A.C. 27.12.2024
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INDEX

DEPARTMENT OF ELECTRONIC SCIENCE

ELECTRONIC SCIENCE

CORE AND DSE COURSES OFFERED BY DEPARTMENT OF ELECTRONIC SCIENCE

VII Semester

Category I

Electronics Course for Undergraduate Programme of study with Electronics as a Single Core Discipline
(B.Sc. Honours in Electronics)

DISCIPLINE SPECIFIC CORE COURSE –19: Control Systems

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Control Systems	4	3	-	1	Class XII passed with Physics + Mathematics/Applied Mathematics + Chemistry OR Physics + Mathematics/Applied Mathematics + Computer Science/Informatics Practices	-

Learning Objectives

The Learning Objectives of this course are as follows:
This course introduces the student to the fundamental understanding of Mathematical modeling and analysis of open loop and closed loop control systems in terms of electrical equivalent circuits. Student would be in position to explain the nature of stability of systems using different criteria and plots. They should be able to identify the Controllability and Observability of a system to explore its applications.

Learning outcomes

The Learning Outcomes of this course are as follows:

- Analyze the concepts of open and closed loop control systems
- Develop the mathematical model of a physical system
- Analyze the stability of control systems with the help of different criteria and plots.
- Identify the needs of different type of controllers.
- Analyze controllability and Observability by state space models.

SYLLABUS OF ELDSC-19 **Total Hours- Theory: 45 Hours, Practicals: 30 Hours**

UNIT – I (11 Hours)

Classification of systems (Definitions only) : Linear and Nonlinear systems, Time invariant and Time varying system, Continuous time and Discrete time system, Dynamic and Static system , SISO and MIMO , Open loop and Closed loop control systems, Transfer functions, Mathematical modelling of Physical systems (Electrical, Mechanical and Thermal) , D.C. motors and A.C. servomotors, block diagram representation & signal flow graph, Mason's Gain Formula, Effect of feedback on parameter variations

UNIT – II (12 Hours)

Test input signals for transient Analysis, transient response of first , second and higher order system for different test input signals , Time domain performance parameters of second order System , Steady state errors and Static error constants

Concept of Stability: Effect of location of poles on stability, Asymptotic stability and Conditional stability, Routh – Hurwitz criterion, Root Locus techniques and their applications. concept and applications of PI, PD and PID controllers .

UNIT – III (11 Hours)

Advantages of frequency domain analysis, Frequency domain specifications, Correlation between time and frequency response, Polar plot, Logarithmic plots (Bode Plots), Gain and Phase margins, Nyquist stability criterion.

UNIT – IV (11 Hours)

Definition of State, State variables and State models, State Space Representation of dynamic systems (Electrical networks and nth order differential equation) , State Transition Matrix, Decomposition of Transfer Function, Controllability and Observability.

Compensation Techniques: Concept of compensation techniques Lag, Lead and Lag-Lead networks

Practical component (if any) – Control Systems Lab

(Hardware and Scilab/MATLAB/Other Mathematical Simulation software)

Learning outcomes

The Learning Outcomes of this course are as follows:

- Perform experiments involving concepts of control systems
- Design experiments for controlling devices like AC/DC motor etc.
- Study behavior of systems

LIST OF PRACTICALS (Total Practical Hours- 30 Hours)

1. To study response of systems for various standard test input signals.
2. To study position and speed control of DC motor.
3. To find torque speed characteristics of AC servomotor.
4. To study time and frequency domain specifications of a control system.
5. To plot Bode, Root locus and Nyquist plots and determine stability .
6. To study the effect of PI, PD and PID controller on closed loop systems.
7. State space analysis for a given Transfer function

Note: Students shall sincerely work towards completing all the above listed practicals for this course. In any circumstance, the completed number of practicals shall not be less than six.

Essential/recommended readings

1. J. Nagrath& M. Gopal, Control System Engineering, New Age International, 2000
2. K. Ogata, Modern Control Engineering, PHI 2002
3. B. C. Kuo Automatic control system‖, Prentice Hall of India, 2000

Suggestive readings

1. Joseph J Distefano, Allen R Stubberud, Ivan J Williams, - Control Systems , Schaum's Out lines , Tata McGraw Hill , third Edition , 2010

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVES (DSE) COURSES OFFERED BY THE DEPARTMENT

DISCIPLINE SPECIFIC ELECTIVES (DSE-1)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Advanced Machine Learning ELDSE7A	4	3	-	1	Class XII passed with Physics + Mathematics/Applied Mathematics + Chemistry OR Physics + Mathematics/Applied Mathematics + Computer Science/Informatics Practices	-

Learning Objectives

The Learning Objectives of this course are as follows:
Machine Learning (ML) has emerged as one of the most dominant and rapidly growing technology which has produced a significant impact in almost all the other sectors of science and technology including consumer electronics, robotics, Internet of Things and preventive health care to name a few. The primary focus of this course is to provide a very comprehensive understanding of various advanced machine learning algorithms which can be used to design efficient automated systems and learning agents which are able to self-adapt and reprogram themselves according to their changing surroundings. These intelligent agents designed using ML algorithms have the ability to self-learn from the consequences of their past actions such that they can make improved decisions in the future

Learning outcomes

The Learning Outcomes of this course are as follows:

- Develop a good understanding of fundamental principles of machine learning
- Formulation of a Machine Learning problem
- Develop a model using supervised/unsupervised machine learning algorithms for classification/prediction/clustering
- Evaluate performance of various machine learning algorithms on various data sets of a domain.

SYLLABUS OF ELDSE-7A **Total Hours- Theory: 45 Hours, Practicals: 30 Hours**

UNIT – I (11 Hours)

Basics of Machine Learning:

A brief overview of types of Machine Learning: Supervised Learning, Unsupervised Learning and Reinforcement Learning. Supervised Learning Vs. Unsupervised Learning. Data pre-processing. Classification Vs. Regression Analysis. Criteria for selecting optimum value training data to test data ratio. Concept of over-fitting and underfitting.

Regression Analysis in Supervised Learning: Linear Regression: Simple Linear Regression, Multiple Linear Regression, Backward Elimination, Polynomial Regression.

UNIT – II (12 Hours)

Classification Algorithms in Supervised Learning:

Linear Models for Classification, Logistic Regression, K-NN Algorithm, Decision Tree Classification Algorithm, Random Forest Algorithm, Support Vector Machine Classifier.

Unsupervised Learning: Clustering, K-Means Clustering Algorithm, Agglomerative Clustering, DBSCAN (density-based spatial clustering of applications with noise), Comparing and Evaluating Clustering Algorithms, Association Rule Learning, Principal Component Analysis (PCA), Non-Negative Matrix Factorization (NMF), Manifold Learning with t-SNE Clustering.

UNIT – III (11 Hours)

Probabilistic Reasoning Models and Bayesian Learning:

Bayesian Networks- representation, construction and inference, Temporal model: concept of Transition probability, Simple Markov Model and Hidden Markov model. Naïve Bayes algorithm.

Reinforcement Learning: Passive Reinforcement learning and Active Reinforcement Learning.

Markov Decision Process Model: MDP formulation, utility theory, utility functions, value iteration, policy iteration and Q- Learning. Elements of MDP Model, concept of Sequential Decision Processing, Example of MDP Problem: Agent in a grid world.

UNIT – IV (11 Hours)

Computational Learning Theory:

Probably approximately correct (PAC) learning model, Sample Complexity for finite hypothesis spaces, Sample Complexity for infinite hypothesis spaces, Mistake bound model of learning.

Instance Based Learning: k-Nearest Neighbor algorithm, Distance Weighted Nearest Neighbor algorithm.

Practical component (if any) – Advanced Machine Learning Lab

(Algorithms to be implemented in Python or any other suitable programming language)

Learning outcomes

The Learning Outcomes of this course are as follows:

- Effectively use the various machine learning tools
- Understand and implement the procedures for machine learning algorithms
- Design Python programs for various machine learning algorithms
- Apply appropriate datasets to the Machine Learning algorithms
- Analyze the graphical outcomes of learning algorithms with specific datasets

LIST OF PRACTICALS (Total Practical Hours- 30 Hours)

1. Perform Simple Linear Regression and Multiple Linear Regression.
2. Write a program to implement Logistic Regression.
3. Program to implement the following algorithms
   i. K-NN classifier
   ii. Decision Tree Classification Algorithm
   iii. Support Vector Machine Classifier
4. Write a program to implement K-Means Clustering Algorithm
5. Program to demonstrate Agglomerative Hierarchical Clustering
6. Write a program for construction and inference of a Bayesian network
7. Write a program to implement Naïve Bayes classifier.
8. Write a program to implement Simple Markov and Hidden Markov Model
9. Program to demonstrate sequential decision processing in Markov Decision Process model by considering the problem of an agent in a grid world

Note: Students shall sincerely work towards completing all the above listed practicals for this course. In any circumstance, the completed number of practicals shall not be less than eight.

Essential/recommended readings

1. Introduction to Machine Learning with Python, by Andreas C. Müller, Sarah Guido, O'Reilly Media, Inc., 2016
2. Machine Learning by Tom. M. Mitchell, Tata McGraw Hill, 1997
3. Introduction to Machine Learning by Nils. J. Nillson, 1998
4. Introduction to Machine Learning by E. Alpaydin," PHI, 2005.

Suggestive readings

1. Machine Learning: A Probabilistic Perspective by Kevin P. Murphy, MIT Press, 2012
2. Pattern recognition and Machine Learning by Christopher M. Bishop, Springer, 2006

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVES (DSE-2)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Neural Networks and Deep Learning ELDSE7B	**4**	**3**	**-**	**1**	**Class XII passed with Physics + Mathematics/Applied Mathematics + Chemistry OR Physics + Mathematics/Applied Mathematics + Computer Science/Informatics Practices**	**-**

Learning Objectives

The Learning Objectives of this course are as follows:
This course introduces the student to the fundamental understanding of the basic principles behind deep learning and focuses on learning complex, hierarchical feature representation from raw data. The course applies and evaluates deep learning on real data set and suggests examples of how deep learning can be used in different contexts in the society. It encourages to read and critically assess papers on deep learning and their applications.

Learning outcomes

The Learning Outcomes of this course are as follows:

- Describe the major differences between deep learning and other types of machine learning algorithms.
- Explain the fundamental methods involved in deep learning, including the underlying optimization concepts.

- Differentiate between the major types of neural network architectures (multi-layered perceptions, convolutional neural networks, recurrent neural networks, etc.) and what types of problems each is appropriate for.
- Select or design neural network architectures for new data problems based on their requirements and problem characteristics and analyze their performance.
- Describe some of the latest research being conducted in the field and open problems that are yet to be solved.

SYLLABUS OF ELDSE-7B **Total Hours- Theory: 45 Hours, Practicals: 30 Hours**

UNIT – I (11 Hours)

Introduction to Deep Learning:

Definition of Deep Learning (as a subset to Machine Learning, Artificial Intelligence), Structure or Elements of Artificial Neural Networks (ANNs) (input layer, hidden layer, output layer), Architecture of NNs, Need for Activation functions (Cost function, Sigmoid function, Threshold function, ReLU function, Hyperbolic Tangent function)

UNIT – II (12 Hours)

Neural Networks:

Linear Models for Classification, Logistic Regression, K-NN Algorithm, Decision Tree Idea of Perceptron, Multi-Layer Perceptron, Feed Forward Networks (FFNs), Backpropagation network, Gradient Descent, Eigen values and eigen vectors, Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Radial Based Networks, Deep Neural Networks, Long Short-Term Memory Networks (LSTMNs), Learning/Training and optimisation algorithms for each type, Restrictive Boltzmann Machines (RBMs), Stacking RBMs, Belief Nets.

UNIT – III (11 Hours)

Principal Component Analysis and Regularization:

Principal component Analysis and its interpretation, Singular Value Decomposition, Autoencoders and relation to PCA, Regularization in autoencoders, Bias Variance Trade-off, L1 and L2 regularization, Early stopping, Ensemble method and Dropout, Optimization and Overfitting and Bagging.

UNIT – IV (11 Hours)

Introduction to CNNs and Deep Learning Application:

Convolution, Correlation, Filtering, Pooling, Deep CNNs, Different deep CNN architectures – LeNet, AlexNet, VGG, ResNet. Weights initialization, Batch normalization, Hyperparameter optimization, Understanding and visualizing CNNs. Greedy layer wise training, Optimization, Autoencoders, Overfitting, Generalisation. Newer optimization methods for neural networks (AdaGrad, RMSProp, Adam), Second order methods for training.

Applications: Virtual Assistants, Chatbots, Image captioning, Self-Driving Cars, Natural Language Processing, Visual Recognition, Fraud Detection.

Practical component (if any) – Neural Network and Deep Learning Lab
(Python- using the Deep Learning Libraries)

Learning outcomes

The Learning Outcomes of this course are as follows:

- Implement fundamental building blocks.
- Apply their learning to real world scenarios.
- Design NN architectures for new Data problems.

LIST OF PRACTICALS (Total Practical Hours- 30 Hours)

1. To predict Handwritten Digits using any Neural Network model.
2. To predict whether the income of a person exceeds a certain amount per year based on specific criteria, using Tensor flow and any data set from a Machine Learning Repository
3. To analyze various aspects of an individual and predict what class of income he/she belongs to (Example: >50k or <=50k) by using census data.
4. Classify photos of cats and dogs using a neural network using Python.
5. To predict the prices of stocks using the "Google stock price" data using LSTM.
6. For dataset (Boston housing price/ India Prima Diabetic) apply regularisation techniques.
7. To build realistic images from textual descriptions of objects like birds, humans, and other animals using GANs. We input a sentence and generate multiple images fitting the description.

Note: Students shall sincerely work towards completing all the above listed practicals for this course. In any circumstance, the completed number of practicals shall not be less than six.

Essential/recommended readings

1. Deep Learning, An MIT Press book, Ian Goodfellow and Yoshua Bengio and Aaron Courville http://www.deeplearningbook.org
2. S. Haykin, Neural Networks and Learning Machines, Prentice Hall of India, 2010
3. Satish Kumar, Neural Networks - A Classroom Approach, Second Edition, Tata McGraw-Hill, 2013

Suggestive readings

1. B. Yegnanarayana, Artificial Neural Networks, Prentice- Hall of India, 1999
2. C.M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVES (DSE-3)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Digital Communication System ELDSE7C	4	3	-	1	Class XII passed with Physics + Mathematics/Applied Mathematics + Chemistry OR Physics + Mathematics/Applied Mathematics + Computer Science/Informatics Practices	-

Learning Objectives

The Learning Objectives of this course are as follows:
The course introduces students to the fundamentals and key modules of digital communication systems with emphasis on digital modulation techniques and error and code detection. The basics of information theory, source coding techniques and entropy of source will also be covered.

Learning outcomes

The Learning Outcomes of this course are as follows:

- To understand the concept of digital communication system.
- To compare various digital modulation and demodulation techniques.
- To understand the effect of noise on system performances.
- To generate coding sequences for different error correcting codes.

SYLLABUS OF ELDSE-7C **Total Hours- Theory: 45 Hours, Practicals: 30 Hours**

UNIT – I (11 Hours)

An overview of sampling theorem and multiplexing.

Random processes, stationary processed, mean, correlation, and covariance functions: autocorrelation function, cross-correlation function, Power spectral density.

Information Theory: Entropy, Information rate and channel capacity: Hartley's law, Shannon Hartley's theorem, Source coding: Huffman coding.

UNIT – II (12 Hours)

Digital base band transmission and Reception: line coding (unipolar RZ, NRZ, Bipolar NRZ, split phase Manchester, differential coding) comparison in performance and Power spectra density. Probability of error, ISI, Matched filter, probability of error using matched filter.

UNIT – III (11 Hours)

Digital Modulation Schemes: ASK, FSK, PSK, DPSK, QPSK, QAM and M-ary coding. Constellation diagram, transmitter and receiver block diagram.

UNIT – IV (11 Hours)

Channel/line coding: ASCII and EBCDIC binary codes, Error, Error detection and correction using parity, checksum, Vertical redundancy Check (VRC), Longitudinal Redundancy Check (LRC), Cyclic Redundancy Check (CRC), Linear block code, Hamming code.

Practical component (if any) – Digital Communication System Lab
(Hardware and/or software using MATLAB/SCILAB)

Learning outcomes

The Learning Outcomes of this course are as follows:

- Understand sampling.
- Understand basic theories and generation and detection of Digital communication techniques.
- Simulate and use software for applications in communication electronics.

LIST OF PRACTICALS (Total Practical Hours- 30 Hours)

1. Study Sampling theorem using software.
2. Study of generation of Unipolar and bipolar RZ & NRZ Line coding.
3. Study of Amplitude Shift Keying (ASK).
4. Study of Frequency Shift Keying (FSK).
5. Simulate Phase Shift Keying (PSK)- Binary Phase Shift Keying (BPSK)- and Quadrature Phase Shift Keying (QPSK) using software.

6. Study of Quadrature amplitude Modulation (QAM).
7. Study the Hamming Code-7bit generation.

Note: Students shall sincerely work towards completing all the above listed practicals for this course. In any circumstance, the completed number of practicals shall not be less than six.

Essential/recommended readings

1. W. Tomasi, Electronic Communication Systems: Fundamentals through Advanced, Pearson Education (2004)
2. S. Haykin, Digital Communication, John Wiley India (2009)
3. B. Sklar, Digital Communication, 2nd Edition, Pearson Education (2006)
4. J.G. Proakis, Fundamentals of Communication Systems, Pearson Education (2006)

Suggestive readings

1. L. W. Couch II, Digital and Analog Communication Systems, Pearson Education (2005)
2. H. P. Hsu, Analog and Digital Communications, Tata McGraw Hill (2006)

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVES (DSE-4)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Optical Communication System ELDSE7D	4	3	-	1	Class XII passed with Physics + Mathematics/Applied Mathematics + Chemistry OR Physics + Mathematics/Applied Mathematics + Computer Science/Informatics Practices	-

Learning Objectives

The Learning Objectives of this course are as follows:
This course introduces the student to the fundamentals of optical communications, including the optical sources at the transmission station, the transmission medium, and the optical detectors at the reception station.

An understanding of the LASERS, optical amplifiers, and design considerations of a fiber optic communication systems, bit error rate and rise time budgeting and power budgeting.

Learning outcomes

The Learning Outcomes of this course are as follows:

- Describe the difference between LED and Laser diode (LD) and choose a proper light source for optical communication.
- System designing of an optical communication system, to calculate the power requirements for a given fiber optic communication link, and hence compute loss and dispersion.
- Understand various low loss optical communication windows, importance of 1330nm and 1550nm wavelengths in optical communications.

- An optical fiber amplifier in general, and erbium doped fiber amplifier in particular.

SYLLABUS OF ELDSE-7D **Total Hours- Theory: 45 Hours, Practicals: 30 Hours**

UNIT – I (12 Hours)
Sources for optical fiber communication: Optical Communication requirements, LASER fundamentals: Absorption and emission of radiation, condition for amplification of radiation, LASER oscillations. Basics of semiconductor lasers, laser diode characteristics, LED characteristics.

UNIT – II (10 Hours)
Detectors for optical fiber communication: Principle of optical detection, PIN photodetector, responsivity and quantum efficiency, speed of response, avalanche photodetector

UNIT – III (12 Hours)
Design considerations of fiber optic communication system: Characterization of an optical fiber: measurement of its radius, numerical aperture, cut-off wavelength (Marcuse's formula) Analog and digital modulation (direct), noise in detection process: shot noise, thermal noise, SNR, Bit error rate (BER), system design: power budgeting, rise time budgeting

UNIT – IV (11 Hours)
Optical Fiber amplifiers: Wavelength dependence of loss and dispersion of a single mode fiber and various loss windows: significance of 1300nm and 1550nm wavelength in optical communications. Introduction to semiconductor optical amplifiers, Block diagram of an optical amplifier at 1550nm communication wavelength, Optical amplification, absorption and emission cross-sections for a typical erbium doped fiber amplifier, Energy levels of erbium ions in silica matrix

Practical component (if any) – Optical Communication System Lab
(Hardware and/or software)

Learning outcomes

The Learning Outcomes of this course are as follows:
- Perform experiments based on LEDs and laser diodes.
- Characterize an optical fiber in terms of measuring its radius, numerical aperture, and cut-off wavelength.
- Design an optical link and calculate the power budgeting.
- Understand an optical fiber amplifier.

LIST OF PRACTICALS (Total Practical Hours- 30 Hours)

1. To study the characteristics of LED.
2. To study the characteristics of semiconductor laser diode.
3. To study the characteristics of Silicon and Germanium photo-detectors.
4. To couple optical light into SMF and MMF and study the fundamental mode pattern and the speckle pattern.
5. To measure the parameters of a single mode optical fiber: radius, numerical aperture, cut-off wavelength.
6. To design an optical communication link and study power budgeting (simulation).
7. To design an optical circuit showing direct analog and digital modulation schemes.
8. To study the bending losses in an optical fiber link.
9. To study an EDFA (simulation).
10. Study of an OTDR instrument.

ONLINE virtual lab:

1. Amrita Vishwa Vidyapeetham Virtual Lab
2. Virtual Labs ofcvlab.vesit.ves.ac.in

Note: Students shall sincerely work towards completing all the above listed practicals for this course. In any circumstance, the completed number of practicals shall not be less than nine.

Essential/recommended readings

1. Ajoy Ghatak and K Thyagarajan, Introduction to Fiber Optics, Cambridge University Press, New Delhi (1999)
2. D.K. Mynbaev and Lowell L. Scheiner, Fiber-Optic Communication Technology, Pearson Education.

Suggestive readings

1. J. M. Senior, Optical fiber communication systems: principles and practice, Pearson Education in south Asia, (2009).
2. J. Gower, Optical communication systems, Pearson Education
3. G. Keiser, Optical communications, McGraw Hills education (2003)
4. M. R. Shenoy, S. K. Khijwania, et al., Fiber optics through Experiments, Viva books (2011)

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVES (DSE-5)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
CMOS Digital VLSI Design ELDSE7E	4	3	-	1	Class XII passed with Physics + Mathematics/Applied Mathematics + Chemistry OR Physics + Mathematics/Applied Mathematics + Computer Science/Informatics Practices	Digital Electronics, Analog Electronics-I & II, Basic VLSI Design

Learning Objectives

The Learning Objectives of this course are as follows:
This course introduces the student to develop the ability to design and analyze combinational and sequential digital circuits using VHDL/Verilog; design methodologies of memory circuits such as SRAM and DRAM; acquire hands-on skills in layout design and to simulate and analyze VLSI circuits, including post-layout simulations

Learning outcomes

The Learning Outcomes of this course are as follows:

- Students will be able to design and analyze CMOS-based combinational and sequential circuits, focusing on performance metrics like power, delay, and reliability.
- Students will gain the ability to design and evaluate memory circuits, including SRAM and DRAM, considering trade-offs in stability, speed, and power.
- Students will demonstrate proficiency in creating and verifying layouts of digital circuits, ensuring adherence to design rules and industry standards.
- Students will effectively utilize EDA tools for circuit design, simulation, and layout verification.

SYLLABUS OF ELDSE-7E **Total Hours- Theory: 45 Hours, Practicals: 30 Hours**

UNIT – I (12 Hours)
HDL: History of HDL; Structure of VHDL; VHDL Modules : entity, architectures, concurrent signal assignment; Data Flow Modelling, Structural Modelling, Behavioural Modelling.

UNIT – II (14 Hours)
Verilog: Verilog/VHDL Comparisons; Module, Data Types, Operators and Expressions, Instantiation and Hierarchical Design, Blocking and Non-Blocking Assignments, Gate Level, Dataflow and Behavioural Modelling, RTL, Verilog Tasks and Functions, Design Flow and Verilog Test Bench

UNIT – III (10 Hours)
SRAM and DRAM : 6T SRAM cell design and read & write-operation, stability analysis and noise margins, stick diagram of a traditional 6T SRAM cell, DRAM architecture and refresh mechanism, DRAM Architecture - One-transistor, Three-transistor and Four-Transistor DRAM cell, DRAM subarray -Open and Folded Bitlines.

UNIT – IV (09 Hours)
Layout Design Rules and DRC : basic layout design rules, metal layers, contacts, and vias in CMOS layouts, design rule checks, layout versus schematic, Inverter Cell Layout. Introduction to - post-layout simulation; parasitic extraction; full-custom layout design; concept of standard cell & parameterized cells; importance of VLSI CAD tools; ASIC design flow vs. FPGA flow.

Practical component (if any) – Digital VLSI Design Lab
(Practicals to be performed using VHDL/Verilog, Ngspcie/LTspice/QUCS, kiCAD/MagicVLSI, XCircuit, OpenRAM, CADENCE/MENTOR GRAPHICS)

Learning outcomes

The Learning Outcomes of this course are as follows:

- Apply VHDL/Verilog to design the Digital Circuits
- Get familiarized with the VLSI design Simulation Tools
- Create Layout of a CMOS inverter and perform design rule checks (DRC).

LIST OF PRACTICALS (Total Practical Hours- 30 Hours)

1. Design Full Adder/Subtractor using VHDL.
2. Design a Counter using VHDL.
3. Design MUX/Multiplier Circuit using Verilog
4. Design ALU using Verilog
5. Design a 6T SRAM cell, simulate its read/write operation.

6. Draw the stick diagram for a CMOS inverter and basic gates like NAND and NOR.
7. Create the layout of a CMOS inverter, ensuring compliance with basic design rules. Perform design rule checks (DRC).
8. Perform post-layout simulation for a CMOS inverter, including parasitic extraction. Analyze the impact of parasitics on circuit performance.

Note: Students shall sincerely work towards completing all the above listed practicals for this course. In any circumstance, the completed number of practicals shall not be less than seven.

Essential/recommended readings

1. J. Bhasker : A Verilog HDL Primer, BSP, 2003, ISBN: 9788178000114, 9788178000114
2. Samir Palnitkar : Verilog HDL-A guide to digital design and synthesis-, Pearson, 2003, ISBN-10 8177589180, ISBN-13 978-8177589184
3. Wayne Wolf : Modern VLSI Design: IP-Based Design, PHI, 2008, ISBN-10 0137145004; ISBN-13 978-0137145003
4. Weste and Harris: CMOS VLSI Design: Circuits and Systems Perspective, Addison-Wesley,2015, ISBN-10 9789332542884; ISBN-13 978-9332542884
5. Kang and Lebelbigi: CMOS Digital IC Circuit Analysis and Design, McGraw Hill, 2002, ISBN-10 0072460539; ISBN-13 978-0072460537

Suggestive readings

1. Jan M. Rabaey, Anantha Chandrakasan, and Borivoje Nikolic: Digital Integrated Circuits: A Design Perspective, Prentice Hall Electronics, 2003, ISBN-10 0130909963; ISBN-13 978-0130909961
2. Randall L. Geiger, Phillip E. Allen, and Noel R. Strader: VLSI Design Techniques for Analog and Digital Circuits, McGraw Hill, 1989, ISBN-10 0070232539; ISBN-13 978-0070232532

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVES (DSE-6)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to Nanoscience ELDSE7F	**4**	**4**	**-**	**-**	**Class XII passed with Physics + Mathematics/Applied Mathematics + Chemistry OR Physics + Mathematics/Applied Mathematics + Computer Science/Informatics Practices**	**-**

Learning Objectives

The Learning Objectives of this course are as follows:
This course introduces the student about nanoscience, which includes the fundamental understanding of effect of size and the related physics involved behind it.

Learning outcomes

The Learning Outcomes of this course are as follows:

- To develop the fundamental base of nanoscience.
- To acquire knowledge of effect of size and the related physics involved behind it.
- To understand the behavior and properties of nanomaterials.

SYLLABUS OF ELDSE-7F **Total Hours- Theory: 60 Hours**

UNIT – I (13 Hours)

Introduction to Nanoscience:

Introduction to Nanoscience: Definition and Importance of Nano, Opportunities at nano scale, Scientific revolution- emergence and challenges of nanomaterial and nanotechnology with examples (daily life, health care and energy)

Implications of Nanoscience and Nanotechnology on Society, Harnessing Nanotechnology for Economic and Social Development

Influence of nano over micro/macro, surface to volume ratio-dangling bonds, chemical activity of nanoparticulates, sensing applications with example of graphene. Size effects-idea about electronic wave function, Population of the conduction and valence bands, Quasi Fermi levels, examples of metal nanoparticles.

UNIT – II (17 Hours)

Introduction to Quantum Theory:

Fundamentals of Quantum Theory: Origins of Quantum Physics, Particle properties of waves: Black body radiation, Photoelectric effect, Compton Effect; Wave properties of particles: De Broglie waves, Wave description, Particle diffraction, The Wave Particle Duality, The Uncertainty Principle, The Wave Packet and the Wave Function, The Schrödinger Equation, The Expectation Value, The Free Particle Solution, The Linear Harmonic Oscillator Problem, The Kronig-Penney Model for Electron in a 1-Dimensional Lattice

UNIT – III (13 Hours)

Quantum Nanoengineering:

Particle in a Box, Quantum Limit: From 3D to 0D, Quantum Confinement in Semiconductors: Potential Step, Potential Barrier, Quantum Well. Atomic structure: Electron orbits, The Bohr atom; Quantum Structure: 2D (Quantum well), 1D (Quantum Wires), 0D (Quantum Dots);

3D Density of States, 2D Model- Energy Eigen values and Density of States, 1D Model-Energy Eigen values and Density of States, Q0D Model- Energy Eigen values

UNIT – IV (17 Hours)

Properties of nanostructures:

Quantum Effect on Properties of Nanomaterials: Melting Point- Variation in bulk vs nanoparticles, nanowires, nanosheets, superheating, liquid drop model (Quantitative); Electronic structure and Optical Properties-band gap dependence on the size of the nanoparticles(quantitative), concept of excitons; Mechanical Properties- ductility, strain hardening, yield stress, dynamic response, creep(qualitative); Dielectric Properties- particle size dependence of refractive constant, extinction coefficient (quantitative), Magnetic Properties-idea about diamagnetism, paramagnetism, ferromagnetism, Curie temperature, remanent magnetization, coercive field; saturated magnetization and its dependence on size and temperature(quantitative)

Size dependent electronic Properties (Classification of materials based on band structures - Brillouin zone – Effect of temperature, Quantized conduction, Ballistic transport, Coulomb blockade).

Practical component (if any) – None

Essential/recommended readings

1. Introductory Nano science by Masuro Kuno, Garland science (2011)
2. Concepts of Modern Physics by Arthur Beiser, TMH Publications
3. Nanophysics and Nanotechnology by Edward L. Wolf Wiley-VCH-2006
4. Nanotechnology: Principles & Practices, S.K. Kulkarni, Springer, 2015.

Suggestive readings

1. Introduction to Nanomaterials and Devices: Omar Manasreh (Wiley)
2. Introduction to Nano, Basics to Nanoscience and Nanotechnology, Amretashis Sengupta, Chandan Kumar Sarkar Editors, 2015, Springer, ISBN 978-3-662-47313-9
3. Textbook of Nanoscience and Nanotechnology, B S Murty and others, 2013, Springer, e-ISBN 978-3-642-28030-6

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVES (DSE-7)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Advanced Embedded System Design with ARM ELDSE7G	4	3	-	1	Class XII passed with Physics + Mathematics/Applied Mathematics + Chemistry OR Physics + Mathematics/Applied Mathematics + Computer Science/Informatics Practices	

Learning Objectives

The Learning Objectives of this course are as follows:

- Demonstrate proficiency in ARM microcontroller programming and interfacing.
- Design and implement efficient embedded systems using ARM Cortex-M3 processors.
- Apply RTOS concepts to solve real-time embedded problems effectively.

Learning outcomes

The Learning Outcomes of this course are as follows:

- Describe the architectural features and instructions of ARM Cortex-M3 microcontroller.
- Apply the knowledge gained for Programming ARM Cortex-M3 for different applications.
- Explain the need of a real time operating system for embedded systems applications

SYLLABUS OF ELDSE-7G **Total Hours- Theory: 45 Hours, Practicals: 30 Hours**

UNIT – I (11 Hours)
ARM Microcontroller Architecture:
Introduction to ARM microcontroller families, features, and applications. Thumb-2 technology, Architecture of ARM Cortex-M3, various units in the architecture, General Purpose Registers, Special Registers, Exceptions, Interrupts, Stack Operation, Reset Sequence, Debugging Support.

UNIT – II (11 Hours)
ARM Cortex-M3 Instruction Set:
Assembly basics, Addressing Modes, Instruction lists and description, Thumb and ARM instructions, Special instructions, Useful instructions, CMSIS, simple assembly language programs.

UNIT – III (11 Hours)
ARM Cortex-M3 Peripherals:
ARM Cortex M3 Peripherals: GPIO control, Timer configurations, and basic Interrupt handling, Introduction to Embedded C programming for ARM. Peripheral programming in Assembly and Embedded C language.

UNIT – IV (12 Hours)
RTOS Based Embedded System Design:
Operating System Basics, Types of Operating Systems, Architecture of an RTOS, Important features of RTOS, Embedded Systems Programming, Locks and Semaphores, Operating System Timers and Interrupts, Exceptions, Tasks. Task states and scheduling, Synchronization, Real-time clock and system clock.

Practical component (if any) – Advanced Embedded System Design with ARM Lab
(Practicals to be performed using Hardware/Simulator)

Learning outcomes

The Learning Outcomes of this course are as follows:

- Write Assembly language/C Language program for ARM Processor.
- Able to interface and program peripherals like LED, actuators, LCD display etc. on ARM Ports.
- Prepare the technical report on the experiments carried.

LIST OF PRACTICALS (Total Practical Hours- 30 Hours)

1. Write a program to perform arithmetic operations on two 32-bit numbers.
2. Write a program to generate an A.P. / G.P. / Fibonacci series.

3. Write a program to sort a given list of 32-bit numbers in ascending/descending/reverse order.
4. Write a program to configure and blink / toggle GPIO pins at a specific rate.
5. Write a program to design a counter (decade, hexadecimal, etc.) on an LCD / 7-segment display.
6. Write a program to read a 4×4 keyboard and display the key code on an LCD / 7-segment display.
7. Write a program to generate PWM signals to control the brightness of an LED.
8. Write a program to control the speed of a DC motor
9. Design RTOS Based Parameter Monitoring and Controlling System for collecting the data from sensor interfaced with microcontroller.
10. Implement a real-time clock using RTOS timers

Note: Students shall sincerely work towards completing all the above listed practicals for this course. In any circumstance, the completed number of practicals shall not be less than nine.

Essential/recommended readings

1. Joseph Yiu, "The Definitive Guide to the ARM Cortex-M3" 2nd Edition, Newnes, (Elsevier), 2010. ISBN: 978-1-85617-963-8.
2. K.V.K.K Prasad, "Embedded Real Time Systems", Dreamtech Publications, 2003. ISBN: 978-8177224610
3. Raj Kamal, "Embedded Systems", 2nd Edition, McGraw Hill Publications, 2010. ISBN: 978-9332901490

Suggestive readings

1. Yifeng Zhu, "Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C", 2nd Edition, Man Press LLC, 2015, ISBN: 978-0982692660
2. Jonathan W. Valvano, "Embedded Systems: Real-Time Operating Systems for ARM Cortex-M Microcontrollers", Createspace Independent Pub, 2011. ISBN: 978-1463590154

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

ELECTRONIC SCIENCE

CORE AND DSE COURSES OFFERED BY DEPARTMENT OF ELECTRONIC SCIENCE

VIII Semester

Category I

Electronics Course for Undergraduate Programme of study with Electronics as a Single Core Discipline

(B.Sc. Honours in Electronics)

DISCIPLINE SPECIFIC CORE COURSE –20: Power Electronics

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Power Electronics	4	3	-	1	Class XII passed with Physics + Mathematics/Applied Mathematics + Chemistry OR Physics + Mathematics/Applied Mathematics + Computer Science/Informatics Practices	-

Learning Objectives

The Learning Objectives of this course are as follows:
This course introduces the student to the fundamental understanding of power control in domestic and industrial applications through semiconductor devices. It also familiarise students with role and advantage of power semiconductor devices in automating the control of heavy machinery or power control circuits. This course forms the basis for bridging the knowledge of circuits, devices, embedded systems, machines and controls systems together, useful for the present era of e-control in every domain.

Learning outcomes

The Learning Outcomes of this course are as follows:

- To get familiarise with and to understand the salient features and applicability of various types semiconductor devices through comparative study for power control
- To understand the construction, working and control of thyristors for power applications
- To learn various methods of conversion between DC and AC power

- To learn concepts involved in efficient electronic power control in DC and AC applications
- To practically apply the learning, for power control in real-life domestic applications

SYLLABUS OF ELDSC-20 **Total Hours- Theory: 45 Hours, Practicals: 30 Hours**

UNIT – I (12 Hours)

Power Semiconductor Devices:

Definition and Applications of Power Electronics, Need and History of Power Semiconductor Devices, Introduction of various Power Semiconductor Devices (Power diodes, different types of Transistors and Thyristors), Vertical structure, Enhancement of voltage blocking and current carrying capability.

Power Transistors: Comparative study (structural, operational, functional, specifications) of Power BJT, Power MOSFET and IGBT as power switch: Vertical structure, Enhancement of voltage and current rating, IV characteristics, Safe Operating Area, switching characteristics/performance, equivalent structure

Second breakdown, saturation and quasi-saturation state in BJT, inversion in IGBT, Latch-up in IGBT

Thyristors: Comparative Study of SCR, DIAC, TRIAC and GTO as power switch: Structure, IV characteristics, utility

Comparative of specifications of Power BJT, Power MOSFET, IGBT, SCR and GTO

UNIT – II (10 Hours)

Semiconductor Controlled Rectifier (SCR):

Dynamic Turn-on and Turn-off characteristics, Turn-on methods, Gate triggering circuits (R, RC and UJT triggering), Gate characteristics, Forced Commutation circuits, Voltage commutation, Current commutation, Load commutation, Two Transistor model, Internal regeneration, Factors affecting the characteristics/ratings of SCR, Protection of SCR, gate protection, di/dt and dv/dt protection using snubber circuit, series and parallel combination of SCRs

UNIT – III (13 Hours)

DC Power Control:

Single phase AC-DC converters: Phase-controlled rectifiers, half wave controlled rectifier with resistive and inductive load, full wave controlled rectifier using centre-tapped transformer and bridge configuration for resistive and inductive load, use of free-wheeling diode

DC-DC converters: Basic chopper circuit and classification, control strategies, step-up/down chopper (using both SCR and MOSFET), Class A-E choppers, Jones Chopper (load sensitive voltage commutation), Morgan's chopper

Applications of Phase-controlled rectifiers and choppers like DC motor speed control (in both directions), Light intensity of LED array, Variable DC power supply

UNIT – IV (11 Hours)

AC-AC converters: variable-voltage single phase AC power control, SCR and DIAC triggered TRIAC for half wave, full wave AC power control with inductive & non-inductive loads variable-frequency AC-AC Converters, introduction to single phase cycloconverters with resistive and inductive loads

DC-AC converters: Classification of inverters, Improved series inverter, limitations of series inverter, Parallel inverter with reactive feedback, single phase bridge inverter, introduction to McMurray Inverter, voltage control using PWM

Thyristor based control of domestic appliances like fan/others and Speed control of induction motors (block diagrams only)
Idea of Applicable IS/IEC Standards for Invertors and UPS.

Practical component (if any) – Power Electronics Lab
(Hardware and Software Simulation using Multisim/MATLAB/Other Electronics Simulation Software)

Learning outcomes

The Learning Outcomes of this course are as follows:

- Functioning and control of different types of transistors and thyristors
- Working of DC Power control circuits
- Working of AC Power control circuits
- To design and develop a small power control system

LIST OF PRACTICALS (Total Practical Hours- 30 Hours)

1. Study of IV characteristics of SCR/TRIAC, MOSFET/IGBT (Familiarity with use of commercially available Data-Sheet)
2. SCR based phase controlled rectifier with (a) R and RC triggering (b) R and RL loads (c) with and without free-wheeling diode
3. SCR/MOSFET based chopper (DC-DC converter)
4. AC-AC voltage controller using SCR/TRIAC (a) R and RC triggering (b) R and RL loads (c) with and without free-wheeling diode
5. Study of series, parallel and bridge inverter
6. Study of single phase cycloconverter
7. Micro-projects based on power electronics (at least one)
    a. DC motor control using SCR/IGBT based rectifier (AC-DC converter)
    b. Battery eliminator with 0-12V, 1A rating

c. AC motor (Fan) speed control using DIAC triggered TRIAC
d. AC voltage controller using TRIAC with UJT triggering
e. SCR based temperature controller using thermistor
f. Light intensity controller in an LED array
g. Any other similar circuit

Note: Students shall sincerely work towards completing all the above listed practicals for this course. In any circumstance, the completed number of practicals shall not be less than five and one micro-project.

Essential/recommended readings

1. Power Electronics, P.C. Sen, TMH
2. Power Electronics Circuits, Devices and Applications, M.H. Rashid, Pearson Education
3. Power Electronics, P.S. Bimbhra, Khanna Publishers
4. Power Electronics, M.D. Singh & K.B. Khanchandani, TMH

Suggestive readings

1. Power Electronics: Devices, Circuits and Industrial Applications, V.R. Moorthi, Oxford University Press
2. Power Electronics, K. Hari Babu, Scitech Publishing
3. An Introduction to Thyristors and their applications, M. Ramamoorty, Palgrave Macmillan/East West Press

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVES (DSE) COURSES OFFERED BY THE DEPARTMENT

DISCIPLINE SPECIFIC ELECTIVES (DSE-1)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Natural Language Processing ELDSE8A	4	3	-	1	Class XII passed with Physics + Mathematics/Applied Mathematics + Chemistry OR Physics + Mathematics/Applied Mathematics + Computer Science/Informatics Practices	-

Learning Objectives

The Learning Objectives of this course are as follows:
This course introduces the student to the fundamental understanding of Natural Language Processing (NLP) which is a rapidly developing field with broad applicability throughout the hard sciences, social sciences, and the humanities. This course is intended as a theoretical and methodological introduction to the most widely used and effective current techniques, strategies and toolkits for natural language processing, with a primary focus on those available in the Python programming language.

Learning outcomes

The Learning Outcomes of this course are as follows:

- Analyze the natural language text.
- Define the importance of natural language.

- Understand the concepts of Text mining.
- Illustrate information retrieval techniques.
- Analyze the natural language text.

SYLLABUS OF ELDSE-8A **Total Hours- Theory: 45 Hours, Practicals: 30 Hours**

UNIT – I (11 Hours)

Overview and Language Modeling:

Overview: Origins and challenges of NLP-Language, Phases and components of NLP, Applications-Information Retrieval, Unigram Language Model, Bigram, Trigram, N-gram, Advanced smoothing for language modelling, Empirical Comparison of Smoothing Techniques, Applications of Language Modelling.

UNIT – II (12 Hours)

Part of Speech and Word Form:

Natural Language Generation, Parts of Speech Tagging, Morphology, Named Entity Recognition, Rule-base and Stochastic POS tagger, Markov Model, Maximum Entropy model, Bag of words, skip-gram, Continuous Bag-Of-Words, Embedding representations for words Lexical Semantics, Word Sense Disambiguation, Knowledge-Based and Supervised Word Sense Disambiguation.

UNIT – III (11 Hours)

Text Analysis, Summarization and Extraction:

Text Summarization – Extraction and Abstraction, Information Extraction - Tokenization, Named Entity Recognition, Relation Extraction, Information Retrieval, Stop-Word, Stemming, Term weighting, Term Frequency, Document Frequency, Document Frequency Weighting (TFIDF), Text Classification (TF-IDF/Term Frequency Technique), Sentiment Mining.

UNIT – IV (11 Hours)

Machine Translation:

Need of MT, Problems of Machine Translation, MT Approaches, Direct Machine Translations, Rule-Based Machine Translation, Knowledge Based MT System, Statistical Machine Translation (SMT), Parameter learning in SMT (IBM models) using EM),

Encoder-decoder architecture, Neural Machine Translation

Practical component (if any) – Natural Language Processing Lab
(Python/MATLAB)

Learning outcomes

The Learning Outcomes of this course are as follows:

- To experiment with the concepts introduced in the course Natural Language Processing.
- Ability to program various techniques of NLP.
- Design and develop applications for text or information extraction/summarization/classification

LIST OF PRACTICALS (Total Practical Hours- 30 Hours)

1. Perform sentence tokenization to break a text paragraph into individual sentences.
2. Perform word tokenization to break a text paragraph into individual words.
3. For the text selected in Practical 1, remove stop words and punctuation marks.
4. Apply the stemming technique to the text document selected in Practical 1 to obtain root words.
5. Perform different forms of lemmatization on the text document selected in Practical 1 to obtain base forms of words.
6. Extract the top 10 most common words in the selected text, excluding stop words.
7. Extract nouns and pronouns from the text and calculate similarities between any two words using a suitable method.
8. Case Study – Sentiment Analysis: Students will preprocess a text dataset (e.g., movie reviews or tweets) using tokenization, stemming, and feature extraction (TF-IDF or word embeddings). They will build and evaluate a sentiment classification model (e.g., Logistic Regression or Naive Bayes) and analyze its performance using metrics like accuracy and F1-score.
9. Case Study-Language identification: Students will work with a multilingual dataset to preprocess text and extract features using character or word-level n-grams. They will train a language classification model (e.g., Naive Bayes or Random Forest) to identify the language of text samples and evaluate it with a confusion matrix and accuracy metrics.

Note: Students shall sincerely work towards completing all the above listed practicals for this course. In any circumstance, the completed number of practicals shall not be less than eight.

Essential/recommended readings

1. Daniel Jurafsky and James H Martin, "Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics and Speech Recognition", 2nd Edition, Prentice Hall, 2008.
2. James Allen, "Natural Language Understanding", 2nd edition, Benjamin/Cummings publishing company, 1995.
3. Gerald J. Kowalski and Mark.T. Maybury, "Information Storage and Retrieval systems", Kluwer academic Publishers, 2000.

Suggestive readings

1. Natural Language Processing with Python – Analyzing Text with the Natural Language Toolkit, Steven Bird, Ewan Klein, and Edward Loper.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVES (DSE-2)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Mobile and Satellite Communication ELDSE8B	**4**	**3**	**-**	**1**	**Class XII passed with Physics + Mathematics/Applied Mathematics + Chemistry OR Physics + Mathematics/Applied Mathematics + Computer Science/Informatics Practices**	**-**

Learning Objectives

The Learning Objectives of this course are as follows:

- To introduce the fundamental concepts of communication systems in the field of wireless communication.
- To identify and discuss the fundamental operation and design problems of wireless communication systems.
- To gain an understanding over the applications of communication in day-to-day real world.

Learning outcomes

The Learning Outcomes of this course are as follows:

- Understand fundamentals of Wireless Communication System
- Comprehend the Protocols and Technologies in the Wireless Environment
- Understand the working of a Cellular Communication System.
- Understand the working of Satellite Communication.

SYLLABUS OF ELDSE-8B **Total Hours- Theory: 45 Hours, Practicals: 30 Hours**

UNIT – I (12 Hours)

Introduction to Wireless Communication: Principle of Wireless Communication: advantages, disadvantages and applications. Cellular Revolution, Spread Spectrum: The Concept of Spread Spectrum, Frequency Hopping Spread Spectrum, Direct Sequence Spread Spectrum, Code Division Multiple Access, Generation of Spreading Sequences, Coding and Error Control: Block Error Correction Codes (Hamming Code and Cyclic Codes), Automatic Repeat request (Flow and Error Control)

UNIT – II (11 Hours)

Wireless LAN Technologies and Protocols: Network Topologies, LAN, MAN, WAN and PAN.Wireless LAN: Applications, Requirements and Technology, Infrared LANs, Spread Spectrum LANs and Narrow Band LANs
Wireless LANs: IEEE 802.11 Protocol Stack,
Broadband Wireless: IEEE 802.16 Protocol Stack,
Bluetooth: Architecture, Applications and Protocol Stack

UNIT – III (11 Hours)

Satellite Communication: Satellite Orbits, Kepler Laws, Satellite Communication Systems, Repeaters and Transponders, Communication Subsystems, Power Subsystem, Telemetry, Command and Control Subsystems, Ground Stations.
Applications: Communication Satellites, Digital Satellite, Surveillance Satellites, Navigation Satellite, GPS.

UNIT – IV (11 Hours)

Cell Phone Technologies: Evolution of Mobile Radio Communication, Paging System, Cordless Telephones Systems, Internet Telephony.
Cellular Telephone Systems: Cellular Concepts, Frequency Allocation, Multiple Access, AMPS, Digital Cell Phone Systems, Advanced Cell Phones, Personal Satellite Communication System.

Practical component (if any) – Mobile and Satellite Communication Lab
(Hardware/Software) The practical needs to be performed on MATLAB/Packet Tracer/VLabs or any other equivalent software/supporting hardware

Learning outcomes

The Learning Outcomes of this course are as follows:

- Understand the basic elements of a wireless communication system.
- Build and understand the various network topologies.
- Understand the concept of various important parameters related to wireless communication systems.

- Prepare the technical report on the experiments carried.

LIST OF PRACTICALS (Total Practical Hours- 30 Hours)

S.No.	Category	Title of Experiment
1	Wireless Communication	Simulate TDMA, FDMA and CDMA for wireless communication using MATLAB or equivalent.
2	Simulation of network topologies	Implement MESH/STAR/RING/BUS topology in Packet Tracer.
3	Tracing across Networks	Connect two different networks using a router in Packet Tracer and show movement of packets from one network to the other.
4	Bluetooth Simulation	Connect two Bluetooth devices-Portable Music Player & Bluetooth speaker and Configure to play music using Packet Tracer.
5	Frequency Reuse	Find the co-channel cells for a particular cell. http://vlabs.iitkgp.ac.in/fcmc/exp6A/index.html
6	Frequency Reuse	Find the cell clusters within certain geographic area. http://vlabs.iitkgp.ac.in/fcmc/exp6B/index.html
7	Sectoring	The aim of the experiment is to understand the impact of many different parameters which influence the downlink C/I ratio. http://vlabs.iitkgp.ac.in/fcmc/exp7/index.html#
8	Handoff	To study the effect of handover threshold and margin on SINR and call drop probability and handoff probability. http://vlabs.iitkgp.ac.in/fcmc/exp8/index.html
9	Calculation of Boundary Coverage Probability	To calculate the probability that the received signal level crosses a certain sensitivity level. http://vlabs.iitkgp.ac.in/fcmc/exp4/index.html
10	Calculation of SINR including Beam Tilt	To understand the concept of co-channel interference and hence Signal to Interference and Noise Ratio. http://vlabs.iitkgp.ac.in/fcmc/exp5/index.html
11	Satellite Network	Simulation of a Satellite Network http://vlabs.iitkgp.ac.in/ant/4/theory/

Note: Students shall sincerely work towards completing all the above listed practicals for this course. In any circumstance, the completed number of practicals shall not be less than ten.

Essential/recommended readings

1. Wireless Communications and Networks by William Stallings (Pearson Education)
2. Principles of Electronic Communication Systems, Third Edition by Frenzel (Tata McGraw Hill)

Suggestive readings

1. Electronic Communication Systems, Fifth Edition by Wayne Tomasi (Pearson Education)
2. Data Communication and Networking, Fourth Edition by Behrouz Forouzan (Tata McGraw Hill)
3. Wireless Communications Principles and Practice, Third Edition by Theodore Rappaport (Pearson Education)
4. Satellite Communications, Third Edition by Dennis Roddy (Tata McGraw Hill)

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVES (DSE-3)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
CMOS Analog VLSI Design ELDSE8C	4	3	-	1	Class XII passed with Physics + Mathematics/Applied Mathematics + Chemistry OR Physics + Mathematics/Applied Mathematics + Computer Science/Informatics Practices	Digital Electronics, Analog Electronics-I & II, Basic VLSI Design

Learning Objectives

The Learning Objectives of this course are as follows:
This course introduces the student to the fundamental understanding of Analog Circuits, Switched Capacitor Circuits, Phase locked loops, Converters and Filters.

Learning outcomes

The Learning Outcomes of this course are as follows:

- Extend the mixed signal design to different applications
- Comprehend the concept of Switched Capacitor Circuits
- Understand different types of Phase Locked Loops
- Build Mixed Signal Circuits and understand different Continuous Time Filters
- Analyze the Data Converter architecture and choose the most appropriate Data Converter for the specified applications

SYLLABUS OF ELDSE-8C **Total Hours- Theory: 45 Hours, Practicals: 30 Hours**

UNIT – I (09 Hours)
CMOS Analog Circuits: Current Sources and Sinks, Current Mirror, Differential Amplifiers, Operational Amplifiers-Basic CMOS Op-Amp design, Operational Transconductance Amplifiers, CMOS Instrumentation Amplifier.

UNIT – II (12 Hours)
Switched Capacitor Circuits: Overview of Switched Capacitor circuits, Basic building blocks, Operation and Analysis, Non-ideal effects in Switched Capacitor Circuits, Switched Capacitor Integrators, First Order Filters

UNIT – III (09 Hours)
Continuous Time Filters: Overview of gm-C (Transconductor-C) filter, CMOS Transconductance Amplifier using Triode and active transistors, MOSFET-C filters

UNIT – IV (15 Hours)
Phased Locked Loop (PLL): Simple PLL, Basic PLL topology, Dynamics of Simple PLL, Overview of Charge Pump PLLs, Applications: Frequency Multiplication and Synthesis and Skew reduction.
Data Converter Fundamentals: Sample and Hold Circuit, Ideal D/A and A/D converter, Quantization Noise, Performance limitations. Types of A/D and D/A converters (overview of any one or two)

Practical component (if any) – CMOS Analog VLSI Design Lab
(Practicals to be performed using Ngspcie/LTspice/QUCS, CADENCE/MENTOR GRAPHICS)

Learning outcomes

The Learning Outcomes of this course are as follows:

- Apply VLSI design methodologies to analyze and design the Analog Circuits
- Comprehend the design and working of Mixed Signal Circuits
- Get familiarized with the VLSI design Simulation Tools

LIST OF PRACTICALS (Total Practical Hours- 30 Hours)

1. Implement a Current Mirror Circuit
2. Implement an Operational-Transconductor Amplifier
3. Implement a Sample and Hold Circuit for a given sampling rate.
4. Implement a First order Switch Capacitor Filter
5. Implement a Simple Phase Locked Loop Circuit
6. Implement a Single-ended First Order Gm-C Filter
7. Implement an A/D converter or D/A converter

Note: Students shall sincerely work towards completing all the above listed practicals for this course. In any circumstance, the completed number of practicals shall not be less than six.

Essential/recommended readings

1. R. Jacob Baker, CMOS Mixed-Signal Circuit Design, Wiley Interscience, 2008, ISBN-10 9788126516575, ISBN-13 978-8126516575
2. Kenneth Martin Chan Carusone, David Johns, Analog Integrated Circuit Design, Wiley Student Edition, 2013, ISBN-10 9788126543939, ISBN-13 978-8126543939
3. Behzad Razavi, Design of Analog CMOS Integrated Circuits, TMH Edition, 2017, ISBN-10 938706784X, ISBN-13 978-9325983274

Suggestive readings

1. Philip E. Allen and Douglas R. Holberg, CMOS Analog Circuit Design, Oxford University Press, International Second Edition/Indian Edition, 2016, ISBN-10 0199765073, ISBN-13 978-0199765072

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVES (DSE-4)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Nanomaterials and their Applications ELDSE8D	4	4	-	-	Class XII passed with Physics + Mathematics/Applied Mathematics + Chemistry OR Physics + Mathematics/Applied Mathematics + Computer Science/Informatics Practices	-

Learning Objectives

The Learning Objectives of this course are as follows:
This course builds the basic background of nanomaterials, nanostructures and their properties. Classification of nanomaterials and its chemistry is explained and in addition to this, they are made aware of the various applications of nanomaterials.

Learning outcomes

The Learning Outcomes of this course are as follows:

- To understand classification of nanomaterials.
- To have a broad idea of applications of nanoscience in various fields.
- To understand carbon technology in nanoscience and nanotechnology.
- To have an idea of nano devices and sensors

SYLLABUS OF ELDSE-8D	**Total Hours- Theory: 60 Hours**

UNIT – I (14 Hours)
Nanomaterials:
Classification of nanomaterials: Nanosized metals and alloys, semiconductor, Ceramics- a comparison with respective bulk materials, Organic compounds and polymers, carbon age-new form of carbon (CNT to Graphene), Nanocomposites.

Nano ceramics: Dielectrics, ferroelectrics and magneto ceramics, Nanopolymers: Preparation and characterization of diblock Copolymer based nanocomposites, Nanoparticles polymer ensembles; Applications of Nanopolymers in Catalysis.

Classification of conducting polymers: Intrinsic and extrinsic conducting polymers - Chemical and electrochemical methods of the synthesis of conducting polymers.

UNIT – II (16 Hours)
Applications of Nanomaterials for Sustainable Environment:
Nanomaterials in Energy Technology- Introduction: Nanotechnology for sustainable energy- Energy conversion process, indirect and direct energy conversion, use of nanoscale catalysts to save energy and increase the productivity in industry.

Electrochemical Energy Storage Systems: Batteries: Primary, Secondary, Lithium, solid-state and molten solvent batteries; Lead acid batteries; Nickel Cadmium batteries; Advanced batteries.

Nanomaterials in Energy Storage: Nano-electrochemical systems, nanomaterials for rechargeable batteries, nanomaterials for fuel cells.

Environmental applications of nanomaterials: Mechanism for remediation of aqueous contaminants, photocatalyst; membranes incorporating nanomaterials, transport processes in membrane technology; nanomaterial-based adsorbents for water and wastewater treatment – adsorption at metal oxide surfaces, hybrid adsorbents.

UNIT – III (14 Hours)
Carbon Nanotechnology:
Introduction to carbon nanotubes and their applications in various industries, supercapacitors, hydrogen storage; Nanomaterials for solar power: Solar energy materials, Solar energy devices, silicon solar technology for clean energy, Light Emitting Diodes, LED displays.

UNIT – IV (16 Hours)

Nano Devices and Sensors:

Introduction to Gas sensors; Characteristics of Gas sensors; Types of Gas sensors; Solid State Gas sensors: Chemiresistive Gas sensors (Semiconducting Metal Oxide based sensors, Carbon Nano Tube based nano sensors).

Miscellaneous applications: Microfluidics and Microsystems, Micro-electromechanical systems, ChemFET (NEMs and MEMS based sensors), Optic Gas sensors, Spectroscopic Gas sensors, Chemical Sensors: Electrochemical Gas Sensors.

Nano magnetism

Magnetism and Magnetic Materials, Basics of Magnetism, Magnetic Domains and Anisotropy, Magnetic Nanostructures, Magnetism of Nanosized Materials, Spintronics technology and the challenges, Electron and nuclear spin devices

Practical component (if any) – None

Essential/recommended readings

1. Introduction to Nanomaterials and Devices : Omar Manasreh (Wiley)
2. Textbook of Nanoscience and Nanotechnology, B S Murty and others, 2013, Springer, e-ISBN 978-3-642-28030-6
3. Nano: The Essentials- Understanding Nanoscience and Nanotechnology, T. Pradeep, TMH Publishing Company Limited
4. Linden, Handbook of Batteries and fuel cells, Mc Graw Hill, (1984).
5. Wiesner, M.R., and Bottero, J.Y. (Ed.) “Environmental Nanotechnology: Applications and Impacts of Nanomaterials” McGraw-Hill, New York. 2007

Suggestive readings

1. Diallo, M., Duncan, J., Savage, N., Street, A., and Sustich, R. (Eds). “Nanotechnology Applications for Clean Water” William Andrew. 2008
2. Martin A Green, Solar cells: Operating principles, technology and system applications, Prentice Hall Inc, Englewood Cliffs, NJ, USA, (1981).
3. Nanosensors: Physical, Chemical, and Biological by Vinod Kumar Khanna, Publisher: CRC Press.
4. Novel Nanocrystalline Alloys and Magnetic Nanomaterials- Brian Cantor

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVES (DSE-5)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Nanomaterials Characterization ELDSE8E	**4**	**3**	**-**	**1**	**Class XII passed with Physics + Mathematics/Applied Mathematics + Chemistry OR Physics + Mathematics/Applied Mathematics + Computer Science/Informatics Practices**	**-**

Learning Objectives

The Learning Objectives of this course are as follows:

- Various existing techniques used in nanotechnology
- Physical principles/concepts involved in fabrication of the materials at nano scale
- Various advanced characterization equipment used to characterize different types of materials.
- Advanced optical and magnetic characterization techniques

Learning outcomes

- The Learning Outcomes of this course are as follows:
- Understand the concept of Top-down and Bottom-UP approaches for synthesis and processing of nanomaterials
- Understand structural and optical characterization of nanoparticles
- Understand electrical and magnetic characterization of nanoparticles

SYLLABUS OF ELDSE-8E Total Hours- Theory: 45 Hours, Practicals: 30 Hours

UNIT – I (11 Hours)

Introduction to Synthesis Approaches:

Concept of bulk versus nanomaterials and dependence of properties on size. Introduction to 'Top down' vs. 'Bottom up' approaches for synthesis of nanostructures (with suitable examples.), Physical, chemical and biological synthesis mechanism. Advantages and disadvantages of top down. Advantages and disadvantages of bottom up

UNIT – II (12 Hours)

Characterization and Data Analysis: Scattering & Imaging techniques:

Structural: X-Ray Diffraction, Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectroscopy, Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM).

UNIT – III (11 Hours)

Characterization and Data Analysis using Spectroscopic techniques:

Optical: Ultraviolet-Visible-Infrared Absorption, Fourier Transform Infrared Spectroscopy, Raman Spectroscopy, Photoluminescence

UNIT – IV (11 Hours)

Characterization and Data Analysis: Electrical and Magnetic

Electrical: Electrochemical techniques (Cyclic Voltammetry), resistivity, Four Probe Method

Magnetic: Magneto-Resistance, Vibrating Sample Magnetometer, , Magneto Optical Kerr Effect, Magnetic Force Microscopy.

Practical component (if any) – Nanomaterials Characterization Lab
(Use any relevant software(s))

Learning outcomes

The Learning Outcomes of this course are as follows:

- Calculate the material parameters of nanomaterials using suitable characterization techniques using secondary data.
- Visit to Research laboratories/ Instrumentation Centre and use advanced tools/techniques for synthesis and characterization of nanomaterials.
- Prepare technical reports of the experiments carried out.

LIST OF PRACTICALS (Total Practical Hours- 30 Hours)

1. XRD analysis of the given XRD spectra using secondary data and thus determine the particle size and other parameters of nanomaterial.

2. To analyze chemical properties of a nanomaterial using UV-Visible spectroscopy secondary data
3. Find out the optical band gap of a nanomaterial using UV-Visible spectroscopy secondary data.
4. Software like ImageJ based structural analysis from secondary data (SEM/TEM).
5. To identify the presence of functional groups in nanomaterials using FTIR secondary data.
6. Report writing and presentation of the Lab Visit

Note: Students shall sincerely work towards completing all the above listed practicals for this course. In any circumstance, the completed number of practicals shall not be less than five.

Essential/recommended readings

1. Introduction to Nanotechnology, Charles P. Poole Jr and Frank J. Owens, Wiley Interscience, 2003.
2. Nanotechnology: Principles & Practices, S.K. Kulkarni, Springer, 2015
3. Nanotechnology Synthesis to Applications, Sunipa Roy, Chandan Kumar Ghosh, Chandan Kumar Sarkar, CRC Press, 2018

Suggestive readings

1. Nanostructures and Nanomaterials Synthesis, Properties, and Applications, Guozhong Gao, Imperial College Press, 2004

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVES (DSE-6)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Digital Control System ELDSE8F	4	3	-	1	Class XII passed with Physics + Mathematics/Applied Mathematics + Chemistry OR Physics + Mathematics/Applied Mathematics + Computer Science/Informatics Practices	-

Learning Objectives

The Learning Objectives of this course are as follows:
This course introduces the students to fundamental concepts, principles and application of digital control system analysis and design. The topics cover classical control design as well as the modern control design methods

Learning outcomes

The Learning Outcomes of this course are as follows:

- Familiarize basic concepts for analysis of discrete-time domain systems.
- Use of pulse transfer function in discrete time systems.
- Stability analysis of digital control systems
- Design of compensators and controllers for desired time/frequency response.
- Design of estimators and observers

SYLLABUS OF ELDSE-8F **Total Hours- Theory: 45 Hours, Practicals: 30 Hours**

UNIT – I (11 Hours)
Digital Control System:
Overview of control systems (open-loop vs closed-loop), Introduction to digital control systems, Continuous-time vs discrete-time control systems, Sampling theory: Sampling theorem and Nyquist rate, Aliasing and anti-aliasing filters, Reconstruction using zero-order hold (ZOH), Quantization effects, Discrete-time signals and systems, Z-transform and pulse transfer functions

UNIT – II (11 Hours)
Stability Analysis:
Stability analysis of discrete-time systems: Jury's stability criterion, Stability analysis using bi-linear transformation, Time response of discrete-time systems-Transient and steady-state responses, Design of sampled data control system-Discrete Root locus analysis, Frequency domain analysis: Bode and Nyquist plots (for sampled systems), Concept of Lyapunov stability

UNIT – III (11 Hours)
Discrete State-space Analysis:
State variable model, State-space representations for discrete-time systems, canonical forms, the solution to discrete-time state-space equation, state transition matrix (STM), controllability, observability and stability of discrete state space models

UNIT – IV (12 Hours)
Design and Analysis of Discrete-time Control System*:
Design of digital control based on the frequency response method Bilinear Transformation and Design procedure in the w-plane, Lead, Lag and Lead-Lag compensators, and digital PID controllers, Deadbeat control design. Design of state feedback controller through pole placement – Necessary and sufficient conditions

*Note: Controllers like digital PID, state-feedback controllers are to be designed in the discrete-time domain to work with sampled data. Software tools like MATLAB/Simulink to simulate and optimize digital controllers.

Practical component (if any) – Digital Control System Lab
(Software Platform: MATLAB/Simulink or similar software)

Learning outcomes

The Learning Outcomes of this course are as follows:

- Perform experiments involving concepts of Digital Control for Automation
- Simulate different types of Digital Filters
- Perform the stability analysis of a system

- Design and simulate controllers using different techniques studied in theory paper
- Prepare the technical report on the experiments carried

LIST OF PRACTICALS (Total Practical Hours- 30 Hours)

1. Simulate the step response of a sampled-data (digital) control system
2. Stability analysis of a system using bode plot, root locus, and pole-zero gain representation
3. To obtain closed loop step and impulse response of a first order unity feedback system
4. Simulate a PD, PI and PID control design with a discrete-time controller. Compare the steady state response.
5. Simulate a frequency-domain controller to transform a continuous-time control design to a discrete-time control design
6. Design and simulate a Frequency-response controller or a State-feedback controller
7. Design of lead-lag compensator

Note: Students shall sincerely work towards completing all the above listed practicals for this course. In any circumstance, the completed number of practicals shall not be less than six.

Essential/recommended readings

1. K. Ogata, "Discrete-Time Control Systems", Second Edition, Prentice Hall.
2. M. Gopal, "Digital Control and State Variable Methods", Fourth Edition, 2012, Tata Mcgraw Hill, ISBN 9780071333276 / 0071333274.
3. B. C. Kuo, "Digital Control Systems", Second Edition, Oxford University Press.

Suggestive readings

1. C. Phillips, H. Nagle, A. Chakrabortty, "Digital Control System Analysis & Design", Pearson
2. G. F. Franklin, J. D. Powell and M. L. Workman, "Digital Control of Dynamic Systems", Addison Wesley, Pearson

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.