA Based Embedded Design: FPGA Design flow, Introduction to Verilog HDL**,** Basic building blocks, Data types of Verolog HDL, Behavioral Modelling, Data Flow Modelling, Structural Modelling, Hierarchal Structural Modelling, Case Studies on Verilog HDL descriptions of Basic Circuits

Unit – V
Modelling of Circuits: Verilog HDL Implementation of Combinational MSI Circuits, Verilog HDL Implementation of Sequential MSI Circuits, Finite Sate Machine Design, Tasks and Functions, Introduction to Test Benches

Suggested Reading:

1	Ming-Bo Lin, Digital System Designs and Practices Using Verilog HDL and FPGAs, Wiley India, 2008
2	Samir Palnitkar, Verilog HDL: A Guide to Digital Design and Synthesis, Pearson Education, 2005
3	Simon Monk, Programming Arduino: Getting Started with sketches, Mc.Hill, 2016

Web Resources:

1	www.arduino.cc
2	www.learn.sparkfun.com/tutorials/arduino

OE 941 EE			WASTE TO ENERGY			
			(OPEN ELECTIVE)			
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	To know the various forms of waste
2	To understand the processes of Biomass Pyrolysis.
3	To learn the technique of Biomass Combustion.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand the concept of conservation of waste
CO-2	Identify the different forms of wastage.
CO-3	Chose the best way for conservation to produce energy from waste.
CO-4	Explore the ways and means of combustion of biomass.
CO-5	Develop a healthy environment for the mankind.

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	-	3	2	3	1
CO-2	3	-	3	2	3	1
CO-3	3	-	3	2	3	1
CO-4	3	-	3	2	3	1
CO-5	3	-	3	2	3	1

Unit – I
Introduction to Energy from Waste: Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digestors

Unit – II
Biomass Pyrolysis: Pyrolysis – Types, slow fast – Manufacture of charcoal – Methods Yields and application – Manufacture of pyrolytic oils and gases, yields and applications.

Unit – III
Biomass Gasification: Gasifiers – Fixed bed system – Downdraft and updraft gasifiers Fluidized bed gasifiers – Design, construction and operation – Gasifier burner arrangement for thermal heating – Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifier operation.

Unit – IV
Biomass Combustion: Biomass stoves – Improved chullahs, types, some exotic designs, Fixed bed combustors, Types, inclined grate combustors, Fluidized bed combustors, Design, construction and operation - Operation of all the above biomass combustors.

Unit – V
Biogas: Properties of biogas (Calorific value and composition) - Biogas plant technology and status - Bio energy system - Design and constructional features - Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - Direct combustion - biomass gasification - pyrolysis and liquefaction - biochemical conversion anaerobic digestion - Types of biogas Plants – Applications - Alcohol production from biomass Bio diesel production - Urban waste to energy conversion - Biomass energy programme in India.

Suggested Reading:

1	Non Conventional Energy, Desai, Ashok V., Wiley Eastern Ltd., 1990.
2	Biogas Technology - A Practical Hand Book - Khandelwal, K. C. and Mahdi, S. S., Vol. I & II, Tata McGraw Hill Publishing Co. Ltd., 1983.
3	Food, Feed and Fuel from Biomass, Challal, D. S., IBH Publishing Co. Pvt. Ltd., 1991.
4	Biomass Conversion and Technology, C. Y. WereKo-Brobby and E. B. Hagan, John Wiley & Sons, 1996.

OE 942 EE	POWER PLANT CONTROL AND INSTRUMENTATION				
	(OPEN ELECTIVE)				
Pre-requisites		**L**	**T**	**P**	**C**
		3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	The operation of different types of power plants.
2	The basic working principle of instruments for measurement of electrical and non-electrical quantities like Temperature Pressure flow level measurements.
3	The instrumentation and protection systems applied in thermal power plant.
4	The control techniques employed for the operation of modern power generation plant

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Explain the different methods of power generation. Along with Piping and Instrumentation diagram of boiler.
CO-2	Select various measurements involved in power generation for measuring electrical and non-electrical parameters.
CO-3	Identify the different types of analyzers used for scrutinizing boiler steam and water.
CO-4	Model different types of controls and control loops in boilers.
CO-5	Illustrate the methods of monitoring and control of different parameters like speed, vibration of turbines

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	1	-	-	-	2
CO-2	3	1	-	-	-	2
CO-3	3	1	-	-	-	2
CO-4	3	1	-	-	-	2
CO-5	3	1	-	-	-	2

Unit – I
Brief survey of methods of power generation, hydro, thermal, nuclear, solar and wind power, importance of instrumentation in power generation, thermal power plants, block diagram, details of boiler processes, Piping and Instrumentation diagram of boiler, cogeneration.

Unit – II
Electrical measurements, current, voltage, power, frequency, power factor etc, non-electrical parameters, flow of feed water, fuel, air and steam with correction factor for temperature, steam pressure and steam temperature, drum level measurement, radiation detector, smoke density measurement, dust monitor.

Unit – III
Flue gas oxygen analyzer: Analysis of impurities in feed water and steam, dissolved oxygen analyzer. Chromatography, pH meter, fuel analyzer, pollution monitoring instruments.

Unit – IV
Combustion control, air / fuel ratio control, furnace draft control, drum level control, main steam and reheat steam temperature control, super heater control, air temperature, distributed control system in power plants, interlocks in boiler operation.

Unit – V
Speed, vibration, shell temperature monitoring and control, steam pressure control, lubricant oil temperature control, cooling system.

Suggested Reading:

1	Sam G. Dukelow, The Control of Boilers, Instrument Society of America, 2nd Edition, 2010.
2	P.K. Nag, „Power Plant Engineering", Tata McGraw-Hill, 1st Edition, 2001.
3	S.M. Elonka and A.L. Kohal, "Standard Boiler Operations", Tata McGraw-Hill, 1st Edition, 1994.
4	R K Jain, "Mechanical and Industrial Measurements", Khanna Publishers, 1st Edition, 1995.
5	E Al Wakil, "Power Plant Engineering", Tata McGraw-Hill, 1st Edition, 1984.

OE 941 ME		OPERATION RESEARCH			
		(OPEN ELECTIVE)			
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Introduce the concepts of optimization techniques
2	Formulation of LPP models
3	Basic concepts of Non-linear programming, Dynamic programming, Game theory are introduced.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Students should able to apply the dynamic programming to solve problems of discreet and continuous variables.
CO-2	Students should able to apply the concept of non-linear programming
CO-3	Students should able to carry out sensitivity analysis
CO-4	Student should able to model the real world problem and simulate it.
CO-5	Student should able to apply graph theory, competitive models, and game theory simulations.

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	1	1	3	2	1	2
CO-2	3	1	2	3	2	-
CO-3	1	3	3	1	2	2
CO-4	3	2	1	3	1	1
CO-5	2	1	3	2	2	2

Unit – I
Optimization Techniques, Model Formulation, models, General L.R Formulation, Simplex Techniques, Sensitivity Analysis, Inventory Control Models.

Unit – II
Formulation of a LPP - Graphical solution revised simplex method - duality theory - dual simplex method - sensitivity analysis - parametric programming.

Unit – III
Nonlinear programming problem - Kuhn-Tucker conditions min cost flow problem - max flow problem - CPM/PERT.

Unit – IV
Scheduling and sequencing - single server and multiple server models deterministic inventory models - Probabilistic inventory control models - Geometric Programming.

Unit – V
Competitive Models, Single and Multi-channel Problems, Sequencing Models, Dynamic Programming, Flow in Networks, Elementary Graph Theory, Game Theory Simulation

Suggested Reading:

1	H.A. Taha, Operations Research, An Introduction, PHI, 2008
2	H.M. Wagner, Principles of Operations Research, PHI, Delhi, 1982.
3	J.C. Pant, Introduction to Optimisation: Operations Research, Jain Brothers, Delhi, 2008.
4	Hitler Libermann Operations Research: McGraw Hill Pub. 2009
5	Pannerselvam, Operations Research: Prentice Hall of India 2010.
6	Harvey M Wagner, Principles of Operations Research: Prentice Hall of India 2010.

OE 942 ME			COMPOSITE MATERIALS			
			(OPEN ELECTIVE)			
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	*Study the concepts of composite construction.*
2	*Learn analysis and designs of composite beams, floors, columns and trusses as per the recommendations of IS codes of practice.*
3	*Apply the concepts for design of multi-storey composite buildings.*
4	*Scope of analysis is restricted to skeletal structures subjected to prescribed dynamic loads.*

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	*Understand the fundamentals of composite construction, and analysis and designs of composite beams.*
CO-2	*Analyse and design the composite floors*
CO-3	*Select suitable materials for composite columns,*
CO-4	*Analyse composite trusses and understand connection details.*
CO-5	*Analyse and design the multi-storey composite buildings*

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
Introduction of composite constructions: Benefits of composite construction - Introduction to IS - BS and Euro codal provisions. Composite beams: Elastic behaviour of composite beams - No and full interaction cases - Shear connectors - Ultimate load behaviour - Serviceability limits - Effective breadth of flange - Interaction between shear and moment - Basic design consideration and design of composite beams.

Unit – II
Composite floors: Structural elements - Profiled sheet decking - Bending resistance - Shear resistance - Serviceability criterion - Analysis for internal forces and moments - Design of composite floors.

Unit – III
Composite columns: Materials - Concrete filled circular tubular sections - Non-dimensional slenderness - Local buckling of steel sections - Effective elastic flexural stiffness - Resistance of members to axial compressions - Composite column design - Fire resistance.

Unit – IV
Composite trusses: Design of truss - Configuration - Truss members - Analysis and design of composite trusses and connection details.

Unit – V
Design of multi-storey composite buildings: Design basis - Load calculations - Design of composite slabs with profile decks - Composite beam design - Design for compression members - Vertical cross bracings - Design of foundation.

Suggested Reading:

1	R.P. Johnson, "Composite Structures of Steel and Concrete - Beams, Slabs, Columns and Frames in Buildings", Blackwell Publishing, Malden, USA, 2004.
2	"INSDAG Teaching Resources for Structural Steel Design", Vol-2, Institute for Steel Development and Growth Publishers, Calcutta, India.
3	"INSDAG Handbook on Composite Construction – Multi-Storey Buildings", Institute for Steel Development and Growth Publishers, Calcutta, India.
4	"INSDAG Design of Composite Truss for Building", Institute for Steel Development and Growth Publishers, Calcutta, India.
5	"INSDAG Handbook on Composite Construction – Bridges and Flyovers", Institute for Steel Development and Growth Publishers, Calcutta, India.
6	IS: 11384-1985, "Code of Practice for Composite Construction in Structural Steel and Concrete", Bureau of Indian Standards, New Delhi, 1985.

OE 943 ME			INDUSTRIAL SAFETY				
			(OPEN ELECTIVE)				
Pre-requisites				**L**	**T**	**P**	**C**
				3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**			40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Causes for industrial accidents and preventive steps to be taken.
2	Fundamental concepts of Maintenance Engineering.
3	About wear and corrosion along with preventive steps to be taken
4	The basic concepts and importance of fault tracing.
5	The steps involved in carrying out periodic and preventive maintenance of various equipments used in industry

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Identify the causes for industrial accidents and suggest preventive measures.
CO-2	Identify the basic tools and requirements of different maintenance procedures.
CO-3	Apply different techniques to reduce and prevent Wear and corrosion in Industry.
CO-4	Identify different types of faults present in various equipments like machine tools, IC Engines, boilers etc.
CO-5	Apply periodic and preventive maintenance techniques as required for industrial equipments like motors, pumps and air compressors and machine tools etc

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
Industrial safety: Accident, causes, types, results and control, mechanical and electrical hazards, types, causes and preventive steps/procedure, describe salient points of factories act 1948 for health and safety, wash rooms, drinking water layouts, light, cleanliness, fire, guarding, pressure vessels, etc, Safety color codes, Fire prevention and firefighting, equipment and methods.

Unit – II
Fundamentals of Maintenance Engineering: Definition and aim of maintenance engineering, Primary and secondary functions and responsibility of maintenance department, Types of maintenance, Types and applications of tools used for maintenance, Maintenance cost & its relation with replacement economy, Service life of equipment.

Unit – III
Wear and Corrosion and their Prevention: Wear- types, causes, effects, wear reduction methods, lubricants-types and applications, Lubrication methods, general sketch, working and applications of Screw down grease cup, Pressure grease gun, Splash lubrication, Gravity lubrication, Wick feed lubrication, Side feed lubrication, Ring lubrication, Definition of corrosion, principle and factors affecting the corrosion, Types of corrosion, corrosion prevention methods.

Unit – IV
Fault Tracing: Fault tracing-concept and importance, decision tree concept, need and applications, sequence of fault finding activities, show as decision tree, draw decision tree for problems in machine tools, hydraulic, pneumatic, automotive, thermal and electrical equipment's like, any one machine tool, Pump, Air compressor, Internal combustion engine, Boiler, Electrical motors, Types of faults in machine tools and their general causes.

Unit – V
Periodic and Preventive Maintenance: Periodic inspection-concept and need, degreasing, cleaning and repairing schemes, overhauling of mechanical components, overhauling of electrical motor, common troubles and remedies of electric motor, repair complexities and its use, definition, need, steps and advantages of preventive maintenance. Steps/procedure for periodic and preventive maintenance of Machine tools, Pumps, Air compressors, Diesel generating (DG) sets, Program and schedule of preventive maintenance of mechanical and electrical equipment, advantages of preventive maintenance. Repair cycle concept and importance.

Suggested Reading:

1	H. P. Garg, "Maintenance Engineering", S. Chand and Company
2	Audels, "Pump-hydraulic Compressors", Mcgraw Hill Publication
3	Higgins & Morrow, "Maintenance Engineering Handbook", Da Information Services.
4	Winterkorn, Hans, "Foundation Engineering Handbook", Chapman & Hall London

OE 941 LA		INTELLECTUAL PROPERTY RIGHTS				
		(OPEN ELECTIVE)				
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Acquaint the students with basics of intellectual property rights with special reference to Indian Laws and its practices.
2	Compare and contrast the different forms of intellectual property protection in terms of their key differences and similarities.
3	Provide an overview of the statutory, procedural, and case law underlining these processes and their interplay with litigation.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand the concept of intellectual property rights.
CO-2	Develop proficiency in trademarks and acquisition of trade mark rights.
CO-3	Understand the skill of acquiring the copy rights, ownership rights and transfer.
CO-4	Able to protect trade secrets, liability for misappropriations of trade secrets.
CO-5	Apply the patents and demonstration of case studies.

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	1	3	2	1	1
CO-2	3	2	1	1	2	-
CO-3	2	2	2	3	2	1
CO-4	1	3	1	2	1	1
CO-5	1	1	2	3	2	3

Unit – I
Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Unit – II
Trade Marks: Purpose and function of trademarks, acquisition of trade mark rights, protectable matter, selecting, and evaluating trade mark, trade mark registration processes.

Unit – III
Law of copy rights: Fundamental of copy right law, originality of material, rights of reproduction, rights to perform the work publicly, copy right ownership issues, copy right registration, notice of copy right, international copy right law. Law of patents: Foundation of patent law, patent searching process, ownership rights and transfer**.**

Unit – IV
Trade Secrets: Trade secrete law, determination of trade secrete status, liability for misappropriations of trade secrets, protection for submission, trade secrete litigation. Unfair competition: Misappropriation right of publicity, false advertising.

Unit – V
New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

Suggested Reading:

1	Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd, 2007.
2	"Mayall, "Industrial Design", McGraw Hill,1992
3	"Niebel, "Product Design", McGraw Hill,1974.
4	"Asimov, "Introduction to Design", Prentice Hall,1962.
5	"Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age",2016.
6	T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand,2008

EC472		MINI PROJECT				
Pre-requisites	-		**L**	**T**	**P**	**C**
			-	-	4	2
Evaluation	**SEE**	-	**CIE**	50 Marks		

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	*To review available literature and formulate structural engineering problems*
2	*To learn the technique of writing reports and prepare presentation*

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Identify structural engineering problems reviewing available literature
CO-2	Study different techniques used to analyse complex structural systems.
CO-3	Able to work on the solutions given problem
CO-4	Present solution by using his/her technique applying engineering principles.
CO-5	Prepare technical report and presentation

Syllabus Contents:
Mini Project will have mid semester presentation and end semester presentation. Mid semester Presentation will include identification of the problem based on the literature review on the topic referring to latest literature available. End semester presentation should be done along with the report on identification of topic for the work and the methodology adopted involving scientific research, collection and analysis of data, determining solutions highlighting individuals' contribution. Continuous assessment of Mini Project at Mid Sem and End Sem will be monitored by the departmental committee

EC462		**EMBEDDED SYSTEM DESIGN LAB**				
			L	**T**	**P**	**C**
Pre-requisites		-	-	-	2	1
Evaluation	**SEE**	-	**CIE**		50 Marks	

Part A: Simulation of basic 8051 programs using Keil μvision

1. Data Transfer -Block move, Exchange, Sorting, Finding largest element in an array.

2. Arithmetic Instructions -Addition/subtraction, multiplication and division, square, Cube –

(16bits Arithmetic operations –bit addressable).

3. Counters

4. Boolean & Logical Instructions (Bit manipulations)

5. Conditional CALL & RETURN

6. Code conversion: BCD –ASCII; ASCII –Decimal; Decimal –ASCII

7. HEX -Decimal and Decimal –HEX

8. Programs to generate delay, Programs using serial port and on-Chip timer /Counter

9. Interfacing Programs Using Keil μvision Software & 8051 Microcontroller Development Board

Part B:

1. Compilation of PIC microcontroller programs using μC Compiler and simulation of Hardware and verification of programs using Proteus Software.

2. Simulation of basic ARM programs using Keil μvision.

EC463	CMOS VLSI Design Lab				
Pre-requisites	-	**L**	**T**	**P**	**C**
		-	-	2	1
Evaluation	**SEE**	-	**CIE**	50 Marks	

Part A:

1. Characteristics of MOSFET.
2. Calculation of rise time and fall time for CMOS inverter.
3. To build a three stage and five stage ring oscillator circuit in 0.18um and 0.13um technology and compare its frequencies and time period.
4. NMOS Common Source Amplifier.
5. Design of Differential Amplifier.
6. Design of Operational Amplifier.
7. Draw the layout of Inverter Circuit.

SEMESTER –III

AC030EC	**RESEARCH METHODOLOGY**				
AUDIT COURSE-I					
Pre-requisites		**L**	**T**	**P**	**C**
		2	-	-	0
Evaluation	**SEE**	60 Marks	**CIE**	40 Marks	

Objectives:

1.Learn to focus on *research related activities.*
2. Learn methods to devise and develop the various research designs
3. Learn basic principles of data collection and analysis techniques
4.Learn the style and format of writing a report for technical papers

Outcomes:*At the end of this course, students will be able to:*

1.	Motivate the orientation towards research related activities
2.	Formulate the research problem, analyze research related information
3.	Identify various sources for literature review and design an experimentation set- up
4.	Apply the basic principles of data collection and analysis techniques
5.	Improve the style and format of writing a report for technical / Journal articles

Program Articulation Matrix

Course outcome	Program outcome					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1						
CO2						
CO3						
CO4						
CO5						

UNIT – I
Research Methodology: Objectives and Motivation of Research, Types of Research, Research Approaches, Significance of Research, Research Methods verses Methodology, Research and Scientific Method, Important of Research Methodology, Research Process, Criteria of Good Research, Problems Encountered by Researchers in India, Benefits to the society in general.
Defining the Research Problem: Definition of Research Problem, Problem Formulation, Necessity of Defining the Problem, Technique involved in Defining a Problem.

UNIT – II
Literature Survey: Importance of Literature Survey, Sources of Information, Assessment of Quality of Journals and Articles, Information through Internet. **Literature Review**: Need of Review, Guidelines for Review, Record of Research Review.

UNIT – III
Research Design: Meaning of Research Design, Need of Research Design, Feature of a Good Design Important Concepts Related to Research Design, Different Research Designs, Basic Principles of Experimental Design, Developing a Research Plan, Design of Experimental Set-up, Use of Standards and Codes.

UNIT – IV
Data Collection: Collection of primary data, Secondary data, Data organization, Methods of data grouping, Diagrammatic representation of data, Graphic representation of data. Sample Design, Need for sampling, some important sampling definitions, Estimation of population, Role of Statistics for Data Analysis, Parametric V/s Non Parametric methods, Descriptive Statistics, Measures of central tendency and Dispersion, Hypothesis testing, Use of Statistical software.
Data Analysis: Deterministic and random data, Uncertainty analysis, Tests for significance: Chi-square, student's t-test, Regression modeling, Direct and Interaction effects, ANOVA, F- test, Time Series analysis, Autocorrelation and Autoregressive modeling.

UNIT – V
Research Report Writing: Format of the Research report, Synopsis, Dissertation, Thesis its Differentiation, References/Bibliography/Webliography, Technical paper writing/Journal report writing, making presentation, Use of visual aids. **Research Proposal Preparation**: Writing a Research Proposal and Research Report, Writing Research Grant Proposal.

Suggested Reading:

1	C.R Kothari, Research Methodology, Methods & Technique; Revised Edition, New Age International Publishers, 2004.
2	R. Ganesan, Research Methodology for Engineers, 1st Edition, MJP Publishers, 2011.
3	RatanKhananabis and SuvasisSaha, Research Methodology, 1st Edition, Universities Press, Hyderabad, 2015.
4	Y.P. Agarwal, Statistical Methods: Concepts, Application and Computation, 1st Edition, Sterling Publs., Pvt., Ltd., New Delhi, 2004
5	Vijay Upagade and AravindShende, Research Methodology, 1st Edition, S. Chand & Company Ltd., New Delhi, 2009
6	G. Nageswara Rao, Research Methodology and Quantitative methods, 2nd Edition, BS Publications, Hyderabad, 2012.

AC031		**ENGLISH FOR RESEARCH PAPER WRITING**				
AUDIT COURSE-II						
Pre-requisites			**L**	**T**	**P**	**C**
			2	-	-	0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Objectives:

1.	*Understand that how to improve your writing skills and level of readability*
2.	*Understand the nuances of language and vocabulary in writing a Research Paper.*
3.	*Develop the content, structure, format of writing a research paper and produce original research papers without plagiarism*

Outcomes:*At the end of this course, students will be able to:*

6.	*Interpret the nuances of research paper writing.*
7.	*Differentiate the research paper format and citation of sources.*
8.	*To review the research papers and articles in a scientific manner.*
9.	*Avoid plagiarism and be able to develop their writing skills in presenting the research work.*
10.	*Create a research paper and acquire the knowledge of how and where to publish their original research papers*

Program Articulation Matrix

Course outcome	Program outcome					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1						
CO2						
CO3						
CO4						
CO5						

Row wise cumulative percentage weightage should be equal to 1.0.

UNIT – I
*Academic Writing:*Meaning & Definition of a research paper– Purpose of a research paper – Scope – Benefits, Limitations – outcomes.

UNIT – II
*Research Paper Format:*Title – Abstract – Introduction – Discussion – Findings, Conclusion – Style of Indentation – Font size/Font types – Indexing – Citation of sources.

UNIT – III
*Research Methodology:*Methods (Qualitative – Quantitative) Review of Literature. Criticizing, Paraphrasing & Plagiarism.

UNIT – IV
*Process of Writing a research paper:*Choosing a topic - Thesis Statement – Outline – Organizing notes - Language of Research – Word order, Paragraphs – Writing first draft – Revising/Editing - The final draft and proof reading.

UNIT – V
*Research Paper Publication:*Reputed Journals – National/International – ISSN No, No. of volumes, Scopus Index/UGC Journals – Free publications - Paid Journal publications – Advantages/Benefits *Presentation Skills:*Developing Persuasive Presentations, Structure of Presentation, Presentation Slides, Presentation Delivery, role of the audience, what to search and cite, how to establish credibility.

References:

1	C. R Kothari, Gaurav, Garg, "*Research Methodology Methods and Techniques*", 4/e, New Age International Publishers.
2	Day R, "*How to Write and Publish a Scientific Paper*," Cambridge University Press, 2006
3	"*MLA Hand book for writers of Research Papers*", 7/e, East West Press Pvt. Ltd, New Delhi
4	Lauri Rozakis, Schaum's, "*Quick Guide to Writing Great Research Papers*", Tata McGraw Hills Pvt. Ltd, New Delhi.

AC032	DISASTER MITIGATION AND MANAGEMENT				
	AUDIT COURSE-II				
Pre-requisites			**L**	**T**	**P**	**C**
			2	-	-	0
Evaluation	SEE	60 Marks	**CIE**		40 Marks

Objectives:

1.	*To impart knowledge in students about the nature, causes, consequences and mitigation measures of the various natural disasters*
2.	*To enable the students to understand risks, vulnerabilities and human errors associated with human induced disasters*
3.	*To enable the students to understand and assimilate the impacts of any disaster on the affected area depending on its position/ location, environmental conditions, demographic, etc.*

Outcomes: *At the end of this course, students will be able to:*

1.	*Learn to demonstrate a critical understanding of key concepts in disaster risk reduction*
2.	*Humanitarian response*
3.	*Critically evaluate disaster risk reduction and humanitarian response policy and Practice from multiple perspectives.*
4.	*Develop an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.*
5.	*Critically understand the strengths and weaknesses of disaster management approaches, planning and programming in different countries, particularly their home country or the countries they work in.*

Program Articulation Matrix

Course outcome	Program outcome					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1						
CO2						
CO3						
CO4						
CO5						

Row wise cumulative percentage weightage should be equal to 1.0.

UNIT – I
*Introduction:*Disaster: Definition, Factors and Significance; Difference between Hazard and Disaster; Natural and Manmade Disasters: Difference, Nature, Types and Magnitude.

UNIT – II
Repercussions of Disasters and Hazards: Economic Damage, Loss of Human and Animal Life, Destruction of Ecosystem.   *Natural Disasters:*Earthquakes, Volcanisms, Cyclones, Tsunamis, Floods, Droughts and Famines, Landslides and Avalanches, Man-made disaster: Nuclear Reactor Meltdown, Industrial Accidents, Oil Slicks and Spills, Outbreaks of Disease and Epidemics, War and Conflicts.

UNIT – III
*Disasters Prone Areas in India:*Study of Seismic Zones; Areas Prone to Floods and Droughts, Landslides and Avalanches; Areas Prone to Cyclonic and Coastal Hazards with Special Reference to Tsunami; Post-Disaster Diseases and Epidemics

UNIT – IV
*Disaster Preparedness:*Monitoring of Phenomena Triggering a Disaster or Hazard; Evaluation of Risk: Application of Remote Sensing, Data from Meteorological and Other Agencies, Media Reports: Governmental and CommUNITy Preparedness.

UNIT – V
*Disaster Risk:*Concept and Elements, Disaster Risk Reduction, Global and National Disaster Risk Situation. Techniques of Risk Assessment, Global Co-Operation in Risk Assessment and Warning, People's Participation in Risk Assessment. Strategies for Survival. Meaning, Concept and Strategies of Disaster Mitigation, Emerging Trends in Mitigation. Structural Mitigation and Non-Structural Mitigation, Programs of Disaster Mitigation in India.

References:

1	R. Nishith, Singh AK, *"Disaster Management in India: Perspectives, issues and strategies"*, New Royal Book Company.
2	Sahni, Pardeep (Eds.), *"Disaster Mitigation Experiences and Reflections"*, PHI, New Delhi.
3	Goel S. L., *"Disaster Administration and Management Text and Case Studies"*, Deep & Deep Publication Pvt. Ltd., New Delhi.

AC033	SANSKRIT FOR TECHNICAL KNOWLEDGE				
AUDIT COURSE-II					
Pre-requisites			**L**	**T**	**P**	**C**
			2	-	-	0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks

Objectives:

1.	*To get a working knowledge in illustrious Sanskrit, the scientific language in the world*
2.	*To make the novice Learn the Sanskrit to develop the logic in mathematics, science & other subjects*
3.	*To explore the huge knowledge from ancient Indian literature*

Outcomes:*At the end of this course, students will be able to:*

1.	*Develop passion towards Sanskrit language*
2.	*Decipher the latent engineering principles from Sanskrit literature*
3.	*Correlates the technological concepts with the ancient Sanskrit history.*
4.	*Develop knowledge for the technological progress*
5.	*Explore the avenue for research in engineering with aid of Sanskrit*

Program Articulation Matrix

Course outcome	Program outcome					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1						
CO2						
CO3						
CO4						
CO5						

Row wise cumulative percentage weightage should be equal to 1.0.

UNIT – I
*Introduction to Sanskrit Language:*Sanskrit Alphabets-vowels-consonants- significance of Amarakosa-parts of Speech-Morphology-creation of new words-significance of synonyms-sandhi-samasa-sutras-active and passive Voice-Past/Present/Future Tense-Syntax-Simple Sentences (elementary treatment only)

UNIT – II
*Role of Sanskrit in Basic Sciences:*Brahmagupthas lemmas (second degree indeterminate equations), sum of squares of n-terms of AP- sulba, sutram or baudhayana theorem (origination of Pythagoras theorem)-value of pie-Madhava's sine and cosine theory (origination of Taylor's series). The measurement system-time-mass-length-temp, Matter elasticity-optics-speed of light (origination of Michaelson and Morley theory).

UNIT – III
Role of Sanskrit in Engineering-I (Civil, Mechanical, Electrical and Electronics Engineering): Building construction-soil testing-mortar-town planning-Machine definition-crucible-furnace-air blower- Generation of electricity in a cell-magnetism-Solar system-Sun: The source of energy, the earth-Pingala chandasutram (origination of digital logic system)

UNIT – IV
*Role of Sanskrit in Engineering-II (Computer Science Engineering & Information Technology):*Computer languages and the Sanskrit languages-computer command words and the vedic command words-analogy of pramana in memamsa with operators in computer language-sanskrit analogy of physical sequence and logical sequence, programming.

UNIT – V
*Role of Sanskrit in Engineering-III (Bio-technology and Chemical Engineering):*Classification of plants- plants, the living-plants have senses-classification of living creatures, Chemical laboratory location and layout- equipment-distillation vessel-kosthi yanthram

References:

1	M Krishnamachariar, "*History of Classical Sanskrit Literature*", TTD Press, 1937.
2	M.R. Kale, "*A Higher Sanskrit Grammar: For the Use of School and College Students*", Motilal Banarsidass Publishers, 2015.
3	Kapail Kapoor, "*Language, Linguistics and Literature: The Indian Perspective*", ISBN- 10: 8171880649, 1994.
4	"*Pride of India*", Samskrita Bharati Publisher, ISBN: 81-87276 27-4, 2007.
5	Shri Rama Verma, "*Vedas the source of ultimate science*", Nag publishers, 2005.

AC034	VALUE EDUCATION				
AUDIT COURSE-II					
Pre-requisites			**L**	**T**	**P**	**C**
			2	-	-	0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks

Objectives:

1.	*Understand the need and importance of Values for self-development and for National development.*
2.	*Imbibe good human values and Morals*
3.	*Cultivate individual and National character.*

Outcomes: *At the end of this course, students will be able to:*

1.	*Gain necessary Knowledge for self-development*
2.	*Learn the importance of Human values and their application in day to day professional life.*
3.	*Appreciate the need and importance of interpersonal skills for successful career and social life*
4.	*Emphasize the role of personal and social responsibility of an individual for all-round growth.*
5.	*Develop a perspective based on spiritual outlook and respect women, other religious practices, equality, non-violence and universal brotherhood.*

Program Articulation Matrix

Course outcome	Program outcome					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1						
CO2						
CO3						
CO4						
CO5						

Row wise cumulative percentage weightage should be equal to 1.0.

UNIT – I
*Human Values, Ethics and Morals:*Concept of Values, Indian concept of humanism, human values; Values for self-development, Social values, individual attitudes; Work ethics, moral and non- moral behaviour, standards and principles based on religion, culture and tradition.

UNIT – II
*Value Cultivation, and Self-management:*Need and Importance of cultivation of values such as Sense-of Duty, Devotion to work, Self-reliance, Confidence, Concentration, Integrity & discipline, and Truthfulness.

UNIT – III
*Spiritual outlook and social values:*Personality and Behavior, Scientific attitude and Spiritual (soul) outlook; Cultivation of Social Values Such as Positive Thinking, Punctuality, Love & Kindness, avoiding fault finding in others, Reduction of anger, forgiveness, Dignity of labour, True friendship, Universal brotherhood and religious tolerance.

UNIT – IV
*Values in Holy Books:*Self-management and Good health; internal & external cleanliness, Holy books versus Blind faith, Character and Competence, Equality, Nonviolence, Humility, Role of Women.

UNIT – V
*Dharma, Karma and Guna:*Concept of soul; Science of Reincarnation, Character and Conduct, Concept of Dharma; Cause and Effect based Karma Theory; The qualities of Devine and Devilish; Satwic, Rajasic and Tamasic gunas.

References:

1	Chakroborty, S.K., *"Values & Ethics for organizations Theory and practice*", Oxford University Press, New Delhi, 1998.
2	2. Jaya Dayal Goyandaka, "*Srimad Bhagavad Gita with Sanskrit Text*", Word Meaning and Prose Meaning‖, Gita Press, Gorakhpur, 2017.

AC035			STRESS MANAGEMENT BY YOGA				
			AUDIT COURSE-II				
Pre-requisites				**L**	**T**	**P**	**C**
				2	-	-	0
Evaluation	**SEE**	60 Marks		**CIE**		40 Marks	

Objectives:

1.	*Creating awareness about different types of stress and the role of yoga in the management of stress.*
2.	*Promotion of positive health and overall wellbeing (Physical, mental, emotional, social and spiritual).*
3.	*Prevention of stress related health problems by yoga practice.*

Outcomes:*At the end of this course, students will be able to:*

1.	*Understand yoga and its benefits.*
2.	*Enhance Physical strength and flexibility.*
3.	*Learn to relax and focus.*
4.	*Relieve physical and mental tension through asanas.*
5.	*Improve work performance and efficiency.*

Program Articulation Matrix

Course outcome	Program outcome					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1						
CO2						
CO3						
CO4						
CO5						

Row wise cumulative percentage weightage should be equal to 1.0.

UNIT – I
Meaning and Definition of Yoga **-** Historical perspective of Yoga - Principles of Astanga Yoga by Patanjali.

UNIT – II
Meaning and Definition of Stress- Types of stress - Eustress and Distress. Anticipatory Anxiety and Intense Anxiety and depression. Meaning of Management- Stress Management.

UNIT – III
Concept of Stress According to Yoga- Stress assessment methods - Role of Asana, Pranayama and Meditation in the management of stress

UNIT – IV
Asanas- (5 Asanas in each posture) - Warm up - Standing Asanas - Sitting Asanas - Prone Asanas - Supine asanas - Surya Namaskar.

UNIT – V
Pranayama- Anulom and Vilom Pranayama - Nadishudhi Pranayama - Kapalabhati Pranayama - Bhramari Pranayama - Nadanusandhana Pranayama. *Meditation Techniques:*Om Meditation - Cyclic meditation: Instant Relaxation technique (QRT), Quick Relaxation Technique (QRT), Deep Relaxation Technique (DRT)

References:

1	Janardhan Swami Yogabhyasi Mandal, "*Yogic Asanas for Group Training - Part-I*", , Nagpur.
2	Advaita Ashrama, "*Swami Vivekananda, "Rajayoga or Conquering the Internal Nature",* (Publication Department), Kolkata.
3	Nagendra H.R and Nagaratna R, "*Yoga Perspective in Stress Management",* Swami Vivekananda Yoga Prakashan, Bangalore.

AC036	PERSONALITY DEVELOPMENT THROUGH LIFE ENLIGHTENMENT SKILLS				
	AUDIT COURSE-II				
Pre-requisites			**L**	**T**	**P**	**C**
			2	-	-	0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks

Objectives:

1. To learn to achieve the highest goal happily
2. To become a person with stable mind, pleasing personality and determination
3. To awaken wisdom in students

Outcomes:*At the end of this course, students will be able to:*

1. Develop their personality and achieve their highest goal of life.
2. Lead the nation and mankind to peace and prosperity.
3. Practice emotional self-regulation.
4. Develop a positive approach to work and duties.
5. Develop a versatile personality.

Program Articulation Matrix

Course outcome	Program outcome					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1						
CO2						
CO3						
CO4						
CO5						

Row wise cumulative percentage weightage should be equal to 1.0.

UNIT – I
Neetisatakam – Holistic Development of Personality- Verses 19, 20, 21, 22 (Wisdom) - Verses 29, 31, 32 (Pride and Heroism) - Verses 26,28,63,65 (Virtue)

UNIT – II
Neetisatakam – Holistic Development of Personality (cont'd) - Verses 52, 53, 59 (don'ts) - Verses 71,73,75 & 78 (do's) - Approach to day to day works and duties.

UNIT – III
Introduction to Bhagavadgeetha for Personality Development - Shrimad Bhagavadgeetha: CHAPTER 2 – Verses 41, 47, 48 - Chapter 3 – Verses 13,21,27,35 - Chapter 6 – Verses 5,13,17,23,35 - Chapter 18 –Verses 45, 46, 48 Chapter – 6: Verses 5, 13, 17, 23, 35; Chapter – 18: Verses 45, 46, 48

UNIT – IV
Statements of Basic Knowledge - Shrimad Bhagavadgeetha: Chapter 2- Verses 56, 62,68 - Chapter 12 – Verses 13, 14, 15, 16, 17, 18 - Personality of Role model from Shrimad Bhagawat Geeta.

UNIT – V
Role of Bhagavadgeetha in the Present Scenario **-** Chapter 2 – Verses 17 - Chapter 3 – Verses 36, 37, 42 - Chapter 4 – Verses 18, 38, 39 - Chapter 18 – Verses 37, 38, 63.

References:

1	Swami Swarupananda Advaita Ashram "*Srimad Bhagavad Gita",* (Publication Department), Kolkata
2	P.Gopinath, *"Bhartrihari's Three Satakam (Niti-sringar-vairagya)*)", Rashtriya Sanskrit Sansthanam, New Delhi

AC037			CONSTITUTION OF INDIA			
AUDIT COURSE-II						
Pre-requisites			**L**	**T**	**P**	**C**
			2	-	-	0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Objectives:

1.	*Understand the premises informing the twin themes of liberty and freedom from a civil rights perspective*
2.	*To address the growth of Indian opinion regarding modern Indian intellectuals' constitutional role*
3.	*Entitlement to civil and economic rights as well as the emergence of nationhood in the early years of Indian nationalism.*

Outcomes: *At the end of this course, students will be able to:*

1.	*Discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics.*
2.	*Discuss the intellectual origins of the framework of argument that informed the conceptualization of social reforms leading to revolution in India.*
3.	*Discuss the circumstances surrounding the foundation of the Congress Socialist Party [CSP] under the leadership of Jawaharlal Nehru*
4.	*The eventual failure of the proposal of direct elections through adult suffrage in the Indian Constitution.*
5.	*Discuss the passage of the Hindu Code Bill of 1956.*

Program Articulation Matrix

Course outcome	Program outcome					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1						
CO2						
CO3						
CO4						
CO5						

Row wise cumulative percentage weightage should be equal to 1.0.

UNIT – I
History of Making of the Indian Constitution: History, Drafting Committee, (Composition & Working) Philosophy of the Indian Constitution: Preamble, Salient Features.

UNIT – II
Contours of Constitutional Rights & Duties: Fundamental Rights, Right to Equality, Right to Freedom, Right against Exploitation, Right to Freedom of Religion, Cultural and Educational Rights, Right to Constitutional Remedies, Directive Principles of State Policy, Fundamental Duties.

UNIT – III
Organs of Governance: Parliament, Composition, Qualifications and Disqualifications, Powers and Functions, Executive, President, Governor, Council of Ministers, Judiciary, Appointment and Transfer of Judges, Qualifications. Powers and Functions.

UNIT – IV
Local Administration: District's Administration head: Role and Importance, Municipalities: Introduction, Mayor and role of Elected Representative CEO of Municipal Corporation, Panchayat raj: Introduction, PRI: Zilla Panchayat, Elected officials and their roles, CEO Zilla Panchayat: Position and role. Block level: Organizational Hierarchy (Different departments), Village level: Role of Elected and Appointed officials, Importance of grass root democracy.

UNIT – V
Election Commission: Election Commission: Role and Functioning. Chief Election Commissioner and Election Commissioners. State Election Commission: Role and Functioning. Institute and Bodies for the welfare of SC/ST/OBC and women.

References:

1	*"The Constitution of India",* 1950 (Bare Act), Government Publication.
2	Dr. S. N. Busi, *"Dr. B. R. Ambedkar framing of Indian Constitution",* 1st Edition, 2015.
3	M. P. Jain, "*Indian Constitution Law",* 7th Edn., Lexis Nexis, 2014.
4	D.D. Basu, *"Introduction to the Constitution of India",* Lexis Nexis, 2015.

AC038			PEDAGOGY STUDIES			
AUDIT COURSE-II						
Pre-requisites			**L**	**T**	**P**	**C**
			2	-	-	0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Objectives:

1.	*To present the basic concepts of design and policies of pedagogy studies.*
2.	*To provide understanding of the abilities and dispositions with regard to teaching techniques, curriculum design and assessment practices and familiarize various theories of learning and their connection to teaching practice.*
3.	*To create awareness about the practices followed by DFID, other agencies and other researchers and provide understanding of critical evidence gaps that guides the professional development*

Outcomes: *At the end of this course, students will be able to:*

1.	*Illustrate the pedagogical practices followed by teachers in developing countries both in formal and informal classrooms.*
2.	*Examine the effectiveness of pedagogical practices.*
3.	*Understand the concept, characteristics and types of educational research and perspectives of research.*
4.	*Describe the role of classroom practices, curriculum and barriers to learning.*
5.	*Understand Research gaps and learn the future directions.*

Program Articulation Matrix

Course outcome	Program outcome					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1						
CO2						
CO3						
CO4						
CO5						

Row wise cumulative percentage weightage should be equal to 1.0.

UNIT – I
*Introduction and Methodology:*Aims and rationale, Policy background, Conceptual framework and terminology - Theories of learning, Curriculum, Teacher education - Conceptual framework, Research questions, Overview of methodology and Searching.

UNIT – II
*Thematic Overview:*Pedagogical practices followed by teachers in formal and informal classrooms in developing countries - Curriculum, Teacher education

UNIT – III
*Evidence on the Effectiveness of Pedagogical Practices***:** Methodology for the in depth stage: quality assessment of included studies - How can teacher education (curriculum and Practicum) and the school curriculum and guidance material best support effective pedagogy? - Theory of change - Strength and nature of the body of evidence for effective

pedagogical practices - Pedagogic theory and pedagogical approaches – Teachers attitudes and beliefs and pedagogic strategies.

UNIT – IV
*Professional Development:*alignment with classroom practices and follow up support - Support from the head teacher and the commUNITy – Curriculum and assessment - Barriers to learning: Limited resources and large class sizes.

UNIT – V
*Research Gaps and Future Directions:*Research design – Contexts – Pedagogy - Teacher education - Curriculum and assessment – Dissemination and research impact.

References:

1	Ackers J, Hardman F, *"Classroom Interaction in Kenyan Primary Schools, Compare"*, 31 (2): 245 – 261, 2001.
2	2. Agarwal M, *"Curricular Reform in Schools: The importance of evaluation"*, Journal of Curriculum Studies, 36 (3): 361 – 379, 2004.
3	Akyeampong K, *"Teacher Training in Ghana – does it count? Multisite teacher education research project (MUSTER)",* Country Report 1. London: DFID, 2003.
4	Akyeampong K, Lussier K, Pryor J, Westbrook J, *"Improving teaching and learning of Basic Maths and Reading in Africa: Does teacher Preparation count?"*International Journal Educational Development, 33 (3): 272- 282, 2013.
5	Alexander R J, *"Culture and Pedagogy: International Comparisons in Primary Education",* Oxford and Boston: Blackwell, 2001.
6	Chavan M, Read India: *"A mass scale, rapid, learning to read campaign",* 2003

AC039		E-WASTE MANAGEMENT				
AUDIT COURSE-II						
Pre-requisites			**L**	**T**	**P**	**C**
			2	-	-	0
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Objectives:

1.	Introduction to E-Waste management
2.	Understanding on resource efficiency and circular economy
3.	E-waste Management rules 2016
4.	RoHS compliances/directives to EEE

Outcomes:*At the end of this course, students will be able to:*

1.	Complete understanding on E-Waste management
2.	Understanding on effective recycling methodologies for e-waste management
3.	Overall understanding about E-waste Management rules 2016 and strategies for e-waste management
4.	Understanding on RoHS compliances for EEE products

Program Articulation Matrix

Course outcome	Program outcome					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1						
CO2						
CO3						
CO4						
CO5						

Row wise cumulative percentage weightage should be equal to 1.0.

UNIT – I
Waste Electrical and Electronic Equipment (WEEE): Flows, Quantities and Management, a Global Scenario; The Importance of Waste Management; Types of Waste- Solid and Liquid; Criteria for EEE/E-Waste Classification; Multivariate Model for E-Waste Estimation; Environmental and Health Effects of Waste Management, Inventorisation of E-Waste and Emerging trends in E-waste disposal with bench marks for depollution - global scenario; Dumping, Burning and Landfill: Impact on the Environment

UNIT – II
Effective Waste Management and Disposal Strategies; Legislative Influence on Electronics Recycling; Waste Management Rules and Their Amendments; Extended Producer Responsibility (EPR) in E-Waste Management; The Role of Collective versus Individual Producer Responsibility in E-Waste Management

UNIT – III
Electronic Waste: Public Health Implications; Restriction of Hazardous Substances (RoHS) Directives in Electrical and Electronic Equipment; Materials Used in Manufacturing Electrical and Electronic Products

UNIT – IV
Recycling and Resource Management: Ecological and Economical Valuation; Life Cycle Assessment (LCA) Approach to Waste Management System; Environmental Incentives for Recycling and Life Cycle Analysis of Materials Recycling Electronic Waste: Challenges and OpportUNITies for Sustainable Management; Resource Recovery from E-waste: Efficiency and Circular Economy; Integrated Approach to E-Waste Recycling: Recycling and Recovery Technologies, Recycling and Recovery Technologies.

UNIT – V
Cases studies: E-waste Generation, collection and recycling

References:

1	Electronic Waste Management and Treatment Technology, Editors: Majeti Narasimha Vara Prasad Meththika Vithanage
2	Electronic Waste Management, Edited by R. E. Hester, R. M. Harrison, RSC Publishing 2009
3	Solid Waste Technology & Management, Christensen, T., Ed., Wiley and Sons., 2011
4	Electronics Waste Management: An India Perspective. Front Cover. Sandip Chatterjee. Lap Lambert Academic Publishing GmbH KG, 2010 - Electronic
5	Handbook of Electronic Waste Management, International Best Practices and Case studies, Elsevier, 2019
6	E-waste: Implications, regulations, and management in India and current global best practices. Author(s): Rakesh Johri, TERI Press

EC481	DISSERTATION-I				
	DISSERTATION PHASE-I				
Pre-requisites	-	**L**	**T**	**P**	**C**
		-	-	20	10
Evaluation	**SEE**	-	**CIE**	100 Marks	

Course Objectives :	
1	*Identification of the research problem*
2	*Discussion of literature survey.*

Course Outcomes :	
CO-1	*Identification of the objectives of the Research Problem.*
CO-2	*Ability to update the latest literature in chosen area of research & establishment of the scope of work.*
CO-3	*Development of the methodology for the chosen research problem and perform basic theoretical /experiment studies.*
CO-4	*Identification of the objectives of the Research Problem.*
CO-5	*Ability to update the latest literature in chosen area of research & establishment of the scope of work.*

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1						
CO-2						
CO-3						
CO-4						
CO-5						

Contents:
Each student will be attached to a faculty member/guide for project. The student will carry out the project which may be development of Software / Hardware / Simulation studies / Design analysis / Experimental related to his/her specialization. The work will be monitored regularly by the guide.   At the end of the semester student will write the report on the work done and submit to the guide. Student has to present his/her work before two faculty members (one guide and other to be appointed by chairman BOS) on a fixed day during last week of the semester in which project is offered. The sessional marks will be awarded jointly by these examiners based on the report, presentation and viva voice

SEMESTER – IV

EC482	**DISSERTATION-II**				
DISSERTATION PHASE-II					
Pre-requisites	-	**L**	**T**	**P**	**C**
		-	-	32	16
Evaluation	**SEE**	100	**CIE**	100 Marks	

Course Objectives :	
1	*Identification of the research problem*
2	*Discussion of literature survey.*

Course Outcomes :	
CO-1	*Expand the defined Research Problem for the dissertation work.*
CO-2	*Conduct of Laboratory/analytical/ software studies*
CO-3	*Analysis of Data, development of models, offer solutions to the research problem and provide conclusions of the work.*

Course outcome	Program Outcome					
	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1						
CO-2						
CO-3						
CO-4						
CO-5						

Contents:
The student will carry out the project under allotted supervisor, which may be development of Software / Hardware / Simulation studies / Design analysis / Experimental related to his/her specialization. The work will be monitored regularly by the guide. At the end of the semester student will write the report on the work done and submit to the guide. Student has to present his/her work before two faculty members (one guide and other to be appointed by chairman BOS) on a fixed day during last week of the semester in which project is offered. The final marks will be allotted based on the report, presentation and viva voce conducted by the external examiner whose name is suggested by Chairman BOS