

Revised Course Structure

M. Tech. (Electronics and Communication Engineering)



Department of Electronics and Communication,

Faculty of Science

University of Allahabad, Prayagraj-211002

(Session 2025-26 onwards)

Department of Electronics and Communication
(J. K. Institute of Applied Physics & Technology)

University of Allahabad, Prayagraj

M. Tech. (Electronics and Communication Engineering)

M.Tech.1st Semester (ECE)						
First Semester	Course Code	L-T-P- C	Credits	Theory Papers/ Practical Labs	Sessional Marks	End Semester Marks
Paper-1	MET101	3-0-0-3	3	Advanced Digital Signal Processing	40	60
Paper-2	MET102	3-0-0-3	3	Advanced Digital Communication System	40	60
Paper-3	MET103	3-0-0-3	3	VLSI Technology	40	60
Paper-4	MET104	3-0-0-3	3	Wireless Sensor and Actuator Networks	40	60
Paper – 5	MET105	3-0-0-3	3	Advanced Antenna Theory and Techniques	40	60
Practical Lab	MEP131	0-0-16-8	8	Practical Lab I	40	60

M.Tech.2nd Semester (ECE)						
Second Semester	Course Code	L-T-P- C	Credits	Theory Papers/ Practical Labs	Sessional Marks	End Semester Marks
Paper-1	MET201	3-0-0-3	3	Advanced Fiber Optic Communication	40	60
Paper-2	MET202	3-0-0-3	3	Techniques of Microstrip Patch Antenna and Design	40	60
Paper-3	MET203	3-0-0-3	3	Internet of Things	40	60
Paper-4	MET204	3-0-0-3	3	Embedded Systems and Design	40	60
Paper – 5	MET2##	3-0-0-3	3	Elective I	40	60
Practical Lab	MEP231	0-0-16-8	8	Practical Lab II	40	60

M.Tech.3rdSemester (ECE)						
Paper	Course Code	L-T-P-C	Credits	Internship / Project	Sessional Marks	End Semester Marks
Internship / Project	MEP331	0-0-40-20	20	Internship / Project (Dissertation and Viva)	240	360

NOTE:

1. Tests for sessional marks evaluation will be held in hybrid mode.
2. End semester examination will be held in offline mode only.

M.Tech.4thSemester (ECE)						
Project	Course Code	L-T-P-C	Credits	Internship / Project	Sessional Marks	End Semester Marks
Internship / Project	MEP431	0-0-40-20	20	Internship / Project (Dissertation and Viva)	240	360

NOTE:

1. Tests for sessional marks evaluation will be held in hybrid mode.
2. End semester examination will be held in offline mode only.

List of Electives for M.Tech

##

1. MET251 Photonics Systems and Biophotonics
2. MET252 Introduction to Nano Science and Nanotechnology
3. MET253 Sustainable and Green Electronics
4. MET254 High Speed Devices and Circuits
5. MET255 5G and beyond in wireless communication

M.TECH FIRST SEMESTER

(Electronics and Communication Engineering)

Paper Code: MET101

Paper 1: Advanced Digital Signal Processing

Total Lectures 40

Unit 1-2: Statistical and Signal Processing

Signal Representation-Signal characteristics and their representation, Transform domain representation, Signal digitization Signal detection and classification, Linear multivariate model, Spatio-temporal signals, Non- parametric spectrum estimation, Least-square, Maximum-likelihood and mean-squared estimation, maximum a posteriori estimation, Wiener filtering, State-space Kalman filters steepest-descent method of filtering Cyclostationary signal analysis.

Unit 3: Adaptive Filters

Convergence and robustness issue in the LMS adaptive filters, Recursive least-square adaptive filters, Transform domain adaptive filters Blind equalization.

Unit 4: Signal Reconstruction:

Signal recovery problems, FBP, Series expansion and algebraic methods, EM method, simulated annealing procedure of reconstruction, Iterative restoration algorithm, Blind Deconvolution.

Unit 5: Time frequency and Multirate Signal Processing

Wavelets and filter banks, Properties of wavelets, New generation of wavelets Framelets, Ridgelets, Beamlets, Lifting methods, Lapped transforms, Orthogonal block transforms. Nonlinear Signal Processing: Introduction to chaotic signals and their processing, Nonlinear maps, Statistics of Markov maps, fractal signals, Morphological signals, Higher-order spectral analysis.

References:

1. Advanced Digital Signal Processing and Noise Reduction: Saeed V. Vaseghi (John Wiley)
2. Digital Signal Processing: J.G. Proakis (PHI)
3. The Digital Signal Processing Handbook : V.K. Madisetti & Douglas B. Williams (CRC Press)
4. Intelligent Signal Processing: Symon Haykin & Kart Koski (IEEE Press)
5. Probability and Random processing with application to Signal processing: Stark & Woods (Pearson Ed. Ltd.)
6. An Introduction to Wavelet Analysis: David F. Walnut (Birkhäuser press)

CO1	Understand and represent signals using statistical and transform-domain methods, and apply estimation techniques for signal analysis.
CO2	Design and use linear and state-space filters like Wiener and Kalman filters for noise reduction and signal enhancement.
CO3	Implement adaptive filters, including LMS, RLS, and blind equalization, for dynamic signal processing applications.

CO4	Apply signal reconstruction and restoration techniques to recover signals from noisy or incomplete data.
CO5	Analyze and process signals using advanced time-frequency, multirate, and nonlinear methods such as wavelets, filter banks, and chaotic signal processing.

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	–	–	–	–	1	–	2	3	2	2
CO2	3	3	3	3	3	–	–	–	–	2	–	2	3	3	3
CO3	3	3	3	3	3	–	–	–	–	2	–	3	3	3	3
CO4	3	3	3	3	2	–	–	–	–	2	–	3	3	3	3
CO5	3	3	3	3	3	–	–	–	–	2	–	3	3	3	3

M.TECH FIRST SEMESTER

(Electronics and Communication Engineering)

Paper Code: MET102

Paper 2: Advanced Digital Communication Systems

Total Lectures 40

Unit 1: Introduction

Review of binary signaling schemes, synchronous and asynchronous demodulation, matched filter and cross-correlator receivers, regenerative repeaters, link budget analysis.

Unit 2-3: Modulation and Demodulation in Presence of Additive White Gaussian Noise and ISI

Different representation of narrow band signals and systems, Spectrum of digital modulated signals, Calculation of probability of error for binary & M-ary signals, digital signaling schemes for coherent and non-coherent demodulation. Comparison of different modulation schemes, Symbol synchronization and carrier recovery circuits. Design of band limited channels without ISI, Design of band limited signals for controlled ISI (partial response signals), Optimum demodulator in presence of ISI & AWGN noise.

Unit 4: Decision and Estimation Theory

Binary decisions with single and multiple observations, multiple decisions, fundamentals of estimation, maximum likelihood and Bayes cost method.

Unit 5: Spread Spectrum Modulation

PN sequences-generation & properties, Notion of Spread Spectrum, Direct sequence binary PSK system- BER, processing gain and antijam margin, Slow and fast frequency hopped spread spectrum, Application of Spread Spectrum systems

References:

1. Principles of Communication: Taub & Schilling (TMH)
2. Digital Communication : J.G. Proakis (TMH)
3. Digital Communication : S. Haykin (Wiley)
4. Decision and Estimation Theory: Melsa & Cohn

CO1	Understand binary signaling, demodulation techniques, matched filters, and link budget analysis.
-----	--

CO2	Analyze modulation and demodulation methods in the presence of AWGN and ISI, and design band-limited channels and signals.
CO3	Calculate error probabilities and design symbol synchronization and carrier recovery circuits for digital systems.
CO4	Apply decision and estimation theory for optimal detection and parameter estimation.
CO5	Implement and evaluate spread spectrum systems, including DS-PSK and frequency-hopped techniques, for secure communication.

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	–	–	–	–	1	–	2	3	2	2
CO2	3	3	3	3	3	–	–	–	–	2	–	2	3	3	3
CO3	3	3	3	3	3	–	–	–	–	2	–	3	3	3	3
CO4	3	3	3	3	2	–	–	–	–	2	–	3	3	3	3
CO5	3	3	3	3	3	–	–	–	–	2	–	3	3	3	3

M.TECH FIRST SEMESTER
(Electronics and Communication Engineering)
Paper Code: MET103
Paper 3: VLSI Technology

Total Lectures: 40

Unit 1: Crystal Growth and Wafer Preparation

Introduction to VLSI Technology: Classification of ICs, features of ICs, monolithic and hybrid ICs. Crystal growth and Wafer Preparation: silicon crystal growth from the melt, crystal orientations, various defects in crystal, wafer preparation and wafer specifications.

Unit 2: IC Fabrication Processes

Epitaxy: Epitaxy and its concepts, growth kinetics of epitaxy, vapour phase epitaxy, molecular beam epitaxy. Oxidation: Theory of growth of silicon dioxide layer, calculation of SiO₂ thickness and oxidation kinetics. Lithography- Photolithography and pattern transfer, optical and electron photolithography, X-ray and ion beam lithography. photoresist, types of photoresist. Etching- dry & wet etching. Diffusion Process- Diffusion in solids, diffusion equation and diffusion mechanisms. Ion implantation- Implantation equipments, high energy implantation, scattering phenomenon, range of implanted ions, implantation damage, annealing. Metallization applications, metallization choices, physical vapour deposition, patterning & problems in metallization.

Unit 3: CMOS Technology and Scaling

Introduction to MOS Technology - CMOS fabrication. Basic Electrical Properties - NMOS Inverter, Z_{pu}/Z_{pd} ratio, CMOS Inverter, Regions of Operation. Scaling - Scaling models and factors, scaling factors for various device parameters.

Unit 4: CMOS Logic Structures

Pass Transistor and Transmission Gates, Switching logic, Two/Three input NMOS&CMOS NAND & NOR gates, CMOS logic structures - Pseudo nMOS, dynamic CMOS, clocked CMOS, CMOS domino, NP-domino logic

Unit 5: VLSI Design

Methodologies Design Description domains. System design and methods – CMOS design methods, CMOS design options.

Reference

1. VLSI Technology, Second Edition, MH, 1988: S. M. Sze.
2. CMOS VLSI Design A Circuits and Systems Perspective, 4th Edition, Pearson 2015: Neil H. E. Weste and David Money Harris
3. VLSI Fabrication Principles, Second Edition, Wiley, 1994: S. K. Gandhi.
4. Basic VLSI Design, 3rd Edition, Prentice Hall, 1995: Douglas A. Pucknell and Kamran Eshraghian.

CO1	Understand IC classification, crystal growth, and wafer preparation processes.
CO2	Analyze and apply IC fabrication techniques including epitaxy, oxidation, lithography, etching, diffusion, ion implantation, and metallization
CO3	Understand CMOS technology, MOS device characteristics, and scaling principles.
CO4	Design and implement CMOS logic structures, including pass transistor, transmission gates, dynamic and domino logic.
CO5	Apply VLSI design methodologies for system-level and CMOS-based circuit design.

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	—	—	—	—	1	—	2	3	2	2
CO2	3	3	3	3	3	—	—	—	—	2	—	2	3	3	3
CO3	3	3	3	3	3	—	—	—	—	2	—	3	3	3	3
CO4	3	3	3	3	3	—	—	—	—	2	—	3	3	3	3
CO5	3	3	3	3	3	—	—	—	—	2	—	3	3	3	3

M.TECH FIRST SEMESTER

(Electronics and Communication Engineering)

Paper Code: MET104

Paper 4: Wireless Sensor and Actuator Networks

Total Lectures 40

Unit 1: Introduction

Evolution of Computing Devices, Network of Computing Devices, wired versus Wireless Networks, Infrastructure versus Ad Hoc Networks, OSI reference model, Sensing and Sensors, smart Sensors Basics, Actuator Control technique

Unit 2:

Introduction Sensing with computing and communication capabilities, wireless sensors networks (WSN), sensor mote platforms, WSN architecture and protocol stack, factors influencing WSN design Wireless sensors and actuator networks (WSAN), main features of WSANs, Applications of WSANs, Military application, Environmental monitoring Health care, MOOD-Based services, positioning and animal tracking, entertainment, logistics, transportation, homes and office industrial applications.

Unit 3:

Anatomy of a sensor node, energy consumption, practical issues of WSANs, Related to energy management, sleep and active state modeling, physical layer, wireless channel effects, Zigbee Technology: IEEE 802.15.4, 6LoWPAN

Unit 4:

Medium Access Control (MAC), challenges of MAC, CSMA Mechanisms, contention based MAC, Reservation based MAAC, Hybrid MAC.

Unit 5:

Routing Protocols for WSN, Background, Data Dissemination and Gathering, routing, Challenges and Design Issues in wireless sensor networks, data centric and flat-Architecture Protocols, Hierarchical protocols, Geographical Routing Protocols, QoS-based protocols

References:

1. Handbok of Modern sensors by Jacob Fraden, Springer
2. Understanding Smart sensor by Randy Frank, Artech House
3. Networking Wireless sensors by BhaskarKrishnamchari, Cambridge
4. Wireless Sensor and Actuator Networks: Technologies, Analysis and Design by R. Verdone, D. Dardari, G. Mazzini, A. Conti- Academic Press Publication.
5. Wireless Sensor Networks: Signal processing and communication perspectives edited by A. Swami, Q. Zhao, Y.W. Hang, L. Tang- Wiley Publication.

CO1	Understand computing and sensor devices, network types, and basic sensing and actuator control techniques.
CO2	Analyze WSN architecture, protocol stack, sensor platforms, and applications in various domains.
CO3	Examine sensor node design, energy consumption, and physical layer protocols including Zigbee and 6LoWPAN
CO4	Understand and apply MAC protocols including contention-based, reservation-based, and hybrid mechanisms.
CO5	Analyze routing protocols, data dissemination, hierarchical and geographical routing, and QoS-based strategies for WSN.

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	—	—	—	—	1	—	2	3	2	2
CO2	3	3	3	3	3	—	—	—	—	2	—	2	3	3	3
CO3	3	3	3	3	3	—	—	—	—	2	—	3	3	3	3
CO4	3	3	3	3	3	—	—	—	—	2	—	3	3	3	3
CO5	3	3	3	3	3	—	—	—	—	2	—	3	3	3	3

M.TECH FIRST SEMESTER

(Electronics and Communication Engineering)

Paper Code: MET105

Paper 5: Advanced Antenna Theory and Techniques

Total Lectures 40

Unit 1: Wire Antennae

Review of antenna basics, Vector Potentials and their applications in field calculation, radiation characteristics of Loop antenna and Helical antenna and their applications.

Unit 2: Aperture type Antennas

Babinet's Principle and complementary antennas, Radiation characteristics Slot and Horn Antennas and their applications, Design of pyramidal and conical horns.

Unit 3: Reflectors and lens Antenna

Study of different types of reflectors, Focussing characteristics, Analysis and design of a Parabolic reflector antenna, Feeding techniques of Parabolic reflector, Cassegrain and Gregorian antenna, Dielectric lens antenna, E-plane and H-plane metal lenses, Luneburg lens antenna.

Unit 4: Microstrip Antenna

Introduction, radiation mechanism and special features of microstrip patch antenna, Advantages and limitations, Application, Feeding techniques- Contactual&non-contactual, Overview and comparison of analytical models for microstrip patch antenna, Analysis and Design of rectangular microstrip patch antenna, Bandwidth enhancement techniques, Comparison of slot antenna with microstrip antenna, Different types of substrate materials used for design of microstrip antenna

Unit 5: Antenna for Special Applications

Ground plane Antenna, Sleeve Antenna, Turnstile Antenna, Superturnstile antenna, Antenna design consideration for satellite communication.

References:

1. Antennas and Wave Propagation: John D Kraus[et.al] [TMH]

2. Antenna Theory: Analysis and Design: C.A. Balanis [John Wiley & Sons]
3. Antennas for All Applications: J.D. Kraus & R.J. Marhefka [McGraw Hill Inc]
4. Microstrip Antenna Design Hand Book: R. Garg, Prakash Bhatia, Inder Bahl [Artech House Publisher]
5. Broadband planar Antennas: Design and Applications Z.N. Chen & MYW Chia [John Wiley & Sons]
6. Microstrip Patch Antenna: Kai Fong Lee & Kwai Man Luk [Imperial College Press]
7. Wideband CDMA for “Third Generation Mobile Communication”: Ojanpera T. & R. Prasad [Artech House]

CO1	Understand antenna fundamentals and analyze loop and helical antenna radiation characteristics.
CO2	Analyze aperture-type antennas including slot and horn antennas and design pyramidal and conical horns..
CO3	Examine sensor node design, energy consumption, and physical layer protocols including Zigbee and 6LoWPAN
CO4	Understand and design microstrip patch antennas, including feeding techniques, models, and bandwidth enhancement..
CO5	Analyze and design antennas for special applications such as ground plane, sleeve, turnstile, and satellite communication.

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	–	–	–	–	1	–	2	3	2	2
CO2	3	3	3	3	3	–	–	–	–	2	–	2	3	3	3
CO3	3	3	3	3	3	–	–	–	–	2	–	3	3	3	3
CO4	3	3	3	3	3	–	–	–	–	2	–	3	3	3	3
CO5	3	3	3	3	3	–	–	–							

M.TECH SECOND SEMESTER
(Electronics and Communication Engineering)
Paper Code: MET201
Paper 1: Photonics Systems and Biophotonics

Total Lectures 40

Unit 1: Semiconductor Photon Sources

Introductions to photonics, Interactions of Photons with Charge Carriers, Light emitting diodes (Surface and Edge emitting), Laser physics (stimulated emission, atomic rate equations, laser pumping and population inversion), Theory of laser oscillations, Characteristics of the Laser Output, Tunable laser source and Pulsed laser, Propagation of optical signal through different types of fibers; different types of attenuation and dispersions, receiver operations and SNR.

Unit 2: Semiconductor Photon Detectors

Photodetectors, Photoconductors, Photodiodes, Avalanche Photodiodes, Array Detectors, Noise in Photodetectors, Receiver structures, the performance of receivers, Power budget and rise time budget equations. Splice and joint losses, misalignment losses.

Unit 3: Electro-optics and Fiber Nonlinearities

Principles of Electro Optics, Electro-Optics of Anisotropic Media, Photo refractivity, Electro absorption, Generation and distribution of tunable millimeter-wave signal using external modulator, Different types of non-linear effects: self-phase modulation, four-photon mixing and solitons.

Unit 4: Biophotonics

Overview of Biophotonics, Biophotonics Spectral Windows, Light Absorption, Structures of Biological Cells and Tissues, Lightwave-Molecular Dipole Interaction, Optical Fibers for Biophotonics Applications

Unit 5: Light-Tissue Interactions and Biosensors

Reflection and Refraction Applications (Refraction in Ophthalmology, Specular Reflection, Diffuse Reflection), Absorption (Absorption Characteristics, Absorption in Biological Tissues), Scattering (Elastic Scattering, Rayleigh Scattering, Raman Scattering), Scattering and Absorption, Light Tissue Interaction Mechanism

(Photobiomodulation, Photochemical Interaction, Thermal Interaction, Photoablation, Photodisruption), Optical Fiber Probe Configurations, Optical Fiber Tip Geometries, Optical Sensors (Biorecognition Optical Fiber Sensors and Microbending Fiber Sensors)

References:

1. Optical Fiber Communication: Gerd Keiser
2. Biophotonics: Concepts to Applications: Gerd Keiser
3. Optical Fiber Communication: John M. Senior
4. Optical Fiber Telecommunication IIIB: Ivon P Kaminow & Kock
5. Fundamentals of Fiber Optics in Telecommunication and Sensors Systems: B P Pal
6. Fiber Optic Sensor: Principles and Applications: B.D. Gupta

CO1	Explain the principles of semiconductor photon sources, including LEDs and lasers; analyze laser physics concepts such as stimulated emission, population inversion, laser oscillation theory, and characteristics of laser output; evaluate optical signal propagation, attenuation, and dispersion in different types of optical fibers
CO2	Describe the operation and characteristics of semiconductor photon detectors, including photoconductors, photodiodes, avalanche photodiodes, and array detectors; analyze receiver structures, noise, power budget, and rise time budget; assess losses due to splices, joints, and misalignment for optical communication systems.
CO3	Illustrate the principles of electro-optics and nonlinear fiber effects; explain electro-optic phenomena in anisotropic media, photorefractivity, electro-absorption, and tunable millimeter-wave signal generation; analyze fiber nonlinearities such as self-phase modulation, four-wave mixing, and solitons.
CO4	Explain fundamental concepts of biophotonics, including light-tissue interactions, spectral windows, and molecular dipole interactions; analyze the structure of biological cells and tissues and the role of optical fibers in biophotonics applications
CO5	Analyze light-tissue interactions including reflection, refraction, absorption, and scattering mechanisms; evaluate optical fiber probe configurations and fiber tip geometries; design and apply optical biosensors, including biorecognition and microbending fiber sensors, for biomedical and sensing applications.

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	–	–	–	–	1	–	2	3	3	2
CO2	3	3	2	3	3	–	–	–	–	1	–	2	3	3	3
CO3	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3
CO4	3	3	2	2	2	–	–	–	–	1	–	2	3	3	3
CO5	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3

M.TECH SECOND SEMESTER
(Electronics and Communication Engineering)
Paper Code: MET202
Paper 2: Techniques of Microstrip Patch Antenna & Design
Total Lectures 40

Unit 1

Microstrip Antenna Design Consideration and characteristics, Patch Parameters, Substrate selection Directivity, Gain, Radiation efficiency, Polarization, Losses and Quality Factor, Bandwidth, Effect of Dielectric cover, Feeding Techniques, Feed Point Location and Finite size Ground Plane.

Unit 2

Microstrip Analytical Models: Transmission line Models, Cavity model, Multiport network model, Basic characteristics of some common Patches: Rectangular Patch, Circular Patch, Semi Circular and Circular sector, Equiangular Patch and annular ring Patch.

Unit 3:

Overview of Broadbanding and Dual banding techniques of microstrip Antenna and their Comparative studies.

Unit 4:

Microstrip Slot antenna: Introduction, Equivalent circuit, Determination of network quantities, Inclined slot, Radiation pattern, CPW- Fed slot antennas, Annular slot and Tapered slot and comparison of slot antennas with Microstrip antennas.

Unit 5:

Loaded Microstrip antennas and applications: Polarization diversity using Microstrip antennas, Frequency agile Microstrip antennas, Varactor-tuned Microstrip antennas, Optical Tuning of patch antennas and Planar Inverted- F antennas.

References:

1. Antennas and Wave Propagation: John D Kraus[et.al] [TMH]
2. Antenna Theory: Analysis and Design: C.A. Balanis [John Wiley & Sons]
3. Antennas for All Applications: J.D. Kraus & R.J. Marhefka [McGraw Hill Inc]
4. Microstrip Antenna Design Hand Book: R. Garg, Prakash Bhatia, Inder Bahl [Artech House Publisher]

5. Broadband planner Antennas: Design and Applications Z.N. Chen & MYW Chia [John Wiley & Sons]
6. Microstrip Patch Antenna: Kai Fong Lee & Kwai Man Luk [Imperial College Press]
7. Wideband CDMA for “Third Generation Mobile Communication”: Ojanpera T. & R. Prasad [Artech House]

CO1	Explain fundamental design considerations and characteristics of microstrip antennas, including patch parameters, substrate, gain, bandwidth, polarization, and feeding techniques.
CO2	Analyze microstrip antennas using transmission line, cavity, and multiport network models; evaluate characteristics of common patch types.
CO3	Illustrate broadbanding and dual-band techniques; compare their performance for practical applications.
CO4	Explain principles, equivalent circuits, and radiation characteristics of microstrip slot antennas; compare with patch antennas.
CO5	Analyze and design advanced microstrip configurations, including loaded antennas, polarization diversity, frequency-agile, varactor-tuned, optical-tuned, and planar inverted-F antennas.

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	–	–	–	–	1	–	2	3	3	2
CO2	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3
CO3	3	3	2	3	3	–	–	–	–	1	–	2	3	3	3
CO4	3	3	2	3	3	–	–	–	–	1	–	2	3	3	3
CO5	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3

M.TECH SECOND SEMESTER
(Electronics and Communication Engineering)
Paper Code: MET203
Paper 3:Internet of Things

Total Lectures 40

Unit 1: INTRODUCTION TO THE INTERNET OF THINGS

Introduction, History of IoT, About objects/things in the IoT, The identifier in the IoT, Enabling technologies of IoT, About the Internet in IoT.

Unit 2: RADIO FREQUENCY IDENTIFICATION TECHNOLOGY (RFID)

Introduction, Principle of RFID, RFID reader, RFID tag, RFID middleware, RFID applications, Logistics and supply chain, Production, Monitoring and Maintenance, Product Safety, Quality and Information, Access Control and Tracking and Tracing of Individuals, Loyalty, Membership and Payment, Household, Other Applications.

Unit 3:RFID DEPLOYMENT FOR LOCATION AND MOBILITY MANAGEMENT

Introduction, Background and related work, Localization and handover management relying on RFID, Conceptual Framework, Technology considerations, Path loss model, Antenna radiation pattern, Multiple tag-to-reader collisions, Multiple readers-to-tag collisions, Reader-to-reader interference, Interference from specific materials, Performance evaluation.

Unit 4: Power Line Communication Technology (PLC)

Introduction, Overview of existing PLC technologies and standards, History of PLC technologies, Different types of in-home PLC technologies, Security, Performances of PLC technologies, Standards and normalization, Architectures for home network applications, Architecture for a high bit-rate home network application, Architecture for low bit-rate home network application, Internet of things using PLC technology, Connecting objects in the indoor environment, Interoperability of connecting objects in the home environment

Unit 5: INTERNET OF THINGS –STANDARDS AND GOVERNANCE

Introduction, Standardizing the IoT, Exploiting the potential of RFID, Identification in the IoT, Promoting ubiquitous networking: anywhere, any when, any what, Safeguarding data and consumer privacy, Bodies subject to governing principles, Substantive principles for IoT governance, IoT infrastructure governance, Further governance issues.

References:

1. The Internet of Things: Connecting Objects to the Web: Hakima Chaouchi - Wiley.
2. RFID Handbook: Klaus Finkenzeller, Wiley.
3. Architecting the Internet of Things: Dieter Uckelmann, Mark Harrison; Florian Michahelles - (Eds.) – Springer 2011.
4. Networks, Crowds, and Markets: Reasoning About a Highly Connected World - David Easley and Jon Kleinberg, Cambridge University Press – 2010.
5. The Internet of Things: Applications to the Smart Grid and Building Automation by - Olivier Hersent, - Wiley -2012.
6. The Internet of Things-Key applications and Protocols: Olivier Hersent, David Boswarthick, Omar Elloumi, Wiley, 2012

CO1	Explain fundamentals of IoT, including history, enabling technologies, identifiers, and the role of the Internet.
CO2	Describe principles, components, and applications of RFID technology in IoT systems.
CO3	Evaluate RFID deployment for location and mobility management; analyze localization, handover, path loss, and interference issues.
CO4	Explain Power Line Communication (PLC) technology; analyze architectures, performance, interoperability, and security for IoT applications.
CO5	Discuss IoT standards, governance, and data privacy; evaluate infrastructure management, ubiquitous networking, and responsible IoT deployment.

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	–	–	–	–	1	–	2	3	3	2
CO2	3	3	2	2	2	–	–	–	–	1	–	2	3	3	3
CO3	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3
CO4	3	3	2	3	3	–	–	–	–	1	–	2	3	3	3
CO5	3	3	2	3	3	–	–	–	–	1	–	2	3	3	3

M.TECH SECOND SEMESTER
(Electronics and Communication Engineering)

Paper Code: MET204

Paper 4: Embedded System and Design

Total Lectures 40

Unit 1: Introduction to Embedded Systems:

Embedded System Overview, Common Design metrics, General Purpose Processors and Application Specific Processors. Software and hardware combination for making an Embedded System. Concept of various types of memories for implementation of Embedded Systems.

Unit 2: Selection Criteria of Hardware for Embedded System Design

Comparing use of Microprocessor and Microcontroller, PLDs and FPGA for developing an Embedded System. Elementary idea of commonly used microcontroller. Criteria for selection of microcontroller and other interfacing hardware. Architectural block diagram of MCS 51 microcontroller family. Memory organization. Code Memory, Data memory and special function register. Internal circuit and capabilities of various I/O ports pins.

Unit 3: Working of microcontrollers

Clock cycles, Machine cycle and Instruction cycles and timing diagrams for various essential control signals. Division of Machine cycles in to states and phases. Instruction length and execution time for instructions. Categorization of instruction and various addressing modes. Conditional and unconditional jump instructions. Boolean instructions. Read pin and read latch instructions. SFRs and their purpose. Control of interrupts. Timers, Power status and I/O functions by SFR's. Addressing of SFR's. Various modes of Timers and their controls.

Unit 4: Interfacing

Block diagram for Input Output Ports internal Structures and their capabilities for 89C51 and 89C2015 Microcontrollers. Interfacing with external devices. Address for ports and pins. Interfacing with external hardware keys and displays devices. Circuits and criteria for interfacing LEDs, Seven segment display.

Unit 5: Programming

Instruction format for instruction of MCS-51 family microcontrollers. Program and Machine control. Boolean variable manipulation. Data transfer. Arithmetic and Logic Operations. Interrupts and data polling for multiple subroutines in a program. Look up tables and use of data stored in code memory.

References:

1. The 8051 Microcontroller and Embedded Systems: Mazidi and Mazidi
2. Solid State circuit design with Microcontrollers: C. K. Dwivedi.
3. The 8051 microcontroller Architecture, Programming and Applications: Ayala Kenneth:
4. Embedded Systems- Architecture, Programming and Design: Raj Kamal
5. Microcontrollers: Raj Kamal

CO1	Explain fundamentals of embedded systems, processor types, hardware-software combination, and memory usage.
CO2	Evaluate hardware selection criteria, microcontroller architectures, memory organization, and interfacing capabilities (MCS-51 family).
CO3	Explain microcontroller operation: clock/machine cycles, instruction execution, addressing modes, SFRs, timers, interrupts, and I/O functions.
CO4	Analyze interfacing techniques for embedded systems: I/O ports, addressing, and interfacing with LEDs, displays, and other peripherals.
CO5	Develop embedded programs: instruction execution, data transfer, arithmetic/logic operations, Boolean manipulation, interrupts, and look-up table usage

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	–	–	–	–	1	–	2	3	3	2
CO2	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3
CO3	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3
CO4	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3
CO5	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3

M.TECH SECOND SEMESTER

(Electronics and Communication Engineering)

Paper Code: MET251

Paper 5: Introduction to Nano Science and Nanotechnology (Elective 1-A)

Total Lectures 40

UNIT 1: Introduction to material and quantum mechanics

Band Theory of Solids, Band theory of Semiconductors, Statistical Mechanics – Fundamental Concepts of Classical Statics (Maxwell-Boltzmann) and Quantum Statistics (Bose-Einstein, Fermi-Dirac statistics), Concept of Fermi level, Basics of Quantum Mechanics, Schrödinger wave equation and its applications.

UNIT 2: Change in material property at Nano scale

Introduction to 0D; 1D; 2D; 3D material, Quantum confinement and Quantum mechanical tunnelling process, Defects in nanomaterials, Properties of Nanomaterial: physical, chemical, mechanical, magnetic, electronic, and optical properties at Nano scale.

UNIT 3: Nano materials and their application in semiconductor devices

Engineering of Nano materials, Basic Types of Nanostructures- Fundamental concepts of semiconductor hetero-junction (Super Lattices and Quantum Wells), Carbon Nanotubes, Nanowires, and Quantum Dots, 2-D metal-oxide material, MXene, Compound Semiconductors, Application of nanomaterials in electronic and optoelectronic devices

UNIT 4: Fabrication methods for nanomaterials

Top-down processes- Ball milling, Optical lithography, E-Beam lithography, Micro machining, Laser Ablation, Bottom-up processes- Physical vapour deposition, Chemical vapour deposition, Self-assembly, Molecular beam epitaxy, Hydrothermal, Auto combustion, Wet chemical, Solvothermal synthesis

UNIT 5: Characterization Techniques

Classification of characterization methods, Principles of Electron Microscopy - Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM), Principle of probe microscopy – Scanning Tunnelling Microscopy (STM) & Atomic Force Microscopy (AFM), Principle and operation of UV-vis-NIR Spectroscopy and photoluminescence spectroscopy, X-RAY Diffraction, Photoluminescence (PL).

References:

1. B.S. Murty, P. Shankar, Baldev Raj, B BRath, James Murday, Textbook of Nanoscience and Nanotechnology, 2013, 1st edition, Springer-Verla Berlin, Heidelberg
2. Arthur Besier, S. RaiChoudhury, ShobhitMahajan, Concepts of Modern Physics, Arthur Beiser, 2015, 7th edition, Mcgraw Hill Education, India
3. T. Pradeep, A Textbook of Nanoscience and Nanotechnology, 2012, 2nd edition, Tata McGraw-Hill Education, New Delhi
4. Narendra Kumar, SunitaKumbhat, Essentials in Nanoscience and Nanotechnology, 2016, 1st edition, John Wiley & Sons, Inc, New Jersey

CO1	Explain fundamentals of material science, band theory, quantum mechanics, and statistical mechanics; apply Schrödinger equation concepts
CO2	Analyze changes in material properties at nanoscale, including quantum confinement, tunneling, defects, and physical/chemical/mechanical/magnetic/electronic/optical properties.
CO3	Describe nanomaterials and their applications in semiconductor and optoelectronic devices, including CNTs, nanowires, quantum dots, 2D metal-oxides, MXenes, and quantum wells.
CO4	Explain fabrication methods for nanomaterials: top-down (ball milling, lithography, laser ablation) and bottom-up (PVD, CVD, self-assembly, MBE, hydrothermal, solvothermal)..
CO5	Apply characterization techniques (SEM, TEM, STM, AFM, UV-Vis-NIR, photoluminescence, XRD) to analyze structural, optical, and electronic properties of nanomaterials

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	—	—	—	—	1	—	2	3	3	2
CO2	3	3	3	3	3	—	—	—	—	1	—	2	3	3	3
CO3	3	3	3	3	3	—	—	—	—	1	—	2	3	3	3
CO4	3	3	3	3	3	—	—	—	—	1	—	2	3	3	3
CO5	3	3	3	3	3	—	—	—	—	1	—	2	3	3	3

M.TECH SECOND SEMESTER
(Electronics and Communication Engineering)
Paper Code: MET252
Paper 5: High Speed Devices and Circuits (Elective 1-B)
Total Lectures 40

Unit 1:

Introduction to Basic Concepts, Requirements of HighSpeed Devices, Circuits & Materials Semiconductors, Ternary Compound Semiconductor and their Application, Crystal Structures in GaAs, Dopants and impurities in GaAs and InP

Unit 2:

Brief Overview of GaAs Technology for High Speed, GaAs and InP Devices for Microelectronics, Ohmic Contacts on Semiconductors, Fermi Level Pinning & Schottky Barrier Diodes

Unit 3:

Metal Semiconductor contacts for MESFET, MESFET Operation & I-V Characteristics

Unit 4:

Hetero Junctions & HEMT, HEMT I-V Characteristics and Transconductance, SiGe Technology, SiGe HBT

Unit 5:

Introduction to Nanoscale MOSFETs, Scaling theory, SOI Technology and Process flow, Fully Depleted and Partially Depleted SOI MOSFETs

References:

1. High Speed Semiconductor Devices: S.M. Sze, Wiley
2. GaAs Devices and Circuits: Michael Shur, Plenum Press
3. Gallium Arsenide High Speed Devices: Physics Technology and Circuit Applications: C.Y. Chang and F. Kat, Wiley
4. High Speed Semiconductor Devices: Circuit Aspects and Fundamental Behavior: H. Beneking, Chapman and Hall, LONDON

CO1	Explain fundamentals of high-speed devices, circuits, and materials including GaAs and InP, ternary compounds, crystal structures, and dopants/impurities.
-----	--

CO2	Analyze GaAs and InP technologies, Ohmic contacts, Fermi level pinning, and Schottky barrier diodes for high-speed applications.
CO3	Describe MESFET devices, metal-semiconductor contacts, operation, I–V characteristics, and high-speed performance parameters.
CO4	Explain heterojunction and SiGe-based devices, HEMTs, HEMT I–V characteristics, transconductance, and SiGe HBTs.
CO5	Understand nanoscale MOSFETs, scaling theory, SOI technology, fully/partially depleted MOSFETs, and process flow for high-speed ICs.

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	–	–	–	–	1	–	2	3	3	2
CO2	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3
CO3	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3
CO4	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3
CO5	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3

M.TECH SECOND SEMESTER
(Electronics and Communication Engineering)
Paper Code: MET253
Paper 5:Introduction to MEMS (Elective 1-C)

Total Lectures 40

UNIT 1:Introduction to Micro-fabrication

Review of Photolithography, Thin Film Deposition, Thermal Oxidation of Silicon, Wet Etching, Silicon Anisotropic Etching, Plasma Etching and Reactive Ion Etching, Doping, Wafer Dicing, Wafer Bonding, Packaging and Integration, Surface Micromachining.

UNIT 2:Electrical and Mechanical Concepts

Conductivity of Semiconductor, Crystal Planes and Orientations, Stress and Strain, Flexural Beam Bending Analysis Under Simple Loading Conditions, Intrinsic Stress, Dynamic System, Resonant Frequency, and Quality Factor,

UNIT 3:Electrostatic and Thermal Sensing and Actuation

Parallel-Plate Capacitor, Applications of Parallel-Plate Capacitors (Inertia Sensor, Pressure Sensor, Flow Sensor, Tactile Sensor, Parallel-Plate Actuators), Interdigitated Finger Capacitors, Applications of Comb-Drive Device (Inertia Sensors, Actuators), Thermal Sensors and Actuators, Fundamentals of Thermal Transfer, Sensors and Actuators Based on Thermal Expansion, Thermocouple and Thermal resistors, Applications (Inertia Sensors, Flow sensors, Infrared sensors)

UNIT 4:Piezoresistive Sensors and Piezoelectric Sensing and Actuation

Expression of Piezoresistivity, Piezoresistive Sensor Material (Single Crystal Silicon, Polycrystalline Silicon), Stress Analysis of Mechanical Elements, Applications of Piezoresistive Sensors (Inertia Sensor, Pressure Sensor, Flow Sensor, Tactile Sensor); Mathematical Description of Piezoelectric Effects, Properties of Piezoelectric Materials, Applications (Inertia Sensor, Acoustic, Flow Sensor, Tactile Sensor)

UNIT 5:Polymer MEMS, Microfluidics and Case Studies

Polymers in MEMS, Applications of polymers, Fluid Mechanics Concepts, Microfluidic channels and valves, Case studies (Capacitive accelerometer, Piezoelectric Gyroscope, DNA amplification, Microbridge gas sensor)

References:

1. MICROSYSTEM DESIGN: S D Senturia, Kluwer Academic Publishers,
2. The MEMS Handbook: Mohamed Gad-el-Hak, CRC press,
3. Bio-MEMS Technologies and Applications: Wanjun Wang, Steven A. Soper, CRC press.
4. Foundations of MEMS: Chang Liu, Prentice Hall.
5. VLSI Technology”, McGraw Hill: S.M.Sze

CO1	Explain fundamentals of microfabrication processes including photolithography, thin-film deposition, etching, doping, wafer bonding, packaging, and surface micromachining.
CO2	Analyze electrical and mechanical concepts in MEMS including conductivity, crystal orientation, stress/strain, beam bending, dynamic systems, resonant frequency, and quality factor..
CO3	Explain electrostatic and thermal sensing and actuation mechanisms and their applications in MEMS devices like sensors and actuators.
CO4	Describe piezoresistive and piezoelectric sensing/actuation principles, material properties, stress analysis, and applications in various MEMS sensors.
CO5	Understand polymer MEMS, microfluidics, and practical case studies including MEMS accelerometers, gyroscopes, DNA amplification, and microfluidic devices.

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	—	—	—	—	1	—	2	3	3	2
CO2	3	3	3	3	3	—	—	—	—	1	—	2	3	3	3
CO3	3	3	3	3	3	—	—	—	—	1	—	2	3	3	3
CO4	3	3	3	3	3	—	—	—	—	1	—	2	3	3	3
CO5	3	3	3	3	3	—	—	—	—	1	—	2	3	3	3

M.TECH SECOND SEMESTER

(Electronics and Communication Engineering)

Paper Code: MET254

Paper 5:Sustainable and Green Electronics(Elective 1-D)

Total Lectures 40

UNIT 1:Introduction to Sustainable and Green Electronics

Definition and Significance of Sustainability in Electronics, Environmental Impacts of Electronics Over the Product Lifecycle, Theoretical Models of Lifecycle Assessment (LCA) in Electronics, Current Policies, Standards, and Regulations (RoHS, WEEE, REACH) with a Focus on Case Studies, Sustainable Development Goals (SDGs) Related to Electronics.

UNIT 2:Materials and Components for Green Electronics

Eco-Friendly Materials, Including Biopolymers and Organic Semiconductors, Nanotechnology in Green Electronics (e.g., Nanomaterials for Energy Storage), Recycling Methodologies and Life-Extension Technologies, Comparative Analysis of Sustainable Materials versus Traditional Materials.

UNIT 3:Energy Optimization and Power Management in Green Electronics

Low-Power and Ultra-Low-Power Electronics, Energy Harvesting and Integration of Renewable Energy Sources (e.g., Solar Cells), Power Management in IoT and Smart Electronics for Sustainability, Optimization Algorithms and AI Applications in Energy-Efficient Design

UNIT 4:Sustainable Manufacturing and Production Technologies

Green Manufacturing Processes: Additive Manufacturing, 3D Printing, Lean Manufacturing, Six Sigma, and Industry 4.0 Principles in Sustainable Production, Circular Economy and its Applications in the Electronics Industry, Environmental Impact Assessment of Production Methodologies

UNIT 5:E-Waste Management and Circular Economy in Electronics

Circular Economy Principles and Applications in Electronics, Design for Disassembly and Modular Electronics, Extended Producer Responsibility (EPR) in E-Waste Management, Emerging Technologies for Recycling the E-Waste.

References:

1. Green electronics manufacturing: creating environmental sensible products: Wang,

- John X. CRC Press, 2012.
2. Green materials for electronics: Irimia-Vladu, Mihai, Eric D. Glowacki, Niyazi S. Sariciftci, and Siegfried Bauer, eds., John Wiley & Sons, 2017.
 3. Sustainable Strategies in Organic Electronics: Marrocchi, Assunta, ed., Woodhead Publishing, 2022.
 4. Emerging green technologies: Sadiku, Matthew NO, CRC Press, 2020.

CO1	Explain sustainability fundamentals, environmental impacts, lifecycle assessment, policies, and SDGs in electronics.
CO2	Analyze materials and components for green electronics, including biopolymers, organic semiconductors, nanomaterials, recycling, and life-extension methods
CO3	Apply energy optimization and power management strategies, including low-power design, energy harvesting, renewable integration, and AI-based optimization..
CO4	Explain sustainable manufacturing and production technologies, including additive manufacturing, 3D printing, lean manufacturing, Six Sigma, Industry 4.0, circular economy, and environmental impact assessment.
CO5	Understand E-waste management and circular economy in electronics, including design for disassembly, modular electronics, EPR, and emerging recycling technologies

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	–	–	–	–	1	–	2	3	2	2
CO2	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3
CO3	3	3	3	3	3	–	–	–	–	2	–	2	3	3	3
CO4	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3
CO5	3	3	3	3	3	–	–	–	–	2	–	2	3	3	3

M.TECH SECOND SEMESTER

(Electronics and Communication Engineering)

Paper Code: MET255

Paper 5:5G and Beyond in Wireless Communication (Elective 1-E)

Total Lectures 40

UNIT 1: Basic of Different Generations in Wireless Communication

Primary development of wireless Communication, 1st generation, 2nd generation, 3rd generation, 4 th generation, and 5th generation of wireless communication, Device-to-Device Communication, Machine to Machine Communications (beyond 5G).

UNIT 2: Materials and Components for Green Electronics

Non-orthogonal NOMA: Modelling of NOMA system, Channel model, Evaluation of Ergodic Rate, Outage Performance and Throughput in a single and multi-hop communication, MIMO, Millimeter Wave Communications for 5G Networks, Advantage of 5G over previous generation.

UNIT 3: Beyond 5G

Integrated Sensing and Communication (ISAC): Modelling and outage performance. Reconfigurable Intelligent Surface (RIS) and outage performance, NOMA and RIS Based Communication, Wireless communication in Internet of Things (IoT) system.

UNIT 4: Fundamental of 6G

Rate-splitting multiple access (RSMA). Terahertz Communication System, Visible Light Communication (VLC). Performance in RSMA, Terahertz Communication and VLC.

UNIT 5:Physical Layer Security in Wireless Communication

Physical Layer Security (PLS) in 5G and Beyond Wireless Communication: PLS in NOMA, ISAC, RIS and IoT Based Communication.

References:

1. 5G and Beyond Wireless Communication Networks, Wiley-IEEE Press: Haijian Sun, Rose Qingyang Hu, Yi Qian.
2. Key Technologies for 5G Wireless Systems, Cambridge University Press: Vincent W. S. Wong, Robert Schober, Derrick Wing Kwan Ng, Li-Chun Wang.

CO1	Explain the evolution of wireless communication (1G–5G) and beyond,
-----	---

	including D2D and M2M communications.
CO2	Analyze advanced 5G communication techniques: NOMA, MIMO, mm Wave; evaluate ergodic rate, outage, and throughput performance.
CO3	Describe beyond 5G technologies: ISAC, RIS, NOMA and IoT-based systems; analyze outage performance and system efficiency.
CO4	Explain fundamentals of 6G communication: RSMA, Terahertz, VLC; evaluate performance metrics and applications.
CO5	Understand and apply physical layer security (PLS) in 5G and beyond systems, including NOMA, ISAC, RIS, and IoT-based communication.

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	–	–	–	–	1	–	2	3	2	2
CO2	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3
CO3	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3
CO4	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3
CO5	3	3	3	3	3	–	–	–	–	1	–	2	3	3	3