PG Department of ELECTRONICS and INSTRUMENTATION TECHNOLOGY

University of Kashmir

Minutes of the M. Tech. Embedded Systems and Solutions Board of Studies (BoS) Meeting

Notes:

A meeting of the postgraduate Board of Studies (BoS) members for M. Tech Embedded Systems and Solutions programme was held in the office chamber of Head of the Department on 17 February 2026. The following were present:

1. Dr. Farooq A. Khanday (Chairman)
   Head, Department of Electronics and Instrumentation Technology, UoK
2. Prof. M. Tariq Banday (Member)
   Professor, Department of Electronics and Instrumentation Technology, UoK
3. Dr. Shabir A. Parah (Member)
   Associate Professor, Department of Electronics and Instrumentation Technology, UoK
4. Dr. Javaid A. Sheikh (Member)
   Associate Professor, Department of Electronics and Instrumentation Technology, UoK
5. Prof. Mohammad Arif Wani (Member)
   Professor, Department of Computer Sciences, UoK
6. Prof. Basharat Ahmad Wani (Member)
   Professor, Department of Physics, UoK
7. Prof. Mohammad Hasan (Member)
   Professor, Department of Electronics Engineering, AMU Aligarh
8. Prof. Dinesh Kumar (Member)
   Vice Chancellor, Shri Vishwakarma Skill University, Haryana and
   Professor, Department of Electronic Science, Kurukshetra University, Kurukshetra
9. Dr. M. Rafiq Beigh (Member)
   Assistant Professor, Department of Electronics, Cluster University Srinagar
10. Ms. Farhat Roohie (Co-Opted Member)
    Scientist C, Department of Electronics and Instrumentation Technology, UoK
11. Dr. Zamir Ahmad Wani (Co-Opted Member)
    Assistant Professor, Department of Electronics and Instrumentation Technology, UoK
12. Ms. Mir Nazish (Member)
    Research Scholar, Department of Electronics and Instrumentation Technology, UoK
13. Ms. Samreen Mehraj (Member)
    Research Scholar, Department of Electronics and Instrumentation Technology, UoK

At the outset, Dr. Farooq A. Khanday, Chairman BoS, welcomed the members, particularly the external subject experts from other premier institutions and highlighted the critical importance of this meeting, which was convened primarily to align the existing M. Tech. Embedded Systems and Solutions programme with the latest curriculum model for postgraduate programmes issued by the All India Council for Technical Education (AICTE) (copy of the AICTE model circulated to members).

The Chairman initiated a detailed discussion on the necessity of revamping the programme to ensure national recognition, regulatory compliance, and improved employability outcomes for graduates. He drew the attention of the committee to specific AICTE directives mandating a standardized, uniform model format for postgraduate degree certificates. These directives emphasize that the degree title must clearly indicate the major/broad discipline of engineering, followed by the specialization.

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Notes:

The committee engaged in a threadbare analysis of the current nomenclature, "M. Tech. Embedded Systems and Solutions," and compared it with the prevailing schemes in top technical institutions across the country. The following key points were raised and discussed in detail:

1. **Academic Standardization and NIRF Ranking:** It was noted that national frameworks like the National Institutional Ranking Framework (NIRF) and accreditation bodies like the NBA (National Board of Accreditation) prioritize programmes with clearly defined and standard nomenclature. A degree titled with a broad, recognized discipline (e.g., Electronics Engineering) carries more weight in ranking parameters and is easier to benchmark against other institutions.
2. **Employability and Public Sector Examinations:** The members highlighted that several Public Sector Undertakings (PSUs) and government recruitment agencies have eligibility criteria that require a degree in a core engineering discipline. A hyper-specialized title like "Embedded Systems and Solutions" might inadvertently restrict candidates from applying for positions that require a broad "Electronics Engineering" background. Changing the major discipline to Electronics Engineering would protect and enhance the employability of graduates in the public sector.
3. **Global Equivalence and Higher Studies:** The external members shared insights on international education systems, noting that foreign universities and employers often find it difficult to map niche programme titles to their standard degree equivalents. A degree in "Electronics Engineering" provides immediate recognition and facilitates smoother admissions into Ph.D. programmes and global job markets.
4. **Future-Proofing and Flexibility:** The committee observed that the field of electronics is rapidly converging. A broad major in Electronics Engineering allows the department to offer contemporary specializations (like VLSI, Embedded Systems, or Communication) without needing to create entirely new degree programmes every few years. This provides structural flexibility and agility in updating the curriculum.

After a detailed discussion of the above points and considering the enclosed AICTE guidelines, the committee unanimously passed the following resolutions:

Resolution 1: Adoption of Standardized Nomenclature

It was resolved that the existing programme titled "M. Tech. Embedded Systems and Solutions" shall henceforth be renamed as **Master of Technology (M. Tech.) in Electronics Engineering**. The earlier title "Embedded Systems and Solutions" shall be subsumed as a specialization under the broader discipline of Electronics Engineering. This change is made to:

- Align the programme nomenclature with AICTE model curriculum guidelines.
- Enhance national benchmarking under NIRF and accreditation parameters of NBA.
- Safeguard and enhance employability in Public Sector Undertakings (PSUs) and government recruitment processes requiring core engineering discipline degrees.
- Ensure global academic recognition and facilitate smoother admission to doctoral programmes and international employment markets.
- Provide structural flexibility for introducing emerging specializations without altering the degree nomenclature.

The degree certificate shall reflect "Master of Technology in Electronics Engineering", along with the chosen specialization.

Resolution 2: Introduction of Specializations

It was resolved that under the umbrella of M. Tech. in Electronics Engineering, the following two contemporary specializations shall be offered:

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Notes:

1. **VLSI & Embedded Systems**
2. **Communication & Signal Processing**

Students shall opt for one specialization track, which will be duly reflected on the degree certificate and academic records.

Resolution 3: Approval of Revised Curriculum Structure

After extensive deliberation on the four-semester structure, course distribution, laboratory components, project pathways, infrastructure requirements, and industry alignment, the Committee resolves as follows:

I. **Common First Year:** The first year (Semesters I & II) shall remain common to both specializations in view of existing faculty strength and infrastructure constraints. Independent specialization from Semester I may be considered in the future subject to resource augmentation.

II. **Analog and Digital CMOS Design Courses:** Separate core courses shall not be introduced at present due to credit constraints. Students may pursue advanced depth through pre-projects and major projects.

III. **Tools and Infrastructure:** The Committee notes with satisfaction that requisite EDA tools have been procured and additional access secured through institutional collaborations and national programmes, ensuring adequate experimental support.

IV. **Internship Quality Assurance:** Internships shall be permitted only at recognized industry partners and reputed academic institutions to maintain programme standards.

V. **Intake Diversification:** In addition to the approved intake of 18 students, 9 additional seats shall be reserved for candidates from outside the state to enhance diversity.

VI. **Fabrication Process for IC and Packaging:** In the absence of in-house fabrication facilities, the course shall be supported through internships at recognized institutions and approved online platforms (e.g., NPTEL/SWAYAM). Internal offering may be considered upon establishment of requisite facilities.

VII. **Foreign Language Course:** A 2-credit course titled **"Foreign Language"** shall be introduced in Semester IV. Expertise from allied university language departments shall be utilized for its delivery.

VIII. **Avoidance of Syllabus Overlap:** The syllabus shall undergo regressive review to eliminate redundancies and ensure progressive learning outcomes.

IX. **Industry & Market Orientation:** Courses shall be periodically reviewed to integrate cutting-edge and industry-relevant topics.

X. **Nanoelectronics Laboratory:** Experiments shall be conducted through simulation using available EDA tools under national support schemes.

XI. **Quantum Computing Prerequisites:** Foundational modules in Quantum Mechanics shall be delivered in collaboration with allied departments (e.g., Physics) to support the Quantum Computing course.

XII. **Project Evaluation Framework:** A detailed and transparent evaluation process for project work shall be incorporated into the final syllabus.

XIII. **Elective Basket Design:** Elective baskets are structured to ensure depth in specialization areas following completion of foundational courses.

XIV. **Project/Internship Pathways:** The curriculum shall clearly define two pathways:

- Pre-project / Pre-internship
- Project / Internship

The choice available to students shall be explicitly specified.

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XV. **Student Training & Skill:** Continuous training and skill development activities shall be prioritised throughout the programme duration.

In light of the above deliberations and resolutions, the Committee hereby approves and recommends the revised programme structure for M. Tech. in Electronics Engineering along with its two specializations and the detailed syllabus (enclosed as Annexure-I) for implementation from the forthcoming academic session (2026), subject to approval by the competent academic authorities.

Semester I (L-T-P-C)	Semester II (L-T-P-C)
Digital and analog CMOS Design (4-0-0-4) **Advanced Embedded Systems Architecture and Firmware Engineering** (4-0-0-4) **Wireless Signal Propagation** (4-0-0-4) **Advanced Digital Signal Processing** (4-0-0-4) **RF and Microwave Circuit Design** (4-0-0-4) **CMOS Design and Embedded Systems Lab** (0-0-4-2) **Signal Processing and Communication-I Lab** (0-0-4-2) *Total Credits (24)*	**FPGA Architectures, Design and Applications** (4-0-0-4) **Internet of Things System Design** (4-0-0-4) **MIMO and Emerging Communication Systems** (4-0-0-4) **Advanced Digital Image Processing** (4-0-0-4) **Introduction to AI & Machine Learning** (4-0-0-4) **FPGA Design, AI and IoT Lab** (0-0-4-2) **Signal Processing and Communication-II Lab** (0-0-4-2) *Total Credits (24)*

Semester III (L-T-P-C)		Semester IV (L-T-P-C)
S1: VLSI & ES	**S2: C & SP**	
Elective 1 (4-0-4-6) 1. Neuromorphic Computing 2. Nanoelectronics 3. Quantum Computing **Elective 2** (4-0-4-6) 1. Secure and Intelligent Embedded Systems 2. Advanced Drone Technology 3. Cyber Physical Systems **Elective 3** (4-0-4-6) 1. Neural Networks and Deep Learning 2. Hardware Architectures for AI 3. Robotics & AI **Pre-Project/Pre-Internship** (0-0-4-2) *Total Credits (20)*	**Elective 1** (4-0-4-6) 1. Machine Learning for Wireless Communication 2. RF Sensing and Imaging 3. Advanced Wireless and Mobile Networks **Elective 2** (4-0-4-6) 1. Multimedia Signal Coding and Communication 2. Computer Vision 3. Speech Signal Processing **Elective 3** (4-0-4-6) 1. Radiating Systems for RF Communication 2. RF and Microwave Measurements 3. Advanced Electromagnetic Engineering **Pre-Project/Pre-Internship** (0-0-4-2) *Total Credits (20)*	**Foreign Language** (Communicative French/ Communicative Russian/ Communicative German) (2-0-0-2) **Research Methodology** (4-0-0-4) **Project/ Internship** (0-0-28-14) *Total Credits (20)*

VLSI & ES: Very Large Scale Integration and Embedded Systems; **C & SP:** Communication and Signal Processing

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Notes:

The meeting concluded with a vote of thanks to the Chair and all members for their valuable inputs.

Members of the committee:

(Dr. Farooq A. Khanday)
Chairman

(Prof. M. Tariq Banday)
Member

(Dr. Shabir A. Parah)
Member

(Dr. Javaid A. Sheikh)
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Member

(Dr. Farooq A. Khanday)
Head of the Department

PG **Department of Electronics** and **Instrumentation Technology**

University of Kashmir, Srinagar - 190006

M. Tech. in ELECTRONICS ENGINEERING

With Specializations in

1. VLSI and Embedded Systems
2. Communication and Signal Processing

Name of the Programme:

M. Tech. in **Electronics Engineering** at *Department of Electronics and Instrumentation Technology, Main Campus, University of Kashmir,* Srinagar.

Introduction:

The M. Tech. in Electronics Engineering stands as a critical academic and professional pathway, fundamentally powering the nation's technological ambitions through its key specializations in VLSI & Embedded Systems, and Communications & Signal Processing. These focus areas are not merely academic tracks but direct responses to India's strategic national imperatives. The VLSI & Embedded Systems specialization is the cornerstone of the India Semiconductor Mission (ISM) and Production-Linked Incentive (PLI) scheme, producing the chip designers, verification engineers, and embedded architects essential for achieving electronics manufacturing self-reliance. Simultaneously, the Communications & Signal Processing specialization fuels the connectivity backbone of the nation, enabling the 5G/6G networks, cyber security, and intelligent signal analysis critical for the Digital India infrastructure, defence modernization, and the sensor-driven networks of the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) & National Quantum Mission (NQM). Together, these specializations equip graduates to bridge the critical gap between design innovation and manufacturing scalability, which is the ultimate goal of the Electronics System Design and Manufacturing (ESDM) policy. Framed by the multidisciplinary and innovation-focused ethos of the National Education Policy (NEP) 2020, the program's curriculum integrates industry-aligned projects, access to advanced EDA tools, and research in cutting-edge labs. This ecosystem, further supported by Start-up India for hardware entrepreneurship and Skill India for niche competencies, ensures that graduates are not only equipped for high-impact R&D roles in semiconductor giants, telecom leaders, and premier agencies like ISRO, DRDO and

Prominent Public/ Private Sector enterprises, but are also primed to become innovators and entrepreneurs, actively scripting India's ascent as a global electronics and digital power.

Duration:

Regular **TWO** Years (**FOUR** Semesters) Degree Programme.

Eligibility:

B.E./B. Tech. or equivalent in Electronics & Communication / Electronics/Electrical & Electronics/ Instrumentation/Micro Electronics/Electronics & Tele-communications/VLSI Design/Electrical, Computer Sciences) or M. Sc. Electronics/ M. Sc. Radio Physics and Electronics/M.Sc. Physics with specialization in Electronics with 55% marks for general category and 50% marks for reserved categories in the qualifying examination from a recognised University / Institute.

Mode of Selection:

Selection of candidates to the programme shall be made on the basis of a valid **GATE Score**. If the seats remain vacant, the university entrance test shall be conducted to fill the vacant seats.

Intake Capacity:

EIGHTEEN (18) to be filled up from Open Merit and Reserved Categories as per the University Admission Policy. In **addition NINE (09)** seats will be reserved for students from outside the state.

Course Fee:

As notified by the University.

Course Structure:

The M. Tech. in Electronics Engineering program is meticulously structured over four semesters to build a robust and specialized skill set, integrating theoretical depth with intensive practical application, and culminating in a significant independent project or industry internship. The curriculum is explicitly designed to align with the demands of national initiatives like the Electronics System Design and Manufacturing (ESDM) policy, the India Semiconductor Mission, and Digital India. The students will study common courses up-to 2[nd] semester and from 3[rd] semester, the students will study the courses pertaining to their chosen specialization. Besides in the third semester, the students can choose between pursuing a project or internship individually under supervision. However, the students shall be allowed to pursue internships only in reputed

MNCs/PSUs/Institutions of their specialization after the approval from the Departmental Committee.

The program begins with a common foundational core in Semester I and II establishing a strong base across both major specializations—VLSI & Embedded Systems and Communications & Signal Processing. The courses are complemented by hands-on labs that immediately translate theory into practice. The semesters carries a substantial 24-credit load, emphasizing a high-intensity, balanced approach between lecture (L), tutorial (T), practical (P), and credit (C) components. The program's pivotal highlight is its innovative and flexible structure in Semester III and IV, where students diverge into their chosen specialization tracks through a rich array of advanced electives, each configured as a combined theory-practice module. This period also includes critical preparatory work through a Pre-Project/Pre-Internship module and a compulsory Research Methodology and IPR course, ensuring scholarly rigor. The program's capstone experience is the dedicated Semester IV, which is almost entirely devoted to a full-time Project or Internship, allowing students to apply their cumulative knowledge in a real-world R&D or industrial setting. Key structural highlights include: a seamless theory-to-practice arc with labs in every semester; an early and deep integration of AI/ML across both hardware and signal processing domains; a unique elective structure where each chosen course bundles significant practical work for in-depth mastery; and a final semester fully dedicated to industry-aligned project work, ensuring graduates are not only theoretically proficient but also production-ready innovators capable of contributing immediately to the national electronics ecosystem. Finally, a course on foreign language in the fourth semester will help students to find opportunities at international level.

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Semester – I (AUG – DEC)

Term	Course Code	Course Title	Hours			Credits	Marks		
			Lecture	Tutorial	Practical		Internal	End Term	Total
Semester I *Course Work (JUL – DEC)*	MEENCDA126	Digital and Analog CMOS Design	4	0	0	4	30	70	100
	MEENCES126	Advanced Embedded Systems Architecture and Firmware Engineering	4	0	0	4	30	70	100
	MEENCWP126	Wireless Signal Propagation	4	0	0	4	30	70	100
	MEENCDS126	Advanced Digital Signal Processing	4	0	0	4	30	70	100
	MEENCRF126	RF and Microwave Circuit Design	4	0	0	4	30	70	100
	MEENCCE126	CMOS Design and Embedded Systems Lab	0	0	4	2	15	35	50
	MEENCSC126	Signal Processing and Communication-I Lab	0	0	4	2	15	35	50
Semester – I (Course Work) Total			**20**	**0**	**8**	**24**	**180**	**420**	**600**

Semester – II (MAR – JUN)

Term	Course Code	Course Title	Hours			Credits	Marks		
			Lecture	Tutorial	Practical		Internal	End Term	Total
Semester II *Course Work (JAN – JUN)*	MEENCFA226	FPGA Architectures, Design and Applications	4	0	0	4	30	70	100
	MEENCIT226	Internet of Things System Design	4	0	0	4	30	70	100
	MEENCEC226	MIMO and Emerging Communication Systems	4	0	0	4	30	70	100
	MEENCDI226	Advanced Digital Image Processing	4	0	0	4	30	70	100
	MEENCAI226	Introduction to AI & Machine Learning	4	0	0	4	30	70	100
	MEENCFM226	FPGA Design, AI and IoT Lab	0	0	4	2	15	35	50
	MEENCSC226	Signal Processing and Communication-II Lab	0	0	4	2	15	35	50
Semester – II (Course Work) Total			**20**	**0**	**8**	**24**	**180**	**420**	**600**

Semester – III (AUG – NOV)

Term	Course Code	Course Title	Hours: Lecture	Hours: Tutorial	Hours: Practical	Credits	Marks: Internal	Marks: End Term	Marks: Total
Specialization 1: VLSI and Embedded Systems									
Semester III *Course Work* (JUL – DEC)	*Elective – 1 (One course to be selected by students)*								
	MEENDNC326	Neuromorphic Computing	4	0	4	6	45	105	150
	MEENDNE326	Nanoelectronics							
	MEENDQC326	Quantum Computing							
	Elective – 2 (One course to be selected by students)								
	MEENDSI326	Secure and Intelligent Embedded Systems	4	0	4	6	45	105	150
	MEENDDT326	Advanced Drone Technology							
	MEENDCP326	Cyber Physical Systems							
	Elective – 3 (One course to be selected by students)								
	MEENDNN326	Neural Networks and Deep Learning	4	0	4	6	45	105	150
	MEENDHA326	Hardware Architectures for AI							
	MEENDRA326	Robotics & AI							
	MEENPPP326	Pre-Project	0	0	4	2	15	35	50
	MEENIPI326	Pre-Internship							
Specialization 2: Communication and Signal Processing									
Semester III *Course Work* (JUL – DEC)	*Elective – 1 (One course to be selected by students)*								
	MEENDML326	Machine Learning for Wireless Communication	4	0	4	6	45	105	150
	MEENDRF326	RF Sensing and Imaging							
	MEENDWM326	Advanced Wireless and Mobile Networks							
	Elective – 2 (One course to be selected by students)								
	MEENDMM326	Multimedia Signal Coding and Communication	4	0	4	6	45	105	150
	MEENDCV326	Computer Vision							
	MEENDSS326	Speech Signal Processing							
	Elective – 3 (One course to be selected by students)								
	MEENDRS326	Radiating Systems for RF Communication	4	0	4	6	45	105	150
	MEENDRM326	RF and Microwave Measurements							
	MEENDAE326	Advanced Electromagnetic Engineering							
	MEENPPP326	Pre-Project	0	0	4	2	15	35	50
	MEENIPI326	Pre-Internship							
Semester – III (Course Work) Total			**12**	**0**	**16**	**20**	**140**	**360**	**500**

Semester – IV (MAR – JUN)

Term	Course Code	Course Title	Hours: Lecture	Hours: Tutorial	Hours: Practical	Credits	Marks: Internal	Marks: End Term	Marks: Total
Semester IV Course Work	MEENCRM426	Research Methodology and IPR	4	0	0	4	30	70	100

and Project/ Internship	Foreign Language Course								
(JAN – JUN)	MEENCCF426	Communicative French	2	0	0	2	15	35	50
	MEENCCR426	Communicative Russian							
	MEENCCG426	Communicative German							
	Project/ Internship								
	MEENPPR426	Project	0	0	28	14	105	245	350
	MEENIIN426	Internship							
Semester – IV (Course Work) Total			6	0	28	20	150	350	500

Note: Credits as specified in the regulation of the programme can be earned from UGC recognised online platforms such as SWAYAM. The maximum number of credits earned shall be governed by the University policy.

Examinations:

Semester – I:

a) **Course Work Examination: Commences in 2nd Week of December.**

Semester – II:

a) **Course Work Examination: Commences in 2nd Week of July.**

Semester – III:

a) **Course Work Examination: Commences in 2nd Week of December.**

Semester – IV:

a) **Internship and Thesis Examination: Commences in 2nd Week of July.**

Assessment and Grades:

Marks Percentage Range (P)	Grade (G)	Grade Letter	Grade Points
90 to 100	Outstanding	A+	10
80 to <90	Excellent	A	9
70 to <80	Very Good	B+	8
60 to <70	Good	B	7
50 to <60	Above Average	C	6
<50	Fail	F	0
0	Absent	Ab	0

Pre-Project and Project work:

In the Pre-Project work, students shall choose a specific topic/area for their project. A supervisor will be assigned to each student, who at the beginning of the 3rd semester shall provide a syllabus and plan of study including relevant research papers to the student.

The project work shall be of six months (Minimum 18 weeks') duration and a student can accumulate 16 credits on successful completion of Project. This is in addition to pre-project work in 3rd semester wherein students shall choose a specific topic/area for their project and undertake its study.

After the completion of project work, students work shall be evaluated by an external examiner. The evaluation will be through Viva-Voce presentation and demonstration.

Pre-Internship and Internship:

In Pre-Internship, students shall choose a specific domain for their Internship and identify prospective organizations and apply for Internship programmes. For Pre-Internship work, a counselor will be assigned to each student, who at the beginning of the 3rd semester shall guide him/her regarding identifying the prospective organizations and applying therein. Given the demand in Fabrication Process for IC and Packaging, the students shall be motivated to do the internships focused on fabrication in recognized industry or academic institutions of excellence.

Internship shall be of six months (Minimum 18 weeks') duration and a student can accumulate 16 credits on successful completion of internship. Internships shall be considered as six months (not less than 18 weeks) of supervised learning carried out at industry or some academic institution of excellence. Students are encouraged to apply for internship in 3rd semester to recognized industries or academic institutions of excellence so that its commencement is ensured at the beginning of 4th semester. After the completion of internship at recognized industries or academic institutions of excellence, students work shall be first be first evaluated by the internal evaluator of the department and after the work done under internship is found fit, the work will be evaluated by an external examiner through Viva-Voce presentation.

Programme Learning Outcomes (PLOs)

After completing the programme:

PLO1. Engineering Knowledge:

The students shall be able to apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to solve complex engineering problems.

PLO2. Problem Analysis and Research Aptitude:

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The students shall be able to identify, formulate, review research literature, and analyze complex engineering problems, reaching substantiated conclusions using the first principles of mathematics, natural sciences, and engineering sciences. Develop the ability to plan, conduct, and report on experimental and simulation-based investigations using state-of-the-art.

PLO3. Design/Development of Solutions and Creativity:

The students shall be able to design innovative solutions for engineering problems & design system components or processes that meet the specified needs with appropriate consideration for public health, safety, and cultural, societal, and environmental considerations.

PLO4.Investigation of Complex Problems:

The students shall be able to use research-based knowledge and research methods, including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PLO5. Modern Tool Usage/Skill Development:

The students shall be able to create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, to complex engineering activities with an understanding of the limitations.

PLO6. The Engineer and Society:

The students shall be able to apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PLO7. Environment, Sustainability and Ethics:

The students shall be able to understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate the knowledge of and need for sustainable development. The students shall be able to apply ethical principles and commit to professional ethics, responsibilities, and norms of engineering practice.

PLO8. Individual and Teamwork:

The students shall be able to function effectively as an individual, member, or leader in diverse teams and multidisciplinary settings.

PLO9: Application of Knowledge

Apply theoretical concepts to design, simulate, and troubleshoot analog and digital electronic circuits and systems for solving real-world problems.

PLO10. Life-long Learning:

The students shall be able to recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Question Paper pattern and Distribution of marks for End Term & Internal Examination

Credits	4		2	
Descriptive Questions	Time: Two and a Half Hours		Time: Two and a Half Hours	
Break up of Semester End & Internal Marks in each Course	End Term	Internal	End Term	Internal
	Questions× Marks		Questions× Marks	
	4× 17.5=70*	4× 7.5=30*	2× 17.5=35*	2× 7.5=15*
Section A: 08 Short Answer Type (in about 30 to 50 words)	8× 2=16 Marks	As prescribed by BOS	8× 1=8 Marks	As prescribed by BOS
Section B: 04 Medium Answer Type with alternatives (in about 200 to 250 words)	4× 6=24 Marks		4× 3=12 Marks	
Section B: 02 out of 04 Long Answer Type (in about 400 to 500 words) questions to be attempted	2× 15=30 Marks		2× 7.5=15 Marks	
Total Marks of Theory in each Course	4× 25=100* Marks		2× 25=50* Marks	

*N.B: The distribution of the marks is based on the rationale that 1 (one) credit=25 marks (External 17.5 + Internal 7.5)

Semester – I *(Course Work)*
MEENCDA126: Digital and Analog CMOS Design

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	0	4	30	70	100	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENCDA126.1	Analyze and model the physical operation of MOS transistors, including subthreshold conduction, channel-length modulation, and body effect, to determine their behavior in both digital and analog circuits.
MEENCDA126.2	Design, simulate, and evaluate static and dynamic digital CMOS logic gates with emphasis on performance metrics and layout techniques.
MEENCDA126.3	Design and analyze foundational analog CMOS building blocks using small-signal models and design parameters.
MEENCDA126.4	Apply the principles of CMOS operational amplifier design and evaluate key performance characteristics.

Detailed Syllabus (04 Theory Credits):

Unit 1: Introduction to Digital CMOS Design (15 Hrs.)

Basic MOS structure and its static behaviour, Advanced technologies: Giga-scale dilemma, Short channel effects, High-k, Metal Gate Technology, FinFET, TFET etc.
Overview of digital VLSI design methodologies – Trends in IC Technology – Advanced Boolean algebra – Shannon's expansion theorem – Consensus theorem – Reed Muller expansion – Synthesis of multiple output combinational logic circuits by product map method – Design of static hazard free, dynamic hazard free logic circuits.
Quality metrics of a digital design: Cost, Functionality, Robustness, Power, and Delay, Stick diagram and Layout, Wire delay models.

Unit 2: Combinational and Sequential CMOS Logic Design (15 Hrs.)

Inverter: Static CMOS inverter, Switching threshold and noise margin concepts and their evaluation, Dynamic behaviour, Power consumption.
Combinational logic: Static CMOS design, Logic effort, Ratioed logic, Pass transistor logic, CMOS transmission gate logic, Dynamic logic, Speed and power dissipation in dynamic logic, Cascading dynamic gates, BiCMOS logic.
Arithmetic circuits in CMOS VLSI - Adders- multipliers- shifter
Sequential logic: Static latches and registers, Bi-stability principle, MUX based latches, Static SR flip-flops, Master-slave edge-triggered register, Dynamic latches and registers, Concept of pipelining, Pulse registers, Non-bistable sequential circuit.

Unit 3: CMOS Amplifiers (15 Hrs.)

Analog Signal Processing, Example of Analog Mixed Signal Circuit Design, current mirrors.
Single stage Amplifier: CS stage with resistance load, diode connected load, current source load, triode load, CS stage with source degeneration, source follower, common-gate stage, cascade stage, Frequency response of CS, Differential Amplifiers: Mirrors: Basic difference pair, common mode response, Differential pair with OS loads, Gilbert cell.

Unit 4: CMOS Operation Amplifier and Applications (15 Hrs.)

Operational amplifiers: One stage OPAMP, Two stage OPAMP, Gain boosting, Common mode feedback, Slew rate, PSRR, Compensation of 2 stage OPAMP.
Introduction to Switched Capacitor Circuits, PLL and Voltage Reference.
Static & Dynamic Characteristics of DAC & ADC, Architectures of DAC & ADC.

Text and Reference Books:

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1. *J. P. Rabaey, A. P. Chandrakasan, B. Nikolic, "Digital Integrated circuits: A design perspective", Prentice Hall electronics and VLSI series, 2nd Edition, 2003.*
2. *Behzad Razavi, "Design of Analog CMOS Integrated Circuits", TMH, 2007.*
3. *Philip E. Allen and Douglas R. Holberg, "CMOS Analog Circuit Design", Oxford, 3rd Edition, 2012.*
4. *R. J. Baker, "CMOS circuit Design, Layout and Simulation", IEEE Inc., 2008.*
5. *S. Kang, and Y. Leblebici, "CMOS Digital Integrated Circuits, Analysis and Design", TMH, 3rd Edition, 2002.*
6. *D. A. Pucknell, and K. Eshraghian, "Basic VLSI Design", PHI, 3rd Edition, 1995.*

CLO-PLO matrix for the course MEENCDA126 (Digital and Analog CMOS Design)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCDA126.1	3	2.5	2	2	1.5	1.5	1.5	2.5	2.7	2.5	**2.17**
MEENCDA126.2	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	**2.41**
MEENCDA126.3	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	**2.41**
MEENCDA126.4	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	**2.41**
Average PLO	**2.62**	**2.5**	**2.52**	**2.52**	**2.62**	**1.5**	**1.5**	**2.5**	**2.7**	**2.5**	**2.35**

Semester – I *(Course Work)*

MEENCES126: Advanced Embedded Systems Architecture and Firmware Engineering

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	0	4	30	70	100	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENCES126.1	Analyze ARM-based processor architectures and evaluate performance, determinism, and power trade-offs.
MEENCES126.2	Design and implement structured firmware for ARM Cortex systems with optimized drivers and startup code.
MEENCES126.3	Apply real-time scheduling, compiler optimizations, and hardware–software co-design for efficient embedded solutions.
MEENCES126.4	Use debugging, tracing, and profiling tools to optimize execution, memory, and energy in industry-grade embedded systems.

Detailed Syllabus (04 Theory Credits):

Unit 1: Advanced Processor and System Architecture Foundations (15 Hrs.)

Evolution of embedded processor architectures from simple microcontrollers to complex system-on-chip platforms; instruction set architecture (ISA) principles including RISC and CISC philosophies; microarchitectural concepts including pipelining, hazards, instruction-level parallelism and branch behavior, in-order versus out-of-order execution relevance in embedded domains; Harvard, Von Neumann and modified Harvard architectures; cache organization, tightly coupled memory and memory hierarchy trade-offs; comparison of embedded processor families including ARM and RISC-V with application-driven architectural selection criteria; architectural trade-offs involving performance, power consumption, determinism and silicon area; trends in heterogeneous and multicore embedded platforms such as CPU, DSP, GPU and TPU integration. ARM big. LITTLE architecture. VLIW, SIMD, and vector processors. Trends in Reconfigurable processors and FPGA-based SoCs.

Unit 2: ARM Cortex Architecture and Processor Subsystems (15 Hrs.)

Architecture model and ecosystem of Arm Ltd.; ARM processor families including Cortex-A, Cortex-R and Cortex-M with domain-specific comparison; detailed architectural study of Cortex-M3 and Cortex-M4 including pipeline organization, Thumb-2 instruction set, exception handling model, Nested Vector Interrupt Controller (NVIC), interrupt latency mechanisms, DSP extensions and floating-point architecture; memory organization including memory maps, bit-banding, Memory Protection Unit (MPU), AHB/APB bus architecture and DMA controller operation; system-level data flow analysis and architectural trade-offs in performance, determinism and power efficiency.

Unit 3: Professional Firmware Engineering and Embedded Software Architecture (15 Hrs.)

ARM-based embedded hardware platforms and development environments such as Keil MDK and Simplicity Studio; Firmware design methodology including boot sequence, startup code, reset handling and vector table organization; linker scripts and memory section placement (.text, .data, .bss), stack and heap configuration; CMSIS abstraction and scalable peripheral driver architecture; embedded C toolchains and cross-compilation process; compiler optimization techniques; structured firmware development practices aligned with industry standards; low-power design techniques including sleep states, clock gating, dynamic voltage and frequency scaling (DVFS) concepts and energy-aware firmware design; real-time design principles and interrupt-driven system implementation; implementation of communication interfaces including SPI, I2C, UART and CAN; system integration and modular firmware architecture for scalable embedded platforms.

Unit 4: Advanced Debugging, Trace, Profiling and Performance Engineering (15 Hrs.)

Embedded debugging methodologies including software-based and hardware-assisted techniques, breakpoints, watchpoints and runtime monitoring under real-time constraints; detailed study of ARM CoreSight architecture including Embedded Trace Macrocell (ETM), Instrumentation Trace Macrocell (ITM) and Data Watchpoint and Trace (DWT); debug communication interfaces such as SWD and JTAG; usage of ARM ULINK debug adapters including ULINK-ME, ULINKpro and ULINKplus for real-time program trace, memory inspection, execution-time measurement and energy profiling; execution analysis, stack and heap monitoring, bottleneck identification and systematic performance optimization strategies for high-performance and industry-grade embedded systems.

Text and Reference Books:

1. *J. Yiu, "The definitive guide to ARM Cortex M3 and Cortex M4 processors", Newnes, 2010.*
2. *W. Wolf, "Computers as components: Principles of embedded computing system design", Morgan Kaufmann, 3rd ed., 2006.*
3. *F. Vahid, & T. Givargis, "Embedded system design: A unified hardware/software introduction", Wiley, 2002.*
4. *M. Barr & A. Massa, "Programming embedded systems", O'Reilly Media, 2006.*
5. *ARM Ltd. (n.d.). ARM architecture reference manuals and technical reference manuals (latest editions). Retrieved from https://developer.arm.com/documentation*
6. *C. Ünsalan, H. D. Gürhan, & M. E. Yücel, "Embedded system design with ARM Cortex M microcontrollers: Applications with C, C++ and MicroPython", Springer Cham, 2022.*
7. *J. D. Bakos, "Embedded systems: ARM programming and optimization" Morgan Kaufmann, 2nd ed., 2024.*

CLO-PLO matrix for the course MEENCES126 (Advanced Embedded Systems Architecture and Firmware Engineering)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCES126.1	3	2.5	2	2	1.5	1.5	1.5	2.5	2.7	2.5	2.17
MEENCES126.2	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	2.41
MEENCES126.3	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	2.41
MEENCES126.4	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	2.41
Average PLO	**2.62**	**2.5**	**2.52**	**2.52**	**2.62**	**1.5**	**1.5**	**2.5**	**2.7**	**2.5**	**2.35**

Semester – I *(Course Work)*

MEENCWP126: Wireless Signal Propagation

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	0	4	30	70	100	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENCWP126.1	Analyze wireless communication system models under fading environments and evaluate BER performance with channel estimation and diversity techniques.
MEENCWP126.2	Model and characterize wireless channels using delay spread, Doppler spread, coherence bandwidth, and coherence time parameters.
MEENCWP126.3	Evaluate the capacity of wireless channels under AWGN, flat fading, and frequency-selective fading conditions with diversity and CSI considerations.
MEENCWP126.4	Design and analyze optimal demodulation and reception techniques, including ML detection, equalization, carrier synchronization, and timing recovery.

Detailed Syllabus (04 Theory Credits):

Unit 1: Principles of Wireless Communications (15 Hrs.)

Wireless Communication Environment, Modelling of Wireless Systems, System Model for Narrowband Signals, Rayleigh Fading Wireless Channel, Baseband Model of a Wireless System, SNR and BER Performance in a Wireless System, Rayleigh BER at High SNR, Channel Estimation in Wireless Systems, BER in Fading Channels, Diversity in Wireless Communications, Multiple Receive Antenna System Model: Symbol Detection, BER and Channel Estimation.

Unit 2: Wireless Channel Modelling (15 Hrs.)

Basics of Wireless Channel Modelling: Maximum Delay Spread, RMS Delay Spread, RMS Delay Based on Average Power Profile. Average Delay Spread in Outdoor Cellular Channels, Coherence Bandwidth, Relation Between ISI and Coherence Bandwidth in Wireless Communication, Doppler Fading and Doppler Shift Computation in Wireless Systems, Doppler Impact and Coherence Time in Wireless Channels, Jakes Model for Wireless Channel Correlation.

Unit 3: Capacity of Wireless Channels (15 Hrs.)

Introduction, Capacity Analysis, Capacity in AWGN, Capacity of Flat Fading Channels, Channel and System Model, Channel Distribution Information (CDI) Known, Channel Side Information at Transmitter and Receiver, Capacity with Receiver Diversity, Capacity Comparisons, Capacity of frequency selective fading channels, Time-Invariant Channels, Time-Varying Channel, Diversity: Introduction, Channel known at transmitter, Alamouti scheme, Equalization, Directly linear equalizers in communication Receiver.

Unit 4: Demodulation and Reception (15 Hrs.)

Maximum likelihood sequence detector, Optimum receiver for Continuous Phase Modulation signals, Optimum receivers for binary signals and M-ary orthogonal signals, Probability of error for envelope, detection of M-ary orthogonal signals and correlated binary signals, Carrier phase estimation- Phase Locked Loop, Decision directed loops, Symbol timing estimation- Maximum likelihood and Non decision directed.

Text and Reference Books:

1. *Rappaport. T.S., "Wireless Communication", Pearson Education, 2003.*
2. *Simon Haykin & Michael Moher, "Modern Wireless Communications", Pearson Education, 2007.*
3. *Aditya, "Principles of Modern Wireless Communication Systems ", McGraw-Hill Education (India) Private Limited, 2016.*
4. *David Tse, Pramod Vishwanath, "Fundamentals of Wireless Communication ", Cambridge University Press, 2005.*
5. *Andrea Goldsmith, "Wireless Communications", Cambridge University Press, 2007.*
6. *Arogyaswami Paulraj, et al, "Introduction to Space-Time Wireless Communications", Cambridge University Press, 2003.*

CLO-PLO matrix for the course MEENCWP126 (Wireless Signal Propagation)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCWP126.1	3	3	1	2	1	2	0	0	2	1	1.5
MEENCWP126.2	3	3	1	2	1	0	0	0	2	1	1.3
MEENCWP126.3	3	3	2	1	1	0	0	0	3	1	1.4
MEENCWP126.4	3	3	3	2	1	1	2	2	3	1	2.1
Average PLO	3	3	1.75	1.75	1	0.75	0.5	0.5	2.5	1	1.575

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Semester – I *(Course Work)*
MEENCDS126: Advanced Digital Signal Processing

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	0	4	30	70	100	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENCDS126.1	Analyze discrete-time signals and use Z-transform techniques to model and characterize digital signal processing systems.
MEENCDS126.2	Apply DFT-based analysis and use Fast Fourier algorithms to perform frequency-domain signal analysis and design digital IIR filters.
MEENCDS126.3	Design and implement multirate digital signal processing systems using decimation, interpolation, polyphase structures, and filter banks for efficient signal conversion and analysis.
MEENCDS126.4	Estimate power spectra of stationary random processes and design optimum and adaptive filters using non-parametric and parametric methods

Detailed Syllabus (04 Theory Credits):

Unit 1: Introduction to DSP (15 Hrs.)

Review of Discrete time signals and systems. Convolution and correlation of discrete time systems, linear time-invariant systems, Sampling, Quantization: uniform and non-uniform quantization and Lloyd–Max quantizer, Review of Z-transform. Discrete System modelling using Z-transform.

Unit 2: Discrete Fourier Transform and Digital Filter design (15 Hrs.)

Discrete Fourier transform, properties of DFT. Frequency domain sampling, linear filtering methods based on DFT, Frequency analysis of signals using the DFT, Decimation in time domain and decimation in frequency domain algorithms. IIR filter design using impulse invariance and bilinear transformation. Notch, comb, and all-pass filters, FIR filters.

Unit 3: Multirate DSP (15 Hrs.)

Decimation and Interpolation, Multistage design of interpolators and decimators; Poly-phase decomposition and FIR structures, Implementation of multirate conversion. Applications of multirate DSP. Digital filter banks: two-channel QMF, DFT, and M-channel filter banks.

Unit 4: Spectral Estimation and Optimum Filtering (15 Hrs.)

Stationary random processes and power spectral estimation. Non-parametric and parametric spectral estimation methods: Periodogram, Bartlett Method, Welch Method, Autoregressive (AR) Method, Yule–Walker Method, Wiener filters, least mean square filters, Recursive least square filters, Power spectrum estimation techniques.

Text and Reference Books:

1. *Alan V. Oppenheim and Ronald W. Schafer, "Discrete-Time Signal Processing", Pearson Education, 3rd Edition, 2010.*
2. *John G. Proakis and Dimitris G. Manolakis, "Digital Signal Processing: Principles, Algorithms, and Applications", Pearson Education, 4th Edition, 2007.*
3. *Sanjit K. Mitra, "Digital Signal Processing: A Computer-Based Approach", McGraw-Hill Education, 4th Edition, 2011.*
4. *P. P. Vaidyanathan, "Multirate Systems and Filter Banks", Prentice Hall, 1st Edition, 1993.*
5. *Monson H. Hayes, "Statistical Digital Signal Processing and Modeling", John Wiley & Sons, 1st Edition, 1996.*
6. *Petre Stoica and Randolph L. Moses, "Spectral Analysis of Signals", Pearson / Prentice Hall, 1st Edition, 2005.*
7. *Simon Haykin, "Adaptive Filter Theory", Pearson Education, 5th Edition, 2013.*

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CLO-PLO matrix for the course MEENCDS126 (Advanced Digital Signal Processing)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCDS126.1	3	3	2	2	2	1	1	1	3	2	2.0
MEENCDS126.2	3	3	3	2	3	1	1	1	3	2	2.2
MEENCDS126.3	3	3	3	2	3	1	1	2	3	2	2.3
MEENCDS126.4	3	3	3	3	3	1	1	1	3	2	2.3
Average PLO	3	3	2.75	2.25	2.75	1	1	1.25	3	2	2.2

Semester – I *(Course Work)*
MEENCRF126: RF and Microwave Circuit Design

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	0	4	30	70	100	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENCRF126.1	Analyze planar transmission lines and their equivalent circuit models for microwave applications.
MEENCRF126.2	Apply network parameter techniques (Z, Y, S, and ABCD matrices) to analyze and design microwave passive components, including power dividers, couplers, and hybrid circuits.
MEENCRF126.3	Design and implement microwave filter structures using appropriate synthesis techniques.
MEENCRF126.4	Design and evaluate microwave active circuits, including amplifiers, mixers, and phase shifters, considering stability and performance criteria.

Detailed Syllabus (04 Theory Credits):

Unit I: Planar Transmission Lines (15 Hrs.)

Lumped-element circuit model of Transmission Line, Terminated Lossless Transmission Lines, VSWR. Planar Transmission Lines: Stripline and Microstriplines, Impedance and Admittance Smith Chart, Matching Techniques: Single Stub, Double Stub L-section matching, Quarter Wave Transformer, Implementation using simulators.

Unit 2: Microwave Network Analysis (15 Hrs.)

Microwave Network Analysis: Impedance and equivalent voltage and current, Impedance and admittance matrix. Scattering Matrix: Reciprocal and Lossless Network Analysis using S-Matrix, Transmission Matrix, Signal Flow Graph. Basic Properties of Couplers and Power Dividers, T-junction Power Divider, Resistive Power Divider, Wilkinson Power Divider, Branch Line Couplers (90 degree hybrid), Rat Race (180 degree hybrid) Coupler.

Unit 3: Microwave Filters (15 Hrs.)

Periodic Structures, Filter Design by Image Parameter Method, Filter Design by Insertion Loss Method, Filter Transformations, Filter Implementation, Stepped Impedance Low Pass Filter, Coupled Line Filters.

Unit 4: Microwave Active Circuits (15 Hrs.)

Active circuits: Phase shifter, Mixer, Single-Stage Transistor amplifier. Amplifier Design: Power gain equations, Impedance matching, Amplifier gain stability, Constant gain circles, Design for maximum gain, DC biasing, and amplifier classes.

Text and Reference Books:

1. David M Pozar, "Microwave Engineering, Fourth Edition", John Wiley & Sons Publications, 2013.
2. Robert E. Collin, "Foundations for Microwave Engineering", Wiley, 2nd Edition, 2000.
3. G. Gonzalez, "Microwave transistor amplifier; design and analysis, Handbook", 2nd addition, Prentice hall Publications, 1984.
4. Lee Young and H. Sobol, Ed. Advances in Microwaves, vol.2 Academic press Inc, 2013.
5. S. Y. Liao, "Microwave circuit and analysis and amplifiers design", Prentice Hall, 1986.

CLO-PLO matrix for the course MEENCRF126 (RF and Microwave Circuit Design)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCRF126.1	3	3	2	1	3	1	1	2	3	1	2.00
MEENCRF126.2	3	3	3	2	2	1	1	2	3	1	2.10
MEENCRF126.3	3	3	3	2	2	1	1	2	3	1	2.10
MEENCRF126.4	3	3	3	2	2	2	2	2	3	1	2.30
Average PLO	3.0	3.0	2.75	1.75	2.25	1.25	1.25	2	3.0	1.0	2.125

Semester – I *(Course Work)*

MEENCCE126: CMOS Design and Embedded Systems Lab

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
0	0	4	2	15	35	50	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENCCE126.1	Integrate system-level considerations into the design flow, using industry-standard EDA tools for schematic capture, simulation (SPICE), and physical layout verification (DRC, LVS)/ Develop and configure bare-metal firmware on ARM Cortex platforms using Embedded C, managing memory, interrupts, and peripherals.
MEENCCE126.2	Developing low-power analog and digital CMOS circuits for industry specific problems/ Design, debug, and optimize modular embedded firmware by analyzing memory usage, compiler behavior, and execution performance.

Detailed Syllabus (02 Lab Credits) (60 Hrs.):

List of Experiments

Use V_{DD}=1.8 V for 0.18 um CMOS process, V_{DD}=1.3 V for 0.13 um CMOS Process and V_{DD}=1 V for 0.09 um CMOS Process.

1.
   a) Plot I_D vs. V_{GS} at different drain voltages for NMOS, PMOS.
   b) Plot I_D vs. V_{GS} at particular drain voltage (low) for NMOS, PMOS and determine V_{TH}.
   c) Plot log I_D vs. V_{GS} at particular gate voltage (high) for NMOS, PMOS and determine I_{OFF} and sub-threshold slope.
   d) Plot I_D vs. V_{DS} at different gate voltages for NMOS, PMOS and determine Channel length modulation factor.
   e) Extract V_{TH} of NMOS/PMOS transistors (short channel and long channel). Use V_{DS} = 30 mV.

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To extract V_{TH} use the following procedure.

i. Plot g_m vs V_{GS} using LTSPICE and obtain peak g_m point.

ii. Plot $y = \frac{I_D}{(g_m)^{\frac{1}{2}}}$ as a function of V_{GS} using LTSPICE/CADENCE VIRTUOSO.

iii. Use LTSPICE/CADENCE VIRTUOSO to plot tangent line passing through peak g_m point in y (V_{GS}) plane and determine V_{TH}.

f) Plot I_D vs. V_{DS} at different drain voltages for NMOS, PMOS, plot DC load line and calculate g_m, g_{ds}, g_m/g_{ds}, and unity gain frequency.

Tabulate your result according to technologies and comment on it.

Use V_{DD}=1.8V for 0.18um CMOS process, V_{DD}=1.2V for 0.13um CMOS Process and V_{DD}=1V for 0.09 um CMOS Process.

a) Perform the following

i. Plot VTC curve for CMOS inverter and thereon plot dV_{out} vs. dV_{in} and determine transition voltage and gain g. Calculate VIL, VIH, NMH, NML for the inverter.

2. ii. Plot VTC for CMOS inverter with varying V_{DD}.

iii. Plot VTC for CMOS inverter with varying device ratio.

b) Perform transient analysis of CMOS inverter with no load and with load and determine t_{pHL}, t_{pLH}, 20%-to-80% t_r and 80%-to-20% t_f. (use VPULSE = 2 V, C_{load} = 50 fF)

c) Perform AC analysis of CMOS inverter with fanout 0 and fanout 1. (Use C_{in}= 0.012 pF, C_{load} = 4 pF, R_{load} = k)

3. Use LTSPICE/CADENCE VIRTUOSO to build a three stage and five stage ring oscillator circuit in 0.18 um and 0.13 um technology and compare its frequencies and time period.

Design combinational and sequential logic circuits using

a) Static CMOS design Technique

b) Ratioed logic Technique

4. c) Pass transistor logic Technique

d) Dynamic logic Technique

Compare Speed and power dissipation of techniques

Perform the following

a) Draw small signal voltage gain of the minimum-size inverter in 0.18um and 0.13um technology as a function of input DC voltage. Determine the small signal voltage gain at the switching point using LTSPICE/Cadence virtuoso and compare the values for 0.18um and 0.13um process.

b) Consider a simple CS amplifier with active load, as explained in the lecture, with NMOS transistor M_N as driver and PMOS transistor M_P as load, in 0.18um technology. $(W/L)M_N$=5, (W/L) MP=10 and L=0.5um for both transistors.

5. i. Establish a test bench, as explained in the lecture, to achieve $V_{DSQ}=V_{DD}/2$.

ii. Calculate input bias voltage if bias current=50 uA.

iii. Use LTSPIC and obtain the bias current. Compare its value with 50 uA.

iv. Determine small signal voltage gain, -3 dB BW and GBW of the amplifier using small signal analysis in LTSPIC (consider 30 fF load capacitance).

v. Plot step response of the amplifier for input pulse amplitude of 0.1V. Derive time constant of the output and compare it with the time constant resulted from -3 dB BW

vi. Use LTSPIC to determine input voltage range of the amplifier

6. Three OPAMP INA. V_{DD}=1.8 V V_{ss}=0 V, CAD tool: Cadence virtuoso. Note: Adjust accuracy options of the simulator (setup->options in GUI). Use proper values of resistors to get a three OPAMP INA with differential-mode voltage gain=10.
Consider voltage gain = 2 for the first stage and voltage gain = 5 for the second stage.

   i. Draw the schematic of op-amp macro model.
   ii. Draw the schematic of INA.
   iii. Obtain parameters of the op-amp macro model such that
      I. low-frequency voltage gain = 5x10[illegible],
      II. unity gain BW (fu) = 500 KHz,
      III. input capacitance=0.2 pF,
      IV. output resistance = 100 Ω,
      V. CMRR=120 dB
   iv. Draw schematic diagram of CMRR simulation setup.
   v. Simulate CMRR of INA using AC analysis (it's expected to be around 6 dB below CMRR of OPAMP).
   vi. Plot CMRR of the INA versus resistor mismatches (for resistors of second stage only) changing from -5% to +5% (use AC analysis). Generate a separate plot for mismatch in each resistor pair. Explain how CMRR of OPAMP changes with resistor mismatches.
   vii. Repeat (iii) to (vi) by considering CMRR of all OPAMPs to be 90 dB.

7. Technology: UMC 0.18um, VDD=1.8V. Use MAGIC or Microwind.
   a) Draw layout of a minimum size inverter in UMC 0.18 um technology using MAGIC Station layout editor. Use that inverter as a cell and lay out three cascaded minimum-sized inverters. Use M_1 as interconnect line between inverters.
   b) Run DRC, LVS and RC extraction. Make sure there is no DRC error. Extract the netlist.
   c) Use extracted netlist and obtain t_{PHL},t_{PLH} for the middle inverter using Eldo.
   d) Use interconnect length obtained and connect the second and third inverter.

Extract the new netlist and obtain t_{PHL} and t_{PLH} of the middle inverter. Compare new values of delay times with corresponding values obtained in part 'c'.

8. Embedded Platform Study
   a) Systematic study of ARM Cortex-based development platforms and toolchains including environments such as Keil MDK, Simplicity Studio and other vendor-supported IDEs depending on institutional resources
   b) Understanding project structure, build configuration, linker settings and memory mapping

9. Bare-Metal Development
   a) Embedded C programming for register-level hardware control; development and extension of bare-metal applications including startup sequence understanding, interrupt handling and peripheral interfacing
   b) Experimentation with core peripherals and communication interfaces; analysis of processor behavior through structured Embedded C implementations and hardware interaction.

10. Firmware Structuring and Debugging
   a) Structured firmware development using Embedded C with modular driver architecture and system-level integration
   b) Experimentation with compilation process, build management and memory organization
   c) Debugging using software and hardware-assisted techniques including breakpoints, watchpoints and runtime inspection; exposure to professional debugging and trace tools subject to availability

11. Performance Exploration
   a) Exploration of compiler optimization impact on code size and execution behaviour
   b) Execution-time measurement, memory profiling and performance observation based on available hardware resources
   c) Progressive extension from basic bare-metal implementation toward optimized and structured firmware design.

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CLO-PLO matrix for the course MEENCCE126 (CMOS and Embedded System Design Lab)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCCE126.1	1.5	1.5	3	2	3	2	2	3	3	2.5	2.35
MEENCCE126.2	1.5	1.5	3	2	3	2	2	3	3	2.5	2.35
Average PLO	1.5	1.5	3	2	3	2	2	3	3	2.5	2.35

Semester – I *(Course Work)*

MEENCSC126: Signal Processing and Communication-I Lab

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
0	0	4	2	15	35	50	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENCSC126.1	Model and simulate wireless communication systems under fading conditions and evaluate performance metrics such as BER, capacity, and diversity gain/Implement and analyze advanced discrete-time signal processing algorithms including Z-transform modeling, DFT/FFT-based analysis, digital filter design, and multirate signal processing using appropriate computational tools/Analyze transmission-line behaviour and implement impedance-matching techniques using EM and microwave CAD tools for accurate microwave network design.
MEENCSC126.2	Analyze wireless channel characteristics such as delay spread, coherence bandwidth, Doppler spread, coherence time, and channel capacity to assess their impact on communication system performance/Design and evaluate spectral estimation and adaptive filtering techniques for real-world signals, and interpret performance using quantitative measures such as PSD, MSE, and convergence behaviour/Design and simulate microwave passive components and active circuits, including power dividers, couplers, filters, and amplifiers, using industry-standard RF design software.

Detailed Syllabus (02 Lab Credits) (60 Hrs.):

List of Experiments

1. Simulation of AWGN Channel and BER Performance Analysis for BPSK/QPSK Modulation.
2. Simulation of Rayleigh Fading Channel and Comparison of BER Performance with AWGN Channel.
3. Computation of RMS Delay Spread, Coherence Bandwidth, and Coherence Time for a Wireless Channel Model.
4. Simulation of Doppler Shift and Time-Selective Fading using Jakes Model.
5. Capacity Calculation of AWGN and Flat Fading Wireless Channels.
6. Verification of convolution and correlation of discrete-time signals using manual implementation and built-in functions.
7. Modeling and analysis of LTI systems using Z-transform concepts, pole-zero plots, and frequency response analysis.
8. Sampling and quantization of signals: Uniform quantization, Lloyd–Max quantizer implementation; Performance comparison using SQNR.
9. Implementation and comparison of DFT and FFT; analysis of computational complexity and execution time.
10. Frequency-domain filtering using DFT: Linear convolution using circular convolution, Overlap-add and overlap-save methods.
11. Design of IIR filters using impulse invariance and bilinear transformation; analysis of magnitude response, phase response, and stability.
12. Design and implementation of notch, comb, and all-pass filters with frequency response evaluation.
13. Implementation of decimation and interpolation; study of aliasing and imaging effects.
14. Multistage decimator and interpolator design using polyphase structures.

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15. Design and implementation of a two-channel Quadrature Mirror Filter (QMF) bank.
16. Power Spectral Density estimation using: Periodogram, Bartlett method, Welch method; Comparative performance analysis.
17. Implementation of adaptive filters: LMS algorithm, RLS algorithm; Evaluation of convergence behavior and Mean Square Error (MSE).
18. Adaptive noise cancellation of speech signal using LMS filtering.
19. Design of a simple multirate audio processing system using filter banks.
20. Studies on Reflection Characteristics of a Terminated Ideal Transmission Line.
21. Studies on the various techniques of impedance matching.
22. Design of Wilkinson Power Divider.
23. Design of Branch Line Coupler (90-degree hybrid).
24. Design of Coupled Line Coupler.
25. Design of a Stepped Impedance Low-Pass Filter.
26. Design of a Low Pass Filter using microstrip series/shunt stubs.
27. Design of Coupled Line Band Pass Filter.
28. Design of a Microwave Amplifier.

CLO-PLO matrix for the course MEENCSC126 (Signal Processing and Communication-I Lab)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCSC126.1	3	3	2	3	3	1	0	3	3	1	2.2
MEENCSC126.2	3	3	3	3	3	1	2	3	3	1	2.5
Average PLO	3	3	2.5	3	3	1	1	3	3	1	2.35

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Semester – II *(Course Work)*

MEENCFA226: FPGA Architectures, Design and Applications

Hours per Week			Credits	Maximum Marks			Examination
Lecture	Tutorial	Practical		Internal	End Term	Total	Hours
4	0	0	4	30	70	100	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENCFA226.1	Design, implement, and verify digital systems using Hardware Description Languages (HDLs) such as VHDL or Verilog, following a structured FPGA design flow encompassing RTL coding, functional simulation, synthesis, timing analysis, and place-and-route.
MEENCFA226.2	Compare and contrast the architecture of modern Field-Programmable Gate Arrays (FPGAs), including the roles and interconnections of Configurable Logic Blocks (CLBs), Block RAM (BRAM), Digital Signal Processing (DSP) slices, programmable I/O blocks, and specialized hard IP cores.
MEENCFA226.3	Apply advanced FPGA design techniques, including pipelining for performance, resource sharing for area optimization, synchronous design principles, and the effective use of clock management blocks (e.g., PLLs, MMCMs) for clock domain management.
MEENCFA226.4	Develop and implement FPGA-based systems for key application domains, such as real-time digital signal processing (FIR filters, FFT), embedded processing using soft-core processors (e.g., MicroBlaze, Nios II), and high-speed interfacing (e.g., memory controllers, Ethernet, PCIe).

Detailed Syllabus (04 Theory Credits):

Unit 1: Logic Synthesis, Simulation and Testing using HDL (15 Hrs.)

Verilog/VHDL/FSM, Verilog AMS.
Library declaration, Entity declaration, Architecture declaration, Data types, Design Modelling Approaches: Data flow modelling, Behavioural modelling, Structural modelling, Signals and variables, Testbench Architecture, Finite State Machine: Theory and Classification, Robust FSM Coding Patterns, Types of simulation, Introduction to Testing Concepts: Boundary scan test, Fault simulation, Automatic test pattern generation, design examples.

Unit 2: Introduction to Programmable Logic (15 Hrs.)

Evolution of Programmable Logic: PROMs, PLAs, PALs, CPLDs; FPGA vs. ASIC: Comparison, Applications, Trade-offs; FPGA Market Overview: Xilinx, Intel (Altera), Lattice, Microchip; FPGA Internal Architecture Overview: CLBs, IOBs, Interconnects, Clock Resources; Configuration Technologies: SRAM, Flash, Anti-fuse. Detailed FPGA Architecture and introduction to in-built macro support.

Unit 3: FPGA Architecture & Timing Analysis (15 Hrs.)

Introduction to various inbuild softcore (ip cores); Embedded Components: Block RAM, DSP Slices, PLL/DCM; Clock Management: Global and regional clock networks. Introduction to softcore based communication protocols e.g AXI4, Wishbone, Peripheral UART, I2C, SPI. Device Architecture and features of various 4th, 5th, & 6th generation FPGAs. Introduction to Basys3, Kria series boards.
Timing Concepts: Setup/Hold Time, Clock-to-Q Delay, Critical Path; Introduction to Static Timing Analysis (STA); Power Consumption Analysis and Optimization.

Unit 4: FPGA Design Methodology, Optimization and Applications (15 Hrs.)

HDL Coding Guidelines for FPGA; Synchronous Design Principles; Design Constraints: Clock, I/O, Timing Exceptions; Introduction to design heuristics(power, area, speed driven), introduction to component based approach, Design Sharing; IP Core Integration and Management; Partial Reconfiguration Concepts; Verification Methodology: Simulation, Formal Verification, Hardware Debugging; Introduction to High-Level Synthesis (HLS).
FPGA in Signal Processing: FIR filters, FFT implementation; FPGA in Embedded Processors: MicroBlaze, Nios II, ARM Cortex; FPGA in Communications: Ethernet MAC, Error Correction; Accelerating Algorithms: Machine Learning, Cryptography; System-on-Chip (SoC) Design with FPGAs.

Text and Reference Books:

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1. Charles H. Roth, Jr, "Digital Systems Design using VHDL", PWS Publishing Company, 2001.
2. Fredrick J. Hill and Gerald R. Peterson, "Computer Aided Logical Design with emphasis on VLSI", 4th edition, Wiley, 1993.
3. Stephen M. Trimberger, "Field Programmable Gate Array Technology", Springer International Edition, 1994.
4. Pong P. Chu, "FPGA Prototyping by VHDL Examples", Wiley, 2008.
5. Wayne Wolf, "FPGA-Based System Design", Prentice Hall, 2004.
6. D. A. Pucknell, and K. Eshraghian, "Basic VLSI Design", PHI, 3rd Edition, 1995.

CLO-PLO matrix for the course MEENCFA226 (FPGA Architectures, Design and Applications)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCFA226.1	3	2.5	2	2	1.5	1.5	1.5	2.5	2.7	2.5	**2.17**
MEENCFA226.2	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	**2.41**
MEENCFA226.3	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	**2.41**
MEENCFA226.4	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	**2.41**
Average PLO	**2.62**	**2.5**	**2.52**	**2.52**	**2.62**	**1.5**	**1.5**	**2.5**	**2.7**	**2.5**	**2.35**

Semester – II *(Course Work)*

MEENCIT226: Internet of Things System Design

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	0	4	30	70	100	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENCIT226.1	Analyze IoT system requirements and design appropriate reference architectures from device to edge and cloud.
MEENCIT226.2	Design and implement embedded IoT nodes with suitable communication protocols and energy-efficient strategies.
MEENCIT226.3	Evaluate architectural trade-offs related to scalability, latency, reliability, and performance in IoT systems.
MEENCIT226.4	Develop secure and scalable end-to-end IoT solutions incorporating middleware, cloud integration, and data management.

Detailed Syllabus (04 Theory Credits):

Unit 1: IoT Foundations and System Design Principles (15 Hrs.)

Evolution and Scope: IoT vs M2M vs CPS, IoT ecosystem and value chain, IoT application domains (IoT, Smart Cities, Healthcare, Agriculture). IoT System Characteristics: Heterogeneity and interoperability, Real-time constraints, Energy-awareness, Scalability challenges IoT System Design Methodology: Requirement engineering for IoT systems, Functional and non-functional requirements, IoT design patterns, Introduction to Digital Twins in IoT. Devices and Sensing Layer: Sensors and actuators, Signal conditioning basics, IoT device classification.

Unit 2: IoT Architectures and Edge–Cloud Integration (15 Hrs.)

IoT Reference Architectures: 3-Layer and 5-Layer models, Device–Gateway–Cloud architecture, Edge–Fog–Cloud continuum, Service-Oriented and Micro services architectures. Architectural Paradigms: Event-driven vs data-centric architectures, Centralized vs distributed IoT, Publish–Subscribe models. Architectural Trade-Offs: Latency vs bandwidth, Energy vs computation, Cost vs reliability, Case-based architecture selection. Industrial & Enterprise IoT Architecture: IoT reference models, Interoperability frameworks.

Unit 3: Embedded IoT Nodes, Networking & Protocol Stack (15 Hrs.)

Embedded Platforms: Arduino, ESP32, STM32, Raspberry Pi, RTOS for IoT nodes, Power management and energy-efficient design. IoT Networking Stack: PHY & MAC considerations, IPv6 and 6LoWPAN, TCP vs UDP. Communication Technologies: Short-range: BLE, ZigBee, Z-Wave, Long-range: LoRaWAN, NB-IoT, LTE-M, Wi-Fi and 5G IoT support. Application Layer Protocols: MQTT, CoAP, HTTP/REST, AMQP. Performance Evaluation: Latency, throughput, QoS, Reliability metrics.

Unit 4: IoT Middleware, Cloud Platforms, Security & Scalability (15 Hrs.)

IoT Middleware: Gateway design, Protocol translation, Message brokers. Cloud-Centric IoT: IoT platforms (AWS IoT, Azure IoT, Google IoT Core), Data ingestion pipelines, Stream processing and analytics, SQL vs NoSQL storage. IoT Security Architecture: Threat landscape, Device authentication and authorization, Secure boot and firmware validation, OTA updates, Data encryption and privacy. Scalability & Reliability: Load balancing, Fault tolerance, Resilient IoT architectures. Case Studies: Industrial IoT (IIoT), Smart City, Smart Healthcare.

Text and Reference Books:

1. *A. Basu, "Building IoT systems: Design scalable IoT systems from edge to cloud", Apress, 2025. https://doi.org/10.1007/979-8-8688-1212-5*
2. *S. Pal, C. Savaglio, R. Minerva, & F. C. Delicato (Eds.), "IoT edge intelligence", Springer, 2024. https://doi.org/10.1007/978-3-031-58388-9*
3. *S. Jha, U. Tariq, G. P. Joshi, & V. K. Solanki (Eds.), "Industrial internet of things: Technologies, design, and applications", Routledge, 2022.*
4. *S. Cherian, A. Kumar, N. Smith & D. M. Wheeler, "Demystifying internet of things security: Successful IoT device/edge and platform security deployment", Apress, 2020.*
5. *M. Milenkovic, "Internet of things: Concepts and system design", Springer Cham., 2020. https://doi.org/10.1007/978-3-030-41346-0.*
6. *S. K. Vasudevan, R. M. D. Sundaram, & A. S. Nagarajan, "Internet of Things", Wiley India, 3rd ed., 2024.*
7. *M. L. Flarence, P. A. Kumar, S. Fairooz, & N. S. Prasad, "IoT architectures and protocols", Quill Tech Publications, 2025.*

CLO-PLO matrix for the course MEENCIT226 (Internet of Things System Design)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCIT226.1	3	2.5	2	2	1.5	1.5	1.5	2.5	2.7	2.5	2.17
MEENCIT226.2	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	2.41
MEENCIT226.3	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	2.41
MEENCIT226.4	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	2.41
Average PLO	**2.62**	**2.5**	**2.52**	**2.52**	**2.62**	**1.5**	**1.5**	**2.5**	**2.7**	**2.5**	**2.35**

Semester – II *(Course Work)*

MEENCEC226: MIMO and Emerging Communication Systems

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	0	4	30	70	100	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENCEC226.1	Understand channel modelling and propagation, MIMO Capacity, space-time coding
MEENCEC226.2	Understand MIMO receivers, MIMO for multi-carrier systems (e.g. MIMO-OFDM), multi-user communications, multi-user MIMO
MEENCEC226.3	Understand cooperative and coordinated multi-cell MIMO, introduction to MIMO in 4G (LTE, LTE-Advanced, WiMAX)
MEENCEC226.4	Perform Mathematical modelling and analysis of MIMO systems

Detailed Syllabus (04 Theory Credits):

Unit I: MIMO Systems (15 Hrs.)

MIMO SYSTEMS - Introduction to MIMO system model - Multiuser MIMO communication - Larger MIMO System; Opportunities & Challenges in large MIMO system; Problems in large dimensions; Channel hardening-Channel hardening in large dimensions; Channel Models - Various distributions - standardized channel models; Channel Models: Effects of spatial correlation - Analysis of spatial correlation; Channel Estimation - Problems in channel estimation; Pilot contamination - Pilot contamination in massive MIMO; Technical challenges - Implementation issues Pilot contamination in massive MIMO; Design of massive MIMO system - Technical challenges.

Unit 2: Multiple Antennas (15 Hrs.)

Multiple Antennas - Multiple Transceivers System analysis - Problems in Multiple Transceivers; Noise coupling - Measuring parameters - Noise coupling in MIMO system; Classification of diversity – Spatial diversity - Temporal diversity - Frequency diversity; Dynamic spatial modulation allocation - frequency modulation allocation - Analysis of frequency modulation allocation; Beam steering - Analysis of Beam steering - Beam forming; mm-Wave Standardization.

Unit 3: Non-Orthogonal Multi-User Technique (15 Hrs.)

Introduction to NOMA, Basic Principles and Features of Non-orthogonal Multi-user Access, Downlink Non-orthogonal Multi-user Transmission, Uplink Non-orthogonal Multi-user Access (LDS-CDMA/OFDM, SCMA, MUSA, PDMA), Concept of downlink NOMA and uplink NOMA, Benefits and Motivation of downlink NOMA and uplink NOMA, Interface Design for downlink NOMA and uplink NOMA, MIMO Support and Performance Evaluations for downlink NOMA and uplink NOMA.

Unit 4: Spatial Signal Processing For 5G and 6G (15 Hrs.)

Massive MIMO Theory, Massive MIMO Channels, Massive MIMO Implementation, Testbed Design, Synchronization, Overview of Millimetre-Wave MIMO Transceiver Architectures, Point-to-Point Single-User Systems, Point-to-Multipoint Multiuser Systems.

Text and Reference Books:

1. *Claude Oestges, Bruno Clerckx. "MIMO Wireless Communications: From Real-world Propagation to Space-time Code Design", Academic Press, 1st edition, 2010.*
2. *Mohinder Janakiraman. "Space - Time Codes and MIMO Systems", Artech House Publishers, 2004.*
3. *Fa-Long Luo, Charlie (Jianzhong) Zhang, "Signal Processing For 5g: Algorithms and Implementations", John Wiley & Sons, Ltd, 2016.*
4. *Theodore S. Rappaport, Robert W.Heath, Robert C.Daniels, James N. Murdock "Millimeter Wave Wireless Communications", Prentice Hall Communications, 2015.*
5. *Athanasios G. Kanatas, Konstantinos S. Nikita, Panagiotis Mathiopoulos, "New Directions in Wireless Communication Systems from Mobile to 5G", CRC Press, 2017.*
6. *Wei Xiang, Kan Zheng, Xuemin (Sherman) Shen, "5G Mobile Communications", Springer, 2017.*
7. *AfifOsseiran, Jose F. Monserrat and Patrick Marsch, "5G Mobile and Wireless Communications Technology", Cambridge University Press, 2016.*
8. *Jonathan Rodriguez, "Fundamentals of 5G mobile networks", John Wiley & Sons, Ltd, 2015.*

CLO-PLO matrix for the course MEENCEC226 (MIMO and Emerging Communication Systems)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCEC226.1	3	3	1	2	1	2	0	0	2	1	1.5
MEENCEC226.2	3	3	1	2	1	0	0	0	2	1	1.3
MEENCEC226.3	3	3	2	1	1	0	0	0	3	1	1.4
MEENCEC226.4	3	3	3	2	1	1	2	2	3	1	2.1
Average PLO	3	3	1.75	1.75	1	0.75	0.5	0.5	2.5	1	1.575

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Semester – II (*Course Work*)
MEENCDI226: Advanced Digital Image Processing

Hours per Week			Credits	Maximum Marks			Examination
Lecture	Tutorial	Practical		Internal	End Term	Total	Hours
4	0	0	4	30	70	100	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENCDI226.1	Analyze and manipulate digital images using basic operations and apply mathematical models such as 2D convolution to represent and process images.
MEENCDI226.2	Apply 2D orthogonal and unitary transforms, for efficient image representation, and perform multiresolution analysis using image pyramids and discrete wavelet transforms.
MEENCDI226.3	Enhance images using spatial, frequency filtering and restore degraded images using algebraic and Wiener filter-based methods.
MEENCDI226.4	Design and implement lossless and lossy image compression techniques and perform image segmentation.

Detailed Syllabus (04 Theory Credits):

Unit 1: Fundamentals of Digital Image Processing (15 Hrs.)

Review of fundamental imaging concepts: Digital Image- Steps of Digital Image Processing, Elements of Visual Perception, Image formation, 2D-sampling and Quantization, Connectivity and Relations between Pixels. Simple Operations- Arithmetic, Logical, Geometric Operations. Mathematical Preliminaries- 2D Linear Space Invariant Systems, 2D Convolution, 2D Spectrum.

Unit 2: Image Transforms and Multiresolution Representation (15 Hrs.)

Two-dimensional orthogonal and unitary transforms and their properties. Two-dimensional DFT, DCT, Hadamard, Haar, and Slant transforms. Karhunen–Loève Transform (KLT) and Singular Value Decomposition (SVD) for optimal image representation. Multiresolution analysis: image pyramids, discrete wavelet transforms, wavelet packets.

Unit 3: Image Enhancement and Restoration (15 Hrs.)

Image Enhancement: Histogram Equalization Technique, Point Processing, Spatial Filtering-in Space and Frequency, Nonlinear Filtering-use of Different Masks Image Restoration: Image Observation and Degradation Model, Circulant and Block Circulant Matrices and its Application in Degradation Model, Algebraic Approach to Restoration-Inverse by Wiener Filtering.

Unit 4: Image compression & segmentation (15 Hrs.)

Image Compression: Redundancy and Compression Models -Loss Less and Lossy. Loss Less- Variable-Length, Huffman, Arithmetic Coding - Bit-Plane Coding, Loss Less Predictive Coding, Lossy Transform (DCT) Based Coding, Image compression standards: JPEG and JPEG2000—principles and algorithms. Coding. Image Segmentation: Edge Detection - Line Detection - Curve Detection - Edge Linking and Boundary Extraction, Boundary Representation.

Text and Reference Books:

1. *Rafael C. Gonzalez and Richard E. Woods, "Digital Image Processing", Pearson Education, 4th Edition, 2018.*
2. *Rafael C. Gonzalez, Richard E. Woods and Steven L. Eddins, "Digital Image Processing Using MATLAB", Gatesmark Publishing, 2nd Edition, 2017.*
3. *Anil K. Jain, "Fundamentals of Digital Image Processing", Prentice Hall, 1989.*
4. *Marin J. Dixon, Prashant Johri, Francesc Guim, Dmitry Shchemelinin, Marcus Carranza, "Advances in Image Processing, Reliability, and Artificial Intelligence", Elsevier, 1st Edition, 2025*
5. *Stephane Mallat, "A Wavelet Tour of Signal Processing: The Sparse Way", Academic Press, 3rd Edition, 2009.*
6. *Bernd Jähne, "Digital Image Processing", Springer, 6th Edition, 2005.*
7. *Maria Petrou and Costas Petrou, "Image Processing: The Fundamentals", Wiley, 2nd Edition, 2010.*
8. *Jae S. Lim, "Two-Dimensional Signal and Image Processing", Prentice Hall, 1990.*
9. *Mark S. Nixon and Alberto S. Aguado, "Feature Extraction and Image Processing for Computer Vision", Academic Press, 4th Edition, 2019.*

CLO-PLO matrix for the course MEENCDI226 (Advanced Digital Image Processing)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCDI226.1	3	3	2	2	2	2	2	1	3	2	2.2
MEENCDI226.2	3	3	3	2	3	2	2	1	3	2	2.4
MEENCDI226.3	3	3	3	3	3	2	2	1	3	2	2.5
MEENCDI226.4	3	3	3	2	3	2	2	2	3	2	2.5
Average PLO	3	3	2.75	2.25	2.75	2	2	1.25	3	2	2.4

Semester – II *(Course Work)*

MEENCAI226: Introduction to AI & Machine Learning

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	0	4	30	70	100	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENCAI226.1	Explain and apply fundamental AI concepts, intelligent agent models, search strategies, and logical knowledge representation techniques to formulate and solve classical AI problems under uncertainty.
MEENCAI226.2	Develop, train, and evaluate supervised machine learning models using linear regression and analyse AI-specific accelerators such as GPUs, TPUs, FPGAs, and ASICs.
MEENCAI226.3	Visualize and interpret data effectively while applying ethical principles and basic classification algorithms to support transparent, fair, and informed data-driven decision making.
MEENCAI226.4	Explain deep learning fundamentals, distinguish it from machine learning, describe ANN neuron models, perceptron architectures, key activation functions and training concepts, and outline CNN/RNN architectures with applications in vision, speech, and NLP.

Detailed Syllabus (04 Theory Credits):

Unit 1: Foundation of AI and Knowledge Representation (15 Hrs.)

Introduction to Artificial Intelligence: definition, scope, and applications, Intelligent agents: characteristics, environments, and performance measures. Problem formulation and state-space representation. Search strategies (overview): Uninformed search (BFS, DFS) Informed search and heuristics. Knowledge representation concepts and importance, Knowledge representation techniques: Propositional logic, First-order predicate logic. Inference mechanisms and reasoning. Rule-based knowledge representation and expert systems (overview). Challenges in knowledge representation: uncertainty and incompleteness.

Unit 2: Introduction to ML: Fundamentals and Linear regression (15 Hrs.)

Introduction to Machine Learning: definition, scope, and applications. Difference between Artificial Intelligence, Machine Learning, and Deep Learning. Types of machine learning: Supervised learning, Unsupervised learning, Reinforcement learning (overview). Machine learning workflow: Data collection and pre-processing, Model training and testing. Fundamentals of supervised learning. Linear regression model: Simple and multiple linear regression, Model representation and assumptions. Cost function and error minimization. Parameter estimation using gradient descent (conceptual). Model evaluation metrics: Mean Squared Error (MSE), Root Mean Squared Error (RMSE), R^2 score. Issues in linear regression: Overfitting and underfitting, Bias–variance trade-off.

Unit 3: Data Visualization and Ethical considerations of Data Science (15 Hrs.)

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Role of data visualization in data analysis and decision making, Types of data visualization: Charts, graphs, and plots, Exploratory vs explanatory visualizations. Principles of effective visualization: Clarity, accuracy, and interpretability, Avoiding misleading visual representations. Overview of visualization tools and libraries (conceptual). Ethical considerations in data science: Data privacy and confidentiality, Data bias and fairness, Transparency and accountability in data-driven systems. Responsible use of data and ethical challenges in real-world applications. Logistic Regression: Classification, Hypothesis Representation, Decision Boundary, Cost function, Decision Trees: Structure, splitting criteria, overfitting, and pruning, k-Nearest Neighbours (k-NN) algorithm.

Unit 4: Introduction to Deep Learning (15 Hrs.)

AI and ML in Health Care: Medical Image Analysis, Disease prediction, Drug Discovery using ML model. AI in Finance and business Analytics: Fraud detection and anomaly detection, credit scoring and risk assessment. AI in Natural Language processing & Computer Vision: Chatbots and virtual assistants, Speech recognition systems, Object detection and face recognition. AI in IoT and Smart Systems: Edge AI applications, Energy Optimization Systems. Ethical, Legal & Social Implications of AI: Bias and Fairness in Systems, Data Privacy and Security, Responsible AI and governance.

Text and Reference Books:

1. *Stuart J. Russell & Peter Norvig, "Artificial Intelligence: A Modern Approach", Pearson Education (Global Edition), 4th Edition, 2021.*
2. *Ethem Alpaydin, "Introduction to Machine Learning", the MIT Press, 4th Edition, 2020.*
3. *Kevin P. Murphy, "Machine Learning: A Probabilistic Perspective", MIT Press, 2012.*
4. *Ian Goodfellow, Yoshua Bengio & Aaron Courville, "Deep Learning", the MIT Press, 2024.*
5. *Kieran Healy, "Data Visualization: A Practical Introduction (conceptual yet academic)", Princeton University Press, 2018.*

CLO-PLO matrix for the course MEENCDA126 (Introduction to AI & Machine Learning)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCAI226.1	2.8	2.7	1.8	2.2	1.5	1.8	1.2	1.1	2.3	1.3	1.87
MEENCAI226.2	2.9	2.4	2.2	2.1	2.8	1.6	1.2	1.1	2.7	1.5	2.05
MEENCAI226.3	2.2	2.3	1.6	2	2.1	2.4	2.8	1.2	2.2	1.6	2.04
MEENCAI226.4	2.9	2.3	2.1	2	2.7	1.6	1.3	1.2	2.8	1.7	2.06
Average PLO	2.7	2.42	1.92	2.07	2.27	1.85	1.62	1.15	2.5	1.52	2.00

Semester – II *(Course Work)*
MEENCFM226: FPGA Design, AI and IoT Lab

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
0	0	4	2	15	35	50	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENCFM226.1	Implement/synthesize digital logic circuits on FPGA hardware using industry-standard Hardware Description Languages (VHDL/Verilog) and Debug & verify FPGA designs using both simulation tools and on board testing techniques/ Design and implement embedded IoT nodes integrating sensing, edge processing, RTOS scheduling, and wireless communication with performance evaluation./To apply state-space representation to implement BFS and DFS algorithms for solving classical AI problems such as Water Jug, 8-Puzzle, Missionaries & Cannibals, and Tower of Hanoi.
MEENCFM226.2	Integrate FPGA resources—including Configurable Logic Blocks (CLBs), Block RAM, clock management tiles (CMTs), and I/O constraints—to develop functional systems/ Develop secure and scalable IoT systems incorporating cloud integration, protocol translation, device provisioning, OTA updates, and end-to-end validation through a mini-project/To develop and evaluate machine learning models by implementing Linear Regression and Logistic Regression with data preprocessing, visualization, prediction, and performance analysis using standard metrics.

Laboratory Work (2 Credits: 60 Hrs.)

List of Experiments

1. **Study of Xilinx boards.**
2. Designing combinational and sequential circuits using VHDL.
   - a) Adders and subtarctors.
   - b) Multiplexers and demultiplexers
   - c) Encoders and decoders
   - d) Flip-Flops
   - e) Counters
   - f) Shift Registers
   - g) RAM
   - h) Basic Microprocessor
3. Designing combinational and sequential circuits on FPGA Kit.
   - a) Adders and subtarctors.
   - b) Multiplexers and demultiplexers
   - c) Encoders and decoders
   - d) Flip-Flops
   - e) Counters
   - f) Shift Registers
   - g) RAM
   - h) Basic Microprocessor
4. Create a finite state machine (traffic light controller).
5. Design a 4-bit ALU with multiple operations.
6. Implement UART transmitter/receiver.
7. Use IP cores (multiplier, FIFO).
8. Experiments on FPGA applications
   - a. Implement 8-tap FIR filter.
   - b. Audio processing application (tone generator/filter).
   - c. Digital communication system (BPSK modulator).
9. Embedded IoT Node Development
   - a) Sensor interfacing and calibration
   - b) Data acquisition and edge preprocessing
   - c) Power measurement and optimization
   - d) RTOS task scheduling experiment
10. IoT Communication & Networking
    - a) MQTT-based publish–subscribe implementation
    - b) CoAP client–server implementation
    - c) LoRa/BLE communication setup
    - d) Latency and packet-loss performance evaluation

11.	Cloud & Middleware Integration a) Gateway implementation and protocol translation b) Cloud dashboard integration (AWS/Azure) c) Data storage and visualization
12.	Security & Scalability Experiments a) Secure device provisioning b) OTA update demonstration c) Secure communication using TLS
13.	Mini-Project: Smart Energy Monitoring/ Industrial Equipment Monitoring/ Smart Agriculture System/ Remote Health Monitoring, etc.
14.	Implement BFS and DFS for solving a simple problem using state-space representation. Example Problems: Water Jug Problem, 8-Puzzle Problem, Missionaries and Cannibals, Tower of Hanoi (state space).
15.	Train a Linear Regression model and evaluate it using metrics. Load dataset (house price / student marks / salary), Pre-process data, split into train-test, Train Linear Regression model, predict output Evaluate using: MSE, RMSE, R^2 score.
16.	Perform visualization and classification using Logistic Regression. Load dataset (Iris / Diabetes / Breast Cancer). Plot visualizations: Histogram, Scatter plot, Correlation heatmap. Train Logistic Regression, evaluate using: Accuracy, Confusion Matrix, Precision, Recall (optional).

CLO-PLO matrix for the course MEENCFM226 (FPGA Design, AI and ARM Microcontroller Lab)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCFM226.1	1.5	1.5	3	2	3	2	2	3	3	2.5	**2.35**
MEENCFM226.2	1.5	1.5	3	2	3	2	2	3	3	2.5	**2.35**
Average PLO	**1.5**	**1.5**	**3**	**2**	**3**	**2**	**2**	**3**	**3**	**2.5**	**2.35**

Semester – II (*Course Work*)

MEENCSC226: Signal Processing and Communication-II Lab

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
0	0	4	2	15	35	50	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	**After the completion of this course the students will be able to:**
MEENCSC226.1	Model and simulate MIMO communication systems and evaluate their performance in terms of BER, capacity, and spatial diversity under various channel conditions/Implement and analyze advanced image processing algorithms including spatial operations, 2D transforms, multiresolution techniques, enhancement, and restoration using computational tools.
MEENCSC226.2	Implement advanced multi-antenna and multi-user techniques including STBC, MU-MIMO, MIMO-OFDM, and beamforming for next-generation wireless systems/Design and evaluate image compression and segmentation techniques, and assess performance using objective quality measures such as PSNR, MSE, and SSIM.

Laboratory Work (2 Credits: 60 Hrs.)

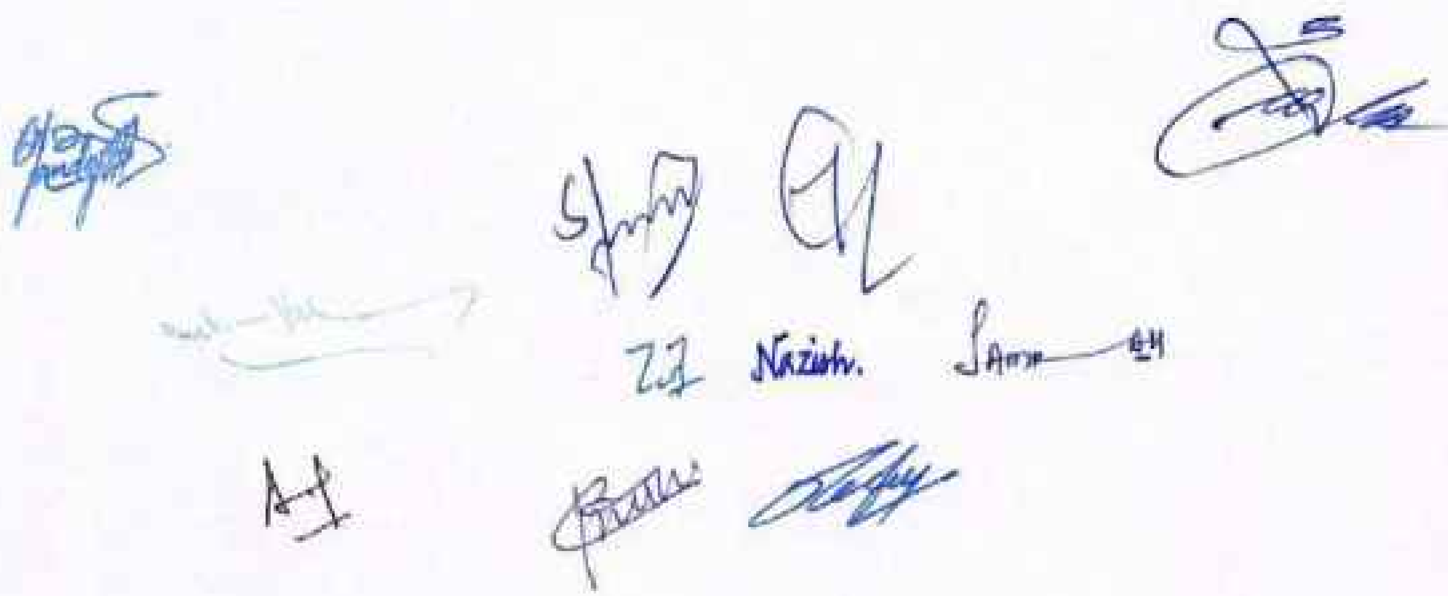
List of Experiments

1. Simulation of 2×2 and 4×4 MIMO Systems under Rayleigh Fading Channel and BER Performance Analysis.
2. Capacity Analysis of MIMO Channels using Singular Value Decomposition (SVD) and Water-Filling Algorithm.
3. Implementation and Performance Comparison of Spatial Diversity Schemes (Alamouti STBC) and MU-MIMO with ZF/MMSE Receivers.
4. Simulation of MIMO-OFDM and mmWave Beamforming for 5G Wireless Communication Systems.

5. Implementation of basic image operations (arithmetic, logical, geometric transformations).
6. 2D convolution and correlation using manual mask implementation and built-in functions.
7. Study of image sampling and quantization (bit-depth reduction and quality evaluation).
8. Computation and visualization of 2D-DFT and magnitude spectrum using FFT.
9. Implementation and comparison of 2D-DFT and 2D-DCT (energy compaction analysis).
10. Image reconstruction using Singular Value Decomposition (SVD) and low-rank approximation.
11. Multiresolution image analysis using Gaussian and Laplacian pyramids.
12. Discrete Wavelet Transform (DWT) based multiresolution decomposition and denoising.
13. Image enhancement using histogram equalization and adaptive histogram equalization (CLAHE).
14. Spatial filtering using low-pass, high-pass, and median filters with PSNR comparison.
15. Image restoration using inverse filtering and Wiener filtering with MSE and PSNR evaluation.
16. Lossless image compression using Huffman coding.
17. DCT-based lossy image compression (JPEG-like implementation and compression ratio analysis).
18. Image segmentation using thresholding (Otsu), edge detection (Sobel/Canny), and region growing.
19. Development of an end-to-end image compression and quality evaluation system.
20. Enhancement and segmentation of medical or satellite images with performance analysis.

CLO-PLO matrix for the course MEENCSC226 (Signal Processing and Communication-II Lab)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCSC226.1	3	3	1	3	3	0	0	2	3	1	1.9
MEENCSC226.2	3	3	3	3	3	1	2	2	3	1	2.4
Average PLO	3	3	2	3	1.5	0.5	1	2	3	1	2.15



Semester – III *(Course Work)*

Specialization I: VLSI and Embedded Systems

MEENDNC326: Neuromorphic Computing

Hours per Week			Credits	Maximum Marks			Examination
Lecture	Tutorial	Practical		Internal	End Term	Total	Hours
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDNC326.1	Explain the foundations of neuromorphic computing, including biological inspiration, neuron models, and spiking neural networks.
MEENDNC326.2	Analyze and evaluate neuromorphic devices, circuits, and architectures for energy-efficient and brain-inspired computation.
MEENDNC326.3	Apply spiking neural network algorithms for AI, robotics, and real-time applications in sensing and edge computing.
MEENDNC326.4	Use neuromorphic computing in everyday applications such as robotics, sensing, Edge computing etc.
MEENDNC326.5	Design, simulate, and implement neuromorphic circuits and spiking neural networks using tools such as Python, Cadence, FPGA, and TCAD.
MEENDNC326.6	Design and devise new architectures for neuromorphic computing.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit 1: Foundations of Neuromorphic Computing (15 Hrs.)

Overview and Motivation: Neuromorphic Computing, Importance in modern technology and potential impact on computing, Challenges of traditional computing and the Von Neumann bottleneck.
Biological Inspiration and Principles: Basic neuroscience concepts: structure and function of neurons and synapses, Understanding brain-inspired computing models and biological processing, Differences between neuromorphic and conventional computing.
Computational Models: Introduction to neuron models: Leaky Integrate-and-Fire (LIF) model, Hodgkin-Huxley, Spiking Neural Networks (SNNs). Learning in spiking neural networks – Stochastic computing – Convolutional spiking neural networks – Reservoir computing – Computing with spikes.

Unit 2: Devices and Circuits for Neuromorphic Systems (15 Hrs.)

Materials for Neuromorphic Systems: Introduction to key materials: phase-change memory (PCM), ferroelectric and spintronic materials, 2D materials, organic materials, and nanowires used in neuromorphic devices.
Neuromorphic Device Basics: Basics of device functionality in brain-inspired computing systems, General introduction to devices capable of spiking behaviour and emulating neuron functions.
Circuit Design and Energy Efficiency: CMOS-based circuit design principles for implementing neuromorphic systems. Crossbar arrays for neuromorphic computation: matrix-vector multiplication. Importance of low-power design and basic strategies for energy-efficient neuromorphic circuits.

Unit 3: SNN Algorithms and Hardware Platforms of Neuromorphic Computing

Spiking Neural Network (SNN) Algorithms: Fundamental algorithms for SNNs, applying algorithms to simple spike-based learning tasks.
Integrated Neuromorphic Systems: Overview of neuromorphic chips and hardware architectures – Intel Loihi, IBM TrueNorth.

Unit 4: Applications of Neuromorphic Computing (15 Hrs.)

Applications in AI and Robotics: Neuromorphic computing for robotics and autonomous systems, Role in self-driving cars and real-time sensor data processing.
Neuromorphic Sensing and Edge Computing: Event-based sensors and neuromorphic sensory systems – Visual, Olfactory, and Gustatory.
Neuromorphic computing in IoT and wearable devices, emphasizing real-time and low-power processing benefits.

Laboratory Work (2 Credits: 60 Hrs.)

List of Experiments

Note: The student is required to attempt at least 10 experiments

1. To design, simulate, and analyze spiking neurons, synapses, and networks using tools like Python and Cadence.
2. Design Mc Cullock Pitts Neuron model in Cadence/HSPICE/FPGA.
3. Design Axon Hillock circuit in Cadence/HSPICE.
4. Using the Axon Hillock circuit, reason what happens to the membrane potential, V_{mem}, when a DC input current is injected in the node V_{mem} itself, and charges up the membrane. Also explain how the spike output Vout of the circuit behaves.
5. Design a FDSOI based single spiking neuron in ATLAS TCAD/Synopsis Sentaurus and study relationship of spiking frequency with different parameters.
6. Design a TFET based single spiking neuron in ATLAS TCAD/Synopsis Sentaurus and study relationship of spiking frequency with different parameters.
7. Analysis of a memristor/RRAM/MTJ based 1T1M crossbar architecture
8. Design and analysis of crossbar arrays for neuromorphic computation in Cadence/HSPICE/FPGA.
9. Design of Spiking Neural Network for image classification using python.
10. Design of Spiking Neural Network for signal classification using python.
11. Design of Spiking Neural Network for image classification on FPGA.
12. Design of Spiking Neural Network for signal classification on FPGA.
13. Design of artificial Visual system for in-sensor computing.
14. Design of artificial Olfactory system for in-sensor computing.
15. Design of artificial Gustatory system for in-sensor computing.

Text and Reference Books:

1. *Sabina Spiga, Abu Sebastian, Damien Querlioz and Bipin Rajendran, "Memristive Devices for Brain-Inspired Computing: From Materials, Devices, and Circuits to Applications—Computational Memory, Deep Learning, and Spiking Neural Networks", Elsevier, 2020.*
2. *Min Gu, Yangyundou Wang, Yibo Dong and Haoyi Yu, "Neuromorphic Photonic Devices and Applications", Elsevier, 2023.*
3. *Farooq A. Khanday, "Energy-Efficient Devices and Circuits for Neuromorphic Computing", Elsevier, 2025.*
4. *Shriram Ramanathan and Abhronil Sengupta, "Introduction to Neuromorphic Computing", Cambridge University Press, 2026.*

CLO-PLO matrix for the course MEENDNC326 (Neuromorphic Computing)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDNC326.1	3	2.5	2	2	1.5	1.5	1.5	2.5	2.7	2.5	2.17
MEENDNC326.2	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	2.41
MEENDNC326.3	2.5	2.5	3	2.7	3	2.5	1.5	2.7	2.7	3	2.61
MEENDNC326.4	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	2.41
MEENDNC326.5	1.5	1.5	3	2	3	2	2	3	3	2.5	2.35
MEENDNC326.6	1.5	1.5	3	2	3	2	2	3	3	2.5	2.35
Average PLO	2.25	2.17	2.73	2.35	2.75	1.83	1.67	2.7	2.8	2.58	2.38

Semester – III *(Course Work)*
Specialization 1: VLSI and Embedded Systems

MEENDNE326: Nanoelectronics

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDNE326.1	Explain the principles of nanotechnology and quantum confinement effects in low-dimensional semiconductor structures (wells, wires, and dots).
MEENDNE326.2	Analyze semiconductor quantum nanostructures including heterojunctions, superlattices, and quantum transport phenomena such as Quantum Hall Effect.
MEENDNE326.3	Analyze and evaluate nanoscale electronic devices.
MEENDNE326.4	Analyze and evaluate nanoscale optoelectronic devices.
MEENDNE326.5	Perform simulations and experiments to study band structures, DOS, quantum transport, I–V characteristics of nanoscale devices, and design QCA-based logic circuits.
MEENDNE326.6	Design and devise new nanoscale devices for electronic and optoelectronic applications.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit 1: Nanotechnology and Nanoelectronics (15 Hrs.)

Introduction to Nanotechnology: size dependent physical properties, Melting point, solid state phase transformations, The Physics of Low-Dimensional Semiconductors: Overview of Schrodinger wave equation, Square quantum well of finite depth, Parabolic and triangular quantum wells, Quantum wires, Quantum dots, Strained layers, band-gap variations-quantum confinement, excitons.

Unit 2: Semiconductor Quantum Nanostructures (15 Hrs.)

Hetero-junctions - Modulation-doped heterojunctions, SiGe strained heterostructures; Quantum wells - Modulation-doped quantum well, Multiple quantum wells (MQW), Super-lattices, Electric Field Transport in Nanostructures: Parallel transport, Perpendicular transport, Quantum transport in nanostructures, Transport in Magnetic Fields and the Quantum Hall Effect.

Unit 3: Electronic Devices Based on Nanostructures (15 Hrs.)

Nano scale MOSFET - MODFETs - Heterojunction bipolar transistors, Resonant Tunnelling Transistor, Hot electron transistors, Single-Electron Transistor, 2D FET, Carbon nanotube (CNT) FET, Magnetic Tunnel Junction (MTJ), Spin-FET and silicon nanowire (SiNW) FET. Quantum Dots and Quantum Cellular Automata (QCA)
MEMS and NEMS. Packaging and characterization of sensors. Nanobiosensor- CNT biosensor, Nanowire Biosensors.

Unit 4: Optoelectronic Devices Based on Nanostructures (15 Hrs.)

Optical luminescence and fluorescence from direct band gap semiconductor nanoparticles, light emission from indirect semiconductors, light emission form Si nanodots. LED and solar cells, advances in solar cell technology, Perovskite and dye sensitized solar cells.
LASER and Photodetectors: Hetero-structure semiconductor lasers–Quantum well semiconductor lasers–Vertical cavity surface emitting lasers (VCSELs) –Strained quantum well lasers, Quantum well and super lattice photo detectors–Quantum well modulators.

Laboratory Work (2 Credits: 60 Hrs.)

List of Experiments

Note: The student is required to attempt at least 10 experiments through simulations using EDA tools available in the department or online.

1. Study the Band-diagrams and Density of State (DOS) Function of Bulk Semiconductor for different nano-materials.
2. Study the Band-diagrams and DOS of Quantum Well Structure for different nanomaterials.
3. Study the Band-diagrams and DOS of Quantum Wire Structure for different nanomaterials.
4. Study the Band-diagrams and DOS of Quantum Dot Structure for different nanomaterials.
5. Study of Quantum Hall Effect.
6. Study the I-V characteristics of Resonant Tunnelling FET.
7. Study the I-V characteristics of Single- Electron Transistor.
8. Study the I-V characteristics of CNTFET.
9. Study the I-V characteristics of Organic Field Effect Transistor (OFET).
10. Study the I-V characteristics of silicon nanowire (SiNW) FET.
11. Study the I-V characteristics of HEMT.
12. Study the operation and characteristics of MTJ and Spin-FET.
13. Design logic structures in QCA.
14. Study the efficiency of different solar cells.
15. Study the characteristics of Photodetector.

Text and Reference Books:

1. *J. M. Martinez-Duart, R.J. Martin-Palma and F. Agullo-Rueda, "Nanotechnology for Microelectronics and Optoelectronics", Elsevier B.V., 2006.*
2. *A. A. Balandin, K. L. Wang, "Handbook of Semiconductor Nanostructures and Nanodevices", American Scientific Publishers, 2005.*
3. *Hari Singh Nalwa, "Encyclopedia of nanoscience and nanotechnology", American Scientific Publishers, 2011.*
4. *Bharat Bhusan, "Handbook of Nanotechnology", Springer, 2017.*

CLO-PLO matrix for the course MEENDNE326 (Nanoelectronics)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDNE326.1	3	2.5	2	2	1.5	1.5	1.5	2.5	2.3	2.5	2.13
MEENDNE326.2	3	2.5	2	2	1.5	1.5	1.5	2.5	2.3	2.5	2.13
MEENDNE326.3	2.5	2.5	3	2.7	2.5	2.5	1.5	2.7	2.3	2.5	2.47
MEENDNE326.4	2.5	2.5	2.7	2.7	2.5	1.5	1.5	2.5	2.3	2.5	2.32
MEENDNE326.5	1.5	1.5	3	2	3	2	2	3	2.3	2.5	2.28
MEENDNE326.6	1.5	1.5	3	2	3	2	2	3	2.3	2.5	2.28
Average PLO	2.33	2.17	2.62	2.23	2.33	1.83	1.67	2.7	2.3	2.5	2.27

Semester – III *(Course Work)*

Specialization I: VLSI and Embedded Systems

MEENDQC326: Quantum Computing

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDQC326.1	Explain the foundational principles of quantum computing, including the postulates of quantum mechanics, qubit representation, and the Bloch sphere, using the mathematical framework of linear algebra and Dirac notation.
MEENDQC326.2	Analyze and implement quantum circuits involving single and multi-qubit gates, entanglement, and quantum protocols such as teleportation and superdense coding, using both theoretical reasoning and Qiskit-based simulations.
MEENDQC326.3	Evaluate and demonstrate the working principles of key quantum algorithms including Deutsch-Jozsa, Grover's search, Quantum Fourier Transform, and Shor's algorithm, and explain the role of quantum parallelism and phase estimation.
MEENDQC326.4	Describe and compare various quantum hardware platforms, analyze the challenges of the NISQ era, and apply quantum error mitigation and variational algorithms (VQE, QAOA) to problems in quantum chemistry and optimization.
MEENDQC326.5	Design, simulate, and visualize quantum circuits and protocols using Qiskit, demonstrating proficiency in quantum state preparation, entanglement, teleportation, and quantum algorithm implementation.
MEENDQC326.6	Model and simulate quantum dynamics and noise using QuTiP, analyze entanglement evolution under decoherence, and apply variational quantum algorithms to solve real-world problems such as molecular ground state energy estimation.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Note: In order to gain fundamental understanding of Quantum Mechanics, expertize from the allied/concerned departments (e.g., Physics) shall be sought to deliver the foundational concepts or co-teach relevant modules.

Unit I: Introduction to Quantum Computing (15 Hrs.)

Nazish.

Quantum Computation: History & Overview, Review of linear algebra: Dirac notation, Hilbert spaces, Unitary, Hermitian, and Normal matrices, Inner product, Outer product, Tensor product, Postulates of Quantum Mechanics, Stern and Gerlach experiment, Qubit, Superposition, Bloch Sphere representation.

Unit 2: Qubits and their programming (15 Hrs.)

Single qubit gates, multi-qubit quantum gates and tensor products, Qiskit programming, Entanglement: Bell state, Quantum Teleportation, Superdense coding, Phase kickback, No-cloning theorem, Density Matrices & Mixed States, Quantum parallelism.

Unit 3: Quantum Computing Algorithms (15 Hrs.)

Deutsch-Jozsa algorithm, Grover search algorithm, Simon's Algorithm, Quantum Fourier Transform, Quantum Phase Estimation, Shor's algorithm, Quantum Addition and Arithmetic, Variational Quantum Algorithms (VQE, QAOA).

Unit 4: Quantum Hardware Platforms (15 Hrs.)

Superconducting Qubits (Transmons), Trapped Ions, Photonic Quantum Computing, Semiconducting Qubits, Topological Qubits, NISQ (Noisy Intermediate-Scale Quantum) Era, Quantum Error Mitigation Techniques, Introduction to Quantum Machine Learning.

Laboratory Work (2 Credits: 60 Hrs.)

List of Experiments

1. Single-Qubit State Creation and Bloch Sphere Visualization (Qiskit): Create quantum states using the Statevector class and visualize them on the Bloch sphere. Apply sequences of Pauli and rotation gates to a qubit and plot the resulting state after each operation. Generate a random pure state and calculate its coordinates (θ, φ) on the Bloch sphere.
2. Entanglement Generation and Bell State Measurement: Construct circuits to create all four Bell states using only Hadamard and CNOT gates. Perform quantum state tomography on each Bell state to reconstruct its density matrix. Calculate the expectation values of the operators XX, YY, and ZZ for each Bell state.
3. Quantum Teleportation Protocol Implementation: Build the complete quantum teleportation circuit with three qubits. Prepare an arbitrary state on the source qubit and teleport it to the destination qubit. Verify teleportation success using state tomography to compare input and output states.
4. Superdense Coding Circuit and Analysis: Implement the superdense coding protocol to transmit two classical bits using one entangled qubit. Create circuits for all four possible messages (00, 01, 10, 11) and verify correct decoding. Calculate the quantum circuit depth and compare with classical communication requirements.
5. Deutsch-Jozsa Algorithm for Function Classification: Implement the Deutsch-Jozsa algorithm for 3-qubit input functions. Create oracles for both constant and balanced functions. Execute the algorithm and verify it correctly identifies function types with one query.
6. Grover's Search Algorithm Implementation: Implement Grover's algorithm to search for a marked item in an 8-element database. Design the oracle to mark multiple solutions simultaneously.
7. Quantum Fourier Transform Circuit Construction: Build a scalable Quantum Fourier Transform circuit for n qubits. Test the QFT on computational basis states and verify the output phase patterns. Implement the inverse QFT and demonstrate it correctly recovers the original state.
8. Variational Quantum Eigensolver Application: Implement VQE to find the ground state energy of a hydrogen molecule (H_2) using a minimal basis set. Design a parameterized ansatz circuit appropriate for the problem. Use the COBYLA optimizer to minimize the energy expectation value. Compare the VQE result with classical exact diagonalization values.
9. Time Evolution of a Two-Level System (QuTip): Simulate the time evolution of a qubit under various Hamiltonians using QuTiP's mesolve. Calculate and plot the population dynamics between $|0\rangle$ and $|1\rangle$ states. Introduce dissipation through Lindblad operators and observe decoherence.
10. Entanglement Dynamics in Coupled Qubits (QuTip): Model two coupled qubits with a Heisenberg-type interaction Hamiltonian. Calculate and plot entanglement measures (concurrence or negativity) over time. Introduce local dephasing noise to one qubit and observe entanglement sudden death.

Text and Reference Books:

1. *Chris Bernhardt, "Quantum Computing for Everyone", The MIT Press, 2020.*
2. *Robert S Sutor, "Dancing with Qubits: How quantum computing works and how it can change the world", Packt Publishing, 2019.*
3. *Scott Aaronson, "Quantum Computing Since Democritus", Cambridge university press, 2013.*
4. *Nielsen M.A, Chuang I.L. "Quantum computation and quantum information". Cambridge university press; 2010.*
5. *Maria Schuld, Francesco Petruccione, "Machine Learning with Quantum Computers", Springer International Publications, 2021.*

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CLO-PLO matrix for the course MEENDQC326 (Quantum Computing)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDQC326.1	3	2.5	2	2	1.5	1.5	1.5	2.5	2.5	2.5	2.15
MEENDQC326.2	3	2.5	2	2	1.5	1.5	1.5	2.5	2.5	2.5	2.15
MEENDQC326.3	2.5	2.5	2.5	2.7	2	2.5	1.5	2.7	2.5	2.5	2.39
MEENDQC326.4	2.5	2.5	2.5	2.7	2	1.5	1.5	2.5	2.5	2.5	2.27
MEENDQC326.5	1.5	1.5	3	2	3	2	2	3	2.5	2.5	2.3
MEENDQC326.6	1.5	1.5	3	2	3	2	2	3	2.5	2.5	2.3
Average PLO	2.33	2.17	2.5	2.23	2.17	1.83	1.67	2.7	2.5	2.5	2.26

Semester – III *(Course Work)*

Specialization I: VLSI and Embedded Systems

MEENDSI326: Secure and Intelligent Embedded Systems

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDSI326.1	Understand emerging security threats and trust mechanisms in embedded and edge systems.
MEENDSI326.2	Design hardware–software co-secure embedded platforms with root-of-trust.
MEENDSI326.3	Implement intelligent (AI/ML-enabled) embedded systems under real-time constraints.
MEENDSI326.4	Analyze trade-offs among security, performance, energy, latency, and cost.
MEENDSI326.5	Implement intelligent (AI/ML-enabled) embedded systems under real-time constraints.
MEENDSI326.6	Analyze trade-offs among security, performance, energy, latency, and cost.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit I: Foundations of Secure Embedded Systems (15 Hrs.)

Embedded Security Landscape: Embedded and IoT threat models, Attack surfaces: firmware, hardware, supply chain, physical access, STRIDE and attack tree methodologies, Case studies: Automotive ECU hacks, IoT botnets. Security Principles: Confidentiality, Integrity, Availability (CIA), Authenticity, Non-repudiation, Secure development lifecycle (SDL), Secure coding practices for embedded C/C++. System-Level Security Architecture: Hardware vs software security trade-offs, Secure memory and isolation, Trust anchors and root of trust, Lifecycle security: manufacturing to deployment. Emerging Topics: Supply chain security, Firmware integrity monitoring, Secure DevOps for embedded systems.

Unit 2: Hardware Security and Trusted Architectures (15 Hrs.)

Hardware Root of Trust: Secure boot and measured boot, Chain of trust architecture, Trusted Platform Module (TPM) basics, ARM TrustZone architecture. Physical Security Mechanisms: Physical Unclonable Functions (PUFs), Secure key storage, Anti-tamper mechanisms. Side-Channel and Fault Attacks: Power and timing analysis, Electromagnetic leakage, Fault injection attacks, Countermeasures and masking. Hardware Trojans & Secure SoC Design: Trojan insertion models, Detection techniques, Runtime iteration, RISC-V secure extensions.

Unit 3: Embedded Cryptography & Secure Communication (15 Hrs.)

Embedded Cryptographic Primitives: AES, SHA, ECC, Lightweight cryptography (PRESENT, Ascon), Post-Quantum Cryptography overview. Key Management & Secure Storage: Secure key provisioning, Hardware security modules, Secure enclaves. Secure Communication Protocols: TLS / DTLS, Secure MQTT, Secure CAN (Automotive), OTA firmware update security. Secure Firmware & Update Mechanisms: Signed firmware, Secure rollback prevention, Secure lifecycle management.

Unit 4: Intelligent & Trustworthy Embedded Systems (15 Hrs.)

Embedded Intelligence: Edge AI concepts, TinyML fundamentals, Neural networks for microcontrollers, Real-time inference constraints. Model Optimization: Quantization, Pruning, Knowledge distillation, Hardware-aware model design. Security of AI-Enabled Embedded Systems: Adversarial attacks, Data poisoning, Model extraction attacks, Secure model deployment. Trustworthy & Explainable AI: Explainable AI (XAI) for embedded systems, Privacy-preserving ML (Federated learning overview), AI hardware accelerators (NPU, TPU, Edge AI SoC). Future directions: Secure AI co-processors.

List of Experiments

1. Embedded Security Implementation
    a) Threat modeling using STRIDE
    b) Secure coding and buffer overflow mitigation
    c) Secure boot implementation
    d) Chain of trust using digital signatures
    e) Firmware signing and verification
2. Cryptography & Secure Communication
    a) AES and SHA implementation
    b) ECC-based key exchange
    c) Secure TLS/DTLS communication
    d) Secure OTA update mechanism
3. Hardware Security & Side Channel
    a) Timing-based side-channel demonstration
    b) Fault injection experiment (simulation-based)
    c) PUF-based key generation demo
4. TinyML & Secure AI Deployment
    a) TinyML model training (TensorFlow Lite Micro)
    b) Deployment on MCU (ESP32/STM32)
    c) Model quantization/pruning
    d) Adversarial attack demonstration
    e) Secure AI model deployment
5. Mini-Project: Secure AI-enabled smart camera/ Secure automotive embedded node/ Intelligent intrusion detection device/ Secure health monitoring embedded device, etc.

Text and Reference Books:

1. R. Anderson, *"Security engineering: A guide to building dependable distributed systems", Wiley, 3rd ed., 2020.*
2. *D. Kleidermacher, & M. Kleidermacher, "Embedded systems security: Practical methods for safe and secure software and systems development", Newnes, 2012.*
3. *P. Warden, & D. Situnayake, "TinyML: Machine learning with TensorFlow Lite on Arduino and ultra-low-power microcontrollers", O'Reilly Media, 2019.*
4. *G. Goodwill, R. Jaxer, & B. Jungwirth, "Practical IoT hacking: The definitive guide to attacking the Internet of Things", No Starch Press, 2020.*
5. *J. Wu, & M. J. Irwin (Eds.), "Introduction to hardware security and trust", Springer, 2016.*
6. *I. Verbauwhede (Ed.), "Secure integrated circuits and systems", Springer, 2011.*
7. *C. Paar, & J. Pelzl, "Understanding cryptography: A textbook for students and practitioners", Springer, 2010.*

CLO-PLO matrix for the course MEENDSI326 (Secure and Intelligent Embedded Systems)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDSI326.1	3	2.5	2	2	1.5	1.5	1.5	2.5	2.7	2.5	2.17
MEENDSI326.2	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	2.41
MEENDSI326.3	2.5	2.5	3	2.7	3	2.5	1.5	2.7	2.7	3	2.61
MEENDSI326.4	2.5	2.5	2.7	2.7	3	1.5	1.5	2.5	2.7	2.5	2.41
MEENDSI326.5	1.5	1.5	3	2	3	2	2	3	3	2.5	2.35
MEENDSI326.6	1.5	1.5	3	2	3	2	2	3	3	2.5	2.35
Average PLO	2.25	2.17	2.73	2.35	2.75	1.83	1.67	2.7	2.8	2.58	2.38

Semester – III *(Course Work)*
Specialization 1: VLSI and Embedded Systems
MEENDDT326: Advanced Drone Technology

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDDT326.1	Model UAV kinematics and dynamics using robotics principles and design advanced control strategies.
MEENDDT326.2	Develop state estimation and sensor fusion algorithms for reliable UAV navigation.
MEENDDT326.3	Implement autonomous navigation, path planning, SLAM, and AI-based perception modules.
MEENDDT326.4	Evaluate UAV communication systems, cybersecurity threats, and airspace regulations.
MEENDDT326.5	Implement and evaluate UAV modeling, control, estimation, and navigation algorithms using simulation and robotics platforms.
MEENDDT326.6	Develop and assess intelligent and secure drone system components, including vision-based AI and communication protocols.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit 1: UAV Dynamics and Robotics Foundations (15 Hrs.)

Evolution and classification of UAVs, UAV system architecture and subsystems, Robotics system fundamentals, Coordinate frames (Body, Inertial, NED, ENU), Rotation representations: Euler angles, rotation matrices, quaternions, Rigid body kinematics and transformations, Newton–Euler dynamic formulation for multirotors, Aerodynamic forces and thrust modelling, Propulsion systems and energy modelling, Performance metrics: endurance, range, payload, flight envelope.

Unit 2: Advanced Control and State Estimation (15 Hrs.)

State-space modeling of UAV systems, PID review and limitations, LQR and LQG control, Nonlinear control: feedback linearization, backstepping, Introduction to Model Predictive Control (conceptual overview), Lyapunov stability fundamentals, Probabilistic robotics basics, Kalman Filter (KF), Extended Kalman Filter (EKF), UKF (overview), IMU-GPS sensor fusion, Error covariance propagation.

Unit 3: Autonomous Navigation, Planning and AI (15 Hrs.)

Fundamentals of mobile robot navigation, Motion models for aerial robots, Localization vs mapping, Waypoint tracking and trajectory generation, Path planning: A*, RRT, RRT*, Obstacle detection and avoidance, Introduction to SLAM (visual & LiDAR concepts), Visual-inertial odometry fundamentals, AI in UAVs: object detection, tracking (overview), Edge AI for UAV systems.

Unit 4: Communication, Security and UAV Ecosystem (15 Hrs.)

UAV communication architecture, Telemetry systems and Ground Control Stations, MAVLink protocol overview, RF communication fundamentals, Multi-UAV coordination (introductory), UAV cybersecurity threats (GPS spoofing, jamming, hijacking), Secure communication basics and encryption concepts, Regulatory frameworks: DGCA (India), FAA (USA), UTM, Ethical, privacy, and societal issues.

List of Experiments

1. Modeling & Control Implementation
   a) Multirotor dynamic modeling (MATLAB/Simulink or Python)
   b) PID vs LQR control tests
   c) Nonlinear control simulation (Backstepping)
2. Estimation & Sensor Fusion
   a) Kalman Filter (KF) implementation
   b) Extended Kalman Filter (EKF) for IMU/GPS fusion
   c) Error covariance analysis
3. Navigation & SLAM
   a) Path planning (A*, RRT, RRT*)
   b) Obstacle avoidance (simulation)
   c) SLAM implementation (ROS/Gazebo)

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4. AI & Security Experiments
   a) Object detection on drone datasets (OpenCV/PyTorch)
   b) Communication setup (MAVLink telemetry)
   c) Secure channel simulation / spoofing awareness experiment

Text and Reference Books:

1. R. W. Beard, & T. W. McLain, "Small Unmanned Aircraft: Theory and Practice", Princeton, NJ: Princeton University Press, 2012.
2. P. G. Fahlstrom, & T. J. Gleason, "Introduction to UAV Systems", Chichester, UK: Wiley, 2012.
3. R. Siegwart, I. R. Nourbakhsh, & D. Scaramuzza, "Introduction to Autonomous Mobile Robots", Cambridge, MA: MIT Press, 2nd ed., 2011.
4. S. Thrun, W. Burgard, & D. Fox, "Probabilistic Robotics", Cambridge, MA: MIT Press, 2005.
5. H. K. Khalil, "Nonlinear Systems", Upper Saddle River, NJ: Prentice Hall, 3rd ed., 2002.
6. J. B. Rawlings, D. Q. Mayne, & M. Diehl, "Model Predictive Control: Theory and Design", Nob Hill Publishing, LLC., 2017.
7. R. Szeliski, "Computer Vision: Algorithms and Applications", Cham, Switzerland: Springer, 2nd ed., 2022.
8. T. S. Rappaport, "Wireless Communications: Principles and Practice", Upper Saddle River, NJ: Prentice Hall, 2nd ed., 2002.
9. R. J. Anderson, "Security Engineering: A Guide to Building Dependable Distributed Systems", Hoboken, NJ: Wiley, 3rd ed., 2020.
10. R. Mahony, V. Kumar, & P. Corke, "Multirotor Aerial Vehicles: Modeling, Estimation and Control of Quadrotor", Cambridge, UK: Cambridge University Press, 2018.

CLO-PLO matrix for the course MEENDDT326 (Advanced Drone Technology)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDDT326.1	3	2.5	2	2	1.5	1.5	1.5	2.5	2.3	2.5	2.13
MEENDDT326.2	3	2.5	2	2	1.5	1.5	1.5	2.5	2.3	2.5	2.13
MEENDDT326.3	2.5	2.5	3	2.7	2.5	2.5	1.5	2.7	2.3	2.5	2.47
MEENDDT326.4	2.5	2.5	2.7	2.7	2.5	1.5	1.5	2.5	2.3	2.5	2.32
MEENDDT326.5	1.5	1.5	3	2	3	2	2	3	2.3	2.5	2.28
MEENDDT326.6	1.5	1.5	3	2	3	2	2	3	2.3	2.5	2.28
Average PLO	2.33	2.17	2.62	2.23	2.33	1.83	1.67	2.7	2.3	2.5	2.27

Semester – III *(Course Work)*
Specialization I: VLSI and Embedded Systems
MEENDCP326: Cyber Physical Systems

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDCP326.1	Explain CPS concepts and develop basic system models.
MEENDCP326.2	Analyze and design CPS architectures with real-time and network considerations.
MEENDCP326.3	Implement embedded sensing, actuation, and networked control in CPS.
MEENDCP326.4	Evaluate safety, security, and reliability issues in CPS and suggest suitable solutions.
MEENDCP326.5	Model and simulate hybrid and networked Cyber-Physical Systems (CPS), including digital twins, event-driven execution, and network-delay analysis.
MEENDCP326.6	Design and implement embedded CPS prototypes integrating real-time scheduling, communication protocols, edge processing, and system-level validation through a mini-project.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit 1: Foundations, Modeling & Digital Twins (15 Hrs.)

Evolution of CPS: CPS vs Embedded Systems vs IoT vs Industry 4.0, CPS characteristics: timeliness, safety, heterogeneity, Application domains: Smart grid, autonomous systems, smart manufacturing, CPS Modeling: Continuous & discrete systems, Hybrid automata, State-space modelling, Formal models (Timed automata basics), Digital Twin & Co-Simulation: Concept of Digital Twin, Model-based design, Cyber-physical co-simulation frameworks.

Unit 2: CPS Architectures & Edge-Cloud Integration (15 Hrs.)

CPS Reference Architectures: Layered architecture, Service-Oriented CPS, SOA vs Microservices in CPS, Industry 4.0 reference model (RAMI 4.0 overview), Distributed & Networked CPS: Centralized vs decentralized control, Event-triggered vs time-triggered systems, Hierarchical CPS, Multi-agent CPS, Edge–Fog–Cloud CPS: Edge intelligence, Cloud-based CPS analytics, AI-enabled CPS, Case Study: Industrial CPS architecture.

Unit 3: Embedded Platforms, Control & Communication (15 Hrs.)

Embedded CPS Platforms: Sensors, actuators, signal conditioning, Microcontrollers & SoC platforms, RTOS concepts, Hardware–software co-design, Real-Time & Networked Control: Real-time scheduling (RM, EDF basics), Networked Control Systems, Latency, jitter, packet loss effects

CPS Communication Technologies: Wired protocols: CAN, Modbus, Wireless: ZigBee, BLE, WiFi, 5G URLLC, MQTT, OPC-UA, Time-Sensitive Networking (TSN), Distributed & Cooperative Control: Consensus algorithms, Multi-agent control basics.

Unit 4: Safety, Security, Resilience & AI in CPS (15 Hrs.)

Safety-Critical CPS: Hazard analysis (STPA basics), Fault detection & diagnosis, Fault tolerance mechanisms, CPS Security: Attack surfaces: Physical, network, software, Secure CPS architectures, Defense-in-Depth, Zero-Trust CPS, AI-based anomaly detection, Formal Verification & Assurance: Model checking basics, Temporal logic (introductory), Runtime monitoring, Resilient & Self-Healing CPS: Adaptive control, Self-reconfiguration, Secure OTA updates, Standards & Certification: IEC 61508, ISO 26262, DO-178C, IEC 62443.

List of Experiments

1. Modeling & Simulation
   a) Hybrid system modeling using MATLAB/Simulink
   b) Digital Twin of a physical process
   c) Event-triggered vs time-triggered simulation
   d) Service-Oriented CPS Simulation
   e) Network delay impact simulation (TrueTime or equivalent)
2. Embedded CPS Implementation
   a) Sensor–Actuator interfacing using microcontroller (Arduino/STM32)
   b) Real-time task scheduling experiment
   c) CAN/MQTT based communication demo
   d) Edge-based data processing demo
   e) Industrial CPS Case Study Simulation
3. Mini-Project: Smart energy CPS/Autonomous line-following robot with network monitoring/Industrial tank level control with remote monitoring/Secure IoT-based CPS, etc.

Text and Reference Books:

1. *R. Alur, "Principles of Cyber-Physical Systems", Cambridge, MA, USA: MIT Press, 2023.*
2. *A. Baliyan, K. S. Kaswan, N. Kumar, K. Upreti and R. Kannan, "Cyber Physical Systems: Concepts and Applications", Abingdon, UK: Routledge, 2023.*
3. *Wei Yu (Ed.), "Edge Intelligence in Cyber-Physical Systems: Foundations and Applications", Elsevier/Academic Press, 2025.*
4. *Uttam Ghosh, Fortune Molango, and D. B. Rawat (Eds.), "Secure and Smart Cyber-Physical Systems", Boca Raton, FL, USA: CRC Press, 2025.*
5. *S. Pasricha and M. Shafique (Eds.), "Embedded Machine Learning for Cyber-Physical, IoT, and Edge Computing: Software Optimizations and Hardware/Software Codesign", Singapore: Springer, 2024.*
6. *N. Sharma, L. K. Awasthi, M. Mangla, K. P. Sharma, and R. Kumar (Eds.), "Cyber-Physical Systems: A Comprehensive Guide", Abingdon, UK: Routledge, 2022.*

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CLO-PLO matrix for the course MEENDCP326 (Cyber Physical Systems)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDCP326.1	3	2.5	2	2	1.5	1.5	1.5	2.5	2.5	2.5	2.15
MEENDCP326.2	3	2.5	2	2	1.5	1.5	1.5	2.5	2.5	2.5	2.15
MEENDCP326.3	2.5	2.5	2.5	2.7	2	2.5	1.5	2.7	2.5	2.5	2.39
MEENDCP326.4	2.5	2.5	2.5	2.7	2	1.5	1.5	2.5	2.5	2.5	2.27
MEENDCP326.5	1.5	1.5	3	2	3	2	2	3	2.5	2.5	2.3
MEENDCP326.6	1.5	1.5	3	2	3	2	2	3	2.5	2.5	2.3
Average PLO	2.33	2.17	2.5	2.25	2.17	1.83	1.67	2.7	2.5	2.5	2.26

Semester – III *(Course Work)*

Specialization 1: VLSI and Embedded Systems

MEENDNN326: Neural Networks and Deep Learning

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDNN326.1	Understand the fundamentals of artificial neural networks and backpropagation.
MEENDNN326.2	Design and train deep learning models such as MLPs and CNNs.
MEENDNN326.3	Apply sequential models like RNN, LSTM, and GRU for sequence data.
MEENDNN326.4	Develop deep learning solutions for real-world applications in vision and NLP.
MEENDNN326.5	Implement and train neural network models using appropriate optimization and evaluation techniques.
MEENDNN326.6	Develop deep learning applications using CNNs, RNNs, transfer learning, and modern frameworks.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit 1: Fundamentals of Neural Networks (15 Hrs.)

Introduction to Artificial Neural Networks (ANN), Biological neuron vs artificial neuron, McCulloch–Pitts neuron model, Perceptron and Multi-layer Perceptron (MLP), Activation functions (Sigmoid, Tanh, ReLU, Softmax), Loss functions (MSE, Cross-Entropy), Gradient Descent and Variants, Backpropagation algorithm.

Unit 2: Deep Learning Architectures (15 Hrs.)

Introduction to Deep Learning, Feedforward Neural Networks, Weight initialization and optimization techniques, Regularization (L1, L2, Dropout), Convolutional Neural Networks (CNN): Convolution, Pooling, Padding, CNN architectures (LeNet, AlexNet overview), Transfer learning basics.

Unit 3: Sequential Models and Advanced Networks (15 Hrs.)

Recurrent Neural Networks (RNN), Back propagation through time, Long Short-term memory, Gated Recurrent units, Vanishing and exploding gradient problem, LSTM and GRU, Sequence-to-sequence models, Attention mechanism (basic idea), Autoencoders, Generative models overview. Convolution Neural networks, Deep Dream, Deep Art, Deep Reinforcement Learning.

Unit 4: Applications and Modern Deep Learning (15 Hrs.)

Deep Learning for Computer Vision, Deep Learning for Natural Language Processing, Transformers (basic introduction), Model evaluation metrics (Accuracy, Precision, Recall, F1-score), Hyperparameter tuning, Deployment basics and ethical issues in AI, Applications: Healthcare, Autonomous Systems, Industry.

List of Experiments

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1.	Neural Networks Lab a) Implementation of Perceptron and Multi-Layer Perceptron (MLP) b) Implementation of activation and loss functions c) Backpropagation algorithm implementation d) Training neural network using Gradient Descent e) Regularization techniques (L1, L2, Dropout) f) Model evaluation using accuracy and loss metrics (Tools: Python, NumPy, TensorFlow / PyTorch)
2.	Deep Learning Applications Lab a) Implementation of Convolutional Neural Network (CNN) for image classification b) Implementation of RNN / LSTM for sequence prediction c) Transfer learning using pre-trained models d) Basic NLP model using embeddings e) Hyperparameter tuning and model optimization f) Mini project: Real-world deep learning application (Tools: TensorFlow / PyTorch, Keras, OpenCV)

Text and Reference Books:

1. *Ian Goodfellow, Yoshua Bengio, Aaron Courville, "Deep Learning", The MIT Press, 2016.*
2. *Simon Haykin, "Neural Networks and Learning Machines", Pearson College Div, 2008.*
3. *Christopher M. Bishop, "Pattern Recognition and Machine Learning", Springer, 2009.*
4. *Aurélien Géron, "Hands-On Machine Learning with Scikit-Learn, Keras & TensorFlow", Shroff/O'Reilly, 2022.*
5. *François Chollet, "Deep Learning with Python"*
6. *Ivan Vasilev et al., "Python Deep Learning", O'Reilly, 2017.*

CLO-PLO matrix for the course MEENDNN326 (Neural Networks and Deep Learning)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDNN326.1	2.9	2.5	2.0	2.0	2.1	1.7	1.6	1.4	2.3	1.7	2.0
MEENDNN326.2	3.0	2.4	2.4	2.2	2.8	1.1	1.4	1.3	2.8	1.6	2.1
MEENDNN326.3	2.9	2.4	2.1	2.2	2.6	1.5	1.3	1	2.6	1.7	2.03
MEENDNN326.4	2.8	2.3	2.5	2.1	2.6	1.4	1.8	1.4	2.5	1.8	2.12
MEENDNN326.5	2.9	2.6	2.2	2.3	2.9	1.5	1.4	1.3	2.7	1.7	2.15
MEENDNN326.6	3.0	2.5	2.6	2.3	3	1.2	1.6	1.2	2.9	2.0	2.23
Average PLO	2.92	2.42	2.3	2.18	2.67	1.4	1.52	1.27	2.63	1.75	2.1

Semester – III *(Course Work)*
Specialization 1: VLSI and Embedded Systems
MEENDHA326: Hardware Architectures for AI

Hours per Week			Credits	Maximum Marks			Examination
Lecture	Tutorial	Practical		Internal	End Term	Total	Hours
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDHA326.1	Understand the computational and memory requirements of AI and machine learning workloads.
MEENDHA326.2	Study modern hardware architectures and their suitability for AI applications.
MEENDHA326.3	Analyse AI-specific accelerators such as GPUs, TPUs, FPGAs, and ASICs.
MEENDHA326.4	Explore performance, power, and latency optimization techniques in AI hardware systems.
MEENDHA326.5	Implement and analyse parallel computing techniques using vector and matrix operations and to demonstrate data and model parallelism through CUDA-based GPU programming.
MEENDHA326.6	Design, train, optimize, and deploy lightweight neural network models for edge-AI applications using model conversion, quantization, and on-device inference techniques.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit 1: Introduction to AI Hardware Architectures (15 Hrs.)

Overview of AI hardware requirements and challenges, Traditional processor architectures (CPUs, GPUs, and memory hierarchies), AI specific hardware accelerators: GPUs, TPUs, and FPGAs, Memory architecture for AI on chip vs. off chip memory, Introduction to parallel computing concepts, Data and model parallelism in AI, Hardware architectures for parallel processing SIMD,MIMD, and SPMD, Multi-core processing and GPU computing, CUDA programming.

Unit 2: Specialized AI Accelerators (TPUs, FPGAs, and ASICs) (15 Hrs.)

Tensor Processing Units (TPUs): Architecture and use cases in AI; Field Programmable Gate Arrays (FPGAs) in AI Design and applications; Application Specific Integrated Circuits (ASICs) for AI; Trade-offs between GPUs, TPUs, FPGAs, and ASICs, Deep learning on FPGAs, Embedded System, Edge Devices (smartphones), ASIC, CPUs and manycore processor.

Unit 3: Memory, Optimization and Energy-Efficiency in AI Hardware (15 Hrs.)

Memory-efficiency and reliability of DNN accelerators: Model size aware Pruning of DNNs, Hardware architecture-aware pruning of DNNs. Memory related tradeoffs in DNN accelerators: Comparison of memory technologies (SRAM, DRAM, DRAM, STT RAM, PCM, Flash) and their suitability for designing memory elements in DNN accelerator, Neural branch. Power consumption and performance trade-offs in AI hardware, Hardware optimization techniques for deep learning, Energy efficient AI hardware design, Power-aware computation for AI models.

Unit 4: Edge AI Computing Paradigm (15 Hrs.)

Definition and motivation for edge AI, Edge vs cloud AI processing, Characteristics of edge workloads (sensor-driven, real-time, intermittent connectivity) Applications: smart cameras, autonomous drones, IoT nodes, wearable devices, industrial automation. Introduction to TinyML, Characteristics of TinyML workloads: Small neural networks, On-device learning vs inference. TinyML hardware platforms: Microcontrollers with AI acceleration, DSP-based inference engines.

List of Experiments

1. Demonstrate parallelism concepts using simple vector operations. Implement training simulation showing data split vs model split (NumPy, PyTorch), CUDA program for vector addition. Implementation of matrix multiplication using CUDA kernels.
2. Train a small NN for classification (MNIST-lite / Iris) (TensorFlow / PyTorch), Convert trained model into TFLite format for edge devices. Apply post-training quantization (FP32 → INT8). Run inference using TFLite Micro (simulation).
3. Implement simple edge AI use case like: Smart camera (object detection concept), IoT sensor anomaly detection.

Text and Reference Books:

1. *John L. Hennessy & David A. Patterson, "Computer Architecture: A Quantitative Approach", Elsevier, 2025.*
2. *David B. Kirk & Wen-mei W. Hwu, "Programming Massively Parallel Processors: A Hands-on Approach", Morgan Kaufmann Publishers, 2012.*
3. *Jason Sanders & Edward Kandrot, "CUDA by Example: An Introduction to General-Purpose GPU Programming", Addison-Wesley Publishers, 2010.*
4. *Vivienne Sze et al., "Efficient Processing of Deep Neural Networks: A Tutorial and Survey", Morgan & Claypool Publishers, 2017.*
5. *Pete Warden & Daniel Situnayake, "TinyML: Machine Learning with TensorFlow Lite on Arduino and Ultra-Low-Power Microcontrollers", O'Reilly Media Publishers, 2019.*

CLO-PLO matrix for the course MEENDHA326 (Hardware Architectures for AI)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDHA326.1	2.8	2.3	1.5	2.2	2.1	1.1	1.2	1	2	1.4	**1.76**
MEENDHA326.2	2.9	2.2	2	2.1	2.3	1.1	1.3	1	2.1	1.5	**2.85**
MEENDHA326.3	3	2.3	2.1	2.2	2.9	1.1	1.3	1.1	2.8	1.6	**2.04**
MEENDHA326.4	2.9	2.7	2.2	2.3	2.4	1.3	2	1.1	2.2	1.6	**2.07**
MEENDHA326.5	3	2.4	2.2	2.3	3	1.1	1.2	1.2	2.9	1.7	**2.1**
MEENDHA326.6	3	2.5	2.8	2.3	2.9	1.4	2.1	1.3	3	2	**2.33**
Average PLO	**2.93**	**2.4**	**2.13**	**2.23**	**2.6**	**1.18**	**1.52**	**1.12**	**2.5**	**1.63**	**2.02**

Semester – III *(Course Work)*
Specialization 1: VLSI and Embedded Systems

MEENDRA326: Robotics & AI

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDRA326.1	Understand robot structure, configurations, kinematics, actuators, and sensors.
MEENDRA326.2	Analyse robot dynamics and design suitable control and trajectory planning methods.
MEENDRA326.3	Apply AI techniques such as search algorithms, logic, and basic machine learning.
MEENDRA326.4	Integrate AI methods for robotic perception, planning, and real-world applications.
MEENDRA326.5	Implement robotic kinematics, trajectory planning, and control algorithms using appropriate tools.
MEENDRA326.6	Develop AI-based solutions for search, learning, and perception in robotic systems.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit 1: Fundamentals of Robotics (15 Hrs.)

History and evolution of robots, Components of robotic system, Robot classification (industrial, mobile, humanoid, service robots). Degrees of Freedom (DOF), Work envelope, Robot configurations (Cartesian, Cylindrical, Spherical, SCARA, Articulated). Forward kinematics, Inverse kinematics, Denavit–Hartenberg (D-H) parameters, Homogeneous transformation matrix. Electric, hydraulic, pneumatic actuators, Position sensors, proximity sensors, force sensor, Encoders.

Unit 2: Robot Dynamics and Control (15 Hrs.)

Newton–Euler formulation, Lagrangian formulation, Torque equation. Trajectory planning, Joint space and Cartesian space planning. Open loop and closed loop control, PID control in robotics, Adaptive and robust control. Differential drive robots, Kinematics of wheeled robots.

Unit 3: Fundamentals of Artificial Intelligence (15 Hrs.)

Introduction to Intelligent systems, Intelligent agents. Types of agents: simple reflex agent, Model-based agent, Goal-based agent, Utility-based agent, learning agents. Concept of Ontology AI. Expert systems. Supervised learning, Unsupervised learning, Reinforcement learning, Classification vs regression.

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Unit 4: AI in Robotics (15 Hrs.)

Image processing basics, Object detection, Feature extraction. Dijkstra's algorithm, SLAM (Simultaneous Localization and Mapping). Perceptron, ANN basics, Deep learning overview. Autonomous vehicles, Industrial automation, Healthcare robots, Humanoid robots, Delivery robots.

List of Experiments

Robotics Lab

1.
  a) Implementation of forward and inverse kinematics
  b) D-H parameter modelling and homogeneous transformation
  c) Trajectory planning (joint and Cartesian space)
  d) PID control of DC motor using encoder feedback
  e) Differential drive robot kinematics simulation.

AI & Intelligent Robotics Lab

2.
  a) Implementation of BFS, DFS, A*, and Dijkstra algorithms
  b) Supervised and unsupervised learning experiments
  c) Basic reinforcement learning simulation
  d) Image processing and object detection using OpenCV
  e) Simple ANN/Perceptron implementation

Text and Reference Books:

1. *John J. Craig, "Introduction to Robotics: Mechanics and Control", Pearson, 2004.*
2. *Mark W. Spong, Seth Hutchinson, M. Vidyasagar, "Robot Modelling and Control", Wiley & Sons, 2005.*
3. *Robert J. Schilling, "Fundamentals of Robotics: Analysis and Control", Prentice Hall India Learning Private Limited, 1996.*
4. *Stuart Russell & Peter Norvig, "Artificial Intelligence: A Modern Approach", Pearson Education, 2022.*
5. *Aaron Martinez & Enrique Fernández, "Learning ROS for Robotics Programming", Packt Publishing Limited, 2015.*
6. *Gary Bradski & Adrian Kaehler, "Learning OpenCV 3", O'Reilly Media, 2017.*
7. *Sebastian Raschka & Vahid Mirjalili, "Python Machine Learning: Machine Learning and Deep Learning with Python, scikit-learn, and TensorFlow 2", Packt Publishing Limited, 2019.*

CLO-PLO matrix for the course MEENDRA326 (Robotics & AI)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDRA326.1	2.9	2.2	2.1	2.1	2.1	1.5	1.4	1.6	2.7	1.4	2
MEENDRA326.2	3.0	2.6	2.4	2.3	2.2	1.2	1.3	1.7	2.8	1.5	2.1
MEENDRA326.3	2.8	2.5	1.9	2.2	2.3	1.4	1.2	1.8	2.1	1.6	1.98
MEENDRA326.4	2.8	2.4	2.3	2.2	2.3	1.6	1.6	1.9	2.4	1.7	2.12
MEENDRA326.5	2.9	2.3	2.2	2.3	3.0	1.5	1.1	1.2	2.9	1.6	2.1
MEENDRA326.6	2.9	2.5	2.6	2.3	2.7	1.8	1.8	1.1	2.8	1.9	2.24
Average PLO	2.88	2.41	2.25	2.23	2.43	1.5	1.4	1.55	2.62	1.62	2.09

Semester – III *(Course Work)*

Specialization 2: Communication and Signal Processing

MEENDML326: Machine Learning for Wireless Communication

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	4	6	45	105	150	2 ½ Hours

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Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDML326.1	Apply mathematics to machine learning problem-solving
MEENDML326.2	Explore the machine learning algorithms
MEENDML326.3	Analyze neural network architecture
MEENDML326.4	Analyze neural network architecture
MEENDML326.5	Develop deep learning models
MEENDML326.6	Demonstrate the physical layer application using a deep learning model

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit 1: Mathematics for Machine Learning (15 Hrs.)

Linear Algebra: Arithmetic of metrics, Norms, Eigen Decomposition, Singular Value Decomposition, Principal Component Analysis, Probability& Information Theory, Conditional Probability, Chain Rule, Baye's Rule, Information Theory, Structure Probabilistic models, Supervised Learning, classification model Algorithm, Regression-Regression models, Algorithm, Logistic regression, Unsupervised Learning: Clustering, Pattern finding using association rule Reinforcement Learning: Q-learning, Q function and Algorithm, Maximum like look estimate, Modeling and Evaluation, Overfitting, underfitting, Bias Variance trade-off.

Unit 2: Basics of Neural Networks (15 Hrs.)

Types of activation functions, Single layer feed-forward network, Multilayer feedforward Network, multi-layer network design, Back propagation algorithm, Practice: Application of single layer neural network for wireless communication, Application of multilayer neural network for wireless communication.

Unit 3: Deep Learning Architecture (15 Hrs.)

Convolutional operation, Convolutional networks, Concept of autoencoder, autoencoder, autoencoder & its types, architecture of Operation LeNET, Alexnet, ZF-NET,VGG- NET, Google NET, ResNet, Architecture of RNN, LSTM, GRV. Convolutional Neural Network for classification, Auto-encoder for wireless data denoising.

Unit 4: Deep Learning for Wireless Communication (15 Hrs.)

The potential of DL for the Physical layers, Auto encodes for end-to-end Communication, Deep MIMO detectors, Different neural architectures for detection, Machine learning for spectrum access & sharing, and Hands-on experience with Python for developing neural networks. Deep Learning for MIMO data decoding, Machine learning for Spectrum detection.

List of Experiments

1. Implementation of Principal Component Analysis (PCA) for Dimensionality Reduction of Wireless Channel Data.
2. Implementation of Linear Regression and Logistic Regression for Wireless Signal Classification.
3. Implementation of K-Means Clustering for Spectrum Occupancy Detection.
4. Simulation of Bias–Variance Trade-off and Overfitting in Wireless Dataset Modeling.
5. Implementation of Single Layer Neural Network for Modulation Classification.
6. Implementation of Multilayer Feedforward Neural Network using Backpropagation for Channel Estimation.
7. Implementation of Convolutional Neural Network (CNN) for Wireless Signal Classification.
8. Autoencoder-Based Denoising of Wireless Signals.
9. Deep Learning-Based MIMO Detection using Fully Connected Neural Networks.
10. Simulation of RNN/LSTM for Time-Varying Wireless Channel Prediction.

Text and Reference Books:

1. *Jason Brownee, "Basics of linear Algebra for Machine learning", Machine learning Mastery, 2018.*
2. *Ethem Alpaydin, "Introduction to Machine learning" Cambridge, MA, MIT press, Second Edition, 2010.*
3. *Saikat Dutt, Subramanian Chandramouli and Amit Kumar Das, "Machine learning", Pearson Education limited, 2019.*
4. *Zsolt Nagy, "Artificial Intelligence and Machine learning Fundamentals", Pack Publishing ltr. 2018.*
5. *Ian Good fellow, Yoshua Bengion and Aaron Courville "Deep learning", Cambridge, MA, MIT Press, 2017.*
6. *https://medium.com/analytics-vidhya/cnns-architectures-lenet-alexnet-vgg-googlenet-resnet-and-more-666091488df5.*
7. *https://towardsdatascience.com/illustrated-10-cnn-architectures-95d78ace614d.*
8. *Fa-longluo," Machine Learning for future wireless Communications", Machine learning for spectrum access and sharing, Wiley-IEEE press, December 2019.*

CLO-PLO matrix for the course MEENDML326 (Machine Learning for Wireless Communication)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDML326.1	3	3	1	2	2	0	0	0	2	1	1.4
MEENDML326.2	3	3	2	3	3	0	0	0	3	1	1.8
MEENDML326.3	3	3	2	3	3	0	0	0	3	1	1.8
MEENDML326.4	3	3	2	3	3	0	0	0	3	2	1.9
MEENDML326.5	3	3	3	3	3	0	0	2	3	2	2.2
MEENDML326.6	3	3	3	3	3	1	1	3	3	2	2.5
Average PLO	3	3	2.17	2.83	2.83	0.17	0.17	0.83	2.83	1.5	1.93

Semester – III *(Course Work)*

Specialization 2: Communication and Signal Processing

MEENDRF326: RF Sensing and Imaging

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDRF326.1	Understand and apply RF/Microwave imaging principles in various sensing applications.
MEENDRF326.2	Design and evaluate antenna systems for RF sensing and imaging.
MEENDRF326.3	Model and interpret imaging signal processing and image reconstruction techniques.
MEENDRF326.4	Analyze radar and imaging system performance in different operational domains.
MEENDRF326.5	Apply RF sensing and imaging technology to practical remote sensing and medical imaging applications.
MEENDRF326.6	Develop algorithms for sensing and imaging applications.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit 1: RF/Microwave Imaging Principles (15 Hrs.)

Introduction to RF and Microwave imaging fundamentals, Electromagnetic wave propagation and interaction with targets, Introduction to electromagnetic scattering, Direct and inverse scattering problems, State-of-the-art in microwave sensing, Basic electromagnetic field relations in free space, Interaction of electromagnetic waves with dielectric materials, Macroscopic electric field and polarization, Electric flux density and dielectric properties, Relative permittivity and dielectric contrast, Scattering parameters and field quantities.

Unit 2: Direct Problem Formulation and Material Interaction (15 Hrs.)

Mathematical formulation of the direct scattering problem, Integral equation formulation (basic concepts), Electric field integral equation, Weak scattering conditions, Scattering from simple dielectric objects, Multiple reflections in inhomogeneous media, Basic transmission line analogy for dielectric interfaces, TE and TM mode illumination concepts, 2D planar geometry formulation.

Unit 3: Radar and SAR Imaging Systems (15 Hrs.)

Introduction to RADAR, RADAR range equation and signal processing, Pulse RADAR and Doppler RADAR, Synthetic Aperture RADAR (SAR), SAR image formation and resolution, CW and FMCW RADAR systems, Imaging RADAR modes, RADAR signal processing and clutter suppression, Tracking and multi-target detection.

Unit 4: Remote Sensing and Biomedical Imaging Applications (15 Hrs.)

Remote sensing with RF and Microwave systems, Earth observation using SAR and radiometric sensors, Agriculture and environmental monitoring, Ground penetrating RADAR (GPR) for subsurface imaging, Medical imaging applications (microwave thermography, UWB imaging), Industrial inspection and NDT applications, Microwave imaging for material characterization, Image interpretation and analysis, Signal acquisition and preprocessing, Motion compensation in SAR imaging, Performance metrics and image quality assessment.

List of Experiments

1. Simulation of Electromagnetic Wave Propagation and Target Scattering using Full-Wave EM Solver.
2. Study of Spatial Resolution and Range Resolution in Time-Domain and Frequency-Domain Imaging using MATLAB.
3. Modeling of Real Aperture Imaging System and Evaluation of Resolution Limits.
4. Design and Simulation of Broadband Microstrip / Vivaldi Antenna for Imaging Applications.
5. Simulation of RADAR Range Equation and Target Detection using MATLAB.
6. Microwave Imaging for Material Characterization using S-Parameter-Based Reconstruction.

Text and Reference Books:

1. *Nikolova NK. "Introduction to Microwave Imaging", Cambridge University Press, 2017.*
2. *Constantine A. Balanis. "Antenna Theory Analysis and Design", 4th edition, John Wiley and Sons, New Jersey, 2016.*
3. *Fawwaz T. "Microwave Remote Sensing: Active and Passive", Artech House Publishers, 2014.*
4. *Collin, Robert E. "Foundations for Microwave Engineering", 2nd Ed. India, Wiley India Pvt. Limited, 2007.*
5. *Andrea R. "Microwave Sensing and Imaging" Mdpi AG, 2022.*

CLO-PLO matrix for the course MEENDRF326 (RF Sensing and Imaging)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDRF326.1	3	2	1	1	1	0	0	0	2	1	1.1
MEENDRF326.2	3	3	2	2	2	0	0	0	2	1	1.5
MEENDRF326.3	3	3	3	2	2	0	0	0	3	1	1.7
MEENDRF326.4	3	2	2	2	2	3	3	0	3	2	2.2
MEENDRF326.5	3	3	2	3	2	1	1	0	3	1	1.9
MEENDRF326.6	3	3	3	3	3	1	0	3	3	1	2.3
Average PLO	**3**	**2.67**	**2.17**	**2.17**	**2**	**0.83**	**0.67**	**0.5**	**2.67**	**1.17**	**1.78**

Semester – III *(Course Work)*

Specialization 2: Communication and Signal Processing

MEENDWM326: Advanced Wireless and Mobile Networks

Hours per Week			Credits	Maximum Marks			Examination
Lecture	Tutorial	Practical		Internal	End Term	Total	Hours
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDWM326.1	Explain the Isochronous Wireless Network Integration Aspects for industrials automation.
MEENDWM326.2	Explore the Isochronous Medium Access Control (MAC) Resource allocation, admission Control and Scheduling in TDMA-based Wireless
MEENDWM326.3	Apply WPCNs in Internet of Things, Enhancement methods of Physical Layer Security in Wireless Powered Communication Network
MEENDWM326.4	Evaluate the performance of Internet of Nano-Things (IoNT) & WBAN architecture
MEENDWM326.5	Analyze the Routing Protocol for WBAN and adaptive W/BAN
MEENDWM326.6	Evaluate adaptive wireless network frameworks for different performance parameters.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit 1: Wireless Network for Real Time Communication in Industrial Application (15 Hrs.)

Introduction, Application Scenario, Problem Exposition, Solution approach, Industrial Wireless Communication IEEE 802, Wireless Network Topologies, Analysis and Classification of industrial network and topology, Industrial Wireless Channel System Model, Isochronous Wireless Network, Case study: Real Time Communication in Industrial Application.

Unit 2: Wireless Powered Communication Network and Security (15 Hrs.)

Overview of Wireless Powered Communication Networks (WPCN), Physical Layer Security Challenges in WPCNs, Applications of WPCNs in Internet of Things, Enhancing Physical Layer Security in WPCN, Accumulate-Then-Transmit, Accumulate-and-Jam, System Model and Protocol Design, Analysis, Performance Evaluation..

Unit 3: Internet of Nano-Things (IoNT) and WBAN (15 Hrs.)

Internet of Nano-Things (IoNT)- Introduction, IoNT opportunity in the 5G Era, IoNT Architecture in 5G, IoNT Design Factors and Assessment, IoNT Physical Layer and 5G, IoNT Communication Protocols and 5G Case study: IoNT in Healthcare applications, Wireless Body Area Network- Introduction- Rational Routing Protocol for WBAN.

Unit 4: Routing Protocol for WBAN and Adaptive WBAN system (15 Hrs.)

System model, Architecture, Rational Routing Protocol for WBAN, Performance, Protocol, Rational Data Delivery Framework, Adaptive WBAN System Model, Packet-Size Optimization for a Battery less WBASN, A Cognitive Routing Protocol for WBAN, Communication Model, Energy-Aware Routing Protocol for Nano-sensor Networks, System Models.

List of Experiments

1. Simulation of IEEE 802-based Industrial Wireless Network and Throughput/Latency Analysis.
2. Modeling of Isochronous Wireless Network and Real-Time Delay Performance Evaluation.
3. Simulation of Wireless Powered Communication Network (WPCN) with Accumulate-Then-Transmit Protocol.
4. Performance Analysis of Internet of Nano-Things (IoNT) Architecture in 5G Environment.
5. Implementation and Performance Comparison of Routing Protocols for WBAN.
6. Energy-Aware Routing Protocol Simulation for Nano-Sensor Networks.
7. Packet Size Optimization and Battery-Less WBASN Performance.

Text and Reference Books:

1. *Henning Trsek, "Isochronous Wireless Network for Real-time Communication in Industrial Automation", Springer-Verlag Berlin Heidelberg, 2016.*
2. *Abbas Jamalipour, Ying Bi, "Wireless Powered Communication Networks from Security Challenges to IoT Applications", Springer Nature Switzerland AG, 2019.*
3. *Fadi Al-Turjman, "Internet of Nano-Things and Wireless Body Area Networks (WBAN)", Taylor & Francis Group, 2019.*

CLO-PLO matrix for the course MEENDWM326 (Advanced Wireless and Mobile Networks)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDWM326.1	3	3	1	2	2	1	0	0	2	1	1.5
MEENDWM326.2	3	3	3	2	3	0	0	0	3	1	1.8
MEENDWM326.3	3	3	2	3	2	0	0	0	2	2	1.7
MEENDWM326.4	3	3	1	2	1	3	0	0	2	2	1.7
MEENDWM326.5	3	3	3	3	3	1	3	2	3	1	2.5
MEENDWM326.6	3	3	2	3	3	0	1	2	3	1	2.1
Average PLO	3	3	2	2.5	2.33	0.83	0.67	0.67	2.5	1.33	1.88

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Semester – III *(Course Work)*

Specialization 2: Communication and Signal Processing

MEENDMM326: Multimedia Signal Coding and Communication

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDMM326.1	Analyze different types of multimedia with emphasis on image data, file formats, and basic color models.
MEENDMM326.2	Describe and differentiate between lossless and lossy image/video compression techniques and explain the basic working principles of JPEG and MPEG standards
MEENDMM326.3	Analyze the fundamentals of digital audio and explain the working principles of major audio compression techniques and standards such as PCM, MP3, and AAC.
MEENDMM326.4	Understand multimedia communication concepts and basic security technologies for multimedia security and digital rights management.
MEENDMM326.5	Implement multimedia compression algorithms for image, audio, and video compression using appropriate computational tools.
MEENDMM326.6	Design and evaluate multimedia communication and security mechanisms including encryption, watermarking, and steganography with performance analysis.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit 1: Introduction to Multimedia (15 Hrs.)

Introduction to multimedia: Audio, Images, Video and their real-world applications, Image data types and file formats: Binary, Grayscale, and Color images, Arithmetic and logical operations on digital Images. Basics of color models: RGB, CMY, CMYK, Simple interconversion between color spaces.

Unit 2: Image and Video Compression (15 Hrs.)

Need for multimedia compression and its importance in storage/communication, Lossless Compression: Run Length Coding, Variable Length Coding, Lossy Compression: DCT-based coding, JPEG standard, Introduction to video compression: concept of motion compensation (basic idea only), Hybrid Video Coder, Intraframe and Inter-frame compression, Introduction to MPEG.

Unit 3: Audio Compression (15 Hrs.)

Fundamentals of Digital Audio: Nature of sound and speech signals, Analog-to-Digital Conversion, Sampling Theorem, Quantization, PCM, DPCM and ADPCM, Bit Rate and Bandwidth, Signal-to-Noise Ratio; Basics of Data Compression: Redundancy in Audio Signals (Temporal, Spectral and Perceptual), Lossless and Lossy Compression, Audio Compression Standards: MPEG-1 Layer III (MP3), Advanced Audio Coding (AAC).

Unit 4: Multimedia Communication and Security (15 Hrs.)

Multimedia information representation and networks (basic concepts only), Need for multimedia security, Multimedia Security Fundamentals: Security requirements (confidentiality, integrity, authentication, non-repudiation), Cryptography basics (symmetric and asymmetric encryption), Hash functions and digital signatures; Multimedia Content Protection: Digital watermarking: Principle and Applications, Digital Rights Management (DRM), Steganography Principle and Applications.

List of Experiments

1. Study of different image file formats (BMP, PNG, and JPEG) and analysis of image data types (binary, grayscale, color).
2. Implementation of basic image operations and color space conversion (RGB to CMY/CMYK and vice versa).
3. Implementation of Run Length Encoding (RLE) and Variable Length Coding for images; compression ratio analysis.
4. Implementation of Huffman coding and arithmetic coding for lossless image compression.
5. DCT-based image compression (JPEG-like implementation); analysis of compression ratio and PSNR.
6. Study of basic video compression concepts: Frame extraction, Motion estimation (block matching concept), Introduction to MPEG compression principles.
7. Implementation of PCM, DPCM, and ADPCM for audio signals; comparison of bit rate and SNR.
8. Study of audio compression using MP3/AAC (conceptual implementation and analysis of perceptual coding effects).
9. Analysis of bandwidth and bit rate requirements for multimedia transmission.

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10. Implementation of basic symmetric and asymmetric encryption for multimedia data.
11. Implementation of hash functions and digital signatures for multimedia integrity verification.
12. Image/audio watermarking and evaluation of imperceptibility.
13. Transform-domain watermarking using DCT or DWT; robustness analysis against noise and compression.
14. Implementation of basic image steganography and extraction.
15. Design and evaluation of a secure multimedia transmission system using encryption and digital watermarking.

Text and Reference Books:

1. *Ze-Nian Li, Mark S. Drew, "Fundamentals of Multimedia", PHI, 2010.*
2. *Mrinal Kr. Mandal Springer, "Multimedia Signals & Systems" International Edition, 1st Edition, 2009.*
3. *Fred Halsall, "Multimedia Communications", Pearson education, 2002.*
4. *K. R. Rao, Zorans. Bojkovic, Dragorad A.M Ivanovic, "Multimedia Communication Systems – Techniques, Stds & Networks" 1st Edition, 2002.*
5. *Ze-Nian Li, Mark S. Drew, "Fundamentals of Multimedia", Pearson Education (LPE), 1st Edition, 2009.*
6. *F. John Koegel Buford, "Multimedia Systems", Pearson Education (LPE), 1st Edition, 2003.*
7. *K.Giri and S. Purah, "Multimedia Security, Algorithm Development, Analysis and Applications", Springer Nature, 2021.*

CLO-PLO matrix for the course MEENDMM326 (Multimedia Signal Coding and Communication)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDMM326.1	3	2	2	1	2	2	1	1	3	2	1.9
MEENDMM326.2	3	3	3	2	3	2	2	1	3	2	2.4
MEENDMM326.3	3	3	3	2	3	2	2	1	3	2	2.4
MEENDMM326.4	3	3	3	2	3	3	3	2	3	2	2.7
MEENDMM326.5	3	2	1	3	2	2	3	3	3	2	2.4
MEENDMM326.6	3	3	1	3	2	2	3	3	3	2	2.5
Average PLO	3	2.67	2.17	2.17	2.5	2.17	2.33	1.83	3	2	2.38

Semester – III *(Course Work)*

Specialization 2: Communication and Signal Processing

MEENDCV326: Computer Vision

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDCV326.1	Model image formation using single and multiple camera systems and apply projective geometry for 3D scene understanding.
MEENDCV326.2	Design and analyze feature extraction, segmentation, and motion estimation algorithms for images and video sequences.
MEENDCV326.3	Apply statistical learning and deep learning techniques to object detection, recognition, and semantic understanding tasks.
MEENDCV326.4	Develop and evaluate end-to-end computer vision systems for real-world applications and research problems.
MEENDCV326.5	Implement geometric modeling, feature extraction, segmentation, and motion analysis algorithms for images and video sequences using appropriate computational tools.
MEENDCV326.6	Design and evaluate machine learning and deep learning based computer vision systems for object detection, recognition, and scene understanding tasks.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit I: Imaging Geometry and Multi-View Vision (15 Hrs.)

Image formation models: monocular and binocular imaging systems. Orthographic and perspective projection. Camera models and camera calibration. Projective geometry and transformations: Euclidean, affine, and projective transformations. Epipolar geometry, fundamental and essential matrices. Homography estimation. Direct Linear Transform (DLT), RANSAC, image rectification. Stereo vision and depth estimation. Multi-view geometry, 3D reconstruction framework, auto-calibration, and structure from motion.

Unit 2: Feature Extraction, Description and Segmentation (15 Hrs.)

Image representations and scale-space theory. Edge detection (Canny, LoG, DoG). Corner and interest point detectors (Harris, Hessian, FAST). Feature descriptors: SIFT, SURF, HOG, GLOH. Feature matching and model fitting. Texture analysis using Gabor filters and wavelets. Image segmentation techniques: thresholding, region growing, edge-based methods, graph-cut, mean-shift, Markov Random Fields (MRFs). Active contours (snakes) and level-set methods. Deformable models and shape representation.

Unit 3: Motion Analysis, Tracking and Spatio-Temporal Vision (15 Hrs.)

Motion detection and estimation: background subtraction and modeling. Optical flow estimation and regularization methods. KLT tracker. Spatio-temporal image analysis. Motion parameter estimation. Stereo motion and dynamic stereo. Structure from motion. Object tracking in video sequences. Applications in surveillance, robotics, and autonomous systems.

Unit 4: Object Recognition and Deep Learning for Vision (15 Hrs.)

Object recognition and classification fundamentals. Shape representation and matching. Feature-space representation and similarity measures. Statistical pattern recognition methods including PCA, LDA, clustering, and dimensionality reduction. Deep learning for computer vision: neural network basics, convolutional neural networks (CNNs), building blocks of CNNs, transfer learning. Advanced architectures: residual networks, skip connections. Training strategies: gradient descent, momentum, RMSProp, Adam, batch normalization, dropout. Vision applications using deep learning: image classification, object detection, semantic segmentation. Overview of recent trends in computer vision research.

List of Experiments

1. Introduction to image handling: Reading, displaying, and saving images, Conversion between grayscale and color images.
2. Basic image operations: Cropping, Resizing, Rotation, Intensity transformations.
3. Histogram computation and histogram equalization.
4. Spatial filtering using convolution: Gaussian smoothing and Laplacian sharpening.
5. Edge detection using Sobel and Canny operators.
6. Corner detection using Harris and FAST algorithms.
7. Feature extraction and matching using SIFT/SURF/ORB descriptors.
8. Image segmentation using thresholding (Otsu method) and region-based segmentation.
9. Motion detection using frame differencing or background subtraction.
10. Optical flow estimation using Lucas–Kanade method.
11. Homography estimation and basic image stitching using feature matching.
12. Stereo vision: disparity map computation and depth estimation.
13. Dimensionality reduction using PCA and classification using k-NN or SVM.
14. Implementation of a simple Convolutional Neural Network (CNN) for image classification using a standard dataset.
15. Transfer learning using a pre-trained deep learning model for object recognition.

Text and Reference Books:

1. *Richard Szeliski, "Computer Vision: Algorithms and Applications", Springer, 2nd Edition, 2022.*
2. *David A. Forsyth and Jean Ponce, "Computer Vision: A Modern Approach", Pearson Education, 2nd Edition, 2012.*
3. *Richard Hartley and Andrew Zisserman, "Multiple View Geometry in Computer Vision", Cambridge University Press, 2nd Edition, 2004.*
4. *Simon J. D. Prince, "Computer Vision: Models, Learning, and Inference", Cambridge University Press, 2012.*
5. *Christopher M. Bishop, "Pattern Recognition and Machine Learning", Springer, 2006.*
6. *Ian Goodfellow, Yoshua Bengio, and Aaron Courville, "Deep Learning", MIT Press, 2016.*
7. *E. R. Davies, "Computer and Machine Vision: Theory, Algorithms, Practicalities", Elsevier, 4th Edition, 2012.*

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CLO-PLO matrix for the course MEENDCV326 (Computer Vision)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDCV326.1	3	3	2	2	3	2	1	1	3	2	2.2
MEENDCV326.2	3	3	3	3	3	2	2	2	3	2	2.6
MEENDCV326.3	3	3	3	3	3	2	2	2	3	2	2.6
MEENDCV326.4	3	3	3	3	3	3	3	3	3	2	2.9
MEENDCV326.5	3	2	1	3	2	2	3	3	3	2	2.4
MEENDCV326.6	3	3	1	3	2	2	3	3	3	2	2.5
Average PLO	3	2.83	2.17	2.83	2.67	2.23	2.33	2.33	3	2	2.53

Semester – III *(Course Work)*

Specialization 2: Communication and Signal Processing

MEENDSS326: Speech Signal Processing

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDSS326.1	Model speech and audio signals using discrete-time and short-time signal processing frameworks.
MEENDSS326.2	Implement spectral, cepstral, and linear predictive algorithms for speech and audio analysis.
MEENDSS326.3	Apply foundational statistical concepts used in speech processing, including feature-space representation and statistical modeling.
MEENDSS326.4	Design and evaluate basic audio watermarking schemes using signal processing and decision-based detection principles.
MEENDSS326.5	Implement speech signal processing algorithms including framing, spectral analysis, cepstral analysis, linear predictive modeling, and feature extraction using appropriate computational tools.
MEENDSS326.6	Design and evaluate speech coding, enhancement, recognition, and watermarking systems, and analyze performance using objective metrics such as SNR, MSE, and recognition accuracy.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit 1: Speech and Audio Signal Models (15 Hrs.)

Speech production mechanism and auditory perception. Source–filter model of speech. Discrete-time representation of speech and audio signals. Framing and windowing. Short-time energy, zero-crossing rate, and voiced/unvoiced detection. Characteristics of speech and audio signals.

Unit 2: Spectral, Cepstral and Feature Extraction Algorithms (15 Hrs.)

Short-Time Fourier Transform (STFT) and spectrogram computation. Pitch estimation using autocorrelation, AMDF, and cepstral methods. Cepstral analysis and liftering. Linear predictive coding (LPC): coefficient estimation, formant estimation, and residual signal. Feature extraction algorithms: MFCC, LPCC, PLP, delta and delta-delta features.

Unit 3: Statistical Foundations for Speech (15 Hrs.)

Feature vectors and feature-space representation of speech signals. Distance measures for speech signals: Euclidean, Mahalanobis, and cepstral distances. Template-based pattern matching. Vector Quantization (VQ) for speech and speaker recognition. Gaussian statistical models for speech signals. Introduction to Hidden Markov Models (HMMs): states, observations, transition probabilities, and basic recognition framework.

Unit 4: Audio Coding, Watermarking and Security (15 Hrs.)

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Speech and audio coding: PCM, DPCM, ADPCM, LPC-based coding (analysis–synthesis model), overview of CELP. Audio enhancement: spectral subtraction and Wiener filtering.

Introduction to audio watermarking and security requirements: imperceptibility, robustness, and capacity. Time-domain watermarking (LSB, echo hiding – overview). Transform-domain watermarking: DCT-based and DWT-based methods. Watermark embedding and extraction. Robustness against common signal processing attacks such as noise addition, filtering, compression, and resampling. Applications in copyright protection and content authentication.

List of Experiments

1. Recording and analysis of speech signals; computation of short-time energy and zero-crossing rate for voiced/unvoiced detection.
2. Implementation of framing and windowing techniques; comparison of different window functions.
3. Computation and visualization of Short-Time Fourier Transform (STFT) and spectrogram.
4. Pitch estimation using autocorrelation, AMDF, and cepstral methods; comparative analysis.
5. Cepstral analysis and liftering of speech signals.
6. Linear Predictive Coding (LPC): coefficient estimation, formant estimation, and residual signal analysis.
7. Feature extraction: MFCC, LPCC, and delta/delta-delta coefficients.
8. Vector Quantization (VQ) for speech or speaker recognition.
9. Template-based pattern matching using Euclidean and Mahalanobis distance measures.
10. Basic Hidden Markov Model (HMM) implementation for a simple speech recognition task.
11. Speech coding techniques: PCM, DPCM, and ADPCM; comparison of bit rate and SNR.
12. Speech enhancement using spectral subtraction and Wiener filtering.
13. Time-domain audio watermarking (LSB or echo hiding).
14. Transform-domain watermarking using DCT or DWT; robustness evaluation against noise and compression.

Text and Reference Books:

1. *L. R. Rabiner and R. W. Schafer, "Digital Processing of Speech Signals", Pearson Education, 1978.*
2. *Thomas F. Quatieri, "Discrete-Time Speech Signal Processing: Principles and Practice", Pearson Education, 1st Edition, 2002.*
3. *J. R. Deller, J. G. Proakis, and J. H. L. Hansen, "Discrete-Time Processing of Speech Signals", Wiley-IEEE Press, 2nd Edition, 2000.*
4. *B. Gold and N. Morgan, "Speech and Audio Signal Processing: Processing and Perception of Speech and Music", Wiley, 1st Edition, 2000.*
5. *L. R. Rabiner and B. H. Juang, "Fundamentals of Speech Recognition", Prentice Hall, 1993.*
6. *Ingemar J. Cox, Matthew L. Miller, Jeffrey A. Bloom, Jessica Fridrich, and Ton Kalker, "Digital Watermarking and Steganography", Morgan Kaufmann, 2nd Edition, 2007.*
7. *Xuedong Huang, Alex Acero, and Hsiao-Wuen Hon, "Spoken Language Processing: A Guide to Theory, Algorithm, and System Development", Prentice Hall PTR, 1st Edition, 2001.*
8. *Daniel Jurafsky and James H. Martin, "Speech and Language Processing", Pearson, 3rd Edition, 2023.*

CLO-PLO matrix for the course MEENDSS326 (Speech Signal Processing)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDSS326.1	3	3	2	2	2	2	1	1	3	2	2.1
MEENDSS326.2	3	3	3	2	3	2	1	1	3	2	2.3
MEENDSS326.3	3	3	3	3	3	2	2	1	3	2	2.5
MEENDSS326.4	3	3	3	2	3	3	3	2	3	2	2.7
MEENDSS326.5	3	2	1	3	2	2	3	3	3	2	2.4
MEENDSS326.6	3	3	1	3	2	2	3	3	3	2	2.5
Average PLO	3	2.83	2.17	2.5	2.5	2.17	2.17	1.83	3	2	2.42

Semester – III *(Course Work)*

Specialization 2: Communication and Signal Processing

MEENDR5326: Radiating Systems for RF Communication

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDRS326.1	Explain the fundamental principles of antenna radiation, polarization, and key performance parameters.
MEENDRS326.2	Analyze and design standard antennas for RF and wireless communication applications.
MEENDRS326.3	Design printed and planar antennas and apply array synthesis techniques to achieve specified radiation characteristics for broadband and cellular systems.
MEENDRS326.4	Examine advanced antenna systems including reflectors, lenses, metasurfaces, and smart antenna architectures.
MEENDRS326.5	Design and simulate dipole, microstrip, array, and reflectarray antennas using full-wave EM tools, and analyze impedance matching, radiation characteristics, phase response, and beamforming performance.
MEENDRS326.6	Evaluate antenna performance experimentally through return loss, radiation pattern, and gain measurements, and correlate measured results with simulation outcomes.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit 1: Basic Antenna Theory (15 Hrs.)

Basic dipole theory: Flared transmission lines, Field equations, Dipoles, Monopoles, Antenna transmission and radiation parameters, Antenna polarization, Antenna miniaturization, and Chu-Harrington limit. Friis transmission equation.

Unit 2: Standard Antennas (15 Hrs.)

Loops, Folded dipoles, Helical antennas, Yagi-Uda, Spiral antennas, Antenna impedance matching and tuning techniques. Aperture theory and equivalence principle, Slot antennas, Horn antennas, leaky wave antennas, Vivaldi antennas.

Unit 3: Planar Antennas and Arrays (15 Hrs.)

Microstrip antennas and feeding techniques, Broadband techniques for printed and planar antennas, Printed monopoles and dipole structures, Antennas for cellular communication, diversity/MIMO techniques. Array synthesis of linear elements, Two-Element Array, N-Element Linear Array: Uniform Amplitude and Spacing, Planar arrays.

Unit 4: Applied Antennas for Wireless Communication (15 Hrs.)

Reflector Antennas, Lens Antennas, Fermat's Principle, Artificial dielectric lens antennas, Metasurface lens antennas, Concept and benefits of smart antennas, Fixed weight beamforming basics, Adaptive beamforming, Intelligent Reflecting Surfaces.

List of Experiments

1. Introduction to CST MWS software tool and EM Simulations.
2. Design of Dipole Antenna in EM Simulations.
3. Design of Microstrip Antenna and Study of Antenna Parameters.
4. A Simulations study of different Matching Techniques for Antennas.
5. Study of pattern synthesis in N-element antenna arrays using EM Simulations.
6. Fixed Weight Beamforming Simulation in MATLAB and EM Simulations.
7. To design, simulate, and analyse a single unit cell (reflectarray element) for reflecting surfaces, and to determine its radiation characteristics (phase response and reflection magnitude) as a function of incident angle and frequency.
8. Measurement of Return Loss of various antennas using VNA.
9. Radiation Pattern Measurement (E-plane & H-plane) of a standard patch antenna, Horn Antenna, and Monopole antenna.
10. To measure the gain of an Antenna Under Test (AUT) using the Gain Transfer Method (Comparison Method) in an anechoic chamber or free-space environment

Text and Reference Books:

1. *J. D Kraus, "Antennas", 2nd edition, TMH Publications, 1988.*
2. *C. A. Balanis, "Antenna theory, analysis and design", 3rd Edition, Wiley publications, 2005.*
3. *Ramesh Garg, P. Bhartia, I Bhal, A. Ittipiboon, "Microstrip antenna design handbook", Artech House publications, 2015.*
4. *Girish Kumar, K. P. Ray, "Broadband Microstrip antennas", Artech House publications, 2002.*
5. *R. S. Elliot, "Antenna Theory and Design", Revised edition, Wiley-IEEE Press., 2003.*
6. *John Thornton, Kao-Cheng Huang, "Modern Lens Antennas for Communications Engineering", Wiley-IEEE Press, 2013.*

CLO-PLO matrix for the course MEENDRS326 (Radiating Systems for RF Communication)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDRS326.1	3	2	1	1	1	2	0	0	2	1	1.3
MEENDRS326.2	3	3	3	2	2	0	0	0	3	1	1.7
MEENDRS326.3	3	3	3	2	2	0	0	0	3	1	1.7
MEENDRS326.4	3	2	2	2	1	1	2	0	2	2	1.7
MEENDRS326.5	3	3	3	3	3	0	0	2	3	1	2.1
MEENDRS326.6	3	3	3	3	3	0	0	3	3	1	2.2
Average PLO	3	2.67	2.5	2.17	2	0.5	0.33	0.83	2.67	1.17	1.78

Semester – III *(Course Work)*

Specialization 2: Communication and Signal Processing

MEENDRM326: RF and Microwave Measurements

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDRM326.1	Explain the principles and practical challenges of RF and microwave measurements, and measure and interpret S-parameters using scalar and vector network analyzers.
MEENDRM326.2	Analyze RF signals and components using spectrum analysis techniques for accurate characterization.
MEENDRM326.3	Evaluate noise, phase noise, and signal generation mechanisms in RF systems.
MEENDRM326.4	Perform antenna measurements, including radiation pattern, gain, efficiency, and polarization characterization.
MEENDRM326.5	Apply RF and microwave measurement techniques using VNAs and spectrum analyzers to characterize impedance, time-domain response, and material properties.
MEENDRM326.6	Interpret experimental results from VSWR, radiation pattern, gain, and spectral measurements to validate antenna and microwave system performance.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit 1: Basics of Microwave Measurements (15 Hrs.)

Concept of Transmission Lines and S-parameters. Traditional Measurement Techniques: The Power Meter, Transmission Measurement, and Reflection Measurement. Basic Vector Measurements, Architecture of the Vector Network Analyzer, Network Analyzer Calibration: TRL calibration, SOLT calibration. Measurement of S-parameters: Wave Separation Techniques.

Unit 2: Spectrum Analysis (15 Hrs.)

Common Measurements Using the Spectrum Analyzer, Types of Signal Analyzers, Basic Idea behind Spectrum Analyzers, Building Blocks of a Spectrum Analyzer, Features of the Spectrum Analyzer, Dynamic Range and Sensitivity, Component Characterization.

Unit 3: Noise Measurement and Signal Generation (15 Hrs.)

Noise Measurement Basics, Special Consideration for Mixers, Phase Noise, Phase Noise Measurement Techniques. Oscillator Circuits: The Crystal Oscillator, Tunable Oscillator, Direct Digital Synthesis, PLL-Based Synthesizers, Fractional N Synthesis.

Unit 4: Antenna Measurements (15 Hrs.)

Antenna Measurement Techniques: Antenna Range, Radiation Pattern, Gain Measurement, Directivity Measurement, Radiation Efficiency, Impedance Measurement, and Polarization Measurement.

List of Experiments

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1. Measurement of VSWR and Return Loss using the slotted line and VNA, comparison of results.
2. Familiarization with a Vector Network Analyzer and Measurement of S-parameters of the Microwave Passive Components.
3. One-Port Calibration (SOLT) and S11 Measurement and calculation of unknown load.
4. Two-Port Calibration and Full S-Parameter Measurement of a two-port device.
5. Time Domain Reflectometry (TDR) using VNA.
6. Measurement of carrier frequency, harmonics, and spurious signals using a spectrum analyzer.
7. Measurement of complex permittivity, loss tangent of a semi-solid sample over a specified frequency range using open open-ended coaxial probe and VNA.
8. To plot the 2D radiation pattern (Polar Plot) of a test antenna and determine its Half-Power Beamwidth (HPBW).
9. To calculate the absolute gain of an unknown test antenna using a comparison technique.

Text and Reference Books:

1. *A. Basu, "Introduction to Microwave Measurements", CRC Press 2014.*
2. *Keysight Technologies Application Notes.*
3. *C. A. Balanis, "Antenna Theory - Analysis and Design", John Wiley-India Edition, 2005.*
4. *IEEE Standards on Antennas.*

CLO-PLO matrix for the course MEENDRM326 (RF and Microwave Measurements)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDRM326.1	3	3	1	3	3	1	0	2	3	1	2
MEENDRM326.2	3	3	1	3	3	1	0	2	3	1	2
MEENDRM326.3	3	3	1	2	2	0	0	0	3	1	1.5
MEENDRM326.4	3	3	1	3	3	1	0	3	3	1	2.1
MEENDRM326.5	3	3	2	3	3	1	1	2	3	1	2.2
MEENDRM326.6	3	3	2	3	3	1	1	3	3	1	2.3
Average PLO	**3**	**3**	**1.33**	**2.83**	**2.83**	**0.83**	**0.33**	**2**	**3**	**1**	**2.01**

Semester – III *(Course Work)*

Specialization 2: Communication and Signal Processing

MEENDAE326: Advanced Electromagnetic Engineering

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	4	6	45	105	150	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENDAE326.1	Apply time-varying and time-harmonic electromagnetic field theory to analyze wave propagation, polarization, reflection, and transmission in different media.
MEENDAE326.2	Examine electromagnetic behavior at material interfaces, including lossy media and metamaterials.
MEENDAE326.3	Apply vector potential methods to analyze radiation and scattering problems.
MEENDAE326.4	Utilize fundamental electromagnetic theorems to solve advanced electromagnetic field problems.
MEENDAE326.5	Model and analyze electromagnetic wave propagation, modal behavior, and reflection–transmission phenomena using full-wave EM simulation tools.
MEENDAE326.6	Simulate and characterize advanced electromagnetic structures, including metamaterials and radiating elements, and extract parameters such as effective material properties and near- and far-field radiation characteristics.

Detailed Syllabus (04 Theory Credits and 02 Lab Credits):

Unit I: Wave Equation and Propagation (15 Hrs.)

Time-Varying Electromagnetic Fields, Time-Harmonic Electromagnetic Fields, Solution to the Wave Equation; Rectangular Coordinate System, Cylindrical Coordinate System, Spherical Coordinate System. Introduction, Transverse Electromagnetic Modes; Uniform Plane Waves in an Unbounded Lossless Medium—Principal Axis, Uniform Plane Waves in an Unbounded Lossless Medium—Oblique Angle, Transverse Electromagnetic Modes in Lossy media, Polarization; Linear Polarization, Circular Polarization, Elliptical Polarization, Poincaré Sphere.

Unit 2: Reflection and Transmission (15 Hrs.)

Normal Incidence—Lossless Media, Oblique Incidence—Lossless Media; Perpendicular Polarization, Parallel Polarization, Total Transmission–Brewster Angle, Total Reflection–Critical Angle, Lossy Media; Normal Incidence, Oblique Incidence, Reflection and Transmission of Multiple Interfaces, Polarization Characteristics on Reflection, Metamaterials; Classification of Materials, Double Negative (DNG) Materials, Negative-Refractive-Index (NRI) Transmission Lines.

Unit 3: Auxiliary Vector Potentials and Radiation (15 Hrs.)

Introduction, The Vector Potential A, The Vector Potential F, The Vector Potential A and F, Construction of Solutions; Transverse Electromagnetic Modes: Source-Free Region, Transverse Magnetic Modes: Source-Free Region, Transverse Electric Modes: Source-Free Region, Solution of the Inhomogeneous Vector Potential Wave Equation, Far-Field Radiation, Radiation and Scattering Equations; Near Field, Far Field.

Unit 4: Electromagnetic Theorems (15 Hrs.)

Duality theorem, Uniqueness theorem, Image theory, Reciprocity theorem, Reaction theorem, Volume equivalence, and surface equivalence theorem.

List of Experiments

1. Introduction to CST/HFSS and MATLAB for Electromagnetic Simulations.
2. Simulation of 1D Wave Equation and Verification of Analytical Solution and Visualization of Uniform Plane Wave Propagation in Free Space.
3. Study of Field Distribution in Rectangular Waveguide (TE10 Mode) and Cutoff Frequency Calculation and Validation (TE & TM Modes).
4. Simulation of Reflection and Transmission at a Dielectric Interface (Normal and Oblique Incidence) and Verification of Brewster Angle.
5. Reflection and Transmission Through Multi-Layer Dielectric Slab, Fabry–Perot Resonance Simulation.
6. Simulation of a Double Negative (DNG) / Negative Refractive Index (NRI) Material Slab and Study of Wave Propagation Characteristics.
7. Simulation of Split Ring Resonator (SRR) Unit Cell and Extraction of Effective Permittivity and Permeability.
8. Near-Field and Far-Field Radiation Analysis of an Electric Dipole using Vector Potential Formulation.

Text and Reference Books:

1. *C. A. Balanis, "Advanced Engineering Electromagnetics", John Wiley & Sons, 2nd Edition, 2012.*
2. *Roger F. Harrington, "Time-harmonic electromagnetic fields", Germany: Wiley, 2001.*
3. *Jordan and Balmain, "Electromagnetic Waves and Radiating Systems", Prentice Hall India Learning Private Limited; 2nd Edition, 2015.*

CLO-PLO matrix for the course MEENDAE326 (Advanced Electromagnetic Engineering)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENDAE326.1	3	3	1	2	2	0	0	0	2	1	1.4
MEENDAE326.2	3	3	2	2	2	0	0	0	2	2	1.6
MEENDAE326.3	3	3	1	2	1	0	0	0	2	1	1.3
MEENDAE326.4	3	3	1	2	1	0	0	0	2	1	1.3
MEENDAE326.5	3	3	2	3	3	1	0	2	3	1	2.1
MEENDAE326.6	3	3	3	3	3	1	1	3	3	2	2.5
Average PLO	3	3	1.67	2.33	2	0.33	0.16	0.83	2.33	1.33	1.7

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Semester – III (*Course Work*)
Specialization 1: VLSI and Embedded Systems
Specialization 2: Communication and Signal Processing
MEENPPP326: Pre Project

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
0	0	4	2	15	35	50	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENPPP326.1	Research, define, and document a project's core scope by constructing a clear project charter that outlines specific objectives, key deliverables, and primary constraints.
MEENPPP326.2	Identify and analyze key stakeholder groups and evaluate the initial feasibility of a project proposal, including an assessment of potential risks and resource requirements.

Detailed Syllabus (02 Lab Credits) (60 Hrs.):

Pre-Project Description

In the Pre-Project work, students shall choose a specific topic/area for their project. A supervisor will be assigned to each student, who at the beginning of the 3rd semester shall provide a syllabus and plan of study including relevant research papers to the student. Each student at the end of the course will submit a survey report regarding the final project and the same will be evaluated for final award of the course. Each Pre-Project work shall be evaluated for correctness, length and breadth of the background work undertaken by the student.

CLO-PLO matrix for the course MEENPPP126 (Pre Project)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENPPP126.1	1	3	2.5	3	2	2	2	2	1	2.5	2.1
MEENPPP126.2	1	3	2.5	3	2	2	2	2	1	2.5	2.1
Average PLO	**1**	**2**	**2.5**	**3**	**2**	**2**	**2**	**2**	**1**	**2.5**	**2.1**

MEENIPI326: Pre-Internship

Course Learning Outcomes (CLOs):

MEENIPI326.1	Craft and curate professional application materials—including a tailored resume and social networking profile—that effectively communicate their unique skills and value proposition to potential employers in their chosen industry.
MEENIPI326.2	Demonstrate workplace-appropriate communication and professional conduct by successfully participating in mock interviews and analyzing case studies related to workplace ethics and expectations.

Detailed Syllabus (02 Lab Credits) (60 Hrs.):

Pre-Internship Description

In Pre-Internship, students shall choose a specific domain for their Internship and identify prospective organizations and apply for Internship programmes. For Pre-Internship work, a counselor will be assigned to each student, who at the beginning of the 3rd semester shall guide him/her regarding identifying the prospective organizations and applying therein. At the successful completion of this course, students will: be able to articulate the mechanics of locating internships and behaving professionally; have produced the tools necessary to secure an appropriate internship; have created a professional portfolio that highlights their accomplishments. The student at the end of the course will submit a survey report regarding the procedure adopted and efforts made by the student in securing an Intern position and the same will be evaluated for final award of the course.

CLO-PLO matrix for the course MEENIPI126 (Pre-Internship)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENIPI126.1	1	1	1.5	1	1	2	2	2.5	0.5	2	1.45
MEENIPI126.2	1	1	1.5	1	1	2	2	2.5	0.5	2	1.45
Average PLO	**1**	**1**	**1.5**	**1**	**1**	**2**	**2**	**2.5**	**0.5**	**2**	**1.45**

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Semester – IV *(Course Work)*
Specialization 1: VLSI and Embedded Systems
Specialization 2: Communication and Signal Processing
MEENCRM426: Research Methodology and IPR

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
4	0	0	4	30	70	100	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENCRM426.1	Understand the basics of research and formulate a viable problem.
MEENCRM426.2	Learn how to design experiments and collect valid data.
MEENCRM426.3	Analyze data effectively and communicate results professionally.
MEENCRM426.4	Understand the protection of intellectual creations.

Detailed Syllabus (04 Theory Credits):

Unit I: Research Methodology & Problem Formulation (15 Hrs.)

Meaning of Research: Objectives, Motivation in Research, Types of Research (Descriptive vs Analytical, Applied vs Fundamental, Quantitative vs Qualitative, Conceptual vs Empirical).
Research Process: Steps involved in research, Criteria of good research.
Research Problem: Defining and selecting a problem, Necessity of defining a problem, Technique involved in defining a problem.
Literature Review: Importance and purpose, Primary and secondary sources, reviews, monographs, patents, web as a source.
Hypothesis: Meaning, Nature, and Types of hypothesis.

Unit 2: Research Design & Data Collection (15 Hrs.)

Research Design: Meaning, Need, Features of good design, Concepts (Dependent/Independent variables, Extraneous variable, Control).
Sampling Design: Steps in sample design, Criteria for selecting a sampling procedure, Characteristics of good sample design.
Data Collection: Primary vs Secondary data; Methods of data collection (Observation, Interview, Questionnaires, Schedules).
Processing & Analysis: Processing operations (Editing, Coding, Classification, Tabulation); Elements/Types of analysis (Descriptive statistics, Inferential statistics).
Tools for data analysis and visualization (SPSS and R).

Unit 3: Statistical Analysis, Interpretation, & Technical Writing (15 Hrs.)

Statistical Analysis: Measures of Central Tendency, Dispersion; Correlation and Regression; ANOVA; Significance testing (t-test, Chi-square test).
Interpretation: Meaning of interpretation, Techniques, Precautions in interpretation.
Technical Writing: Structure and components of a research report/thesis; Layout (Title, Abstract, Introduction, Review of Literature, Methodology, Results, Discussion, References, Appendices).
Presentation: Oral presentation, Posters; Avoiding plagiarism and ethical issues, Plagiarism detection tools (Turnitin and iThenticate)
Tools for academic writing and citation management (Grammarly, Mendeley, Zotero, and EndNote).

Unit 4: Intellectual Property Rights (IPR) (15 Hrs.)

Introduction to IPR: Concepts, Meaning, and Need for Intellectual Property; Types of IP: Patents, Trademarks, Copyrights, Industrial Designs, Geographical Indications (GI), Trade Secrets.
Patents: Definition, Criteria for patentability (Novelty, Inventive step, Industrial applicability), Process of filing a patent, Provisional and complete specification.
Patent Treaties: Patent Cooperation Treaty (PCT), TRIPS Agreement.
Copyright & Trademarks: Ownership, Rights, Transfer, Infringement.
Patent Search & Filing: Patent databases; Procedure for filing in India (Role of IPO).

Text and Reference Books:

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1. *C. R. Kothari, "Research Methodology –Methods and Techniques", New Age Publications, New Delhi, 2009.*
2. *R. Panneerselvam, "Research Methodology", Prentice-Hall of India, New Delhi, 2004.*
3. *Ranjit Kumar, "Research Methodology: A Step by Step Guide for beginners", 2nd Edition, Pearson Education India, 2005.*
4. *J. P. Mishra, "An Introduction to Intellectual Property Rights", Central Law Publications, 2012.*
5. *Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd, 2007.*
6. *T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008.*

CLO-PLO matrix for the course MEENCRM126 (Research Methodology and IPR)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCRM426.1	2.5	3	1.5	2.5	1.5	2.5	2	2	1	2	2.05
MEENCRM426.2	2.5	3	1.5	2.5	1.5	2.5	2	2	1	2	2.05
MEENCRM426.3	2.5	3	1.5	2.5	1.5	2.5	2	2	1	2	2.05
MEENCRM426.4	1.5	2	3	1.5	2.5	2.5	2	2	1.5	2	2.05
Average PLO	**2.25**	**2.75**	**1.87**	**2.25**	**1.75**	**2.5**	**2**	**2**	**1.12**	**2**	**2.05**

Semester – IV *(Course Work)*

Specialization 1: VLSI and Embedded Systems
Specialization 2: Communication and Signal Processing
MEENCCF426: Communicative French
MEENCCR426: Communicative Russian
MEENCCG426: Communicative German

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
2	0	0	2	15	35	50	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENCCF/R/G426.1	Able to speak, read and write the concerned language at the elementary level.
MEENCCF/R/G426.2	Explore international opportunities in the field of the chosen specialization.

Detailed Syllabus (02 Theory Credits):

Note: End semester examination will be of 35 marks out of which 25 marks will be for written part and 10 marks will be for oral part.

Unit 1: Part-I (written) (20 Hrs.)

Functional grammar based on the textbook
Comprehension of simple texts
Translation of simple passages/simple sentences into English and vice-versa

Unit 2: Part II (Oral) (10 Hrs.)

Listening comprehension
Reading of texts
General questions

Text and Reference Books:

1. *To be prescribed during the course study.*

CLO-PLO matrix for the course MEENCRM126 (Research Methodology and IPR)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCCF/R/G426.1	0.5	0.5	0.5	0.5	1	1	1	1	1.5	2	0.95
MEENCCF/R/G426.2	0.5	0.5	0.5	0.5	1	1	1	1	1.5	2	0.95
Average PLO	**0.5**	**0.5**	**0.5**	**0.5**	**1**	**1**	**1**	**1**	**1.5**	**2**	**0.95**

Semester – IV

MEENPPR426: Project

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
0	0	28	14	105	245	350	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENPPR426.1	Generate potential project ideas using structured brainstorming techniques.
MEENPPR426.2	Define the core problem or opportunity the project will address.
MEENPPR426.3	Formulate a clear and measurable project goal statement.
MEENPPR426.4	Identify key project stakeholders and analyze their interests.
MEENPPR426.5	Develop a project scope statement outlining key deliverables.
MEENPPR426.6	Estimate required resources (time, budget, personnel) for project tasks.
MEENPPR426.7	Create a project schedule with realistic milestones and deadlines.
MEENPPR426.8	Identify potential risks and constraints that could impact project success and propose basic mitigation strategies for identified project risks..
MEENPPR426.9	Assess the initial feasibility of a project plan.
MEENPPR426.10	Assign team roles and responsibilities based on individual strengths.
MEENPPR426.11	Collaborate effectively with team members using project management tools.
MEENPPR426.12	Document project progress and challenges systematically.
MEENPPR426.13	Justify project decisions and plans in a formal presentation.
MEENPPR426.14	Produce a final project report summarizing the process and outcomes.

Detailed Syllabus (16 LAB Credits) (480 Hrs.):

Description

Project and Thesis shall be of six months (Minimum 18 weeks') duration and a student can accumulate 16 credits on successful completion of Project. This is in addition to pre-project work in 3rd semester wherein students shall choose a specific topic/area for their project and undertake its study.

- A thesis committee comprising of the head of the Department, external expert, supervisor and at least two more faculty members will serve thesis and oral examiners for each student pursuing thesis.
- A soft copy of the thesis in .pdf format (in specific style) should be sent to thesis committee, before its final submission. The Thesis committee shall examine it for suitability of publication (including any possible plagiarism) before the thesis goes in print and for binding.
- After the completion of project work, students work shall be evaluated by an external examiner. The End term marks of 245 shall be evaluated for viva-voce, demonstration, and evaluation of thesis/project.

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CLO-PLO matrix for the course MEENPPR126 (Project)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENPPR426.1	2	2	0	3	1	1	1	1	0	2	1.3
MEENPPR426.2	2	2	0	3	2	1	1	1	1	2	1.5
MEENPPR426.3	1.5	2	0	3	2	2	2	1	1	2	1.65
MEENPPR426.4	1	2	0	1	1	1	1	1	1	2	1.1
MEENPPR426.5	1	1	0.5	2	2	1	1	1	1	2	1.25
MEENPPR426.6	0.5	1	1.5	2	1	2	2	2	1	2	1.5
MEENPPR426.7	0.5	0.5	0.5	1	1	2	2	1	0	1	0.95
MEENPPR426.8	0	0.5	0.5	2	1	1	1	1	0	2	0.9
MEENPPR426.9	0	0.5	0	1.5	1	0.5	0.5	1	0	1	0.6
MEENPPR426.10	0	0.5	1	0.5	1	0	0	3	0	2	0.8
MEENPPR426.11	0.5	0.5	0.5	0.5	1	0	0	3	0	2	0.8
MEENPPR426.12	0.5	0.5	1	1.5	1	1.5	1.5	1	0	2	1.05
MEENPPR426.13	0	2.5	3	0.5	1	2	2	1	0	2	1.4
MEENPPR426.14	0	1	3	0.5	3	2	2	2	0	2	1.55
Average PLO	0.68	1.18	0.82	1.57	1.36	1.21	1.21	1.43	0.36	1.86	1.17

Semester – IV

MEENIIN426: Internship

Hours per Week			Credits	Maximum Marks			Examination Hours
Lecture	Tutorial	Practical		Internal	End Term	Total	
0	0	28	14	105	245	350	2 ½ Hours

Course Learning Outcomes (CLOs):

Unit-Wise CLOs	After the completion of this course the students will be able to:
MEENIIN426.1	Apply theoretical knowledge and technical skills to solve authentic workplace problems.
MEENIIN426.2	Complete discipline-specific tasks and projects under professional supervision.
MEENIIN426.3	Demonstrate proficiency with industry-standard tools, software, or equipment.
MEENIIN426.4	Exhibit professional conduct, including punctuality, accountability, and a strong work ethic.
MEENIIN426.5	Communicate effectively and professionally with colleagues, supervisors, and clients.
MEENIIN426.6	Manage time effectively to balance multiple tasks and meet deadlines.
MEENIIN426.7	Adapt to the organizational culture and dynamics of a professional workplace.
MEENIIN426.8	Collaborate productively within a team to achieve departmental goals.
MEENIIN426.9	Build professional relationships and expand their industry network.
MEENIIN426.10	Reflect critically on personal strengths and areas for professional growth.
MEENIIN426.11	Document daily tasks, accomplishments, and key learning experiences.
MEENIIN426.12	Connect practical work experiences back to academic theories and concepts.
MEENIIN426.13	Articulate their contributions to the organization in a final presentation or report.
MEENIIN426.14	Evaluate personal career interests and pathways based on the internship experience.

Detailed Syllabus (16 LAB Credits) (480 Hrs.):

Description

Internship shall be of six months (Minimum 18 weeks') duration and a student can accumulate 16 credits on successful completion of internship.

- Students will be permitted to carry out Internships only at recognized in industry partners or academic institutions of excellence to maintain the program's high standards.
- Internships shall be considered as six months (not less than 18 weeks) of supervised learning carried out at industry or some academic institution of excellence. Students are encouraged to apply for internship in 3rd semester to companies or academic institutions so that its commencement is ensured at the beginning of 4th semester.
- The head of the Department and counsellor will collect a mid-term feedback to ensure smooth progress towards the completion of internship. At the time of completion of the internship, a certificate (satisfactory/unsatisfactory) and marks from concerned person of the organization shall be collected by the head of the Department. An Internship committee comprising of Head of the Department, External Expert, counsellor, and two faculty members of the department shall collect the report from the student and evaluate it. The certificate from the organization where internship was carried will be given due consideration. If the certificate is unsatisfactory then the Internship committee will review the matter and if they agree with the given certificate, the student has to carry on the internship again at same or different place.
- After the completion of internship, students work shall be evaluated by an external examiner. The End term marks of 245 shall be evaluated for viva-voce, demonstration, and evaluation of internship report.

CLO-PLO matrix for the course MEENIIN126 (Internship)

Unit-Wise CLOs	PLOs										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENIIN426.1	3	2	2	1	1	2	2	2	2	1	1.8
MEENIIN426.2	1	1	2	1	2	2	3	3	1	2	1.8
MEENIIN426.3	0.5	1	2	1	3	3	3	3	1	1	1.85
MEENIIN426.4	0	0	0.5	0	0	3	3	3	1.5	3	1.4
MEENIIN426.5	0	0	0	0	1	3	3	3	1.5	3	1.45
MEENIIN426.6	0	0	1	1	1	3	3	3	1	3	1.6
MEENIIN426.7	0	0	0	0	0	3	3	3	1	3	1.3
MEENIIN426.8	0	0	0	0	0	3	3	3	1	3	1.3
MEENIIN426.9	0	0	0	1	0	3	3	3	1	3	1.4
MEENIIN426.10	0	1	1	2	1	2	2	3	1.5	3	1.65
MEENIIN426.11	0	2	1	2	3	2	2	1	2	2	1.7
MEENIIN426.12	0	2	1	2	2	0	2	1	2.5	2	1.45
MEENIIN426.13	0	1	0	2	2	1	2	3	2	2	1.5
MEENIIN426.14	0	0	1	2	2	1	2	3	2	2	1.5
Average PLO	0.32	0.71	0.82	1.07	1.28	2.21	2.57	2.64	1.5	2.36	1.55

CLOs-PLOs Mapping Matrix for all the courses

Unit-Wise CLOs	PLO										Average CLO
	1	2	3	4	5	6	7	8	9	10	
MEENCDA126	2.62	2.5	2.52	2.52	2.62	1.5	1.5	2.5	2.7	2.5	**2.35**
MEENCES126	2.62	2.5	2.52	2.52	2.62	1.5	1.5	2.5	2.7	2.5	**2.35**
MEENCWP126	3	3	1.75	1.75	1	0.75	0.5	0.5	2.5	1	**1.575**
MEENCDS126	3	3	2.75	2.25	2.75	1	1	1.25	3	2	**2.2**
MEENCRF126	3	3	2.75	1.75	2.25	1.25	1.25	2	3.0	1.0	**2.125**
MEENCCE126	1.5	1.5	3	2	3	2	2	3	3	2.5	**2.35**
MEENCSC126	3	3	2.5	3	3	1	1	3	3	1	**2.35**
MEENCFA226	2.62	2.5	2.52	2.52	2.62	1.5	1.5	2.5	2.7	2.5	**2.35**
MEENCIT226	2.62	2.5	2.52	2.52	2.62	1.5	1.5	2.5	2.7	2.5	**2.35**
MEENCEC226	3	3	1.75	1.75	1	0.75	0.5	0.5	2.5	1	**1.575**
MEENCDI226	3	3	2.75	2.25	2.75	2	2	1.25	3	2	**2.4**
MEENCAI226	2.7	2.42	1.92	2.07	2.27	1.85	1.62	1.15	2.5	1.52	**2.00**
MEENCFM226	1.5	1.5	3	2	3	2	2	3	3	2.5	**2.35**
MEENCSC226	3	3	2	3	1.5	0.5	1	2	3	1	**2.15**
MEENDNC326	2.25	2.17	2.73	2.35	2.75	1.83	1.67	2.7	2.8	2.58	**2.38**
MEENDNE326	2.33	2.17	2.62	2.23	2.33	1.83	1.67	2.7	2.3	2.5	**2.27**
MEENDQC326	2.33	2.17	2.5	2.23	2.17	1.83	1.67	2.7	2.5	2.5	**2.26**
MEENDSI326	2.25	2.17	2.73	2.35	2.75	1.83	1.67	2.7	2.8	2.58	**2.38**
MEENDDT326	2.33	2.17	2.62	2.23	2.33	1.83	1.67	2.7	2.3	2.5	**2.27**
MEENDCP326	2.33	2.17	2.5	2.23	2.17	1.83	1.67	2.7	2.5	2.5	**2.26**
MEENDNN326	2.92	2.42	2.3	2.18	2.67	1.4	1.52	1.27	2.63	1.75	**2.1**
MEENDHA326	2.93	2.4	2.13	2.23	2.6	1.18	1.52	1.12	2.5	1.63	**2.02**
MEENDRA326	2.88	2.41	2.25	2.23	2.43	1.5	1.4	1.55	2.62	1.62	**2.09**
MEENDML326	3	3	2.17	2.83	2.83	0.17	0.17	0.83	2.83	1.5	**1.93**
MEENDRF326	3	2.67	2.17	2.17	2	0.83	0.67	0.5	2.67	1.17	**1.78**
MEENDWM326	3	3	2	2.5	2.33	0.83	0.67	0.67	2.5	1.33	**1.88**
MEENDMM326	3	2.67	2.17	2.17	2.5	2.17	2.33	1.83	3	2	**2.38**
MEENDCV326	3	2.83	2.17	2.83	2.67	2.23	2.33	2.33	3	2	**2.53**
MEENDSS326	3	2.83	2.17	2.5	2.5	2.17	2.17	1.83	3	2	**2.42**
MEENDRS326	3	2.67	2.5	2.17	2	0.5	0.33	0.83	2.67	1.17	**1.78**
MEENDRM326	3	3	1.33	2.83	2.83	0.83	0.33	2	3	1	**2.01**
MEENDAE326	3	3	1.67	2.33	2	0.33	0.16	0.83	2.33	1.33	**1.7**
MEENPPP326	1	2	2.5	3	2	2	2	2	1	2.5	**2.1**
MEENIPI326	1	1	1.5	1	1	2	2	2.5	0.5	2	**1.45**
MEENCRM426	2.25	2.75	1.87	2.25	1.75	2.5	2	2	1.12	2	**2.05**
MEENCCF/R/G426	0.5	0.5	0.5	0.5	1	1	1	1	1.5	2	**0.95**
MEENPPR426	0.68	1.18	0.82	1.57	1.36	1.21	1.21	1.43	0.36	1.86	**1.17**
MEENIIN426	0.32	0.71	0.82	1.07	1.28	2.21	2.57	2.64	1.5	2.36	**1.55**
Average PLO	**2.43**	**2.38**	**2.18**	**2.21**	**2.24**	**1.45**	**1.4**	**1.87**	**2.45**	**1.89**	**2.06**