SEMESTER 7

APPLIED ELECTRONICS AND INSTRUMENTATION

SEMESTER S7

ELECTRONIC DESIGN AUTOMATION

Course Code	PEAET741	CIE Marks	40
Teaching Hours/Week (L:T:P:R)	3:0:0:0	ESE Marks	60
Credits	3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	-	Course Type	Theory

Course Objectives:

1. To understand the algorithm behind electronic design automation based on graph theory
2. To familiarize algorithms used for partitioning and layout compaction in Integrated circuits
3. To equip with placement and routing algorithm used in VLSI industry

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	Graph Terminology - Basic graph theory terminology, Data structures for representation of graphs. Graphs Search Algorithms - Breadth First Search, Depth First Search, Topological Sort. Shortest Path Algorithms - Dijkstra's Shortest Path Algorithm and Floyd Warshall Algorithm	9
2	Design Automation - VLSI Design Flow, VLSI Design Styles Partitioning Algorithms - Kernighan-Lin Algorithm, Fiduccia-Mattheyses Algorithm (Basic algorithmic description only) Layout - Layout Layers and Design Rules, Physical Design Optimizations	9
3	Compaction - Applications of Compaction Maximum Distance Constraints. Placement - Wirelength Estimation, Weighted Wirelength, Maximum Cut Size, Wire Density. Placement Algorithm - Quadratic Placement. Floor planning - Slicing Floorplan, Non-Slicing Floorplan Floorplan Representations - Constraint Graph, Sequence Pair	9

4	Global Routing - Terminology and Definitions Maze Routing Algorithm - Lee's Algorithm Detailed Routing - Horizontal and Vertical Constraint Graph Channel Routing Algorithm -Left-Edge algorithm Basic concepts of Static Timing Analysis	**9**

Course Assessment Method

(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	Assignment/ Microproject	Internal Examination-1 (Written)	Internal Examination- 2 (Written)	Total
5	**15**	**10**	**10**	**40**

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24 Marks)**	• Each question carries 9 marks. • Two questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub divisions. **(4x9 = 36 Marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Apply Search Algorithms and Shortest Path Algorithms to find various graph solutions.	**K3**
CO2	Outline VLSI Design Flow and Design Styles and apply partitioning algorithms on graphs representing netlist	**K3**
CO3	Illustrate Design Layout Rules and apply different algorithms for layout compaction	**K3**
CO4	Make use of various algorithms to solve placement, floorplan and routing problems	**K3**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2		3							3
CO2	3	3	2		3							3
CO3	3	3	2		3							3
CO4	3	3	2	2	3							3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	VLSI Physical Design: From Graph Partitioning to Timing Closure	Jin Hu, Jens Lienig, Igor L. Markov, Andrew B. Kahng	Springer	2011
2	Algorithms for VLSI Design Automation	Gerez,S abih H	John Wiley & Sons	2006
3	Algorithms for VLSI Physical Design Automation	Sherwani, Naveed A	Kluwer Academic Publishers,	1999

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	VLSI Physical Design Automation: Theory and Practice	Sadiq M. Sait and H. Youssef	World Scientific	1999
2	CMOS VLSI Design : A circuits and systems perspective	Neil H. E. Weste and David Money Harris	Pearson	4th Edition, 2015
3	VLSI Design Methodology Development	Thomas Dillinger	Pearson	1st Edition, 2020

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://nptel.ac.in/courses/106105161
2	https://nptel.ac.in/courses/106105161
3	https://nptel.ac.in/courses/106105161
4	https://nptel.ac.in/courses/106105161

SEMESTER S7

ELECTRIC VEHICLES AND RENEWABLE TECHNOLOGIES

Course Code	PEAET742	CIE Marks	40
Teaching Hours/Week (L: T:P: R)	3:0:0:0	ESE Marks	60
Credits	3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	None	Course Type	Theory

Course Objectives:

1. To familiarize Vehicle Performance and Propulsion Systems.
2. To Illustrate Energy Systems and Renewable Sources

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	**Conventional Vehicles** - Basics of vehicle performance, Vehicle power source characterization, Transmission characteristics. **Introduction to Electric Vehicles** - History of electric vehicles, Classification of electric vehicles. Overview of EV challenges. Overview of EV technologies-motor drive technology, energy source technology, battery charging technology, vehicle-to-grid technology. **Vehicle Dynamics & Load Forces -** Mathematical models to describe vehicle performance, vehicle load forces: aerodynamic drag, rolling resistance, grading resistance, vehicle acceleration, Calculation of motor power from traction torque, Simple Numerical problems. **Electric Drive-trains -** Basic concept of electric traction, electric drive-train topologies (Basics only), Power flow control in electric drive-train topologies, Fuel efficiency analysis.(Derivations not required)	9
2	**DC Drives -** Motoring using a PM DC Machine - DC motor electric drive using DC-DC converter - Generating/Braking using a PM DC Machine. **PMSM Drives -** Review of PMSM motor basics – Independent control of orthogonal flux and torque (concept only)- Field Oriented Control (FOC) – Sensor based and sensorless control (block diagram only).	9

	Sizing the drive system - Matching the electric machine and the Internal Combustion Engine (ICE) , Sizing the propulsion motor, Sizing the power electronics-Switch technology selection, Ripple capacitor design, Switching frequency and PWM	
3	**Battery based energy storage systems** - Types of battery-battery parameters-units of battery energy storage - capacity rate, - cell voltage - specific energy - cycle life - self-discharge. Battery management system. **Other storage topologies** - Fuel Cell based energy storage systems-Supercapacitors - Hybridization of different energy storage devices. **Overview of Electric Vehicle Battery Chargers** –Types of chargers-On-board chargers, Off- board chargers, Wireless charger (Concept only). Electric Vehicle Supply Equipment (EVSE) - Grid to EVSE to On-board chargers to battery pack power flow block schematic diagrams – V2G concept. Introduction to AC and DC charging stations (Basics and Block diagram only). Types of Connectors - CHAdeMO, CCS Type1 and 2, GB/T.	**9**
4	**Renewable Energy sources -** World Energy Scenario, Indian Energy Scenario, Comparison of Conventional and Non-Conventional Energy Resources; Solar Energy: Introduction- Solar Photovoltaic –Solar Cell fundamentals, characteristics, cell efficiency, applications, Wind Energy– Introduction–Wind Turbine Types (HAWT and VAWT) - Wind power curve-Betz's Law-Power from a wind turbine, Tidal Energy –Principle of Tidal Power, Components of Tidal Power Plant (TPP), Classification of Tidal Power Plants, Advantages and Limitations of TPP.	**9**

Course Assessment Method
(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	Assignment/ Microproject	Internal Examination-1 (Written)	Internal Examination- 2 (Written)	Total
5	**15**	**10**	**10**	**40**

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24marks)**	• Each question carries 9 marks. • Two questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub divisions. **(4x9 = 36 marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Familiarise the performance of conventional vehicles and electric vehicles	**K2**
CO2	Analyse the various drive train topologies for electric vehicles	**K3**
CO3	Discuss the propulsion unit for electric vehicles and selection of drive systems	**K3**
CO4	Analyse the various energy storage systems and energy management strategies	**K3**
CO5	Illustrate the different renewable energy sources	**K2**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3		2									3
CO2	3		2									3
CO3	3		2		2							3
CO4	3		2		2							3
CO5	3		2		2							3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Electric Vehicle Technology Explained	James Larminie and John Lowry,	Wiley	2nd Edition, 2012
2	Electric and Hybrid Vehicles: Design Fundamentals	Iqbal Husain	CRC Press	2nd Edition, 2010
3	Renewable Energy Sources and Emerging Technologies	D. P. Kothari, K. C. Singal and Rakesh Ranjan	PHI	3rd Edition, 2021

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Elementary Concepts of Power Electronic Drives	K Sundareswaran	CRC Press	1st Edition, 2019
2	Non-Conventional Energy Resources	Sawhney G. S.	PHI	1st Edition, 2012
3	Sensored Field Oriented Control of 3-Phase Permanent Magnet Synchronous Motors (Application Notes)	Ramesh T Ramamoorthy, Brett Larimore, Manish Bhardwaj	TI	NA

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://nptel.ac.in/courses/108106170 https://archive.nptel.ac.in/courses/108/106/108106182/
2	https://nptel.ac.in/courses/108106170 https://archive.nptel.ac.in/courses/108/106/108106182/
3	https://archive.nptel.ac.in/courses/108/106/108106182/
4	https://archive.nptel.ac.in/courses/108/106/108106182/

SEMESTER S7

NON-LINEAR CONTROL SYSTEMS

Course Code	PEAET743	CIE Marks	40
Teaching Hours/Week (L: T:P: R)	3:0:0:0	ESE Marks	60
Credits	3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	-	Course Type	Theory

Course Objectives:

1. To understand non-linear system behaviour.
2. To perform stability analysis of non-linear control systems.
3. To design non-linear controllers.

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	**Introduction -** Linear vs non-linear system, Common Nonlinearities in control systems, non–linear system behaviour, examples, Autonomous and non-autonomous systems, equilibrium points. **Phase Plane Analysis -** Singular points, construction of phase portraits, method of isoclines only, phase plane analysis of linear systems, phase plane analysis of non-linear systems, local behaviour of non-linear systems. Stability of limit cycles, Poincare, bendixon theorems.	**9**
2	**Describing Function -** Describing Function Fundamentals, Describing functions of common nonlinearities - hysteris, backlash, relay, deadzone, saturation and combined effects. Application of describing function for stability analysis of autonomous system with single nonlinearity (relay, dead zone and saturation only).	**9**
3	**Stability of nonlinear systems -** Lyapunov theory (review) - autonomous and non-autonomous systems equilibrium points, Stability in the sense of Lyapunov, asymptotic stability and exponential stability, Linearization and local stability, Lyapunov's direct method, positive definite functions and Lyapunov functions, Lyapunov theorem for local stability and global stability.	**9**

	Analysis based on Lyapunov's direct method, LTI systems - simple problems.	
4	Krasovskii's method, Variable gradient method for constructing Lyapunov functions-simple examples, Popov's stability criterion. Non-Linear control system design-desired behaviour of nonlinear systems- Issues in constructing non-linear controllers- available methods of non-linear control design.	**9**

Course Assessment Method
(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	Assignment/ Microproject	Internal Examination-1 (Written)	Internal Examination- 2 (Written)	Total
5	**15**	**10**	**10**	**40**

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24marks)**	• Each question carries 9 marks. • Two questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub divisions. **(4x9 = 36 marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Illustrate Nonlinear System Behavior and Phase Plane Analysis	**K3**
CO2	Apply Describing Functions for Stability Analysis	**K3**
CO3	Evaluate System Stability Using Lyapunov Methods	**K5**
CO4	Design Nonlinear Controllers	**K4**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2									3
CO2	3	2	2									3
CO3	3	2	2									3
CO4	3	2	2									3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Control System Engineering	Nagarath I. J. and Gopal M.	New Age Publishers	6e, 2017
2	Applied Nonlinear Control	Jean Jacques Slotine and Weiping Li	Prentice Hall Inc	1991

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Nonlinear Systems	H. K. Khalil	Pearson Education	3/e, 2002
2	Nonlinear Systems: Analysis, Stability, and Control	Shankar Sastry	Springer	1999
3	Nonlinear and Optimal Control Systems	by Thomas L. Vincent, Walter J. Grantham	Wiley	1/e, 1997
4	Nonlinear Process Control	Michael Henson, Dale E. Seborg	Prentice Hall	1997

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://archive.nptel.ac.in/courses/108/106/108106024/
2	https://archive.nptel.ac.in/courses/108/106/108106024/
3	https://archive.nptel.ac.in/courses/108/106/108106024/
4	https://archive.nptel.ac.in/courses/108/106/108106024/

SEMESTER S7

MOBILE ROBOTICS

Course Code	PEAET744	CIE Marks	40
Teaching Hours/Week (L: T:P: R)	3:0:0:0	ESE Marks	60
Credits	3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	-	Course Type	Theory

Course Objectives:

1. To familiarize types of locomotion and sensors for mobile Robots
2. To perform localization, path planning, kinematic modelling and control of mobile robots

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	Legged locomotion - Leg configurations and stability, Examples of legged robot locomotion. Wheeled locomotion - conventional wheels, special wheels, drive types - Differential drive, Tricycle, Omnidirectional, Synchro drive, Ackerman steering, Skid steering. **Case study -** Basic simulation of a turtle bot in ROS, Building a Visual Robot Model with URDF from Scratch, Building a Movable Robot Model with URDF.	9
2	Sensors for Mobile Robots - Sensor classification, characterizing sensor performance, Wheel/motor sensors, Heading sensors, Ground-based beacons, Active ranging, Motion/speed sensors, Vision-based sensors. Representing Uncertainty in sensor measurements - Statistical representation, Error propagation - combining uncertain measurements. **Case study** - Adding sensors to the robot models in ROS	9
3	Robot Localization, Error propagation model, Probabilistic map-based localization - Kalman method, Other Examples of Localization Systems,	9

	Landmark-based navigation, Positioning beacon systems. Path planning of mobile robots - Road map, Cell decomposition, Potential field - Obstacle avoidance (Bug algorithm), Vector field histogram, Dynamic window approach **Case study** - Familiarization with 2D navigation stack, Basic ROS Navigation, Start robots in simulation	
4	Kinematic model of unicycle robot and differential drive robot, and car like mobile robot or steered robot. Control of mobile robots - Control of differential drive robot and steered robot based on its kinematic model. **Case study** (Overview only) - design and implementation of a differential drive robot capable of moving to a point, following a line and following a path. **Case study** - Control of a differential drive robot in ROS to move to a goal location	**9**

Course Assessment Method

(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	Assignment/ Microproject	Internal Examination-1 (Written)	Internal Examination- 2 (Written)	Total
5	**15**	**10**	**10**	**40**

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24 marks)**	• Each question carries 9 marks. • Two questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub divisions. **(4x9 = 36 marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Familiarize types of locomotion and sensors for mobile Robots	**K2**
CO2	Perform localization and path planning for mobile robots	**K3**
CO3	Develop kinematic model of mobile robots	**K3**
CO4	Control the mobile robots to follow different paths	**K3**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3		3							3
CO2	3	2	3		3							3
CO3	3	2	3		3							3
CO4	3	2	3		3							3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Introduction to Autonomous Mobile Robots	R. Siegwart, I. R. Nourbakhsh and Davide Scaramuzza	The MIT Press	2nd Edition, 2011
2	Introduction to Mobile Robot Control	Spyros G. Tzafestas	Elsevier	1st Edition, 2013
3	Robotics, Vision and Control: Fundamental Algorithms in MATLAB,	Peter Corke	Springer Tracts in Advanced Robotics,	2nd Edition, 2017
4	Robot Operating Systems (ROS) for Absolute Beginners	Lentin Joseph and Aleena Johny	Apress	1st Edition, 2018

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Learning ROS for Robotics Programming	Aaron Martinez and Enrique Fernández	Packt Publishing Ltd	2nd Edition, 2015
2	Building Smart Robots Using ROS	Robin Tommy, Ajithkumar Narayanan Manaparampil and Rinu Michael	BPB	1st Edition, 2022
3	Programming Robots with ROS: A Practical Introduction to the Robot Operating System	Morgan Quigley, Brian Gerkey, William D. Smart	O'Reilly	Greyscale Indian Edition, 2016
4	Modern Robotics: Mechanics, Planning, and Control	Kevin M. Lynch, Frank C. Park	Cambridge University Press	1st Edition, 2017

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://nptel.ac.in/courses/112106298
2	https://nptel.ac.in/courses/112106298
3	https://nptel.ac.in/courses/112106298
4	https://nptel.ac.in/courses/112106298

SEMESTER S7

CRYPTOGRAPHY

Course Code	PEAET746	CIE Marks	40
Teaching Hours/Week (L:T:P:R)	3:0:0:0	ESE Marks	60
Credits	3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	-	Course Type	Theory

Course Objectives:

1. To introduce fundamental concepts of symmetric and asymmetric cipher models
2. To understand the basics of authentication

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	**Introduction to Cryptography** Introduction to cryptography, Need for cryptography, Kirchhoff's principle. Symmetric Cipher Models - Substitution techniques, Transposition techniques, Rotor machines, Steganography. Block Cipher - Design principles and modes of operation. The Data Encryption Standard, Strength of DES. Differential and linear Cryptanalysis	9
2	IDEA - Primitive operations, Key expansions, One round, odd round, Even Round, Inverse keys for decryption. AES - Basic Structure, Primitive operation, Inverse Cipher- Key Expansion, Rounds, Inverse Rounds. Stream Cipher –RC4	9
3	Number theory - Fundamental Theorem of arithmetic, Fermat's Theorem, Euler's Theorem, Euler's Totient Function, Extended Euclid's Algorithm, Modular arithmetic. Public key Cryptography - Principles of Public key Cryptography Systems,	9

	RSA algorithm. Key Management - Diffie-Hellman Key Exchange	
4	Basics of Elliptic curve cryptography Authentication - Authentication functions, Message authentication codes, Hash functions- SHA -1, Security of Hash functions and MACs. Introduction to Digital signatures - Digital signature standards	**9**

Course Assessment Method

(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	Assignment/ Microproject	Internal Examination-1 (Written)	Internal Examination- 2 (Written)	Total
5	**15**	**10**	**10**	**40**

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24marks)**	• Each question carries 9 marks. • Two questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub divisions. **(4x9 = 36 marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Summarize various encryption techniques	**K2**
CO2	Analyse the concepts in cryptographic algorithms	**K4**
CO3	Apply the principles of number theory in cryptographic algorithms for encryption/key exchange	**K3**
CO4	Illustrate authentication and digital signature schemes	**K2**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3		3							3
CO2	3	3	3		3							3
CO3	3	3	3		3							3
CO4	3	3	3		3							3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Cryptography Engineering: Design Principles and Practical Applications	Niels Ferguson, Bruce Schneier, Tadayoshi Kohno	John Wiley & Sons	2nd Edition, 2010
2	Cryptography and Network Security	Behrouz A. Forouzan and Debdeep Mukhopadhyay	McGraw Hill	3rd Edition, 2015
3	Introduction to Cryptography with Coding Theory	Wade Trappe, Lawrence C. Washington	CRC Press	2nd Edition, 2006

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Handbook of Applied Cryptography	Alfred Menezes, Paul C. van Oorschot, Scott A. Vanstone	CRC Press	5th Edition, 2010
2	Cryptography: Theory and Practice	Douglas R. Stinson	Chapman and Hall/CRC	3rd Edition, 2006
3	Guide to Elliptic Curve Cryptography	Hankerson, D.J., Menezes, A., Vanstone, S.A.	Springer	2004
4	Advanced Engineering Mathematics	Merle C. Potter, David C. Wiggert	Wiley	10th Edition, 2012

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://nptel.ac.in/courses/106105162
2	https://nptel.ac.in/courses/106105162
3	https://nptel.ac.in/courses/106105162
4	https://nptel.ac.in/courses/106105162

SEMESTER S7

COMPUTER VISION

Course Code	PEAET745	CIE Marks	40
Teaching Hours/Week (L: T:P: R)	3:0:0:0	ESE Marks	60
Credits	5/3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	-	Course Type	Theory

Course Objectives:

1. To provide foundational knowledge and practical skills in traditional computer vision techniques, including image processing, feature extraction, and object recognition
2. To analyze and optimize visual data using classical algorithms and methods

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	**Overview of Computer Vision and Image Processing -** Introduction to computer vision, applications, history, and challenges. Basics of image formation, pinhole camera model, image representation (grayscale, color spaces), and digital image properties (resolution, bit depth) Image filtering (smoothing, sharpening) and histogram processing	8
2	**Feature Detection & Morphological Processing -** Edge detection (Canny), Keypoint detection (Harris corner detector), blob detection and feature descriptors (SIFT, SURF) Basic morphological operations (erosion, dilation), opening, closing, boundary extraction, and applications in segmentation.	10
3	**Image Segmentation and Object Detection -** Thresholding methods (global, adaptive), region-based segmentation, clustering-based techniques (K-means, Mean Shift), and edge-based segmentation. Sliding window approach, Haar cascades, Histogram of Oriented Gradients (HOG), and template matching	8
4	**Motion Analysis and 3D Vision -** Background subtraction, frame differencing, temporal differencing, and basic optical flow concepts (Lucas-	10

	Kanade method). Tracking algorithms (Kalman filter, Mean Shift). Principles of stereo vision, epipolar geometry, disparity maps, depth estimation, Structure from Motion (SfM), camera calibration, and 3D reconstruction	

Course Assessment Method

(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	*Internal Ex*	*Evaluate*	*Analyse*	*Total*
5	**15**	**10**	**10**	**40**

Criteria for Evaluation (Evaluate and Analyse): 20 marks

Evaluation Methods:

1: Practical Experiments Using Design and Analysis Tools (10 marks)

- Students should do minimum 3 experiments.
- Students will implement and analyze computer vision techniques using tools like OpenCV, Python/MATLAB.

2: Course Project (10 marks)

- Comprehensive project involving design, implementation, and analysis of computer vision techniques.
- Project phases - Proposal, Design, Implementation, Testing, Final Report, Presentation, and Viva Voce.

Experiments:

Experiment 1: Image Transformation and Filtering

Objective: Implement image transformations and filtering techniques.

Tools: OpenCV, Python / MATLAB.

Steps:

1. Apply image transformations (translation, rotation, scaling).
2. Perform image filtering (smoothing, sharpening).
3. Analyze the effects of different parameters on image processing results.

Experiment 2: Feature Detection and Description

Objective: Implement feature detection and description algorithms.

Tools: OpenCV, Python / MATLAB.

Steps:

1. Detect features using Harris corner detector, SIFT, and SURF.
2. Compare and analyze the effectiveness of different feature descriptors.

Experiment 3: Image Segmentation and Morphological Processing

Objective: Apply image segmentation and morphological processing techniques.

Tools: OpenCV, Python / MATLAB.

Steps:

1. Implement thresholding, region-based, and clustering-based segmentation.
2. Perform morphological operations (erosion, dilation).
3. Evaluate segmentation results and analyze applications.

Experiment 4: Object Detection and Tracking

Objective: Implement object detection and tracking techniques.

Tools: OpenCV,Python / MATLAB.

Steps:

1. Apply object detection methods (Haar cascades, HOG).
2. Implement tracking algorithms (Kalman filter, Mean Shift).
3. Visualize and analyze detection and tracking results.

Experiment 5: Stereo Vision and 3D Reconstruction

Objective: Perform stereo vision and 3D reconstruction.

Tools: OpenCV, Python/MATLAB.

Steps:

1. Compute disparity maps from stereo images.
2. Estimate depth and perform 3D reconstruction.
3. Analyze the accuracy and quality of 3D reconstruction

Sample Project Topics:

1. Developing a Real-Time Object Detection and Tracking System Using Traditional Computer Vision Techniques
2. Implementation of a Robust Image Segmentation Algorithm for Medical Imaging
3. Building a Stereo Vision System for Depth Estimation and 3D Reconstruction
4. Shape Analysis and Object Recognition Using Feature Descriptors
5. Motion Detection and Tracking in Surveillance Videos

Criteria for Evaluation: Lab Experiments (10 marks)

Understanding of Concepts (3 marks)

- Demonstrates a thorough understanding of the theoretical concepts related to the experiments.
- Correctly explains the purpose and expected outcomes.

Implementation and Accuracy (3 marks)

- Correctly implements the neural network models using appropriate tools.
- Ensures the design functions as expected with minimal errors.

Analysis and Problem-Solving (2 marks)

- Effectively analyzes the model performance and identifies issues.
- Demonstrates problem-solving skills in addressing challenges encountered during experiments.

Documentation and Reporting (1 mark)

- Provides detailed documentation of the experimental setup, process, and outcomes.
- Includes visualizations, code snippets, and analysis of results.

Presentation and Communication (1 mark)

- Clearly presents the experiments and their results.
- Able to answer questions and explain design choices.

Course Project (10 marks)

Project Proposal and Planning (2 marks)

- Submits a well-defined project proposal outlining objectives, methodology, and expected outcomes.
- Demonstrates thorough planning and a clear timeline for the project.

Design and Implementation (3 marks)

- Implements the project design accurately using appropriate tools and techniques.
- The design is functional and meets the project objectives.

Innovation and Creativity (2 marks)

- Introduces innovative ideas or unique approaches in the design and implementation.
- Demonstrates creativity in solving problems or optimizing designs.

Analysis and Testing (2 marks)

- Effectively analyzes the project design to identify and address any issues.
- Conducts thorough testing to verify the functionality and performance of the model.

Final Report and Presentation (1 mark)

- Submits a comprehensive final report detailing the project, including objectives, design, methodology, analysis, and results.
- Clearly presents the project and its outcomes, and effectively communicates the key points.

End Semester Examination Marks (ESE):

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24marks)**	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 3 sub divisions. Each question carries 9 marks. **(4x9 = 36 marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Understand and explain the fundamental concepts of computer vision techniques.	**K3**
CO2	Implement and analyze various image processing and feature detection techniques.	**K4**
CO3	Apply and evaluate image segmentation, object detection, and tracking methods.	**K5**
CO4	Analyze and optimize 3D vision and motion analysis techniques, including structure from motion and shape analysis.	**K5**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping od Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3										3
CO2	3	3	2	2	2							3
CO3	3	3	2	2	2							3
CO4	3	3	2	2	2							3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Computer Vision: Algorithms and Applications	Richard Szeliski	Springer	2022
2	Multiple View Geometry in Computer Vision	Richard Hartley, Andrew Zisserman	Cambridge University Press	2022
3	Digital Image Processing	Rafael C. Gonzalez, Richard E. Woods	Pearson	2023
4	Computer Vision: A Modern Approach	David L. Poole, Alan Mackworth	Prentice Hall	2023

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Handbook of Mathematical Models in Computer Vision	Nikos Paragios, Yunmei Chen, Oliver D Faugeras	Springer	2023
2	Image Processing, Analysis, and Machine Vision	Milan Sonka, Vaclav Hlavac, Roger Boyle	Cengage Learning	2022

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://archive.nptel.ac.in/courses/106/105/106105216/
2	https://archive.nptel.ac.in/courses/106/105/106105216/
3	https://archive.nptel.ac.in/courses/106/105/106105216/
4	https://archive.nptel.ac.in/courses/106/105/106105216/

SEMESTER S7

INSTRUMENTATION SYSTEM DESIGN

Course Code	**PEAET795**	**CIE Marks**	40
Teaching Hours/Week (L: T:P: R)	3:0:0:0	**ESE Marks**	60
Credits	5/3	**Exam Hours**	2 Hrs. 30 Min.
Prerequisites (if any)	PCAET602 Industrial Instrumentation, PCAET502 Process Dynamics and Control	**Course Type**	Theory

Course Objectives:

1. To impart knowledge on the design of signal conditioning circuits required for various sensors
2. To develop the skills needed to design transmitters, Analog/Digital PID controller, Data loggers and Alarm Annunciator
3. To familiarize with the design orifice and control valve sizing

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	**Introduction and Standards** Concepts of instrument design, functional requirements and specifications. Standards – Military, Industrial, and Commercial standards. BIS standards, ANSI standards, NEMA standards, DIN standards. **Piping and Instrumentation Diagram** P & I D Symbols, line numbering, line schedule, overview of various stages in P&I D development, P&I D for pumps, compressors process vessels, absorber and evaporator. **Design of signal conditioning circuits** Design of V/I Converter and I/V Converter, Signal conditioning circuit for pH electrodes, Design of Air-purge Level Measurement, Signal conditioning circuit for Thermocouple, RTD and Thermistor, Overview of Cold Junction Compensation and Linearization – software and Hardware approaches.	**9**

2	**Design of Transmitters** – Overview of 2 wire and 4 wire transmitters, Design of RTD based Temperature Transmitter, Thermocouple based Temperature Transmitter and Smart Transmitters. **Control Valves** - Characteristics, valve equation, types of valves- Globe valve, ball valve, gate valve, butterfly valve, needle valve, valve positioner, valve selection criteria.	**9**
3	**Orifice and Control valve sizing** - Orifice, Venturi and flow nozzle sizing - Liquid, Gas and steam services. Control valve sizing – Liquid, Gas and steam services. Overview of Rotameter Design **Design of Data logger and PID controller** Design of ON/OFF Controller using Linear Integrated Circuits, Electronic PID Controller, Basics of Microcontroller based digital two-degree of freedom PID Controller, Microcontroller based Data Logger, Basic architecture of PC based Data Acquisition Cards.	**9**
4	**Control Panel Design** Basics of operating console and control room panel design. Control room environment for electronic equipment - heat dissipation, forced air circulation and humidity considerations. Grounding and shielding- protection against electrostatic discharge. Design of Alarm and Annunciation circuit - Alarm and Annunciation Circuits using Analog and Digital Circuits – Design of Programmable Logic Controller for any two simple applications	**9**

Course Assessment Method

(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	*Internal Ex*	*Evaluate*	*Analyse*	*Total*
5	**15**	**10**	**10**	**40**

Criteria for Evaluation (Evaluate and Analyse): 20 marks

- The project needs to be done as an individual project.
- The project can be done as design and simulation or complete hardware implementation
- Simulations may be done using tools like LabVIEW/MATLAB/Scilab
- The students should design any one of the following systems with industrial standards

1. An industrial instrumentation system that can measure physical parameters like temperature, level, humidity or flow with P&I diagrams
2. An industrial Data logger/ Data acquisition system
3. Design and simulation of controllers suitable for various processes.
4. A PLC based automation system.

At the completion of the project, the students should be familiar with the following:

- Select an appropriate components for measurement or control
- Interface various sensors/actuators to the digital systems
- Parameters to be considered while developing the system for industrial purposes
- Instrumentation drawings
- Use of simulation tools for industrial system design

The project deliverables consist of the following components:

- Detailed design specifications
- Identification and resolution of technical challenges
- Designed and developed algorithms
- Implementation results and performance evaluations
- Comprehensive project report, incorporating methodology, results, challenges, and recommendations.

End Semester Examination Marks (ESE):

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24marks)**	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 3 sub divisions. Each question carries 9 marks. **(4x9 = 36 marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Design signal conditioning circuits for temperature sensors, V/I and I/V converters	**K3**
CO2	Design of transmitters, data logger, PID controller and alarm circuits	**K3**
CO3	Carry out orifice and control valve sizing for different services	**K3**
CO4	Design control panels	**K3**
CO5	Design automation systems with PLCs	**K6**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3									3
CO2	3	3	3									3
CO3	3	3	3									3
CO4	3	3	3									3
CO5	3	3	3		3							3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Instrument Engineers Handbook - Process Control and Optimization	Bela G. Liptak	CRC Press	4th Edition, Vol.2, 2008.
2	Introduction to Process Engineering and Design	Thakore and Bhatt	McGraw Hill	2nd Edition, 2007
3	Process Control Instrumentation Technology	C. D. Johnson	Prentice Hall	8th Edition, 2015
4	Electronic Instrument Design	Kim Fowler	Oxford	Reprint 2015

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Principles of Measurement Systems	Bentley	Pearson Education	4th Edition, 2015
2	Flow Measurement Engineering Handbook	R.W. Miller	McGraw Hill	1996.
3	Measurement Systems Application and Design	E.O. Dobelin	McGraw Hill	4th Edition, 1989
4	Process/Industrial Instruments and Controls Handbook	Gregory K. McMillan, Douglas M. Considine	Mc Graw Hill	5th Edition, 1999
5	Hand Book of transducer	Harry N Nortan	PHI	1st Edition, 1989
6	A Course in Electronic Measurements and Instrumentation	A K Sawhney	Dhanpath Rai & Co	2021
7	Piping and Instrumentation Diagram Development	Moe Toghraei	Wiley	1st Edition, 2019

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://archive.nptel.ac.in/courses/108/105/108105064/
2	https://archive.nptel.ac.in/courses/108/105/108105064/
3	https://nptel.ac.in/courses/108105088
4	https://nptel.ac.in/courses/108105088

SEMESTER S7

POWER PLANT INSTRUMENTATION

Course Code	PEAET751	CIE Marks	40
Teaching Hours/Week (L: T:P: R)	3:0:0:0	ESE Marks	60
Credits	3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	-	Course Type	Theory

Course Objectives:

1. To introduce the basics of Power Generation.
2. To familiarize the various measurement techniques and control strategies adopted in Power Plants.

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	**Introduction to Power Plants -** Brief survey of methods of power generation - hydro, nuclear, solar and wind power. **Thermal Power Plant** - Introduction to thermal power plant processes, building blocks, Boilers, Different Types – Pulverized Fuel Boiler. Importance of instrumentation in Power Generation.	9
2	**Fuel Circuit** (Basics only) - Furnace, Combustion Process, Fuel Systems, Pressurized Ball Mill, Air Preheater, Air Supply for Mills. Treatment of Flue Gases, Soot Blowers. **Steam and Water Circuit** - Steam Generation, Super heater, Attemperator, Reheater, Steam Turbine, Condenser, Cooling Tower, Deaerator, Economizer, Alternator, Feed Water Treatment	9
3	**Measurement of non-electrical parameters in power plants -** Metal temperature measurement, Pressure and Temperature measurement of Water and Steam, Drum Level Measurement, Smoke Density Measurement. **Measurement of Electrical Parameters -** Current, Voltage, Power, Frequency and Power Factor.	9

4	**Introduction to turbine supervising system -** Pedestal vibration, Shaft vibration, Eccentricity measurement. Installation of non-contacting transducers for speed measurement. **Controls in Power Plants** (Basics only) **-** Steam temperature control, Feed water Control, Boiler-following operation, Turbine – following operation, Co-ordinated unit control. Distributed control systems. Interlocks in boiler operation.	**9**

Course Assessment Method

(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	Assignment/ Microproject	Internal Examination-1 (Written)	Internal Examination- 2 (Written)	Total
5	**15**	**10**	**10**	**40**

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24marks)**	• Each question carries 9 marks. • Two questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub divisions. **(4x9 = 36 marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Explain the basic principle behind different methods of Power Generation	**K2**
CO2	Summarize the working of a Thermal Power Plant	**K2**
CO3	Apply various techniques for measurement of electrical and non-electrical parameters in a thermal Power Plant	**K3**
CO4	Describe about the Turbine monitoring system and control strategies adopted in Power Plants	**K2**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2									3
CO2	3	2	2									3
CO3	3	2	2		2							3
CO4	3	2	2		2							3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Power Plant Control and Instrumentation	David Lindsley	IET	1st Edition, 2000
2	Modern Power Station Practice	P.C Martin, I.W Hannah	Pergamon Press, London	3rd Edition, 1993
3	Power Plant Performance	A. B. Gill	Butterworths, London	1st Edition, 1984

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Modern Power Station Practice – Volume F	M. W. Jervis	Pergamon Press, London.	3rd Edition, 1991
2	The Control of Boilers	Sam G. Dukelow	ISA Press, New York	2nd Edition, 1991

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://archive.nptel.ac.in/courses/112/107/112107291/
2	https://archive.nptel.ac.in/courses/112/107/112107291/
3	https://archive.nptel.ac.in/courses/112/107/112107291/
4	https://archive.nptel.ac.in/courses/112/107/112107291/

SEMESTER S7

LOW POWER VLSI

Course Code	**PEAET752**	**CIE Marks**	40
Teaching Hours/Week (L:T:P:R)	3:0:0:0	**ESE Marks**	60
Credits	3	**Exam Hours**	2 Hrs 30 Mins
Prerequisites (if any)	GBPHT121 Physics for Electrical Science, PCAET302 Electronic Devices and Circuits	**Course Type**	Theory

Course Objectives:

1. To identify various sources of power dissipation and power reduction techniques in MOS devices.
2. To apply clocked and non-clocked design styles for logic circuit implementation.
3. To familiarize various adiabatic and reversible logic circuit implementations.

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	**Sources of power dissipation in CMOS circuits** Dynamic Power Dissipation - Charging and Discharging capacitance power dissipation. Short Circuit Power dissipation - Short Circuit Current of Inverter, Short circuit current dependency with input and output load, Glitching Power. Static Power Dissipation - Leakage Power Dissipation. Gate level power analysis - Capacitive, internal, and Static power dissipation of gate level circuit.	**10**
2	**Power Reduction Techniques** Supply voltage Scaling Approaches - Multi VDD and Dynamic VDD Leakage power reduction Techniques - Transistor stacking, VTCMOS, MTCMOS, DTCMOS, Dynamic power dissipation - Power gating, Clock gating, Transistor and Gate Sizing for Dynamic and Leakage Power Reduction.	**8**

3	**Circuit design styles** Clocked design style - Basic concept, Domino logic (domino NAND gate), Differential Current Switch Logic. Non-clocked circuit design style - fully complementary logic, NMOS and pseudo–NMOS logic, differential cascade voltage switch logic (DCVS)	**9**
4	**Adiabatic switching** Adiabatic charging, adiabatic amplification, One stage and two stage adiabatic buffer, Adiabatic logic gates, pulsed power supplies, Reversible logic basic concepts	**9**

Course Assessment Method
(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	Assignment/ Microproject	Internal Examination-1 (Written)	Internal Examination- 2 (Written)	Total
5	**15**	**10**	**10**	**40**

End Semester Examination Marks (ESE):

In Part A, all questions need to be answered, and in Part B, one full question out of two questions need to be answered

Part A	Part B	Total
• Total of 8 Questions (2 Questions from each module), each carrying 3 marks **(8x3 =24 marks)**	• 2 questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub-divisions. • Each question carries 9 marks. **(4x9 = 36 marks)**	**60**

Course Outcomes (COs)

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

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Model the capacitive, short circuit and leakage power dissipation in CMOS circuits	**K3**
CO2	Design lower power CMOS circuits by applying various techniques for power reduction	**K3**
CO3	Implement logic circuits using clocked and non-clocked design styles	**K3**
CO4	Implement the logic functions using adiabatic and reversible logic structures	**K3**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3									3
CO2	3	3	3									3
CO3	3	3	3		2							3
CO4	3	3	3		2							3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Practical Low-Power Digital VLSI Design	Gray K. Yeap	Springer India	2008
2	Low-power CMOS VLSI Circuit Design	Kaushik Roy and Sharat C. Prasad	Wiley	2009

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Low-Power Digital VLSI Design: Circuits and Systems	Abdellatif Bellaouar, Mohamed Elmasry	Springer Science (Originally published by Kluwer Academic)	1995
2	Low Power Digital CMOS Design	Anantha P. Chandrakasan, Robert W. Brodersen	Kluwer Academic	2012
3	Low power CMOS circuits	Christian Piguet	Taylor and Francis	2018
4	Low Voltage, Low Power VLSI Subsystem	Kiat -Seng Yeo, Kaushik Roy	McGraw Hill Education	2017

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://archive.nptel.ac.in/courses/106/105/106105034/
2	https://archive.nptel.ac.in/courses/106/105/106105034/
3	https://archive.nptel.ac.in/courses/106/105/106105034/
4	https://archive.nptel.ac.in/courses/106/105/106105034/

SEMESTER S7

LINEAR ALGEBRA IN AI AND ML

Course Code	PEAET753	CIE Marks	40
Teaching Hours/Week (L: T:P: R)	3:0:0:0	ESE Marks	60
Credits	3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	GYMAT101 Mathematics for Electrical Science-1, GYMAT201: Mathematics for Electrical Science-2	Course Type	Theory

Course Objectives:

1. To master matrix and vector operations for linear algebra computations
2. To use linear algebra in fields like engineering and data analysis, focusing on practical applications

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	**Linear Equations -** Gaussian Elimination and Matrices, Ill-Conditioned Systems. **Rectangular Systems and Echelon Forms -** Row Echelon Form and Rank, Consistency of Linear Systems, Homogeneous Systems, Non homogeneous Systems. **Matrix Algebra -** Addition and Transposition, Linearity, Matrix Multiplication, Properties of Matrix Multiplication, Matrix Inversion, Inverses of Sum sand Sensitivity, Elementary Matrices and Equivalence, The LU Factorization.	9
2	**Vector Spaces -** Spaces and Subspaces, Four Fundamental Subspaces, Linear Independence, Basis and Dimension, Classical Least Squares, Linear Transformations, Change of Basis and Similarity, Invariant Subspaces	9
3	**Norms, Inner Products, and Orthogonality -** Vector Norms, Matrix Norms, Inner-Product Spaces, Orthogonal Vectors, Gram–Schmidt Procedure, Unitary and Orthogonal Matrices, Orthogonal Reduction, Complementary Subspaces, Range-Null Space Decomposition, Orthogonal Decomposition, Singular Value Decomposition, Orthogonal Projection, Importance of Least Squares.	9

	Determinants - Properties of Determinants	
4	**Eigenvalues and Eigenvectors -** Elementary Properties of Eigensystems, Diagonalization by Similarity Transformations, Functions of Diagonalizable Matrices, Systems of Differential Equations, Normal Matrices, Positive Definite Matrices, Nilpotent Matrices and Jordan Structure, Jordan Form. **Perron–Frobenius Theory -** Positive Matrices, Non-negative Matrices, Stochastic Matrices and Markov Chains	**9**

Course Assessment Method

(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	Assignment/ Microproject	Internal Examination-1 (Written)	Internal Examination- 2 (Written)	Total
5	**15**	**10**	**10**	**40**

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24marks)**	• Each question carries 9 marks. • Two questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub divisions. **(4x9 = 36 marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Perform basic matrix operations, including addition, multiplication, and inversion, and analyze their properties and applications	**K3**
CO2	Apply methods such as Gaussian elimination and LU decomposition to solve linear systems and interpret the solutions	**K3**
CO3	Explore the concepts of vector spaces, linear independence, bases, and dimensions, and apply these to understand linear transformations and change of basis	**K3**
CO4	Compute eigenvalues and eigenvectors, use them to diagonalize matrices, and apply these concepts to solve practical problems in various fields	**K3**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	2	2									3
CO2	3	2	2	2								3
CO3	3	3	2	2								3
CO4	3	3	2	2	2							3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Matrix Analysis and Applied Linear Algebra	Carl D. Meyer	SIAM	2nd Edn. 2023

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	A Second Course in Linear Algebra	Stephan Ramon Garcia Roger A. Horn	Cambridge University press	1st Edn. 2017
2	Analysis and Linear Algebra: The Singular Value Decomposition and Applications	James Bisgard	American Mathematical Society	1st Edn. 2021
3	Introduction to Linear Algebra	Gilbert Strang	Wellesley-Cambridge Press,U.S.	6th Edn. 2023

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://nptel.ac.in/courses/111108066
2	https://nptel.ac.in/courses/111108066
3	https://nptel.ac.in/courses/111108066
4	https://nptel.ac.in/courses/111108066

SEMESTER S7

REAL TIME OPERATING SYSTEMS

Course Code	PEAET754	CIE Marks	40
Teaching Hours/Week (L: T:P: R)	3:0:0:0	ESE Marks	60
Credits	3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	PBECT404 Microcontrollers	Course Type	Theory

Course Objectives:

1. To identify the basic Operating System concepts and scheduling techniques
2. To familiarize Real-Time system characteristics and synchronization mechanisms
3. To familiarize and implement Real-Time task scheduling algorithms
4. To apply Real-Time operating systems in practical scenarios

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	**Introduction to Operating Systems** Objectives and Functions of Operating Systems, Types of OS, concept of the kernel within an operating system. Process Management - Process States, Process Control Block and Operations on process. Process Scheduling - Scheduling Algorithms – First Come First-Served (FCFS), Shortest Job First (SJF), Priority Scheduling, Round Robin (RR). Advanced Scheduling Techniques (Basics only) - Multilevel Queue Scheduling, Multilevel Feedback Queue Scheduling.	10
2	Real Time Operating Systems (RTOS) - Structure and characteristics of RTOS. Task Management - Task states and Task synchronization. Semaphores - Type, usage of semaphores for synchronization. Inter task communication mechanisms (Basics only) - message queues, pipes, event registers and signals.	8

3	Real-Time Task Scheduling and Constraints - Task Constraints. Task Scheduling - Aperiodic Task Scheduling (Jackson's Algorithm and Horn's Algorithm). Scheduling with Precedence Constraints - LDF and EDF. Periodic Task Scheduling (Basics only) - Rate Monotonic Scheduling (RMS), Deadline Monotonic Scheduling (DMS). Real-Time Kernel - Structure, State transition diagram and Kernel primitives.	**9**
4	**Real-Time Operating Systems in Practice** Feature and applications of FreeRTOS and Linux. Overview of commercial real-time operating systems - PSOS, VRTX and RT. Case Study - MicroC/OS-II (Features, threads and task scheduling basics only). Real-Life Applications - Adaptive cruise control - practical implementation challenges and solution.	**9**

Course Assessment Method

(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	Assignment/ Microproject	Internal Examination-1 (Written)	Internal Examination- 2 (Written)	Total
5	**15**	**10**	**10**	**40**

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24marks)**	• Each question carries 9 marks. • Two questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub divisions. **(4x9 = 36 marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Identify the functions of operating systems and solve process scheduling problems.	**K3**
CO2	Illustrate the different types of semaphores used for process synchronization and explain different inter task communication mechanisms.	**K2**
CO3	Model and solve aperiodic task scheduling problems by utilizing scheduling algorithms.	**K4**
CO4	Illustrate the implementation of a real time system.	**K3**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3								3
CO2	3	3	3	3								3
CO3	3	3	3	3								3
CO4	3		3	3		3				3		3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Real-Time Concepts for Embedded Systems	Qing Li with Caroline Yao	CMP Books	1/e, 2003
2	Hard Real Time Computing Systems Predictable Scheduling Algorithms and Applications	Giorgio C. Buttazzo	Springer	3/e, 2011
3	Operating System	Rohit Khurana	Vikas	2/e, 2016

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Operating Systems Internals and Design Principles	William Stallings	Pearson	9/e, 2018
2	Operating System Concepts	Abraham Silberschatz	Wiley	10/e, 2018
3	MicroC/OS-II The Real-Time Kernel	Jean J Labrosse	CRC Press	2022

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://archive.nptel.ac.in/courses/106/105/106105172/
2	https://archive.nptel.ac.in/courses/106/105/106105172/
3	https://archive.nptel.ac.in/courses/106/105/106105172/
4	https://archive.nptel.ac.in/courses/106/105/106105172/

SEMESTER S7

WIRELESS SENSOR NETWORKS

Course Code	PEAET756	CIE Marks	40
Teaching Hours/Week (L: T:P: R)	3:0:0:0	ESE Marks	60
Credits	3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	-	Course Type	Theory

Course Objective:

1. The course aims to expose students to computer networks taking a top-down approach of viewing from the layer of user applications and zooming into link layer protocols

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	Introduction, application, and challenges of wireless sensor networks (WSN). **Wireless LANs and PANs -** Introduction, Fundamentals of WLANs, IEEE 802.11 standard, HIPERLAN standard, Bluetooth**.** **Wireless WANs and MANs** (Basics only) **-** Cellular architecture, 2G/3G/4G/5G Cellular Networks, WLL**.** **IEEE 802.15 Standard-** Physical layer, Data link layer, MAC protocols. **Wireless Internet.**	**9**
2	**Network architecture** - Sensor network scenarios, Optimization goals and figures of merit, Design principles of WSNs, Service interfaces of WSNs. **Communication Protocols** - Physical layer - Wireless channel and communication fundamentals, Physical layer and transceiver design considerations in WSNs.	**9**
3	Mobile ad hoc networks and wireless sensor networks, Field buses and wireless sensor networks, Enabling technologies for wireless sensor networks. Mobile IP, TCP in wireless domain, TCP-BUS and Ad Hoc TCP, Split TCP, WAP, optimising Web over wireless.	**9**

4	WSN architecture - Single node architecture - Hardware components, Energy consumption of sensor nodes, Low power wireless sensor networks. Routing protocols (Basics only) - LEACH, PEGASIS and RPL. Overview of Operating systems and execution environments. Case Study (Basics only) - TinyOS and nesC.	**9**

Course Assessment Method

(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	Assignment/ Microproject	Internal Examination-1 (Written)	Internal Examination- 2 (Written)	Total
5	**15**	**10**	**10**	**40**

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24 marks)**	• Each question carries 9 marks. • Two questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub divisions. **(4x9 = 36 marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Explain the principles of wireless networks concepts and their standards	**K2**
CO2	Illustrate various concepts on the basics of wireless sensor networks and mobile adhoc networks	**K2**
CO3	Develop single node wireless sensor architecture	**K3**
CO4	Analyse the network architecture and the communication protocols of wireless sensor networks	**K4**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	2	2		2							3
CO2	3	2	2		2							3
CO3	3	2	2		2							3
CO4	3	2	2		2							3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Ad Hoc Wireless Networks: Architectures and Protocols	Siva Ram Murthy C. and Manoj B. S.	Pearson Education	2nd Edition , 2005
2	Protocols and Architectures for Wireless Sensor Networks	Holger Karl and Andreas Willig	John Wiley	1st Edition, 2007

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Wireless Communications and Networks	William Stallings	Prentice Hall	2nd Edition, 2004
2	Fundamentals of Wireless Sensor Networks - Theory and Practice	Waltenegus Dargie , Christian Poellabauer	John Wiley	1st Edition, 2010

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://nptel.ac.in/courses/106105160
2	https://nptel.ac.in/courses/106105160
3	https://nptel.ac.in/courses/106105160
4	https://nptel.ac.in/courses/106105160

SEMESTER S7

PATTERN RECOGNITION

Course Code	PEAET755	CIE Marks	40
Teaching Hours/Week (L: T:P: R)	3:0:0:0	ESE Marks	60
Credits	5/3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	GNEST305 - Introduction to Artificial Intelligence and Data Science	Course Type	Theory

Course Objectives:

1. To introduce the fundamental algorithms for pattern recognition
2. To instigate the various classification and clustering techniques

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	**Basics of pattern recognition system** – Introduction, various applications, classification of pattern recognition systems. Design of Pattern recognition system, Pattern recognition Life Cycle. **Statistical Pattern Recognition** - Review of probability theory, Gaussian distribution, Bayes decision theory and Classifiers, Optimal solutions for minimum error and minimum risk criteria, Normal density and discriminant functions, Decision surfaces.	9
2	**Parameter estimation methods** - Maximum-Likelihood estimation, Expectation-maximization method, Bayesian parameter estimation. Concept of feature extraction and dimensionality, Curse of dimensionality, Dimension reduction methods - Fisher discriminant analysis, Principal component analysis, Hidden Markov Models (HMM) basic concepts, Gaussian mixture models	9
3	**Non-Parameter methods** - Non-parametric techniques for density estimation - Parzen-window method, K-Nearest Neighbour method. **Non-metric methods for pattern classification** - Non-numeric data or	9

	nominal data. Decision trees, Concept of construction, splitting of nodes, choosing of attributes, overfitting, pruning. Linear Discriminant based algorithm - Perceptron	
4	**Artificial Neural networks.** Multilayer perceptrons, learning by gradient descent, Back Propagation algorithm. Classifier Ensembles: Bagging, Boosting/AdaBoost. **Unsupervised learning** - Clustering, Algorithms for clustering: K-means and Hierarchical methods, Cluster validation	**9**

Course Assessment Method

(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	*Internal Ex*	*Evaluate*	*Analyse*	*Total*
5	**15**	**10**	**10**	**40**

Criteria for Evaluation (Evaluate and Analyze): 20 marks

- Each student should design, implement, and analyze a pattern recognition system for various applications.
- System development can be accomplished using
  - Python: OpenCV, NumPy, Scikit-image
  - MATLAB
- **Each student should do minimum four microprojects from basic level and two microprojects from advanced level.**

Basic Level

1. K-Nearest Neighbors (KNN) Classification:

- **Goal:** Classify iris species based on their measurements.
- **Approach:** Calculate the Euclidean distance between a new iris sample and all training samples. Classify the new sample based on the majority class of its k nearest neighbors.

2. Naive Bayes Classification:

- **Goal:** Predict the iris species based on its measurements.
- **Approach:** Assume independence between features and calculate the probability of each species given the feature values. Classify the new sample based on the highest probability.

3. Decision Tree Classification:

- **Goal:** Create a decision tree to classify iris species.
- **Approach:** Use algorithms like ID3 or C4.5 to construct a tree based on the features and their values. Classify new samples by traversing the tree.

4. Support Vector Machines (SVM) Classification:

- **Goal:** Find the optimal hyperplane to separate the iris species.
- **Approach:** Use SVM algorithms like linear SVM or kernel SVM to find the decision boundary. Classify new samples based on their position relative to the hyperplane.

5. Neural Network Classification:

- **Goal:** Train a neural network to classify iris species.
- **Approach:** Create a simple neural network with one or two hidden layers and train it using backpropagation. Classify new samples by feeding them to the trained network.

6. Feature Engineering and Visualization:

- **Goal:** Explore the relationships between features and visualize the data.
- **Approach:** Create visualizations like scatter plots, histograms, and box plots to understand the distribution of features and identify potential correlations. Experiment with feature engineering techniques to improve classification performance.

7. Ensemble Methods:

- **Goal:** Combine multiple classifiers to improve performance.
- **Approach:** Use methods like bagging, boosting, or stacking to create an ensemble classifier. Evaluate the performance of the ensemble compared to individual classifiers.

Advanced Level

1. K-Nearest Neighbors (KNN) for Image Classification:

- **Dataset:** MNIST dataset (handwritten digits)
- **Approach:** Calculate Euclidean distance between test image and all training images. Classify test image based on the majority class of its k nearest neighbors.
- **Learn:** Understand the concept of distance measures, nearest neighbors, and how they can be used for classification.

2. Naive Bayes for Text Classification:

- **Dataset:** IMDB dataset (movie reviews)
- **Approach:** Calculate the probability of a word belonging to a class and use Bayes' theorem to classify documents.
- **Learn:** Understand the concept of probability, conditional probability, and how Naive Bayes can be applied for text classification.

3. Decision Trees for Iris Classification:

- **Dataset:** Iris dataset (flower species)
- **Approach:** Construct a decision tree based on the features and their values. Classify test instances by traversing the tree.
- **Learn:** Understand the concept of decision trees, information gain, and how they can be used for classification.

4. Support Vector Machines (SVM) for Binary Classification:

- **Dataset:** Breast cancer dataset
- **Approach:** Find the optimal hyperplane that separates the classes. Classify test instances based on their position relative to the hyperplane.
- **Learn:** Understand the concept of margins, kernels, and how SVMs can be used for classification.

5. Perceptron for Binary Classification:

- **Dataset:** XOR dataset
- **Approach:** Implement a simple perceptron and train it to learn the XOR function.
- **Learn:** Understand the concept of neurons, weights, and how a perceptron can be used for classification.

6. Neural Networks for Image Classification:

- **Dataset:** MNIST dataset (handwritten digits)
- **Approach:** Implement a simple feedforward neural network with one or two hidden layers and train it using backpropagation.
- **Learn:** Understand the concept of neural networks, activation functions, backpropagation, and how they can be used for classification.

The project deliverables consist of the following components:

- Detailed design specifications
- Identification and resolution of technical challenges
- Designed and developed algorithms
- Implementation results and performance evaluations
- Comprehensive project report, incorporating methodology, results, challenges, and recommendations.

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24marks)**	• Each question carries 9 marks. • Two questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub divisions. **(4x9 = 36 marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Understand the major approaches in statistical and syntactic pattern recognition	**K2**
CO2	Explain the various parameter estimation and pattern classification techniques	**K2**
CO3	Illustrate the basic concepts of ANN and unsupervised learning	**K3**
CO4	Design pattern recognition systems	**K6**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3											3
CO2	3	3	3	3								3
CO3	3	3	3	3								3
CO4	3	3	3	3								3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Pattern Recognition and Machine Learning	C M Bishop	Springer	1st Edition, 2006
2	Pattern Classification and scene analysis	R O Duda, P.E. Hart and D.G. Stork	John Wiley	2nd Edition, 2001

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Pattern Recognition Engineering	Morton Nadier and Eric Smith P	John Wiley & Sons, New York.	1st Edition, 1993.
2	Pattern Recognition: Statistical, Structural and Neural Approaches.	Robert J. Schalkoff	John Wiley & Sons Inc., New York.	1st Edition, 2007.
3	Pattern Recognition	S.Theodoridis and K. Koutroumbas	Academic Press.	4th Edition, 2009.
4	Machine Learning	Tom Mitchell	McGraw-Hill	1st Edition, 2017
5	Pattern Recognition Principles.	Tou and Gonzales	Wesley Publication Company, London.	1974.

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://nptel.ac.in/courses/117105101
2	https://nptel.ac.in/courses/117105101
3	https://nptel.ac.in/courses/117105101
4	https://nptel.ac.in/courses/117105101

SEMESTER S7

INTERNET OF THINGS BASED SYSTEM DESIGN

Course Code	PEAET785	CIE Marks	40
Teaching Hours/Week (L:T:P:R)	3:0:0:0	ESE Marks	60
Credits	5/3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	-	Course Type	Theory

Course Objectives:

1. To understand about the fundamentals of Internet of Things, its building blocks and their characteristics
2. To select suitable network architecture and use appropriate protocols for a given IoT application

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	**Introduction to Internet of Things** Definition, basic IoT block diagram, Characteristics of IoT devices – power, computational constraints. IoT Architecture – Middle ware based architecture and Service oriented architecture M2M Communication – M2M system model, device domain, network domain, application domain, M2M v/s IoT. Typical application areas of IoT – Smart homes, Agriculture and Smart city	9
2	**IoT Hardware** Commercially available sensors (Operating principles only) – Temperature and humidity sensor (DHT11/22), Gas Sensor (MQ series), Ultrasonic distance sensor (HC-SR04). Actuators (Working principles only) – DC motors, Solenoid based valves, electro-mechanical relay, solid state relay, stepper motors Embedded boards – Overview of typical microcontroller and single board	9

	computers boards used in IoT applications – Arduino Uno, ESP32, Raspberry Pi (Overview only)	
3	**IoT Communication** IoT device gateways, Overview of IP addressing – IPv4, IPv6. Network address translation (overview only) IoT infrastructure protocols (only overview and key features required) – RFID, Zigbee, Bluetooth, BLE, NFC, DASH7, LoRa, 6LoWPAN, SigFox, NB-IoT, WiFi. Overview of Cellular Communication for IoT (LTE 4G only)	**9**
4	**Application Protocols and Cloud Computing** (fundamental concepts only required) Message Queue Telemetry Transport (MQTT) – architecture, Quality of Service levels. HTTP REST API, Constrained Application Protocol (CoAP) – architecture, request-response model. Typical use cases of MQTT, CoAP and REST API in IoT networks. Cloud computing – overview of architecture. cloud models - Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS), and Infrastructure-as-a-Service (IaaS). Emerging Trends in IoT - AI Integration, 5G, and Beyond.	**9**

Course Assessment Method

(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	*Internal Ex*	*Evaluate*	*Analyse*	*Total*
5	**15**	**10**	**10**	**40**

Criteria for Evaluation (Evaluate and Analyse): 20 marks

Evaluation Methods:

- Each student should develop an IoT based system
- **The system developed should include IoT Protocols and web/smartphone based user interface/dashboard for controlling/monitoring the IoT based system**
- The project details and the outcomes to be evaluated are as follows

Project: Design, simulate and realize an IoT based system

- Design Specifications
    - Detailed specifications of the system are to be made after conducting study of the place/facility where the system is to be deployed
- System design
    - Develop a block diagram of the system
    - Select sensors, actuators, embedded boards and power source required for the system
    - Select the communication protocol required for the system
- System development
    - Develop the code for the embedded components of the system
    - Develop the application code for IoT protocols (eg, MQTT, CoAP)
    - Develop the user interface/dashboard for controlling/monitoring the IoT based system
- Hardware implementation and integration of the system
    - Assemble the various hardware components of the system
    - Test the functionality of the system in a controlled environment
    - Deployment of the system in the field
    - Sensor data collection and analysis

Sanple Projects:

- Home automation system
- Smart metering
- Logistics tracking
- Precision agriculture
- Air Quality Monitoring System
- Health Monitoring System

Evaluation parameters:

- Relevance of the project idea
- Design of the system
- Use of IoT protocols and web/smartphone based user interfacce
- Hardware Implementation and Testing
- Innovation and Creativity
- Final Report and Presentation

Project Deliverables:

1. Detailed design specifications of the IoT based system
2. Hardware implementation and deployment of the system in field condition
3. Comprehensive project report including methodology, results, challenges, and recommendations

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24 Marks)**	• Each question carries 9 marks. • Two questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub divisions. **(4x9 = 36 Marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Explain in a concise manner the architecture of IoT	**K2**
CO2	Identify various hardware components used in IoT	**K3**
CO3	Illustrate the various connectivity technologies and application protocols in IoT	**K2**
CO4	Design and develop IoT systems	**K6**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3									3
CO2	3	2	3									3
CO3	3	2	3									3
CO4	3	2	3		3							3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Introduction to IoT	Sudeep. Misra, A. Mukherjee, and A. Roy	Cambridge University Press	1st Edition, 2021
2	Internet of Things: A Hands-on Approach	Arshdeep Bahga and Vijay Madisetti	Orient Blackswan	1st Edition, 2015
3	Internet of Things (IoT) Architecture and Design Principles	Raj Kamal	McGraw Hill	2nd Edition, 2022

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	The Internet of Things	Samuel Greengard	The MIT Press Essential Knowledge Series	1st Edition, 2015
2	The Internet of Things: How Smart TVs, Smart Cars, Smart Homes, and Smart Cities Are Changing the World	Michael Miller	QUE	2015
3	IoT Fundamentals	Hanes David, Salgueiro Gonzalo, Grossetete Patrick, Barton Rob, Henry Jerome	Pearson	1st Edition, 2017
4	Introduction to Industrial Internet of Things and Industry 4.0	Sudip Misra, Chandana Roy, Anandarup Mukherjee	CRC Press	1st Edition, 2020
5	Getting Started with the Internet of Things	Cuno Pfister	O'Rielly	1st Edition, 2011
6	Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystem	Ovidiu Vermesan, Peter Friess	River Publishers	1st Edition, 2013
7	Internet of things: A survey on enabling technologies, protocols, and applications.	A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari and M. Ayyash	IEEE Communications Surveys & Tutorials	2015

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://archive.nptel.ac.in/courses/106/105/106105166/ https://online.stanford.edu/courses/xee100-introduction-internet-things
2	https://archive.nptel.ac.in/courses/106/105/106105166/ https://online.stanford.edu/courses/xee100-introduction-internet-things
3	https://archive.nptel.ac.in/courses/106/105/106105166/ https://online.stanford.edu/courses/xee100-introduction-internet-things
4	https://archive.nptel.ac.in/courses/106/105/106105166/ https://online.stanford.edu/courses/xee100-introduction-internet-things

SEMESTER S7

INTERNET OF THINGS

Course Code	OEAET721	CIE Marks	40
Teaching Hours/Week (L:T:P:R)	3:0:0:0	ESE Marks	60
Credits	3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	-	Course Type	Theory

Course Objectives:

1. To understand about the fundamentals of Internet of Things, its building blocks and their characteristics
2. To select suitable network architecture and use appropriate protocols for a given IoT application

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	**Introduction to Internet of Things** Definition, basic IoT block diagram, Characteristics of IoT devices – power, computational constraints. IoT Architecture – Middle ware based architecture and Service oriented architecture M2M Communication – M2M system model, device domain, network domain, application domain, M2M v/s IoT. Typical application areas of IoT – Smart homes, Agriculture and Smart city	9
2	**IoT Hardware** Commercially available sensors (Operating principles only) – Temperature and humidity sensor (DHT11/22), Gas Sensor (MQ series), Ultrasonic distance sensor (HC-SR04). Actuators (Working principles only) – DC motors, Solenoid based valves, electro-mechanical relay, solid state relay, stepper motors Embedded boards– Overview of typical microcontroller and single board computers boards used in IoT applications – Arduino Uno, ESP32, Raspberry Pi (Overview only)	9

3	**IoT Communication** IoT device gateways, Overview of IP addressing – IPv4, IPv6. Network address translation (overview only) IoT infrastructure protocols (only overview and key features required) – RFID, Zigbee, Bluetooth, BLE, NFC, DASH7, LoRa, 6LoWPAN, SigFox, NB-IoT, WiFi. Overview of Cellular Communication for IoT (LTE 4G only)	**9**
4	**Application Protocols and Cloud Computing** (fundamental concepts only required) Message Queue Telemetry Transport (MQTT) – architecture, Quality of Service levels. HTTP REST API, Constrained Application Protocol (CoAP) – architecture, request-response model. Typical use cases of MQTT, CoAP and REST API in IoT networks. Cloud computing – overview of architecture. cloud models - Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS), and Infrastructure-as-a-Service (IaaS). Basic overview of fog computing.	**9**

Course Assessment Method

(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	Assignment/ Microproject	Internal Examination-1 (Written)	Internal Examination- 2 (Written)	Total
5	**15**	**10**	**10**	**40**

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24 Marks)**	• Each question carries 9 marks. • Two questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub divisions. **(4x9 = 36 Marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Explain in a concise manner the architecture of IoT	**K2**
CO2	Identify various hardware components used in IoT	**K3**
CO3	Illustrate the various connectivity technologies in IoT	**K2**
CO4	Design and develop IoT systems	**K3**
CO5	Understand the fundamentals of cloud computing for IoT	**K2**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3									3
CO2	3	2	3									3
CO3	3	2	3									3
CO4	3	2	3		3							3
CO5	3	2	3		3							3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Introduction to IoT	Sudeep. Misra, A. Mukherjee, and A. Roy	Cambridge University Press	1st Edition, 2021
2	Internet of Things: A Hands-on Approach	Arshdeep Bahga and Vijay Madisetti	Orient Blackswan	1st Edition, 2015
3	Internet of Things (IoT) Architecture and Design Principles	Raj Kamal	McGraw Hill	2nd Edition, 2022

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	The Internet of Things	Samuel Greengard	The MIT Press Essential Knowledge Series	1st Edition, 2015
2	The Internet of Things: How Smart TVs, Smart Cars, Smart Homes, and Smart Cities Are Changing the World	Michael Miller	QUE	2015
3	IoT Fundamentals	Hanes David, Salgueiro Gonzalo, Grossetete Patrick, Barton Rob, Henry Jerome	Pearson	1st Edition, 2017
4	Introduction to Industrial Internet of Things and Industry 4.0	Sudip Misra, Chandana Roy, Anandarup Mukherjee	CRC Press	1st Edition, 2020
5	Getting Started with the Internet of Things	Cuno Pfister	O'Rielly	1st Edition, 2011
6	Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystem	Ovidiu Vermesan, Peter Friess	River Publishers	1st Edition, 2013
7	Internet of things: A survey on enabling technologies, protocols, and applications.	A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari and M. Ayyash	IEEE Communications Surveys & Tutorials	2015

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://archive.nptel.ac.in/courses/106/105/106105166/ https://online.stanford.edu/courses/xee100-introduction-internet-things
2	https://archive.nptel.ac.in/courses/106/105/106105166/ https://online.stanford.edu/courses/xee100-introduction-internet-things
3	https://archive.nptel.ac.in/courses/106/105/106105166/ https://online.stanford.edu/courses/xee100-introduction-internet-things
4	https://archive.nptel.ac.in/courses/106/105/106105166/ https://online.stanford.edu/courses/xee100-introduction-internet-things

SEMESTER S7

MEMS

Course Code	OEAET722	CIE Marks	40
Teaching Hours/Week (L: T:P: R)	3:0:0:0	ESE Marks	60
Credits	3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	-	Course Type	Theory

Course Objectives:

1. To introduce the technology of micro electro mechanical systems
2. To understand the materials and manufacturing processes of MEMS

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	MEMS and Micro Systems – Introduction, Applications – multidisciplinary nature of MEMS. Principles and examples of Micro sensors and micro actuators – micro accelerometer, comb drives, Micro grippers – micro motors, micro valves, micro pumps, Shape Memory Alloys. Actuation and Sensing techniques - Thermal sensors and actuators, Electrostatic sensors and actuators, Piezoelectric sensors and actuators, magnetic actuators	10
2	Review of Mechanical concepts - Stress, Strain, Modulus of Elasticity, yield strength, ultimate strength – General stress strain relations – compliance matrix, Mechanical Properties of Silicon and Related Thin Films. Overview of commonly used mechanical structures in MEMS - Beams, Cantilevers, Plates, Diaphragms – Typical applications	8
3	Scaling laws in miniaturization - scaling in geometry, scaling in rigid body dynamics, Trimmer force scaling vector, scaling in electrostatic and electromagnetic forces, scaling in electricity and fluidic dynamics. Materials for MEMS - Silicon, Silicon compounds – Silicon Nitride, Silicon	9

	Dioxide, Poly Silicon, Silicon Piezo resistors. Polymers in MEMS – SU-8, PMMA, PDMS, Langmuir – Blodgett Films	
4	Micro System fabrication processes – Photolithography, Ion implantation, Diffusion, Oxidation, Chemical vapour deposition, Etching. Overview of Micro manufacturing – Bulk micro manufacturing, Surface micro machining, LIGA process, Basics of Micro system Packaging- Surface bonding, Anodic bonding	**9**

Course Assessment Method

(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	Assignment/ Microproject	Internal Examination-1 (Written)	Internal Examination- 2 (Written)	Total
5	**15**	**10**	**10**	**40**

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24marks)**	• Each question carries 9 marks. • Two questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub divisions. **(4x9 = 36 marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Understand the working principles of micro sensors and actuators	**K2**
CO2	Analyze and design the mechanical structures in MEMS	**K3**
CO3	Apply the scaling laws in the design of micro systems	**K3**
CO4	Understand the micro fabrication processes and MEMS materials	**K3**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2									3
CO2	3	3	3	2								3
CO3	3	3	3	2								3
CO4	3	2	2	2								3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Foundations of MEMS	Chang Liu	Pearson	2/e, 2012
2	MEMS and Microsystems Design and Manufacture	Tai-Ran Hsu	TMH	1/e, 2002

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	VLSI Technology	Chang C Y and Sze S. M.	McGraw-Hill, New York	1/e, 2000
2	Microsensors: Principles and Applications	Julian W Gardner	John Wiley and sons	1/e, 1994
3	Fundamentals of Micro fabrication,	Mark Madou	CRC Press, Newyork	1/e, 1997
4	Microsystem design	Stephen D. Senturia	Springer(India)	2/e, 2006
5	Electromechanics and MEMS	Thomas B. Jones	Cambridge University Press	2/e, 2001

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://nptel.ac.in/courses/117105082
2	https://nptel.ac.in/courses/117105082
3	https://nptel.ac.in/courses/117105082
4	https://nptel.ac.in/courses/117105082

SEMESTER S7

EMBEDDED SYSTEMS

Course Code	OEAET723	CIE Marks	40
Teaching Hours/Week (L: T:P: R)	3:0:0:0	ESE Marks	60
Credits	3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	-	Course Type	Theory

Course Objectives:

1. To introduce the building blocks of Embedded System and various Embedded Development strategies
2. To impart knowledge of RTOS and processor scheduling algorithms

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	**Introduction to Embedded Systems** Definition of Embedded System, Embedded Systems Vs General Computing Systems, History of Embedded Systems, Classification, Major Application Areas, Purpose of Embedded Systems, Characteristics and Quality Attributes of Embedded Systems	9
2	**Typical Embedded System** Core of the Embedded System – General Purpose and Domain Specific Processors – ASICs, PLDs, Commercial Off-The-Shelf Components (COTS). Memory – ROM, RAM, Memory according to the type of Interface, Memory selection for Embedded Systems, Introduction to sensors and Actuators for Embedded Systems	9
3	**RTOS Based Embedded System Design** Operating System Basics, Types of Operating Systems, Tasks, Process and Threads, Multi processing and Multi-tasking, Task Scheduling.	9

	Basics of Task Communication – Shared Memory, Message Passing. How to Choose an RTOS	
4	**Embedded System Development Process** Overview of embedded system development process – Waterfall model and spiral model. Requirements analysis, System Architecture design, Selection of processor, development platform and tools selection, coding issues and code optimization basics of testing and debugging. Introduction to verification and validation	**9**

Course Assessment Method

(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	Assignment/ Microproject	Internal Examination-1 (Written)	Internal Examination- 2 (Written)	Total
5	**15**	**10**	**10**	**40**

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24marks)**	• Each question carries 9 marks. • Two questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub divisions. **(4x9 = 36 marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Understand fundamental embedded systems design paradigms, architectures, possibilities and challenges	**K2**
CO2	Analyze the sub systems of an embedded system and their interaction in the functionality of the embedded systems	**K2**
CO3	Practically apply gained theoretical knowledge to develop embedded systems	**K3**
CO4	Apply formal techniques of simulation, testing, verification and validation in designing reliable and safe embedded systems	**K3**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	3		3							3
CO2	3		3		3							3
CO3	3	2	3		3							3
CO4	3		3		3	3	3					3

Note: *1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation*

Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Introduction to Embedded Systems	Shibu K. V	Tata McGraw Hill	2nd Edition, 2017
2	Embedded System Design – A unified hardware/software Introduction	Frank Vahid, Tony Givargis	John Wiley	2006
3	Embedded Systems- Architecture, Programming and Design	Raj Kamal	Tata McGraw Hill	3rd Edition, 2017
4	Embedded Systems: An Integrated Approach	Lyla B. Das	Pearson	1st Edition, 2012

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Embedded System Design	Steve Heath	Elsevier/ Newnes	2nd Edition, 2002
2	Embedded Microcontrollers and Processor Design	Greg Osborn	Pearson	2011
3	Embedded Microcomputer Systems – Real Time Interfacing	Jonathan W. Valvano	Cengage Learning	2rd Edition, 2011

Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://nptel.ac.in/courses/108102045
2	https://nptel.ac.in/courses/108102045
3	https://nptel.ac.in/courses/108102045 https://archive.nptel.ac.in/courses/106/105/106105172/
4	https://nptel.ac.in/courses/108102045 https://archive.nptel.ac.in/courses/106/105/106105172/