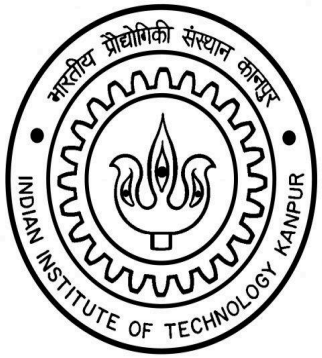

Indian Institute of Technology Kanpur

MODULE OF STUDY

OF

2023-2024

Content

Department of CIVIL ENGINEERING (CE)

Programme Name: Sustainable Construction Practices and Project Management (SCPM)

Module ID	Module Title	Credit	Description	Content

CE911	Green Construction for Sustainable Built Environment	5	To learn about various features/parameters of our built environment focusing largely on buildings that affect our environment and what are the best practices in terms of building construction, material and energy savings that can ensure sustainable infrastructure and general well- being of the residents. This module covers the following broad topics: Green construction technology, Green buildings, Energy saving, Environment-friendly building material, Indoor air pollution, Sustainable infrastructure.	• **Natural Resources and Environment**
				  ○ Environment, natural resources, natural disasters, building types, resilience and material properties
				• **Building Construction and Impact on Water**
				  ○ Water efficiency, rainwater harvesting, sanitary needs, wastewater treatment
				• **Indoor Environmental Quality**
				  ○ Material property, indoor air, VOC, SBS, Aerosol
				• **Green Building Materials**
				  ○ LCA, waste management, recycle & reuse
				• **Green Building Design and Construction**
				  ○ Passive design, material economy, time, safety and cost planning, commissioning
				• **Energy Efficiency**
				  ○ Design modifications, solar and passive HVAC and energy saving systems, renewable resources
				• **Built Environment Carbon footprint**
				  ○ Carbon cycle, climate effects, construction economics and material balance
				• **Case Studies from India**
				  ○ Green building success stories from India
				• **Tour of CESE (Green building at IITK)**
				  ○ Looking at various green construction and salient energy-saving building features

CE912	Value Engineering	5	The concept of Value Engineering (VE) evolved during WW-II when shortages of materials and labour necessitated changes in methods, materials and traditional designs. Professionals often need to raise production and productivity many-fold and achieve far greater performance levels than ever before. These sometimes come from even existing technology, old worn-out equipment and facilities, and despite the scarcity of capital, lack of requisite skills in labour, socio-economic and mandatory pressures, poor infrastructure etc. The scarcity of resources coupled with a high rate of consumption would make imperative not only the conservation of all available resources but more importantly, the prevention of unnecessary use of resources. This is where VE will secure results. Competitiveness depends on the ability to improve product design and quality. It also depends on how quickly the industry reacts to market changes and takes advantage of the often short life-cycle of high-technology products. Accomplishing these goals would require the necessary skills and tools to get the job done cost-effectively. That is what VE helps to accomplish.	• **VE Concept, Theory and Fundamentals**
				  ○ Introduction, Value, How to add value, VE, VE job plan, Techniques employed, Technique with a difference, Benefits
				• **VE Job Plan**
				  ○ Selection of project, Selection of team members, General phase, Information phase, Function phase, Creation phase, Evaluation phase, Investigation phase, Implementation phase
				• **Habits, roadblocks and attitudes**
				• **Functional Analysis**
				• **Creative thinking**
				• **Managing the VE study**
				• **Cost modeling**
				• **Life cycle costing**

CE913	Vibration Analysis and Mitigation	5	This module aims at imparting the essential knowledge on the analysis of vibrations encountered in civil engineering systems (such as buildings, bridges, transmission towers, chimneys and others), implications of vibrations in structural design and alternate avenues of vibration mitigation. In	• Need for vibration analysis; Dynamic loading and relevance; Idealization of systems: Single and Multi-degree of freedom system (SDOF/MDOF); Discrete and Continuous systems • Free and forced vibration of SDOF system under dynamic loading, harmonic and arbitrary dynamic loading

			particular, the involvement of structural dynamics in the context of earthquake and Wind engineering will be emphasized, given their importance in the safe design of structures and infrastructural facilities under such extreme events. .	• Analysis of MDOF system (generalized coordinates, eigenvalue analysis, matrix and modal time history analysis) • Continuous systems: rods (axial vibrations), beams (axial, shear, axial and flexural vibrations) • Introduction to earthquake analysis using response spectrum method • Introduction of wind-induced vibrations

CE921	Environmental Geotechnology	5	Environment Accomplishingology is an emerging and exciting field that offers numerous technical challenges and great opportunities to understand multi-disciplinary problems and develop solutions to protect public health and the environment and encourage sustainable development. Environmental Geotechnology broadly focuses on waste containment and treatment of pollution sites. The former is usually a preventive activity, while the latter is corrective measures. This module deals with the basic principles, mechanisms, and technology relevant to waste containment systems. Special focus will be given to sustainable materials used in waste containment systems. Engineers and scientists will learn concepts of environmental technology suitable for planning the disposal of waste and designing waste containment systems involving geosynthetic materials.	• **Principles and processes related to soil, water and chemical interactions:**
				  ○ Integrated solid waste management; Soil-water-waste interaction; Soil and waste characteristics
				• **Containment systems:**
				  ○ Contaminant release mechanisms; Waste containment principles; Current practice of waste disposal; Active and Passive containment systems; Elements of containment system
				• **Application of geosynthetics:**
				  ○ Types of geosynthetics; organization by function; Testing methods; Construction methods
				• **Site selection and Geoenvironmental investigations:**
				  ○ Site selection for landfills; Siting criteria; Geophysical methods; Geotechnical investigation; Characterization of landfill sites; Risk assessment
				• **Design Principles and Practices:**
				  ○ Barrier composition; Single and double-lined landfill design, liner materials- clay, geosynthetics amended

				soils and other admixtures; slope stability

CE922	Corrosion in Engineering Materials and Prevention	5	The module emphasises the need for understanding the corrosion in materials from scientific and engineering perspectives. After briefly covering the thermodynamics and kinetics of corrosion, engineering corrosion aspects will be discussed by citing several examples of corrosion failures and ways to protect the material for corrosion mitigation. The module also explores the corrosion aspect of engineering materials used in civil engineering and structures. Finally, failure analysis of structures under exposure to corrosives and how to decide the protection methods will be addressed. The module will benefit the students of civil, mechanical, aerospace and metallurgical/materials engineering. It would also benefit the personnel directly associated with industries where corrosion-related failure is experienced on a regular basis.	• **Corrosion Fundamentals:**
				  ○ Importance of corrosion, Practical aspect and Electrochemical nature of corrosion, Thermodynamics and Kinetics of corrosion(Pourbaix and Evans diagram)
				• **Forms of corrosion:**
				  ○ Uniform, Galvanic: micro and macro galvanic couple, Selective leaching, Intergranular, Crevice, Pitting, Erosion-corrosion, Stress and corrosion. Atmospheric corrosion
				• **Corrosion protection methods**:
				  ○ Design, Materials, Environment, Inhibitor, Coatings and change of electrochemical potentials
				• **Failure analysis and to decide protection methods:**
				  ○ Failures related to Storage tank, Rebar structures (roof, pillar, underground and underwater structures, Bridge corrosion, Fastener, Automobiles

CE923	Costing, Cost Monitoring & Cost Control in Infrastructure Projects	5	Costing and Cost Control is one of Key parts of Construction Management in Infrastructure Projects. According to the Ministry of Statistics and Program Implementation, out of 1605 Infrastructure Projects valued above INR 150 Crores, 379 projects have been delayed, leading to cost overruns of INR 4.64 Lac Crores as of April 2023.
			Construction Projects are notorious for
				• **Basics of Costing**
				  ○ Concept of Cost/ Significance of Cost / Types of Cost in Infrastructure Projects
				• **Costing and Estimation at Tender Stage**
				  ○ Contractor and Client Perspective
				• **Tools and Methods of Costing & Cost Monitoring at execution stage of Infrastructure Project**
				• **Approach of Cost Control in Infrastructure Project**

			exceeding their budgets, but it's still eye-popping to see the actual figures. A recent study found that just 25% of projects came within 10% of the Budget in the preceding three years. It means 3/4th of the projects are having cost overrun, and that too by more than double-digit percentage. Cost Control in construction is the difference between making a profit and absorbing a loss in many cases. The detailed cost control procedure typically involves project planning, project estimation, budgeting, and preconstruction analysis while simultaneously monitoring & controlling expenditure. Cost Control is a key part of construction management, and if we don't do it right, projects will be in constant chaos.	○ Concept of Variance ● **Conceptual Understanding on Cost vs Cash Flow vs Working Capital Dynamics in Project Management Decision Making – Live Case Study** ● **Concepts of ROCE & EVA in a Project Management**
CE931	Quality and Safety Management in Construction Practices	5	This module will cover the following broad topics: Diverse nature of EPC projects; Concerns relating construction economics, Factors influencing quality and safety of a project's construction; Site inspection, Inspection Test Procedure (ITP), Site Tests generally conducted for concrete structures integrity; Project Documentation; Concepts of quality control and Quality Management, Objectives, definitions, systems, ISO 9000 family of standards, Third-party certification, QC in construction and large projects; Concept of VARIATION or Design Change Order; Archiving records (pre-award and post-award) Concepts of quality control: Objectives, definitions, systems, ISO 9000 family of standards, third-party certification;	● Green Field and Brown Field Projects Definitions and Criticality. Major Definitions in a project Contract, stakeholders, Archiving Records Pre-award and post-award, Civil & Structural Project Specification, Standard Drawings ● Project Quality Management System, Definitions (QMS), Quality Control, Quality Assurance, Project Specific Quality Plan, Relevant ISO List, PQP (Project Quality Plan), Technical and Quality audits, Non-conformance and corrective action; Preparation of Purchase Order / MR (Typical sample) Vendor selection and inspection methodology, Third-party inspection services ● Engineering Quality Management, Inspection Test Procedure, Quality Control Procedure and Group, Inspection Record; List of Concrete works ITP, Safety related to ITP, Categorisation of TPI

			Basic construction safety: Construction Hazards, Human factors in construction safety, SIMOP (Simultaneous Operation) and Constructability review, introduction to occupational health and safety, problem areas in construction safety; **Safety engineering**: Training, audit, management practices, safety planning, PPE; **Case studies and examples**: Quality and safety issues in steel construction and Reinforced Concrete construction.	items, Non-conformance, Corrective action, CAR sample, Internal quality audit, CPAR forms Variation / Design Change. CIN Sample, Project Deliverable lists ● Construction quality control, Mechanical completion requirement, Sampling procedures, Weld repair rates, Sampling of concrete cubes, Cost impact on project ● Basic construction safety: HSE Practices Philosophy and its guidelines, Occupational Health Philosophy, Codes and Practices, HSE Construction Hazards and HSE Plan, Human factors in construction safety, Safety Signs, Types and Categories; 3D SIMOP (Simultaneous Operation) and Constructability review, What If Analysis, Hazardous Risk Matrix, introduction to occupational health and safety ● Problem areas in construction safety, job-site safety assessment, safety planning, safety audit, Legal issues in quality and safety, HSE Tracking Registrar ● Escape and Evaluation: Occupational Health Safety, Regulatory framework, HSE Management practices, HSE Studies and Training, Audit Details and SMART Audit recommendation, HSE Deliverables and Important terminology PPE, Mandatory PPE, Hazard Assessment and selection of PPE, Important Definitions about construction accidents / Man hour loss, in Construction Industry.
CE932	Material Science Aspects of Modern Concrete	5	This module introduces students to the scientific aspects of concrete using empirical models and results from scientific techniques to understand the microstructural changes that happen inside concrete during	● **Overview** ○ Important properties for modern concrete, Review of provisions in IS 456: 2000 or other codes, Need for Material Science Aspects in learning and understanding

			property development. Thus, learning this module will facilitate students in the following ways:- Provide a better understanding of modern concrete in a coherent fundamental manner instead of an arbitrary way- Provide approaches for the development of new products related to cement - based materials- Understanding deterioration mechanisms of cracked concrete due to durability Crack inspection of concrete members in buildings and other concrete.	engineering properties ● **Cement Hydration using Models** ○ Stages in Cement Hydration, Importance of hydrated compounds, Power and other Models, Microstructural aspects (degree of hydration and gel-to-space ratios) and Volume relationships, Understanding porosity and permeability of paste systems ● **Understanding workability of concrete through rheological models** ○ Basis of flow tests, Types & classes, Principles involved,Models for pastes and mortars, Factors affecting workability, Understanding codal provisions for workability,Strategies for designing flowable concrete etc. ● **Understanding hydration, setting time characteristic and curing using other material science tools** ○ Calorimetric Techniques, Thermogravimetry Analysis, X-ray Diffractogram Analysis, Pore solution analysis, etc.,Principles or factors involved in tests, Provisions in IS codes for setting time assessment, Curing techniques and technologies, etc. ● **Understanding strength and Permeability using different Approaches** ○ Understanding property through Ingredients, paste systems, ITZ, and other properties, Strength estimations (using formulas and codal provisions), Strength tests and basis, factors affecting test ● **Understanding shrinkage and creep using models**

				○ Process and Mechanisms Involved, Types, Test Methods,Their Principles and Limitations, Models and Relationships,Codal provisions
CE933	Core Project-I	5	A project work on real-life problems.	● To extend the use of resources(financial, manpower, material) in construction projects judiciously ● To foster firmly adoption of economically advantageous and sustainable change in construction projects
CE934	Project management and controls	5	Construction projects involve a great deal of time and capital, necessitating effective construction project management skills required to complete projects within stipulated time and budget limits while adhering to safety and quality standards. This course aims to equip project managers with skills required for planning, scheduling, budgeting, coordinating and supervising construction projects.	● **Introduction to Construction Project Management** ○ What is a project? How are projects organized? Project life cycle and stakeholders Activities, durations, and work breakdown structure ● **Project scheduling** ○ Network diagrams Fundamentals of scheduling Development of baseline schedules Gantt chart, Critical path method, PERT, Precedence diagram method ● **Types of plans and their uses** ○ Material plan, Plant & machinery (P&M) plan, Worker plan, Finance plan ○ Resource scheduling, resource leveling and schedule crashing ○ Impact on direct and indirect costs ● **Updating and revising project schedules** ○ Revising project plans
CE941	Quantitative Methods in Project	5	The module will provide fundamental knowledge of quantitative methods in	● **Basic Statistics for Project Management** ○ Descriptive Statistics ○ Probability Theory

	Management		Project Management. The module will cover basic statistics, predictive modeling, Multicriteria decision-making and operations research techniques frequently used in project management. The module will attempt to equip students with quantitative methods useful for project management. The tutorial in the module will help prepare students to develop the necessary skills required for analyzing and solving various real-life project management-related problems.	○ Probability Distributions ○ Inferential Hypothesis Testing ○ ANOVA Analysis • **Regression Analysis for Project Management** ○ Correlation, Simple regression, multiple regression • **Forecasting Techniques for Project Management** ○ Moving Average, Exponential Smoothing, Winter's Method, ARIMA model • **Multicriteria Decision-making (MCDM) Techniques for Project Management** ○ AHP & Topsis Technique • **Network Optimization Approach in Project Management** ○ CPM & PERT ○ Time cost Trade-off ○ Linear Programming ○ Transportation and Assignment Problems ○ Goal Programming • **Six Sigma and Lean in Project Management**. ○ Kano Model, QFD, DMAIC Principal, Inventory Control, Lean Management
CE942	Risk Assessment and Mitigation in Infrastructure Project	5	To understand the Risks associated with Infrastructure Projects in India from the Contractor's perspective and mitigation measures during the Pre-Bid stage and Execution Stage.	• **What are Major Risks in an Infrastructure Project** ○ Various types of Risks Associated with EPC Infrastructure Projects • **Methods of reading a contract agreement to assess Risks at the pre-tender stage & framework of Risk mitigation during pre-tender stage** ○ Spotting risks by reading a contract agreement and categorizing of various risks at Pre-Bid Stage

				○ Rating of Risks and framework for Risk Score based of severity and impact of risks ● **Legal Aspects in Risk Management in an Infrastructure Project** ○ Legal Checks during Risk Assessment of an Infrastructure Project ● **Risks Analysis and Mitigation Measures during Execution Stage** ○ Risks Identification during execution stage ○ Risk Score based on severity and impact of risks ○ Risk mitigation measures ○ Risk Ownership ● **Risks associated in a Developmental Infrastructure Project** ○ Type of Risks from a developer's perspective in a Developmental Infrastructure Projects under Public Private Partnership basis (PPP).
CE943	Elective Project – II	5	This project work will give the students hands-on experience on various topics.	Capstone Project
CE944	Contract Management and Administration	5	To learn Basic Terminologies Issued in Engineering Contracts in FEED and EPC Projects, Understanding of EPC Project Contract Preparation and Invitation to Tender as per FIDIC style. Type of Engineering Projects Contracts. The risk involved with NEC CONTRACTS. Pre Contract Management and Post Contract Management. Arbitration and Conciliation.	● **Introduction to Construction Contracts and Key Terminologies** ○ What is a contract? ○ What constitutes a construction contract? ○ What are the unique characteristics of a Construction contract? ○ Key terminologies: Bank Guarantee, Security deposit, Tender bond, Liquidated damage, Earnest money deposit, Technical Clarifications ● **Types of Construction Contracts**

				○ Different types of contract; Advantages & disadvantages; EPC Contract; Public private partnership (PPP) ● **Tendering process** ○ Owner perspective – floating of tenders, pre tendering activities, sub-contractor prequalification. ○ Contractor perspective – cost estimation, submission of bids, bidding strategies ● **Construction Contract Administration in India** ○ CPWD, MES, and FIDIC Contract ○ Indian contract act ○ Arbitration Act ● **Dispute resolution** ○ Claims, counterclaims, disputes ○ Dispute resolution techniques: negotiation, mediation, arbitration, and judicial
CE945	Principles and Practice of Sustainable Ground Improvement Methods	5	Ground improvement is essential in infrastructural projects when construction happens in problematic soils and under difficult geotechnical and geoenvironmental conditions. The state of the practice for ground improvement methods is ahead of the theory. The course presents the critical knowledge and skills that are required to take advantage of the cost-effective use of ground improvement methods for infrastructure, commercial and industrial development. The course addresses various ground modifications along with principles, novel materials, design issues, and construction procedures. Engineers and scientists will learn the need for ground modification, selection of appropriate	● **Principles and processes related to ground modification**: ○ Problematic geomaterials and conditions, ground modification methods and classification, novel geomaterials. ● **Mechanical modification**: ○ Densification principle; compaction curve, soil structure and fabrics; compaction control tests; concept of shallow and deep compaction, field compaction equipment, deep dynamic compaction; vibro-compaction; design methods and quality control. ● **Hydro-Mechanical modification:** ○ Precompression and consolidation principles; methods- preloading, sand drain, prefabricated vertical drain, stone

			methods, suitable analysis, design methods and construction practices.	column, vacuum consolidation; design considerations and quality control. ● **Bio-Chemical modification:** ○ Clay mineralogy; admixture-based soil stabilization; traditional and non-traditional admixtures; mechanism of treatment; principles of grouting. ● **Reinforced soil**: ○ Reinforced soil principles and mechanisms; mechanically stabilized earth walls and geosynthetic reinforced soil slopes; design steps and construction practices

Department of Computer Science and Engineering (CSE)

Programme Name : Cyber Security (CY)

Module ID	Module Title	Credit	Description/Objective	Content
CS961	Introduction to Cryptography	5	The module covers the basics of finite field Arithmetic, private and public-key cryptography, existing cryptosystems and their security, Cryptanalysis of existing systems and more.	• Basics of finite field Arithmetic • Private and Public-key cryptography • Existing cryptosystems and their security. • Cryptanalysis of existing systems.
CS962	Operating System Principles	5	Practical understanding of operating system design is desirable for application developers, system software developers, security professionals and system administrators. The goal of this course is to provide better understanding of the OS from the system programmer's perspective with emphasis on security-related OS design principles such as separation of privileges at different levels and resource multiplexing with isolation guarantees.	• Introduction to OS, System call API for process, working of a shell • Address space and virtual memory and the APIs. File management APIs

CS963	Computer Networks I	5	The objective of this course is to introduce students with the concepts of networking Including protocols, LAN, WAN and wireless networks.	• **Introduction and Background**
				  ○ Basics of computer communication and networking
				  ○ TCP/IP layering
				• **Physical Layer**
				  ○ Basics of time/frequency domain representation of signals, Bandwidth, Data Rate, Channel capacity
				  ○ Different types of transmission media,

				errors in transmission: attenuation, noise, Repeaters, Amplifiers, Gain, Path loss ○ Encoding (NRZ, NRZI, Manchester, 4B/5B etc.) and Modulation (Amplitude and angle modulation) ○ Multiplexing (TDM, FDM), Spread spectrum ● **Link Layer** ○ Aloha, CSMA, CSMA/CD, CSMA/CA protocols ○ Ethernet, including Gigabit Ethernet and WiFi (802.11) a quick exposure to Token Ring, Sliding Window, Stop and Wait protocols ○ Error detection and correction (Parity, CRC), Checksum ○ Sliding Window, Stop and Wait protocols ○ Design, specifications of popular technologies, switching
CS964	Introduction to Application Security, Mobile Security and Critical Infrastructure Security	5	Discover software bugs that pose cyber security threats, explain and recreate exploits of such bugs in realizing a cyber attack on such software and explain how to fix the bugs to mitigate such threats. Articulate the urgent need for cyber security in critical computer systems, networks and world wide web and explain various threat scenarios. Articulate the issues of Cyber Security in Mobile Computing Systems such as Android. Articulate the well-known cyber-attack incidents, explain the attack scenarios,	● **Application Security** ○ Control hijacking attacks – buffer overflow, integer overflow, bypassing browser memory protection ○ Sandboxing and Isolation ○ Privilege, access control and Operating System Security ○ Tools and techniques for writing robust application software ● **Security in Mobile Platforms** ○ Android vs. iOS security model, threat models, information tracking, rootkits ○ Threats to mobile applications, analysers for Mobile Applications to discover Security vulnerabilities ○ Android Security Architecture, Trust Zone

			and explain mitigation techniques. Articulate the cyber threats to critical infrastructures.	Architecture, SE Linux ● **Issues of Critical Infrastructure Security and SCADA Security** ○ Security Issues in Industrial Control Systems (ICS) and Operational ○ Technology (OT) ○ NIST Cyber Security Framework for ICS ○ SCADA Security and Threat Models ○ Intrusion Detection in ICS/OT systems
CS971	Computer Networks II	5	The objective of this course is to introduce students with the concepts of network, transport and application layer protocols of the TCP/IP protocol stack.	● **Network Layer** ○ Network layer functions, Router architecture, Internet protocols IPv4 and IPv6, NAT, ARP ○ Routing algorithms i.e. Link State and Distance vector protocols, Intra and inter-AS routing protocols i.e. OSPF and BGP, ICMP, SDN architecture ● **Transport Layer** ○ UDP, TCP: Connection establishment and termination ○ TCP flow and congestion control, timers, retransmission, TCP extensions ○ Introduction to sockets and socket programming ● **Application Layer** ○ Application layer details, client-server vs P2P, HTTP, email service, web caching, DNS ● **Network Security (may be)** ○ Concepts of symmetric and asymmetric key cryptography, Public vs private key cryptosystem, Authentication protocols, Message integrity
CS972	Introduction to	5	**Matrices and Gaussian Elimination**:	● Matrices, Geometry of Linear Equations, Matrix

	Linear Algebra		Geometry of Linear Equations, Matrix Notation and matrix multiplication, Gaussian elimination, Row transformations, row exchanges, triangular factors, Inverses, transposes, solving Ax=b, A=LU decomposition. **Vector Spaces**: Vector spaces, subspaces, solving Ax=0 and Ax=b, Linear independence, Basis, bases and dimension. Four fundamental subspaces of a matrix. Linear Transformations. **Orthogonality**: Orthogonal vectors, orthogonal subspaces, Projections onto lines, projections onto subspaces and least squares, Gram-Schmidt. Example: Fast Fourier Transform, Fourier series. **Determinants**: Introductions, properties of the Determinant, Formulas for the Determinant,Applications. **Eigenvalues and Eigenvectors**: Diagonalization of Matrix, Powers A^k, Complex Matrices, Similarity Transformation, *Difference Equations and powers A^k, *Differential Equations and e^{At}. **Positive Definite Matrices**: Minima, Maxima, Saddle points, Tests for Positive definiteness, Singular Value Decomposition SVD. *Matrix norm, Condition number, Iterative methods for Ax=b, Linear Programming *represents optional topics.	notations, Gaussian elimination ● Row exchanges, Triangular factors, LU=b,inverses, transposes, intro to vector space, solving Ax=0 ● Solving Ax=b, linear independence , basis, dimension, four subspaces. Orthogonality definition, projections onto lines ● Projections onto subspaces, Least squares minimization, orthogonal bases, Gram-Schmidt, FFT, Fourier transforms ● Determinants, Properties, formulas, applications, area, volume etc. ● Eigenvalues and e-vectors:diagonalization, Complex matrices,similarity transformations. * A^k, e^{At} ● Positive Definite Matrices, minima-maxima, saddle pt, tests of psd, SVD, ● Reserved for overflow. Additional topics: Matrix norm, condition no, Linear Programming
CS973	Machine Learning for Cyber Security	5	1. Articulate and explain which problems in Cyber Security may be solvable with Machine Learning.	● Basic Probability theory and Distributions ● Linear Regression (uni- and multi-variate) and Logistic Regression

			2. Understand and implement machine learning algorithms and models for Cyber Security problems such as malware analysis, intrusion detection, spam filtering, fraud detection, online behavior analysis etc.
			3. Get basic hands-on experience with supervised, unsupervised learning methods.
			4. Understand basic theory of supervised and unsupervised machine learning.
			5. Understand feature extraction from data.
			Even though we will not make it mandatory to implement machine learning models for a cyber security problem, more advanced students with programming skills may also be able to develop tools for cyber defense using machine learning having taken this course. However, that will not be evaluated.
				• **Basic Classification Techniques**
				  ○ Bayesian Classification
				  ○ Other Classification Techniques
				• **Unsupervised Learning**
				  ○ Spectral Embedding, Manifold detection and Anomaly Detection
				• **Supervised Learning**
				  ○ Decision Trees
				  ○ Ensemble learning
				  ○ Random Forest
				• Cyber Security problems that can be solved using Machine learning
				• Malware Analysis, Intrusion Detection, Spam detection, Phishing detection,
				• Financial Fraud detection, Denial of Service Detection

CS974	Introduction to Web Security, Network Security, and Defenses	5	To understand and discover security vulnerabilities on browser side web applications and corresponding security threats.
			
			To understand and discover vulnerabilities on t web server-side and corresponding security threats.
			
			To understand and discover mitigation techniques to reduce the risk of cyber-attacks on web applications.
				• **Network Security**
				  ○ Security Issues in TCP/IP – TCP, DNS, Routing (Topics such as basic problems of security in TCP/IP, IPSEC, BGP Security, DNS Cache poisoning etc)
				  ○ Network Défense tools – Firewalls, Intrusion Detection, Filtering
				  ○ DNSSec, S-BGP, IPSec
				  ○ Threat Models, Denial of Service Attacks, DOS-proof network architecture
				  ○ Wireless-LAN Security – WEP, WPA, WPA2 and WPA3
				  ○ Threat Modelling, Attack Surfaces, and

			To understand and discover security vulnerabilities in Networked Systems, Protocols and the Internet. To Understand and discover security vulnerabilities in Wireless LAN and defence.mechanisms against such vulnerabilities.	other comprehensive approaches to network design for security ● **Web Security** ○ Security architecture of World Wide Web, Security Architecture of Web ○ Servers, and Web Clients ○ Web Application Security – Cross Site Scripting Attacks, Cross Site Request Forgery, SQL Injection Attacks ○ Content Security Policies (CSP) in web ○ Session Management and User Authentication, Session Integrity ○ Https, SSL/TL
CS980	Cyber Laws, Case Studies and Trends	5	The importance of cyber Laws and Extant Cyber Laws in India. Comparison between CyberLaws regime in India and US/Europe.	● The importance of Cyber Laws and Extant Cyber Laws in India ● Comparison between Cyber Law regime in India and US/Europe ● Cyber Security Regulation ● Cyber Security Standards ● Cyber Security Policies, Architecture, and Compliance ● Compliance Automation ● Case Studies from the field
CS981	Advanced Topics on Cryptography	5	This course focuses on some recent advanced topics on cryptography. The first part of this course would focus on public key cryptography and the impact of quantum computing on cryptographic applications. Public key cryptography plays a major role in maintaining the security and integrity of communication channels. However, due to the advent of quantum computing, existing public-key cryptographic algorithms like RSA or elliptic	● **Public Key Cryptography** ○ RSA and Elliptic Curve Cryptography (ECC) ○ Attack on RSA and ECC ● **Quantum Computing** ○ Quantum Gates, Multi Qubit States ○ Deutsch ’s Algorithm ○ Bernstein-Vazirani Algorithm ○ Quantum Fourier Transformation ○ Shor’s algorithm ● **Lattice Based Cryptography**

			curve cryptography will cease to remain secure. Shor's algorithm can find prime factors of integer numbers efficiently on quantum computers, thus undermining the basic security assumption of RSA and elliptic curve cryptography. In this course, we will cover the basic concepts and traditional attacks on public key cryptography, followed by some concepts on quantum computing and Shor's algorithm. Additionally, we would also describe very briefly a post-quantum secure public key algorithm, based on lattice-based cryptography. The second part of the course would focus on advanced cryptographic protocols like authentication, attestation, bit-commitment protocols and oblivious transfer etc. The contents selected for the course are based on research papers from top-tier journals and conferences such as IEEE TIFS, IACR TCHES, IEEE TC, ACM TECS, IEEE TVLSI, DAC, DATE etc.	○ Learning with error ○ CRYSTALS-Kyber ● **Security Protocols** ○ Authentication, Attestation, Bit Commitment and Oblivious Transfer ○ PUF Based Authentication ○ Remote Attestation
CS982	Computational Number Theory for Cryptographers	5	The module covers Elementary Operations, Polynomials, Integer Lattices, Elliptic Curves and more.	The module covers Elementary Operations, Polynomials, Integer Lattices, Elliptic Curves and more.
CS983	Embedded, Cyber Physical Systems and IoT Security	5	To understand different IoT system architecture and related components. To know various sensors and actuators used in IoT applications.	● **Introduction to IoT** ○ New trends and applications ○ IoT architecture – 3,5,7 layers approach ○ Middleware ○ Fog computing

			To develop an IoT system in a simulated environment. To obtain the knowledge of various communication protocols and networking strategies used in IoT systems . To understand security threats in IoT systems, attack detection methodologies and digital forensics of IoT systems. To get an overview of new trends and applications in various domains.	○ Sensors and actuators ● **IoT communication protocols** ○ NFC, RFID ○ Bluetooth, Zigbee, Wifi etc ○ MQTT, HTTP etc ● **IoT sensor networks** ○ Network topologies ○ Challenges in designing wireless sensor networks ○ Optimization techniques ○ Routing protocols ○ Network structure ● **IoT security** ○ Device security ○ Communication security ○ Attack detection techniques ○ Digital Forensics ● **IoT applications using AI/ML/DL methods** ○ Smart cities ○ Healthcare ○ Agriculture ○ Manufacturing
CS984	Introduction to Hardware Security	5	To understand and discover security vulnerabilities of physical implementation of cryptographic algorithms . Will get to know about different hardware security threats like side channel attacks, hardware Trojans, fault attacks. Will obtain knowledge about passive side channel attacks(power and electromagnetic attacks) and corresponding countermeasures. Will obtain knowledge about fault attacks	● **Passive Side Channel Attacks** ○ Introduction to Side Channel Attacks ○ Power Side Channel Attacks: Simple Power Attack ○ Power Side Channel Attacks: Difference of Mean and Correlation Power Attack ○ Evaluation of Side Channel Attacks: TVLA and Success rate ○ Power Attack Countermeasures ● **Fault Attacks and Hardware Trojan** ○ Introduction to Fault Attacks ○ Fault Attacks on AES ○ Fault Attacks on ECC

			and corresponding countermeasures. To understand and discover security vulnerabilities of different micro-architectural attacks. Will get to know hardware security primitives like Physically Unclonable functions (PUF), True Random Number Generator (TRNG), Logic locking and security Protocol.	○ Introduction to Hardware Trojan ○ Hardware Trojan Examples ● **Micro-Architectural Attacks** ○ Introduction to Cache Attacks ○ Spectre and Meltdown ○ Performance Counter based Attacks ● **Hardware Security Primitives** ○ Introduction to Physically Unclonable Functions (PUF) ○ Example of PUFs ○ Introduction to True Random Number Generators (TRNGs) ○ TRNG examples ○ Logic Locking: Attacks and Countermeasure ○ Security Protocols
CS985	Introduction to Malware Analysis	5	The module covers malware classification, types, and platform-specific issues with malware, Intrusion into IT and operational network (OT) and their signs, manual malware infection analysis, signature-based malware detection and classification – pros and cons, and need for machine learning-based techniques, and more.	● Malware classification, types, and platform specific issues with malware, Intrusion into IT and operational network (OT) and their signs. ● Manual Malware Infection analysis, signature-based malware detection and classification –pros and cons and need for machine learning based techniques. ● Static Analysis, Dynamic Analysis and Hybrid Analysis of Windows Malware, Linux Malware and Android Malware Case Studies of Malware Analysis from most recent conferences, Presentations and Discussions and Implementations
CS986	Game Theory	5	The module covers non-cooperative game theory, complete information sequential move games, complete information simultaneous move games, incomplete information games, cooperative Game	● **Non-cooperative game theory** ○ Quantitative models of strategic interaction: rationality, intelligence, common knowledge ○ Complete information simultaneous move games – normal form representation

			Theory, and more.	○ Ideas of equilibria: domination of strategies, Nash equilibrium ○ Existence results for mixed and pure Nash equilibrium ○ Correlated equilibrium. ● **Complete information sequential move games – extensive form representation** ○ Perfect and imperfect information extensive form games ○ Equilibria concepts – subgame perfect equilibrium, perfect Bayesian equilibrium, analogies ○ with pure and mixed Nash equilibrium ● **Incomplete information games** ○ Bayesian games ○ Equilibria concepts tied to the belief system ○ Nash and Bayesian equilibria in incomplete information games ● **Cooperative Game Theory** ○ Utility representation in form of coalition ○ Transferable utilities game ○ Imputation, core, Shapley value, nucleolus
CS987	Advanced Critical Infrastructure Security	5	To Identify the key research questions in cyber-security of critical infrastructure. To apply research methods which includes survey, experiments, and articulation of research problems in this area and methods for finding solutions to selected problems. To become adept at the use of machine learning for cyber security. To present in written and/or verbal form key	● Critical Infrastructure and Cyber Physical Systems ● Introduction to PLC/SCADA/OT ● Dynamics of CPS and Attack Surfaces ● IT-OT Convergence and enhanced Attack surfaces ● Intrusion to Affect Physical Dynamics ● Intrusion Detection Methods – Rule Base ● Intrusion Detection Methods – Machine Learning Based ● Modeling of Cyber Physical Systems and Cyber Attacks ● Risk Aware Cyber Security of Cyber Physical Systems

			findings in the specific subject area of the course from contemporary research papers. To read and analyze research papers from journals and conferences in the specific subject area of the course	
CS988	Honeypots and Deception Technologies for Advanced Protection	5	The module covers Cyber Threat Intelligence Collection Techniques, OSINT, Deception Technology for Monitoring Cyber Threat, Client-Side Deception Techniques, Service side Deception techniques, IT honeypots, OT honeypot, ICS Honeypots and more.	• Cyber Threat Intelligence Collection Techniques • OSINT • Deception Technology for Monitoring Cyber Threat • Client-Side Deception Techniques – Honey Tokens, Honey Credentials, Honey Files etc • Service side Deception techniques – IT Honeypots, OT Honeypots, and ICS honeypots • IT honeypots – for services such as SQL DB, Web, SSH, Telnet and other services • OT honeypot – SCADA Honeypots • ICS Honeypots – Conpot and IoT Honeypots
CS989	Introduction to Blockchain Technology	5	The module covers Basic Cryptographic primitives used in Blockchain Secure, Collision-resistant hash functions, digital signature, public-key cryptosystems, zero-knowledge proof systems, basic Distributed System concepts, Blockchain 2.0, Blockchain 3.0, E-Governance and other contract enforcement mechanisms, and more.	• Basic Cryptographic primitives used in Blockchain – Secure, Collision-resistant hash functions,digital signature, public key cryptosystems, zero-knowledge proof systems • Basic Distributed System concepts – distributed consensus and atomic broadcast, Byzantine fault-tolerant consensus methods • Basic Blockchain (Blockchain 1.0) – concepts germane to Bitcoin and contemporary proof-of-work based consensus mechanisms, operations of Bitcoin blockchain, crypto-currency as application of blockchain technology • Blockchain 2.0 – Blockchains with smart contracts and Turing complete blockchain scripting –issues of correctness and verifiability, Ethereum platform and its smart contract mechanism

				• Blockchain 3.0 – Plug-and-play mechanisms for consensus and smart contract evaluation engines, Hyperledger fabric platform • Beyond Cryptocurrency – applications of blockchain in cyber security, integrity of information, • E-Governance and other contract enforcement mechanisms • Limitations of blockchain as a technology and myths vs. reality of blockchain technology

Department of ECONOMIC SCIENCES (ECO)

Programme Name: Climate Finance and Sustainability (CFS)

Module ID	Module Title	Credit	Description	Content
ECO921	Business Environment & Strategy	5	This module is designed better to understand macroeconomic dynamics within the business and the economy. It also offers an understanding of how the business will succeed in a dynamic business environment with competitive strategies.Finally understanding how business decisions are made.	• **Macroeconomics:** Key Macroeconomic Variables and their relevance to Business, Basics on Monetary and Fiscal Policy, India's Economic Environment, Green Banking and Sustainability, Central bank vs Government in Climate Risk Management. • **Understanding Open Economy**: Balance of Payment, Capital and Current Account, Exchange Rate Determination, Business Cycles, International Trade, Environment, and Climate Change: CBAM – Free Trade, WTO Negotiations. • **Business Environment**: Concepts, Internal and External environmental variables, Introduction to Risks - Political, Legal, Environmental, Technological, Reputational Risks. • **Strategic Management**: Environmental Scanning, Industry Analysis, Internal Scanning, Sustainable Value Chain, Product Life Cycle. • **Strategy Formulation**: Business Strategy and Corporate Strategy (climate change), Competitive Tactics and Strategies, Basic types of Strategic Alliances, Portfolio Analysis of Business Units or Products offered by a Company.

				• **Case Analysis**: Detailed procedure involved in a Case Analysis.
ECO922	Foundations of Finance	5	To provide a foundational understanding of finance and accounting. The module will prepare the students for advanced knowledge of electives and real-life applications.	• **Measuring the Time Value of Money:** Future and Present Values, Annuities, Perpetuities, Compounding and Measuring Returns, Time Value of Money v/s Sustainability • **Risk and Return Analysis:** Basics of Portfolio Construction, Mean-Variance Framework, Optimal Portfolio Analysis with Riskless Asset, Capital Allocation Framework, Optional Portfolios with Multiple Assets, Riskiness of Portfolio and Types • **Fixed Income Securities:** Bond and its Types, Valuations, Yield Curve and Duration, Green Bonds • **Derivatives:** Mechanics of Futures Markets, Forwards Contracts, Valuations, Options - Payoff structure, Basic Trading strategies using Options, Vanilla Swaps • **Basic Accounting of Firms:** Financial Statements, Income Statement, Balance sheet, Cash flow Statement, Discussion on CSR Funds • **Financial Analysis Techniques:** Financial Ratios - Activity, Liquidity, Solvency, Profitability, and Valuation Ratios, Capital Structure of the Firm, Business Risk and Scenario and Simulation Analysis, Environmental Costs, and Negative Externalities.

ECO923	Data Analysis in R and Python	5	The stream of climate finance and sustainability requires workable exposure to data analysis skills. This module is designed to fulfill the need for data analysis requirements with balanced exposure to theory and hands-on training in R and Python. Another added feature is to analyze the data based on its nature and composition.	• **Introduction**: Overview: Different types of Data (structured and unstructured), Basic Statistics, and Graphical Analysis. • **Introduction to R and Python:** Introduction to R and Python Environments • **Linear Regression**: Assumptions, Diagnostics, Specifications, and Forecasts • **Panel Data Modelling:** Basics of Panel Data Modelling – Fixed and Random Effects and GMM • **Cross-sectional Data Modelling**: Logit, Probit, Tobit, and other Variants and their Applications • **Time-series Modelling**: Basics of AR and MA, ARIMA Modelling and Forecasts
ECO924	Introduction to Alternative Finance	5	This module exposed different derivatives products and their valuations.The Module will first introduce the products and then analyze them deeply from the perspectives of their nature and investment attributes. Understanding alternative finance is crucial as it helps analyze carbon products efficiently and may also help launch a new product.	• **Forwards, Futures & Options:** Valuations and Cost of Carry Model (seasonal & non-seasonal), Convenience Yield, Spread Arbitrage, Pricing of Forwards for Storable Consumption Commodities • **Electricity Derivatives**: Spot Market of Electricity: DAM, DAC, TAM, Daily-term Ahead Market, Price Discovery Process, Indian Electricity Derivatives Market • **Weather Derivatives**: Spot Market of Electricity: DAM, DAC, TAM, Daily-term Ahead Market, Price Discovery Process, Indian Electricity Derivatives Market • **Carbon Derivatives**: Cap-and-Trade, CER, ERU, and Emission Trading Standards, Switching Prices, Carbon Credits • **Freight and Water**: Functioning of Freight Exchanges, Freight Indexes, and Water Derivatives Valuations • **Hedging and Speculation with Futures**: Types of Hedges, Profit Margin Hedging,

				Inverse Hedging, Enhancements, Speculation, and Investment Process, Cross-hedge, Tailing the Hedge
ECO925	Climate Change Finance and Investment	5	The Module aims to provide students with the macro-level knowledge and understanding of principal concept upon which climate change policy is based , a framework on how the global political environment , government and businesses manage the business risk and how to quantify the scale of the challenge in terms of the value of assets at risk and integrating climate risk into investors framework.	• **Political Economy of Global Environment**: Global Firms in International Environmental Politics, Business Power and Business Conflict, Overconsumption v/s Overpopulation Debate, CASE Study on Global Climate Change • **Global Climate Environment & Business Risk**: Global Environmental Policy Norms, Energy Policy, and Climate Change, Trans-national Environmental Activism, Business as a Global Actor, International Negotiations, Corporate Climate Risk - Regulatory, Physical, and Business Risks • **Role of Government and Financial Institutions in Adapting Climate Change:** Introduction to the Governmental Tools and Institutions used to Support Climate Finance Objectives, Mapping International and Domestic Climate Finance and Investment, The role of Public Finance Institutions - Domestic Promotional Banks, Multilateral Development Banks, Export Credit Agencies • **Impact of Climate Change on Finance**: Physical Impacts on Unregulated Sectors, on Carbon-regulated Sectors and Financial Services, Institutional Investors, and their Activism • **Climate Finance:** Determinants of Climate Finance, Climate Policies: Mitigation and Adaptation, Introduction to Clean Energy Finance, Ethical Considerations with National and International Climate Finance

				• **Financial Mechanism and Instruments**: Economic Instruments for Climate Change (concession finance, blended finance, bonds, guarantees, results-based payments), Climate Risk and Stock Pricing, Pollution Premium, Corporate Risk-taking Behaviour, Risk Management Strategies amid Climate Change Risk.
ECO926	Carbon Pricing, Trading and Markets	5	To provide a theoretical and practical understanding about carbon pricing , trading and markets. The exposure to different carbon trading mechanisms, carbon accounting and carbon offset markets are some of key features of this module.	• **Overview of Carbon Pricing:** Fundamentals of Carbon Pricing, Market Failures, Externalities, Coase Theorem, Carbon Taxes, Carbon Markets, Institutional Topics in Cap-and-Trade International Carbon Markets and Future of Carbon Pricing • **Global Carbon Markets:** Introduction to Climate Meetings – Kyoto and Paris Agreements, CDM, JI and CERs and ERUs, Cap-and-Trade, Global Emission Trading Platforms, EU-ETS, and other Markets, their Comparative Analysis • **Voluntary Carbon Market**: Carbon Accounting-Footprints, Auditing of Carbon, Scopes 1-3 of Carbon Emissions, Carbon Offsetting Mechanism - Supply and Demand, International Offset Mechanisms, Voluntary Carbon Offset Standards – Verified Carbon Standard, Gold Standard, Plan Vivo Standard, American Carbon Registry, SBTi Commitment • **Carbon Offset Market**: Voluntary Offsetting Market, Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) and its Traded Instruments, Buying and Selling Offset Credits – Forward and Spot Sales. Global Offset Exchanges – Voluntary Carbon Emissions Offset Futures – Basis Markets

				• **Carbon Border Adjustment Mechanism**: CBAM and its Operation Rules. Its Impact on Cross-border Trade and Developing and Developed Countries Relations, CBAM and Carbon Leakage and its Impact on Carbon Offset Market • **Emission Trading in India**: PAT Analysis, Escerts and RECs Specifications, Trading of Escerts and RECs on Energy Exchanges. Future Directions of Carbon Trading in India
ECO927	Introduction to Sustainable Finance	5	This module provides an understanding of current trends of integration of environmental and social criteria in the investment process. It engages in reflections about the potential for impact of different ESG strategies for real economy and environment. Understand and apply key concepts to asset allocation and portfolio analysis using ESG data using available software.	• **ESG Materiality and Responsible Investing Approach:** 3 pillars of ESG Model and Selection of Material ESG Issues, Screening, Thematic and Selecting Responsible Investment Approaches • **ESG Ratings and Assessment of Corporates:** Anatomy of ESG ratings or ESG Score, Characteristics of ESG Indicators and Ratings, Commercial players in ESG ratings, Sustainalytics, MSCI, RepRisk ESG Business Intelligence, Ceres, JUST Capital • **Responsible Investment across Different Asset Classes:** Equities, Fixed Income, Real Estate, Commodity Investments, Mutual Funds, Indices, ESG in Managing Sovereign Wealth and Government Sponsored Funds, Future of ESG Investing • **Asset Allocation and Portfolio Analysis:** Risk and Return Assessment for ESG Portfolios, Asset Allocation and Portfolio Analysis, Concept, and Application of Diversification and Hedging, Comparison of ESG Portfolios and Conventional Portfolios

				• **Sustainability and Asset Pricing:** Sustainable CAPM, ESG Integration in Value, Momentum, and Growth Factors • **Sustainable Blue Economy**: Taxonomy of Blue Economy Sectors and Activities, Blue Economy and Small Countries and Coastal Population, CASE on "Impact of climate change on Blue Economy of the Indian Ocean Region"
ECO928	Sustainable Reporting and Disclosure Practices	5	The module provides a strategic and technical understanding about the sustainability reporting practices followed worldwide with the focus on social, environmental and governance reporting standards. This will prepare the students to evaluate the real world cases and transition that businesses are making towards sustainability.	• **Introduction to Sustainability:** Meaning, Scope, TBL, CSR to ESG • **Sustainability Reporting Framework:** Drivers to Sustainability Reporting, GRI, UN Global Compact, Principles of Responsible Investing, Integrated Reporting Practices • **Legal Framework, Conventions, and Treaties:** Brundtland Commission, Kyoto Protocol, Bali Roadmap, UN Conference on Sustainable Development, UN Paris Agreement, COP26, COP27 • **Concept of Circular Economy**: 10 R's, Steps towards a Circular Economy, Principals for Circular Economy • **Concept of Environmental, Social and Governance:** ESG Disclosures and its importance, Greenwashing, ESG Reporting Frameworks, Comparison of ESG, SRI and Impact Investing • **Case Analysis**: Welspun India Limited: A Sustainability Journey
ECO929	Machine Learning for Climate and Carbon Finance	5	To provide a practical exposure to machine learning techniques including supervised, unsupervised, and deep learning models for climate finance and clean energy big data analysis.	• **Fundamentals of Bonds**: Basic Terminologies of Bond Markets, Par Value, Discount, Premium, Maturity, Coupon Interest Rate, Operations of Conventional Bonds, Yield to

				Maturity, And Collateral, Interest Rate Risk, Credit Risk, And Credit Spread ● **Fundamentals of Green Bonds: Green Bond Basics:** Current State Of Play, The Sustainable Debt Market, Green Bond Definitions, The Green Bonds Taxonomy & Classification Systems, Green Bond Policy Landscape ● **Green Bond Pricing:** Basics of Yield Curve, Green Bonds Pricing in the Primary Market, Spread Compression, Greenium, On The Curve, New Issue Premium, Secondary Market Analysis – Vanilla Spread, Vanilla Average ● **Green Bond Market Development:** Green Bond Market Development: Global and Regional; Sovereign Green Bond Market Evolution, Benefits and Impact and Transition Finance, International Benchmark, and some Relevant Case Studies ● **Green Loans & Green Microfinance:** Fundamentals and its Mechanism, Benefits and Valuations, Principles, Assessment of Green Microfinance ● **Sustainable Debt Market in India:** Social & Sustainability and Sustainability-Linked Bonds, Sectoral Overview of Green Bonds, ESG Funds, Taxonomy, Reporting and Regulatory Ecosystem and Current Outlook
ECO930	Green Bonds – Pricing and Valuations	5	The aim of this module is to provide an in-depth understanding about the green bond markets and their associated dimensions in the primary and secondary markets. The sustainability and sustainability-linked bonds, green loans and green microfinance are some of the highlights of the module.	● **Fundamentals of Bonds:** Basic Terminologies of Bond Markets, Par Value, Discount, Premium, Maturity, Coupon Interest Rate, Operations of Conventional Bonds, Yield to Maturity, And Collateral, Interest Rate Risk, Credit Risk, And Credit Spread ● **Fundamentals of Green Bonds**: Green Bond Basics: Current State Of Play, The Sustainable

				Debt Market, Green Bond Definitions, The Green Bonds Taxonomy & Classification Systems, Green Bond Policy Landscape ● **Green Bond Pricing:** Basics of Yield Curve, Green Bonds Pricing in the Primary Market, Spread Compression, Greenium, on The Curve, New Issue Premium, Secondary Market Analysis – Vanilla Spread, Vanilla Average ● **Green Bond Market Development:** Green Bond Market Development: Global and Regional; Sovereign Green Bond Market Evolution, Benefits and Impact, and Transition Finance, International Benchmark, and some Relevant Case Studies ● **Green Loans & Green Microfinance**: Fundamentals and its Mechanism, Benefits and Valuations, Principles, Assessment of Green Microfinance ● **Sustainable Debt Market in India**: Social & Sustainability and Sustainability-Linked Bonds, Sectoral Overview of Green Bonds, ESG Funds, Taxonomy, Reporting and Regulatory Ecosystem and Current Outlook.
ECO931	Financial Modelling to Clean Energy Products	5	Understanding the basic tenets of equity and financial derivatives required tools. This course is designed to provide an in-depth understanding of the tools and techniques are necessary for analyzing the financial data of different frequencies.	● **Overview:** An overview of Clean Energy Finance and its Investment Attributes, Significance of Statistical Modelling with Conventional Equities and Other Alternative Assets, International Clean Energy Indices and their Trading Attributes ● **Dynamics of Clean Energy Equities**: Fundamentals of Clean Energy with Crude Oil and other Energy Products, Technology Stocks, Green Bonds and ESG Ratings, Calculation of Systematic and Non-systematic Risk of Clean Energy Equities

				• **Price Discovery Process**: Modelling Cointegration Process, Market Integration and Relational Analysis, Price Discovery in the Commodities Derivatives Market, Applications in offset Products • **Risk Management in Energy Products**: Methods to Calculate Time-Varying Volatility, Univariate and Multivariate Setup, Calculation of Dynamic Portfolio Weights and Hedge Ratios, Volatility Spillover Analysis, Green Bonds vs Conventional Bonds • **Modelling Multivariate Setup**: Introduction to Multivariate Time-series Models and Estimation of Causal Inferences between Green Bonds and Energy Products and their Interactions with Economy-specific Fundamentals • **Firm-level Analysis**: Firm-Level Analysis, Data Curation and Modelling, Application of Panel Data Models, Time-Series and Cross-Sectional Validations, Case Studies
ECO932	Project -I	5	To Provide a practical and applied exposure to the covered module. Students will be encouraged to formulate a research problem and submit a report.	Capstone Project

Programme Name : Business Finance and Public Policy (BFPP)

Module ID	Module Title	Credit	Description	Content
ECO901	Pricing	5	The course helps in the understanding of the decision making process of firms and individuals. In a way, the course introduces	• Problem Solving and Decision Making • Simple Pricing • Monopoly, Monopsony, and Price Discrimination

			tools to understand the basics of Modern Economic Analysis. The approach is different from a typical traditional introduction. From the beginning of the course, the focus has been set on Pricing.	• Strategic Games and Pricing • Making Decision with Uncertainty
ECO902	Economic and Financial Data Analysis	5	The primary objective of this course is to equip the participants with various statistical tools and techniques along with their applications used in Economics and Finance. Through this course, the participants will develop an ability to analyze the data by applying appropriate quantitative methods. This course serves as a prerequisite for future courses such as Machine Learning, Advanced Financial Econometrics, Probability and Stochastic Systems, and Program Evaluation. The course also involves use of statistical software such as R to demonstrate the various concepts.	• Descriptive Statistics • Correlation • Simple and Multiple Linear Regression • Time Series Analysis
ECO903	Introduction to Finance and Accounting	5	The module focuses on the fundamentals of finance and accounting. It prepares you for advanced knowledge of electives and real-life applications.	• Time value of money • Fundamentals of portfolio construction, mean-variance framework, capital allocation and optimization with multiple assets. • Fixed income securities • Introduction to derivatives • Fundamentals of accounting • Financial analysis techniques
ECO904	Game Theory and Strategy	5	Strategic interactions are pervasive in all walks of life.This module aims to systematically study these strategic interactions, focusing on their applications in Businesses and Public Policy.	• Tales of Strategy and Basic Ideas [Choice, Chance, and Strategic Moves] • Sequential games and Simultaneous Moves [Making Strategies Credible] • Interpreting and Manipulating Information

				• Applications: Voting, Auction, Adverse Selection, and Signaling • Mechanism Design • Cooperative Games and Bargaining • Using Game Theory to Shape Strategy and Other Case Studies
ECO905	Money and Banking	5	The module aims to provide a broad understanding of the different instruments of money markets and banking operations. The module will help the participants develop an interest in the banking sector and short-term money market operations.	• Overview of the Indian financial system. • Money and its forms • Banking sector • Interest rate analysis • Central bank and monetary policy • Financial regulation
ECO906	Global Economy and International Finance	5	This course examines the economics of international markets, and how international considerations affect financial economic models. The objective is to equip students, policy makers and decision makers with the analytical tools needed to make informed financial decisions and to create awareness of issues that arise in today's competitive global environment.	• Globalization and International Trade • Foreign Exchange Market • Forward Markets and Exchange Risk • Balance of Payments • Exchange Rate Systems • Interest Rate Parity Conditions • Exchange Rate Determination
ECO907	Applied Macroeconomics	5	The course provides tools to analyze economies subject to macroeconomic influences, both foreign and domestic. The focus is on developing insights to aid in sensible policy advice as well as investment decisions.	• Real Economic Activity • Inflation, Relative Prices and Expectations • Monetary Policy and Accounts • Fiscal Systems • Financial Stability • External Accounts
ECO908	Applied Corporate Finance	5	This module provides an in-depth understanding of some of the critical topics in corporate and it is also an extension to -.ECO903	• Basics of corporate finance. • Capital Budgeting • Stock valuation • Return and Risk through systematic risk models • Cost of capital

				• Long-term financing
ECO909	Economics of Platforms	5	Digital platforms such as Amazon, Zomato, Uber, Netflix and Facebook have become an essential part of our life. This course is an attempt to systematically study the economics of these platforms, emphasizing their applications in Public Policy and Businesses.	• What are Platforms? • The Role of Ratings and Recommendations • A Primer on Network Goods • Platform or Not Platforms? • Platform Pricing • Platform Design
ECO910	ML Applications	5	This course will cover advanced Machine Learning (ML) algorithms for Economics, Finance and Public Policy. A variety of Machine Learning tools such as the Linear Regression, Logistic Regression, Support Vector Machines, Discriminant Analysis and several others will be studied followed by their rigorous analysis. Another important aspect of the program is to study data pre-processing techniques such as Principal Component Analysis for feature selection. Furthermore, other schemes will also be discussed for clustering, such as K-means, Probabilistic Clustering, Naïve Bayes and Decision Tree Classifiers. It is also intended to cover algorithms from modern Probabilistic Inference, Online Learning and Probabilistic Graphical Models to comprehensively analyze their performance. These will involve concepts such as Likelihood Maximization, Bayesian Learning and Independent Component Analysis.	• Linear Regression • Logistic Regression • Support Vector Machines • Linear Discriminant Analysis • Naive Bayes • Decision Tree Classifiers (DTC) • K-Means and Probabilistic Clustering • Principal Component Analysis

ECO911	Advanced Financial Econometrics	5	The primary objective of this course is to equip the students with various tools and techniques and their applications for better understanding and investment decisions. Through this course, the students will develop an ability to analyze the data by applying appropriate quantitative methods.	• Overview of financial econometrics, statistical foundations: data, the data, descriptive statistics and data summary, visualizing and describing data • Role of linear regression in financial data modeling, assumptions, violations, diagnostics two-stage procedures • Introduction to time series, autocorrelation and forecasting techniques. • Fixed effects and random effects and instrumentation process • Logit, Probit, Tobit and other variants and their applications • Monte Carlo simulations, Variance reduction techniques, bootstrapping and random number generation
ECO912	Probability and Stochastic Systems	5	An understanding of probability is critical to study a world replete with randomness and uncertainty. This course will give students tools needed to understand data, economics and finance. Students will learn not only how to solve challenging technical problems but also be exposed to various ways in which probability is applied in the real world.	• Probability • Random Variables • Limit Theorems • Markov Chains and Poisson Processes • Statistical Inference
ECO914	Contemporary Issues in the Indian Economy	5	The primary aim of this module is to equip the students with the knowledge of how the Indian economy functions. Basic concepts will be explained, along with exposure to relevant data. Policy implications will be discussed keeping in mind the latest developments in the Indian scenario.	• Introduction to basic macroeconomic indicators of the Indian economy • Budget analysis and fiscal frameworks • Sectoral understanding • Monetary and financial developments • Socio-economic analysis • External outlook
ECO915	Program	5	This course aims to equip the participants	• Overview of Causal Inference

	Evaluation		with principles and techniques for causal inference in social science. These tools and techniques find wide application in policy evaluation. This is particularly useful to the bureaucrats and industry experts involved in the grassroots-level monitoring and implementation of public policies.	• Foundations of Randomized Control Trial(RCTs) • Non-randomized designs (IV and DID) • Further topics (RDD, Synthetic control)
ECO916	Public Finance	5	The module covers different dimensions of public finance and is expected to provide a practical understanding of public finance from policy making to its implications. The model answers the why and how of public finance.	• Basics about public finance, understanding key terms: decentralization, taxes, deficits and debts, interventions, and regulatory role of the government • Utility maximization techniques – utility mapping and budget constraints, social welfare and social inefficiencies, and competitive equilibrium • Understanding relevant quant models in public finance • Introduction to government budgeting, fiscal rules, cash vs capital accounting, static vs dynamic scoring, short-run and long-run aspects of government • Externality theory – negative and positive aspects, public sector remedies to externalities, approaches of handling externalities, public goods – public and private provisions • Foundations of political economy, Lindhal pricing, preference aggregation, voter models, basics of public choice and fiscal federalism
ECO917	Project I	5	Project I	Capstone Project
ECO918	Innovation Systems and Policy	5	The course will delve into what it takes to develop a national innovation ecosystem- to make firms competitive at world-scale, move away from low technology to high-end technology, invest higher in R&D, public	• **Breaking the Middle Income Trap through Innovation** ○ Middle Income Trap; Moving from service to innovation led economy; Firm as a focal point of Innovation

			funding of research for private sector, using Indian demand as a leverage for innovation, prioritizing research in higher education system through Governmental funding, creating and leveraging large scale high quality researchers. The course also studies existing policy frameworks for innovation including the Nation S&T Policy, Startup India, Digital India and Make in India Programmes, Atal Innovation Mission and the gaps in the current National Innovation System. The course would also delve into innovation and technology demands of high tech areas of current interest including Semiconductors, Artificial Intelligence, Quantum, Minerals and Blue Economy. The Course will use Case Studies and practical experiences from the field to create insights and understandings.	• **Theoretical Perspectives**
				  ○ Blue Ocean-Red Ocean Strategy; Disruption Theory (Clay Christensen), Porters Porter's 5 forces of innovation and other theoretical frameworks
				• **Innovation Systems- Global Perspectives**
				  ○ Learnings from experiences of other countries (Japan, South Korea, China, US and others)
				• **India tasters innovation**
				  ○ India's successes in innovation IT, Healthcare and Biotech, Defense Case Study: Aadhaar, UPI, DEPA Case Study: iDEX
				• **Government Policies and Innovation**
				  ○ Leveraging India's Innovation Policy Framework- Make in India, Digital India, Startup India, Fund of Funds, Other Funding Programmes, Atal Innovation Mission, National S&T Policy, Venture Capital funds, Data sharing and open data initiative, tax structure and incentives, Government procurement etc.
				  ○ Case Study: Map Policy and the Drone Rules
				  ○ Case Study: Medical devices regulation-approval of Indian designed ventilator
				• **Technology trends and Innovation for leadership in emerging technologies**
				  ○ Why Critical and Emerging Technologies are important? Innovation in semiconductor, Artificial Intelligence, UAV, Quantum computing, Critical minerals and Deep Ocean technologies
				  ○ Case study: India Semiconductor Initiative.

				● **Innovation: Intellectual Property** ○ Protection of Intellectual Property, Balancing openness and protection Case Study: Mission Raksha Gyanshakti ● **Developing National Innovation Ecosystem** ○ Product Policy Framework Higher Education ○ Human Resource Development and Jobs ○ Financial Markets and Venture Capital Regulatory framework
ECO919	How to Read an Economy's Report-card	5	We encounter news on macroeconomic concepts like GDP, inflation, unemployment etc. every day in the newspapers and magazines of general interest. The objective of this course is to introduce students to look at macroeconomic data critically. Students will be introduced to the key macroeconomic concepts, followed by demonstration of the corresponding data. By the end of the course, students should be able to read and critically assess news pieces concerning macroeconomic concepts and articles from The Economist, The New York Times, Wall Street Journal, Financial Times etc.	● State of the economy ● Money, monetary policy, interest rates. ● Fiscal policy ● The external sector ● Social sectors and employment ● Inequality and poverty ● Institutions

Department of ELECTRICAL ENGINEERING (EE)

Programme Name : Artificial Intelligence and Machine Learning (AIML)

Module ID	Module Title	Credit	Description	Content

EE950	Data Analytics & Data Structures (DADS)	5	This course is a hands-on introduction to basic concepts in data analytics, data structures and visualization. The course provides the students with a comprehensive introduction to programming using Python and shell scripting, enabling them to work in a linux environment, access remote servers and effectively debug their code. Additionally, the course aims to extensively cover data structures, including their implementation, manipulation, and analysis, while also teaching concepts such as file I/O formats, data readers,data visualization techniques like t-SNE, and the concept of Big-O notation. By the end of the course, students will have gained the necessary knowledge and tools to analyze data effectively using Python and navigate the Linux environment.	• **Introduction and Preliminaries**
				  ○ Introduction to programming in python
				  ○ Shell scripting
				  ○ Working in Linux
				  ○ Accessing remote servers
				  ○ Debugging
				• **Data reading**
				  ○ File I/O formats
				  ○ Data readers
				• **Visualization**
				  ○ Data Visualization,
				  ○ t-SNE
				• **Data structures**
				  ○ Big-O notation
				  ○ Data structures

EE951	Introduction to Linear Algebra	5	This is an introductory linear algebra course that aims to provide students with a solid foundation in mathematical concepts and techniques relevant to machine learning. This course covers basic linear algebra topics such as vectors and matrices, singular value and other decompositions, solving systems of equations, linear independence, eigenvalue decomposition, and positive definite matrices.	• Vectors, vector operations, vector spaces, matrices, basic matrix operations, matrix multiplication • Inner products, norms, linear functions • Linear systems, LU and QR factorization • Singular Value Decomposition, Spaces associated with a matrix, • Linear independence, Basis and Dimension, • Solving Ax=b, Determinant,

				• Eigenvalues, Eigenvalue decomposition, Positive Definite Matrices • Matrix calculus

EE952	Introduction to Machine Learning	5	This course aims at introducing the students to Machine Learning techniques used for various engineering applications. The lectures will focus on mathematical principles and there will be coding based assingments for implementation, introducing students to tools such as sklearn and keras.	• **Introduction to Preliminaries**
				  ○ Classification,Regression,Reinforcement Learning
				  ○ Evaluation Measures
				  ○ Basic Probability Theory
				• **Linear Model**
				  ○ Linear Regression
				  ○ Linear Classification
				• **Unsupervised Learning**
				  ○ Clustering
				  ○ Gaussian Mixture Model
				  ○ And visualization
				• **Supervised Learning**
				  ○ Regression
				  ○ Image Classification
				• **Time series Processing**
				  ○ Time series Analysis
				  ○ Dynamic Time warping
				• **ML at Scale**
				  ○ Parameter Tuning
				  ○ Model selection
				  ○ Validation and testing

EE953	Basics of Optimization	5	This is an introductory optimization course that seeks to introduce the various unconstrained optimization methods widely used in machine learning, particularly training of supervised models.	• **Introduction and Preliminaries**
				  ○ Motivation
				  ○ Simple examples
				  ○ Local vs. global optimum
				  ○ Gradient of a function
				  ○ Numerical gradient
				• **Convexity**
				  ○ Convex Sets & functions
				  ○ Convex optimization problems

				○ Optimality Condition ● **Gradient Descent** ○ Narrative Optimization ○ Gradient descent ○ Line search ○ Momentum ● **Constrained Optimization** ○ Constrained optimization ○ Penalty methods ● **Stochastic Gradient Descent** ○ Stochastic gradient descent ○ Implementation aspects
EE954	Deep Learning Fundamentals	5	The objective of the course is to provide students with a solid foundation in the principles, algorithms and techniques of deep learning. The course aims to enable students to understand and apply deep learning models, architectures, and training methodologies to solve complex problems in various domains such as computer vision, natural language processing, and data analytics.	● **Introduction to Deep** ○ Overview of neural networks and deep Learning learning ○ Historical development and key milestones ○ Applications of deep learning in various domains ● **Artificial Neural Networks** ○ Perceptron and multilayer perceptron ○ Activation functions and feedforward propagation ○ Backpropagation algorithm and gradient descent ● **Optimization Algorithms** ○ Stochastic gradient descent (SGD) ○ Adaptive optimization methods (e.g., Adam, RMSprop) ○ Regularization techniques (e.g., dropout, LI/L2 regularization) ● **Convolutional Neural Networks CNNs** ○ Motivation and architecture of ○ Convolutional layers and pooling (CNNs) operations

				○ Training CNNs for image classification ● **Recurrent Neural Networks (RNNs) processing** ○ Introduction to sequential data processing ○ Architecture of RNNs and recurrent cells ○ Training RNNs for sequence modeling tasks ○ Long Short-Term Memory (LSTM) Networks ● **Generative Models** ○ Introduction to generative modeling ○ Variational Autoencoders (VAEs) ○ Generative Adversarial Networks (GANs) ● **Transfer Learning and Pretrained Models** ○ Introduction to transfer learning ○ Using pre-trained models for new tasks
EE955	Probability and Statistics for Machine Learning	5	This course aims to provide fundamentals of probability theory and statistics required for machine learning. It's Designed for machine learning students and aims to provide them with a solid mathematical foundation in probability theory and statistics essential for ML applications . The course covers the random variables, their distributions,statistics, and estimation.	● **Introduction** ○ Introduction to Probability ○ Random Variables ● **Distributions** ○ Distribution (CDF) ○ Probability Mass Function and Probability Density Function ○ Conditional Probability and Independence, The Law of Total Probability ○ Variance and the Expected Value, Covariance and Correlation ● **Examples of Probability Distributions** ○ Discrete RVs e.g. Bernoulli, Binomial,Poisson Distribution ○ Continuous RVs, e.g. Normal, uniform,

				Gamma. ○ Multivariate Distribution ● **Statistics** ○ Limit theorems, The Law of Large Numbers The Central Limit Theorem,Deviation ○ Descriptive Deviation ○ Bayesian Inference ○ Estimation of RVs, Maximum Likelihood Estimation, Maximum Likelihood Estimation for Gaussian Distributions ○ Confidence Intervals ○ Hypothesis Testing and P-Values ○ Chi-Square Test for Independence and Goodness of Fit
EE956	ML for Audio Processing	5	This course aims at introducing the students to machine learning (ML) techniques used for various audio processing applications. There will be spectral processing techniques for analysis and transformation of audio signals. The lectures will focus on mathematical principles, and there will be coding based assignments for implementation.	● **Introduction to speech and music** ○ Speech and languages ○ Music: Indian and western ● **Digital signal processing** ○ Digital signal processing basics ○ Fourier Transforms ○ Pitch and melody ● **Machine Learning Review** ○ Machine Learning basics ○ Neural Networks (Dense, CNN, RNN,LSTMs) ● **Audio Classification** ○ Audio embeddings ○ Radio Scene Classification ● **Automatic Speech Recognition (ASR)** ○ Acoustic and Language models ○ GMM-HMM based ASR ○ DNN-HMM based ASR ○ End-to-end deep ASR ● **Music Information Retrieval**

				○ Music transcription ○ Music tagging ● **Audio Search** ○ Embeddings and Hashing ○ Search methods
EE957	Computer Vision	5	This course provides an introduction to the field of computer vision, focusing on the fundamental concepts, algorithms and applications. Students will learn about image processing, feature extraction, object detection, recognition and tracking. The course will also cover deep learning techniques for computer vision tasks. Through lectures, programming assignments students will gain hands-on experience in developing computer vision applications.	● **Introduction** ○ Overview of computer vision ○ Applications of computer vision ○ Basic image processing operations ○ Image restoration ○ Image filtering ○ Image enhancement ● **Perception from visual data** ○ Image classification ○ Image segmentation ○ Object recognition and detection ○ Object Tracking ○ Motion-based tracking ○ Feature-based tracking ● **Image generation** ○ Image stitching and panorama creation ○ Image-based lighting ○ Generative AI ○ Stereo vision ○ Depth estimation ○ Structure from Motion (SfM) ● **Applications** ○ Video analysis ○ Facial recognition ○ Human pose estimation ○ Medical image analysis ○ Autonomous vehicles
EE958	Natural Language	5	Natural language(NL) refers to the language spoken/written by humans. NL is the primary	● **Introduction** ○ Introduction

	Processing		mode of communication for humans. With the growth of the world wide web, data in the form of text has grown exponentially. It calls for the development of algorithms and techniques for processing natural language for the automation and development of intelligent machines. This course will primarily focus on understanding and developing techniques, statistical learning algorithms and models for processing language. We will have a statistical approach towards natural language processing, wherein we will learn how one could develop natural language understanding models from statistical regularities in large ·corpora of natural language texts while leveraging linguistics theories.	○ Why is NLP hard? ○ Linguistics fundamentals ● **Language Models, tagging, and parsing** ○ Language Models: n-grams, smoothing, class-based, brown clustering ○ Sequence Labeling: HMM, MaxEnt,CRFs, related applications of these models e.g. Part of Speech tagging, etc. ○ Parsing: CFG, Lexicalized CFG, PCFGs,Dependency parsing ● **Applications** ○ Named Entity Recognition, ○ Coreference Resolution, ○ text classification, ○ toolkits e.g. Spacy etc ● **Advanced Topics** ○ Distributional Semantics: distributional hypothesis,vector space model etc. ○ Distributed Representations: Neural Networks (NN), Backpropagation,Softmax, Hierarchical Softmax ○ Word Vectors: Feedforward NN,Word2Vec, GloVE, Contextualization(ELMo, etc.), Subword information (FastText etc.) ○ Deep Models: RNNs, LSTMs, Attention,CNNs, applications in language etc. ○ Sequence to Sequence models:machine translation and other applications ○ Transformers: BERT, transfer learning,and applications

				○ Graph Neural Networks: basic architecture, GCN, and applications
EE959	ML with Large Datasets	5	This is an introductory optimization course that seeks to introduce the various unconstrained optimization methods widely used in machine learning, particularly training of supervised models	● **Introduction and spark Preliminaries** ○ Distributed Computing, databricks ○ Visualization, dimensionality reduction ○ Distributed linear regression ● **Basic algorithms** ○ Kernel approximations ○ Logistic regression, hashing ○ Distributed trees ● **Deep Learning** ○ Deep learning, automatic differentiation ○ Large Scale Optimization ○ Optimization for DL ○ Hyperparameter tuning ● **Distributed learning** ○ Parallel distributed DL ○ Federated Learning ● **Advanced Topics** ○ Neural architecture search ○ Model compression
EE960	AI in IoT	5	The objective of the course is to equip students with the knowledge and skills to effectively apply artificial intelligence techniques in the context of Internet of Things (IoT)systems. By covering the basics of IoT communication and security aspects alongside AI applications, the course aims to enable students to design, develop, and deploy intelligent IoT solutions that leverage the power of AI algorithms and models.	● **Introduction to IoT** ○ New Trends and applications ○ IoT architecture ○ Middleware ○ Fog computing ○ Sensors and actuators ● **IoT Communications and Sensor Networks** ○ NFC, RFID ○ Bluetooth, Zigbee, Wifi ○ MQTT, HTTP ○ Network Topologies ○ Challenges, Routing and optimization ● **IoT Security**

				○ Device security ○ Communication Security ○ Digital Forensics ● **AI in IoT** ○ Smart Cities ○ Healthcare ○ Agriculture ○ Manufacturing
EE961	AI in Healthcare	5	This course explores the applications of artificial intelligence (AI) in the healthcare domain. Students will learn about the fundamental concepts of AI, machine learning and deep learning and how they are applied to various healthcare tasks. The course will cover topics such as medical image analysis, clinical decision systems, electronic health records and personalized medicine.	● **Introduction** ○ Overview of AI and its impact on healthcare ○ Ethical considerations in AI-driven healthcare ○ Challenges and opportunities in AI adoption ○ Machine learning fundamentals ● **Visual data analysis in medical domain** ○ Feature engineering and feature selection for medical domain ○ Introduction to medical imaging modalities (e.g., X-ray, MRI) ○ Image data formats in medical domain ○ Image segmentation and feature extraction ○ Deep learning for medical image analysis ○ Instruments and sensor analysis in medical domain ● M**L and rule based disease diagnosis** ○ Role of AI in clinical decision making ○ Rule-based systems and expert systems ○ Machine learning models for diagnosis and prognosis

				○ Explainability and interpretability in clinical decision support ● **Healthcare records processing and robotics in healthcare** ○ Overview of electronic health records ○ Data mining techniques for EHR analysis ○ Predictive modeling using EHR data ○ AI approaches in drug discovery and development ○ Virtual screening and molecular docking ○ Genomic data analysis and personalized medicine ○ Robotics applications in surgery and Rehabilitation ○ Surgical planning and assistance systems ○ Human-robot interaction in healthcare settings
EE962	Industrial AI and Automation/ AI in Industry and Automation	5	This course explores the applications of artificial intelligence (AI) in industrial settings and automation processes. Students will learn about the use of AI techniques such as machine learning, robotics, sensory data and image processing in various industries. The course will cover topics such as smart manufacturing, predictive maintenance, supply chain optimization and intelligent automation. Through lectures, case studies and hands-on assignments students will gain an understanding of how AI is transforming industries and enabling efficient and intelligent automation.	● **Introduction to AI in Industry and Automation** ○ Overview of AI and its impact on industries ○ Role of automation in industrial processes ○ Challenges and opportunities in adopting AI in industry ● **Robotics and automation** ○ Introduction to Industrial Robotics ○ Robot kinematics and dynamics ○ Robot control systems and Programming ○ Collaborative robots and human-robot interaction

				• **Industry 4.0**
				  ○ Concepts of smart manufacturing and Industry 4.0
				  ○ AI-enabled quality control and defect detection
				  ○ Predictive maintenance and condition monitoring
				  ○ Digital twin technology and virtual Commissioning
				• **Future trends and emerging applications**
				  ○ Optimization of supply chain processes
				  ○ Demand forecasting using AI techniques
				  ○ Route optimization and fleet Management
				  ○ Warehouse automation and inventory management
				  ○ Cognitive automation and decision support systems
				  ○ Workflow automation and business process optimization
				  ○ Fraud detection and risk assessment using AI
				  ○ Algorithmic trading and portfolio Management
				  ○ Chatbots and virtual assistants in Banking
				  ○ AI in agriculture and food production
				  ○ AI in transportation and autonomous vehicles

EE963	Reinforcement Learning	5	In this course we will explore how an agent (via interactions with the environment) can learn by trial and error. This is quite different from supervised machine learning and comes close to how humans learn by interactions.	• **Introduction**
				  ○ RL task formulation
				  ○ Action space, state space, environment
				• **Dynamic Programming**
				  ○ Tabular based solution

			Reinforcement Learning (RL) deals with problems that require sequential decision making. This course will explore foundations of reinforcement learning. We will study different algorithms for RL and later in the course we will explore how functional approximation in RL algorithms could be done using neural networks giving rise to deep reinforcement learning.	○ Dynamic Programming ○ Monte Carlo ○ Temporal Difference ● **Functional Approximation and Deep RL** ○ Value based Deep Reinforcement Learning : Functional Approximation in RL, NFQ (Neural Fitted Q Iteration), DQN (Deep Q- Network), Double DQN,Dueling DDQN, PER (Prioritized Experience Replay) ○ Policy Based and Value Based Algorithms: REINFORCE, Vanila Policy Gradient (VPG), A3C {Asynchronous Advantage Actor Critic), Generalized Advantage Estimation {GAE),Advantage Actor-Critic {A2C), SARSA ○ Advanced Actor Critic: DDPG {Deep Deterministic Policy Gradient), TD3(Time Delayed DDPG), SAC {Soft Actor Critic), PPO (Proximal Policy Optimization) ● **Advanced Topics** ○ Model-based RL ○ Imitation Learning ○ Meta-Learning ○ Multi-agent Learning ○ POMDP
EE964	Project	5	The goal of this module is to have the students do an industry-relevant project in a topic related to machine learning. A module may have one or more instructors, who will decide the topics of the projects in consultation with the enrolled instructors.	● Sentiment analysis ● Advanced image classification ● Fraud Detection ● Recommendation Systems ● Spam Email Classification ● Disease Diagnosis ● Stock Price Prediction

			The project will typically involve design and development of a novel ML model or algorithm. A specific project may be split across at most two modules.	• Object Detection • Facial Emotion Recognition • Natural Language Generation
EE965	Unsupervised Learning	5	The objective of this course is to introduce the students to unsupervised machine learning techniques used for various engineering applications. The students will gain the skills to extract valuable insights from datasets lacking a specified target or labeled variable. The lectures will focus on underlying mathematics principles as well as application problems in various domains. The Students will also be introduced to unsupervised learning libraries such as sklearn.	• Introduction and K-means Clustering • Hierarchical and Spectral Clustering • Dimension Reduction- Linear and Nonlinear • Matrix Factorization, NMF optimization • Graphical Models, Bayesian Networks, Markov Random Fields • Mixture Models and EM • Approximate Inference

Programme Name: Next Generation Wireless Technologies (NGWT)

***Initially Communication System (COMM)**

Module ID	Module Title	Credit	Description	Content

EE900	Applied Linear Algebra for Wireless Communic	5	Linear Algebra for communication, signal processing and ML modules are required to design, analyze and optimize state-of-the-art wireless systems. The objective of this module is to teach linear	• **Introduction to Vectors**
				  ○ Vectors and Linear Combinations
				  ○ Length and Dot Products
				  ○ Matrices
				• **Solving Linear Equations**

	ations		algebra concepts which are applicable to such wireless communication systems.	○ Vectors and Linear Equations ○ Idea of Elimination ○ Elimination Using Matrices ○ Rules for Matrix Operations ○ Inverse Matrices ○ Transposes and Permutations ● **Vector Spaces and Subspaces** ○ Spaces of Vectors ○ Nullspace of a matrix ○ Complete solution of a system of equation ○ Independence, Basis and Dimensions ○ Dimensions of the Four Subspaces ● **Orthogonality** ○ Orthogonality of the Four Subspaces ○ Projections ○ Least Squares Approximations ● **Determinants** ○ Properties of Determinants ○ Permutations and Cofactors ● **Eigenvalues and Eigenvectors** ○ Introductions to Eigenvalues ○ Diagonalizing a matrix ○ Symmetric matrices ○ Positive Definite matrices ● **Singular Value Decomposition** ○ Bases and matrices
EE901	Probability and Random Processes	5	This module will focus on strengthening the foundation of probability keeping its application in communications in mind. It discusses the concepts of probability space, random variables, their CDF and PDF/PMF, functions of random variables, random variable transformations, the Law of Large Numbers and random	● Introduction to probability theory ● Introduction to Probability and Probability Space ● Properties of Probability Measure ● Random Variables ● Distribution of Random Variables ● CDF and PDF/PMF, Continuous and Discrete Random Variables, Examples of Random Variables ● Expectation and Moments ● Variance, MGF

			processes.	• Functions of Random Variables • Transformation of discrete random variables • Transformation of continuous random variables • Multiple Random Variables • Random Variable Transformation • Sampling of random variable and empirical statistics using computer simulations • Conditional Expectation Distribution • Limit Theorems • Law of Large Numbers, Central Limit Theorem, Deviations • Introduction to Random Processes and Examples • Distribution of Random Processes • Random Processes via Linear Systems

EE902	Advanced ML Techniques for Wireless Technology	5	This module will cover advanced Machine Learning (ML) algorithms for Wireless Communication. A variety of Machine Learning tools such as the Linear Regression, Logistic Regression, Support Vector Machines, Discriminant Analysis and several others will be studied, followed by their rigorous analysis. Another important aspect of the program is to study data pre-processing techniques such as Principal Component Analysis for feature selection. Furthermore, other schemes will also be discussed for clustering, such as K-means, Probabilistic Clustering, Naïve Bayes and Decision Tree Classifiers. It is also intended to cover algorithms from modern Probabilistic Inference, Online Learning and Probabilistic Graphical Models to comprehensively analyze their	• **Linear Regression**
				  ○ Regression applications,
				  ○ Nomenclature,
				  ○ Problem formulation and solution,
				  ○ Online learning
				• **Logistic Regression**
				  ○ Logistic function,
				  ○ Parametric modeling,
				  ○ Likelihood maximization,
				  ○ Online learning for parameter estimation
				• **Support Vector Machines**
				  ○ SVM applications,
				  ○ Parallel hyperplanes,
				  ○ Maximum margin classifier,
				  ○ Soft classifier
				• **Linear Discriminant Analysis**
				  ○ Multivariate Gaussian modeling,
				  ○ Likelihood Ratio test,
				  ○ Discriminant function
				• **Naïve Bayes**

			performance. These will involve concepts such as Likelihood Maximization, Bayesian Learning, and Independent Component Analysis.	○ Discrete feature vectors, Naïve ○ Bayes assumption, ○ Calculation of posterior probabilities, ○ Laplacian smoothing ● **Decision Tree Classifiers(DTC)** ○ DTC structure, ○ choice of best attribute, ○ Concept of Entropy, ○ Mutual Information or Information Gain ● **K-Means and Probabilistic Clustering** ○ Unsupervised learning, ○ K-Means procedure, ○ EM Algorithm, ○ Soft clustering ● **Dual SVM, Probabilistic Graphical Models** ○ Dual SVM, ○ Kernel SVM, ○ Bayesian networks, Factorization of PDF, ○ Bayesian inference over graphs
EE903	Machine Learning for Signal Processing	5	This module aims at introducing machine learning (ML) techniques used for various signal processing applications. There will be spectral processing methods for the analysis and transformation of signals. The lectures will focus on mathematical principles, and there will be coding-based assignments for implementation. Prior exposure to ML is not required. Intuitive understanding and illustrative examples will be provided for an easy grasp of the principles.	● **Digital Signal Processing basics** ● **Machine Learning basics** ○ Supervised Machine Learning ○ Model Evaluation ● **Linear Regression and Classification** ● **Neural Networks** ● **Programming Tools: Tensorflow and Keras** ● **Unsupervised Machine Learning** ● **Gaussian Mixture Models** ● **Some Applications in Signal Processing (time permitting)**
EE904	Deep Learning	5	Recently, the deep learning techniques have become popular and widely used in	● Introduction and applications of AI, ML and DL ● DL applications and concepts in communications

	for Communications		industrial applications, autonomous driving, robotics and automation, healthcare, disease diagnosis and finding its applications in communication engineering. Its impressive image generation ability has found application in art, paintings and ancient image recovery. This module will cover deep learning, machine learning methods and their applications in communications. Deep learning for communications is a novel field that offers many attractive interdisciplinary research areas at the interface between information theory, machine learning and communications engineering.	• Mathematical basics for ML • Regression and Classification • Neural networks and optimization algorithms • Convolutional neural networks • State of the art CNN architectures • Feature representation and learning • Programming demo application (python) • Ground penetrating radars and applications • Input signals representation and classification (audio, image) • Millimeter-waves and object detection • Load balancing and optimal resource allocation • Optical communication and pattern recognition • Wi-Fi and indoor localisation • AI for satellite communication
EE905	Detection and Estimation Theory	5	The goal of this module is to introduce the fundamentals of detection and estimation. The module will cover several applications from signal processing and communications, also.	• Structure of statistical reasoning, Introduction to Estimation theory, • Review of Random variables, vectors, processes, and their statistical description, • Estimation: Minimum Variance Unbiased Estimator, Cramer Rao Lower Bound (CRLB) for scalar and vector parameters, Estimation: Maximum Likelihood Estimation (MLE), Maximum Aposteriori Estimation (MAP), Linear Least Squares (LLSE) with examples of Gaussian mixture modeling (GMM) and Hidden Markov Modeling (HMM), • Detection: Introduction, Neyman Pearson theorem, Binary and Multiple hypothesis testing, Examples, Spectrum Estimation: Non-Parametric (Periodogram, Welch methods) and Parametric (MVDR method).
EE906	Speech and Audio	5	This module aims to introduce the students to topics in automatic speech	• Linear Algebra Refresher • Probability Theory Refresher

	Coding for Communication		and audio processing.	• Digital Signal Processing Refresher • Psychoacoustic principles • Linear Predictive Coding • Filter Bank Representations • Cepstral Representations • Audio quantization and bit allocation • Audio coding standards: MPEG
EE907	Basics of Convex Optimization	5	Convex optimization has recently been applied to a wide variety of problems in EE, especially in signal processing, communications, and networks. The aim of this module is to train the students in application and analysis of convex optimization problems in signal processing and wireless Communications. At the end of this module, the students are expected to: • Be able to recognize convex optimization problems arising in these areas. • Be able to recognize 'hidden' convexity in many seemingly non-convex problems; formulate them as convex problems.	• Background on Linear Algebra • Convex Sets • Convex functions • Convex Optimization Problems, Linear Programs, Quadratic Programs, SOCP • Duality theory, KKT conditions • Semidefinite Programming
EE908	Convex Optimization in SPCOM	5	Convex optimization has recently been applied to a wide variety of problems in EE, especially in signal processing, communications and networks. The aim is to train the students in the application and analysis of convex optimization problems in signal processing and wireless communications.	• Background on Linear algebra (Inner Product, Norm, EVD, SVD) • Affine sets, convex sets, cones • Convex functions, zeroth, first and second order conditions for convexity • Convex optimization problems, change of variables, LP, QP • Second order cone programming, Robust optimization • Lagrange duality, KKT conditions

				• Conjugate functions, Linear Fractional Programming • Zero Sum Games • Geometric Programming and applications in power control • Schur's complement, Linear matrix inequality, SDP • Semidefinite relaxation

EE909	Estimation for Wireless Communications	5	This module covers principles of estimation theory and algorithms for wireless communication systems. Estimation theory provides a large variety of tools and techniques that are widely applied in the design and implementation of 4G/5G wireless systems. Various signal processing procedures in communication systems, such as channel estimation, equalization, synchronization etc. which are also employed in MIMO (Multiple-Input Multiple-Output) and OFDM (Orthogonal Frequency Division Multiplexing) based 3G/ 4G wireless systems, are based on fundamental concepts in estimation theory. Further, recent research developments in areas such as Wireless Sensor Networks (WSNs) also employ several tools from estimation theory towards distributed parameter estimation, etc. Therefore, principles of estimation are naturally of significant interest in research and industry, which will be introduced in this module.	• **Introduction and Maximum Likelihood**
				  ○ Basics of Estimation,
				  ○ Maximum Likelihood (ML)
				  ○ Application: Wireless Sensor Network
				  ○ Reliability of Estimation
				• **Application in wireless systems channel estimation**
				  ○ Application: Wireless Fading Channel
				  ○ Estimation, Cramer-Rao Bound for Estimation
				• **ML for vector parameters**
				• **Vector ML applications**
				• **MMSE Principle for scalar parameters**
				• **MMSE for vector parameters**
				• **Application of MMSE for OFDM channel**
				• **Application of MMSE for MIMO Channel**

EE910	Digital	5	The fundamentals of digital	• **Introduction**

	Communication Systems I		communication systems, emphasizing the physical layer aspects of communications. The module discusses, among other topics, modulation techniques and optimum receivers for the AWGN channel. The module will give tools to analyze and characterize the performance of digital communication systems.	○ An introduction to digital communication ○ Communication channels and models ○ Review of signals ○ Representation of lowpass and bandpass signals ● **Mathematical preliminaries** ○ Signal space representation of waveforms ○ A brief introduction to random variables ○ Complex Random variables ○ A brief introduction to random processes ● **Memoryless modulation** ○ Digital Modulation: An Introduction ○ Pulse Amplitude Modulation, Phase Shift Keying, and Quadrature Amplitude Modulation ○ Orthogonal, bi-orthogonal, and simplex signaling ● **Modulation with memory** ○ Continuous Phase Frequency Shift Keying ○ Continuous Phase Modulation ● **Optimum receivers for AWGN channels** ○ Optimal Detection fort a vector AWGN channel ○ Waveform and vector AWGN channels ○ Optimal Detection for Binary Antipodal Signaling ○ Correlation Receiver, Matched Filter Receiver ● **Probability of error computation for coherent detection** ○ Optimal detection and error probability for ASK or PAM, and PSK signaling. ○ Optimal detection and error probability for QAM signaling ○ Optimal Detection and error Probability for Orthogonal,Bi-Orthogonal and Simplex

				Signaling . . ● **Noncoherent detection** ○ Noncoherent detection of carrier modulated signals ○ Error Probability of Orthogonal signaling with noncoherent detection ○ Differential Phase Shift Keying ● **Detection of signals with memory** ○ Maximum likelihood sequence estimator: .viterbi Algorithm ○ Optimum receivers for CPM signals
EE911	Data Communication Networks	5	This module gives a first introduction to networked systems and the Internet. The goal is to provide some insight into the reasons behind the architecture of the modern-day networks and the principles of designing reliable networked systems.	● Computer networks and the Internet, fundamentals of circuit and packet switching, ● Network simulation using Netsim, packet capture using Wireshark, ● Application layer, Transport layer, Network layer, Routing algorithms, Link layer, ARQ protocols, Error detection and correction, Medium access control protocols, ● Wireless networks and mobility
EE912	Simulation Techniques for Modern Wireless	5	Numerical evaluation is a quick way to evaluate complex systems where analysis is difficult. Most of the telecommunication industry relies on simulations to test their methodology. Academicians use simulation to validate their analysis and extend their results for complex systems. This module will focus on simulation methodologies in the field of communication with a great focus on their actual implementations. The module is a balanced version of theory and implementation. It would discuss fundamental tools in numerical	● **Introduction to** ○ Introduction to ○ Introduction to Simulation Methodology ● **Signal/Systems** ○ Representation of Signals ○ Representation of Systems ● **Random Signals** ○ Random Variables ○ Random Signals ● **System Dynamics** ○ Numerical Techniques ○ Differential Equations and Markov Chains ● **Monte-Carlo Simulations** ● **Link Level Simulation**

			techniques and their applications to communications.	○ Simulation of a communication channel-I ○ Simulation of a communication channel-II ○ Wireless Channel -I ○ Wireless Channel -II ● **Advanced Link Level Simulation** ○ Advanced Modulation ○ MIMO ● **System Level Simulation** ○ Mobile Ad-hoc Networks ○ Cellular Networks ○ Millimeter wave and THz Networks
EE913	Foundations of Information Theory and Data Compression	5	In this module, we will answer two fundamental questions in communications that information theory answers, namely, what is the ultimate data rate at which we can reliably communicate over a channel, and what is the ultimate data compression that we can achieve. In addition to theory, we will also cover practical compression algorithms.	● Introduction: Entropy, Relative Entropy, Mutual Information; Information Inequalities ● Block to variable length coding: Kraft's inequality.Shannon- Fano coding, Huffman coding, adaptive Huffman coding; ● Variable to block length coding: Tunstall coding; Block to block length coding: Typical sequences; ● Variable to variable length coding-I: Arithmetic codes, LZ77, LZ78, LZW algorithms. ● Asymptotic Equipartition Property. ● Coding for sources with memory. ● Image Compression: Discrete Cosine Transform, JPEG.
EE914	Error Control Codes: Theory and Practice	5	In this module, students will study the design of error-correcting codes for applications in communication systems. In particular, the students will study the theory of design of linear block codes and convolutional codes with examples from the current state of the error correcting codes such as turbo codes, LDPC codes, and polar codes.	● **Introduction to Error Control Coding** ○ Introduction ○ Decoding Strategies ● **Linear Block Codes** ○ Linear Block Codes: An Introduction ○ Decoding of linear block codes ● **Linear Block Codes: Examples & Distance Properties** ○ Distance properties of linear block codes ○ Some linear block codes

				○ Reed-Muller codes ● **Convocational Codes** ○ Convolutional Codes:An Introduction ○ State Diagram & Trellis Diagram ○ Classification of convolutional encoder ○ Realization of convolutional encoder ● **Decoding of Convolutional Codes** ○ Viterbi decoding ○ BCJR algorithm ● **Turbo Codes** ○ Turbo codes: An introduction ○ Turbo Decoding ● **LDPC Codes** ○ Low-density parity-check codes: An introduction ○ Decoding of low-density parity check codes-I: Bit Flipping Algorithm ○ Decoding of low-density parity check codes-II: Belief Propagation Algorithm ● **Polar Codes** ○ Polar codes: An introduction ○ Decoding of polar codes-I: Successive cancellation decoder ○ Decoding of Polar codes-II: Successive cancellation list decoder
EE915	PYTHON-Based Machine Learning Simulation for Wireless Systems	5	As part of the course, Students will participate and successfully complete several PYTHON-based projects and case-studies on key ML techniques such as Linear Regression, Logistic Regression , Support Vector Machines, Linear Discriminant Analysis, Principal Component Analysis and other.Students will also develop the skills to effectively use integrated development	● **Introduction to PYTHON libraries,ML Packages, Principal Component Analysis (PCA) :** Introduction to PYTHON Libraries and PCA algorithm, Project1: PCA -Based Clustering ● **Linear Regression**Regression applications, Problem formulation and solution , Project2: PYTHON-Based Regression ● **Logistic Regression :** Logistic function, Likelihood Maximization , Project3: PYTHON for Logistic Regression

			environments (IDEs) in PYTHON for tackling more extensive ML projects in the future.	• **Support Vector Machines:** SVM application, Maximum margin classifier, Kernel SVM, Project4: PYTHONProject for SVC • **Naive Bayes:** Discrete feature vectors, Naive Bayes assumption, Calculation of posterior probabilities, Project 5: Naive Bayes Classification using PYTHON • **Linear Discriminant Analysis:** Multivariate Gaussian Modeling, Likelihood Ratio test , Project 6: PYTHON-based LDA • **Decision Tree Classifiers (DTC):** DTC structure, Mutual Information or Information Gain, Project 7: Building a Decision Tree Classifier using PYTHON • **K-Means and Probabilistic Clustering:** Unsupervised learning, K-Means procedure, Project 8: Clustering Analysis using PYTHON

EE916	Digital Communication Systems II	5	In this module, we will cover the fundamentals of digital communication systems, emphasizing the physical layer aspects of communications. Our focus will be on signal design and Communication through band-limited channels and Communication over multipath fading channels in the second part of the module. Theory and practice of 5G wireless communication systems.	• **Communication over Bandlimited Channels-I**
				  ○ Signal Design for Bandlimited Channels: The Nyquist Criterion for No ISI
				  ○ Partial-Response Signals
				  ○ Data Detection for Controlled ISI.
				• **Communication over Bandlimited Channels-II**
				  ○ Probability of Error for Detection of M-ary PAM Signaling Using Partial Response Signals
				  ○ Signal Design for Channel with Distortion
				  ○ Optimum Receiver for Channels with ISI and AWGN
				• **Equalization-I**
				  ○ Linear Equalization: Zero Forcing Criterion
				  ○ Linear Equalization: Minimum Mean Square Error Criterion
				  ○ Decision-Feedback Equalization
				  ○ Equalization at the Transmitter=Tomlinson-

				Harashima Precoding ● **Equalization-II** ○ Adaptive Equalizer: LMS Algorithm ○ Adaptive Equalizer: RLS Algorithm ● **Communication over Fading Channels-I** ○ Characterization of Fading Multipath Channels ○ Signal Propagation Characteristics ○ Types of Fading ○ Simulation of Fading Channels ● **Communication over Fading Channels-II** ○ Optimum Receivers for Fading Channels Under Different Conditions such as ○ Optimum Receivers for Fading Channels Under Different Conditions such as ● **Synchronization-I** ○ Carrier Recovery and Symbol Synchronization in Signal Demodulation ○ Maximum-Likelihood Carrier Phase Estimation ○ Phase-Locked Loop ● **Synchronization-II** ○ Decision-Directed PLL ○ Non-Decision-Directed Loops ○ Maximum-Likelihood Timing Estimation ○ Non-Decision-Directed Timing Estimation ○ Joint Estimation of Carrier Phase and Symbol Timing
EE917	PYTHON-Based Simulation, Design and Analysis of Wireless	5	As a part of this module, students will participate and successfully complete several PYTHON-based projects on key 4G/5G wireless technologies such as Multiple-Antenna Systems, OFDM, MIMO, MIMO-OFDM in significant detail. Students will also be introduced to	● **Introduction to PYTHON** ○ Introduction to PYTHON Programming and Packages for Simulation and Analysis of Communication Systems. ● **Wireless channel modeling and digital system simulation** ○ PYTHON-Based Wireless Channel

	Systems		various concepts from a practical perspective, such as beamforming, channel estimation, optimization, detection, and bit-error-rate (BER) performance. In these projects, students will also gain exposure to a variety of Python libraries and develop the skills to effectively use integrated development environments (IDEs) for tackling more extensive projects in the future.	Modeling and Analysis. ○ PYTHON-Based Digital Comm. System Simulation and Performance. ● **Wireless system simulation and analysis** ○ PYTHON-Based Wireless System Simulation and Performance. ● **Multiple antenna systems, beamforming, diversity and BER performance** ○ PYTHON-Based MRC Beamforming for Multi-Antenna Systems. ○ PYTHON-Based EGC and Selection Combining for Multi-Antenna Systems. ● **MIMO systems – Transceiver design and Analysis** ○ PYTHON - Based MIMO ZF/MMSE Receive Design ○ PYTHON- Based MIMO ML Receiver Design. ● **MIMO optimization for rate maximization, MIMO channel Estimation** ○ SVD-Based MIMO optimization. ○ PYTHON - Based MIMO channel estimation – ML and MMSE estimators. ● **Orthogonal Frequency Division Multiplexing (OFDM) Simulation** ○ PYTHON-based 4G/ 5G OFDM System ● **High-Speed MIMO OFDM technology for 4G and 5G** ○ PYTHON-based Project for Simulation and Performance of 4G/5G MIMO-OFDM Technology.
EE920	Wireless Communication	5	The module has both theoretical and practical flavours. It aims to explain the fundamental concepts and insights behind the development of modern 4G/	● AWGN channel modeling, SNR concept and BER performance for BPSK, QPSK and higher order modulations ● Fading channel models, BER analysis, Deep fade

			5G wireless communication technologies such as OFDM, MIMO, and Multi-user MIMO.	• Multiple antenna systems, Beamforming and diversity concepts • MIMO Technology, Linear Receivers ZF, MMSE and performance • SVD, Precoding/Combining in MIMO, Optimal Power Allocation, Space Time Block Codes • Single carrier vs. Multi Carrier implementation, IFFT/ FFT receivers in OFDM, Cyclic prefix and circular convolution • MIMO OFDM system model, transmission/ reception and receiver structure • Wireless channel models, delay spread, frequency selective/frequency flat channels, mobility and Doppler modeling
EE921	MIMO Wireless Communication	5	This module will cover state-of-the-art multiple-input multiple-output (MIMO) wireless transmitter and receiver designs which are being used in the 5G cellular systems.	• Review of mathematical basics: Linear algebra and information theory • Wireless communication basics: Capacity of single-antenna wireless channels • Single-cell single-user MIMO: Full transmit and receive channel state information (CSI), Capacity and transceiver design, Receive CSI alone • Capacity and transceiver design • Linear and non-linear ZF/MMSE receivers • Space-time coding, Diversity concepts
EE922	Simulation-Based Design of 5G-NR Wireless Standard	5	Students normally have good theoretical background in wireless communications systems, but negligible exposure on the use of this theory to design practical wireless systems. Many jobs in the wireless communication industry require design of standards-based practical wireless systems. The main objective of	• **5G-NR transmission structure:** ○ use cases – eMBB (enhanced Mobile Broadband), mMTC (massive Machine Type Communications) and URLLC(Ultra-Reliable Low-Latency Communications) ○ 5G Spectrum, ○ Principles of adaptive modulation and

			this module is to bridge the gap between the theory and practice of 5G NR wireless communication systems, and consequently, the gap between the academia and the industry. This module will teach: i) Underlying concepts of 5G NR transceiver blocks. ii) How to read the 5G NR standard documents to understand the transceiver specifications. Students will then design and simulate a 5G NR-compliant wireless system in MATLAB. The module, therefore, involves a MATLAB coding component, which will also be considered for evaluation.	coding ○ ARQ and HARQ protocols, frame structure ● **5G-NR Transport-Channel Processing** ○ Notion of transport block (TB), ○ CRC generation for TB, code block segmentation, ○ LDPC coding ideas, rate matching, ○ crumbling, modulation, baseband passband representation, Resource Mapping ● **Reference Signal Design 5G-NR Initial Access** ○ Cell-specific reference signal ○ Demodulation reference signal ○ Concept of synchronization signals and broadcast channels.
EE923	Analysis of Wireless Systems	5	This module will cover tools from stochastic geometry to model and analyze modern wireless systems being used in 4G and 5G systems. After completion of the module, the students should be able to apply mathematical tools from stochastic geometry in their own research to analyze modern wireless Systems.	● Need to analytical frameworks, Poisson point process, Boolean Models, Campbell theorem, Probability generating functional, Marked Point process, ● Performance analysis: SINR and rate coverage, System level analysis of MANET, Analysis of downlink cellular network, uplink networks, ● Modeling blockages via Boolean models, Modeling of Cyber-Physical Systems, ● System level analysis of millimeter (mmWave) and TeraHertz (THz) networks, ● System level analysis of Visible light communication
EE924	Advanced Modulation	5	This module will cover modern modulation and multiple access	● **OFDM** ○ Evolution of cellular communications,

	and Multiple Access for Next Generation Wireless Systems		schemes that are potential candidates for futuristic communication systems.	Orthogonal Frequency Division Multiplexing (OFDM), Peak-to-Average Power Ratio Reduction in OFDM System, Phase Noise in OFDM ● **FBMC and GFDM** ○ Filter Bank Multicarrier Modulation (FBMC), OQAM, Block Spread FBMC, Pruned DFT-Spread FBMC-OQAM,universal filtered multicarrier modulation (UFMC), Spectrally precoded OFDM (SP-OFDM) Generalized Frequency Division Multiple Access ● **OTFS** ○ Orthogonal Time Frequency and Space (OTFS), waveform design for OTFS, OTFS with index Modulation, signal detection, performance evaluation, STBC-OTFS, SM-OTFS, OTFS-OMA, OTFS-NOMA, Zak Transform Perspective of OTFS ● **NOMA** ○ Non-Orthogonal Multiple Access, Downlink and Uplink NOMA, MIMO-NOMA, Cooperative NOMA, NOMA in HetNets, NOMA in Millimeter Wave Communications, NOMA in Cognitive Radio Networks, NOMA based D2D communications ● **SCMA, LDSMA and GFMA** ○ Sparse Code Multiple Access (SCMA): Codebook design, Decoder design Grant-Free SCMA: Collision Resolution,

				Low-Density Spreading Multiple Access (LDSMA): LDS-CDMA, LDS-OFDM, MC-LDSMA, Radio Resource Allocation, Grant Free Multiple Access (GFMA): Resource Configuration, HARQ Procedure, Contention and Resolution, UE Activity, Detection ● **IDMA, IGMA and PDMA** ○ Interleave Division Multiple Access (IDMA): Transmitter, Receiver, Performance Evaluation, Power Control. Superposition Coded Modulation (SCM). Random Access, IDMA in MIMO systems, Interleave-Grid Multiple Access (IGMA): Transmission Schemes, Interleaving and Grid-Mapping Process, Receiver, Performance Evaluation, Pattern Division Multiple Access (PDMA): Uplink, Downlink, Pattern Matrix Design, Detection Algorithms. ● **HDMA, ODMA** ○ Holographic-Pattern Division Multiple Access ○ (HDMA): Reconfigurable Holographic Surface (RHS), Holographic Pattern Construction, Multi-User Holographic Beamforming Performance Analysis, Super-Sparse On-Off Division Multiple Access (ODMA), Random Access vs Multiple Access ● **RSMA** ○ Rate Splitting Multiple Access (RSMA):

				Downlink, Uplink, PHY architecture, Resource Allocation. Multi-cell RSMA, RSMA in MIMO systems
EE925	RF Systems for Communication	5	RF front end is an important part of the wireless communication system. A system designer needs to understand the performance of various components, such as transmission lines, matching systems, filters, amplifiers, oscillators, antennas, etc. So that the students can be integrated efficiently. This module introduces various parameters, such as scattering matrix, 1 DB compression, third-order intercept point, noise figure, etc. Which are used to specify the performance of RF components. The module then focuses on block-level descriptions of RF systems, system calculations, and trade-offs in block-level specifications to achieve overall performance. Finally, the module ends with an exposure to some of the RF measurements using vector network analyzer and spectrum analyzer.	• Parameters used to specify the performance of RF components, • transmission lines, • scattering matrix, • 1 DB compression, • third-order intercept point, noise figure, phase noise, etc., • RF system block-level description of RF system, • System calculations and trade-off in the block level specifications to achieve the overall performance RF Measurements using vector network analyzer and spectrum analyzer, antennas.
EE930	Detection for Wireless/ Detection for Wireless Communication and Machine	5	This module aims to cover principles of detection theory and algorithms for wireless communication systems and machine learning (ML) applications. Concepts in detection lay the foundation for several procedures in the implementation of 4G/5G wireless systems, especially at the receiver.	• **Introduction and Maximum Likelihood Detection** ○ Basics of Detection ○ Maximum Likelihood (ML) Detection ○ Likelihood Ratio Test (LRT) • **Application in wireless systems** ○ Binary Hypothesis Testing ○ Probabilities of Detection and False Alarm

	Learning		Detection techniques play a fundamental role in the demodulation of the symbols toward mapping them to a digital constellation. Furthermore, detection algorithms also play a vital role in Machine Learning (ML) applications towards face recognition, fraud detection etc. Also, decision rules based on detection theory are used extensively for primary user discovery in cognitive radio (CR) technology, slated for use in 5G and beyond networks. Distributed detection techniques are of significant interest toward decision-making and learning in Wireless Sensor Networks (WSNs) that power IoT applications in 5G. Hence, principles of detection theory are of great value for research, design and implementation of wireless communication systems and machine learning, which will be rigorously covered in this module.	○ Probability of Error ● **NP Criterion, Multiple Hypothesis Testing** ○ Neyman-Pearson Criterion for Optimal Detection, ○ Multiple Hypothesis Testing ○ Face Recognition ● **MAP Detector, Gaussian Discriminant Analysis** ○ Maximum A Posteriori Probability ○ (MAP) Detection rule ○ Probability of Error Gaussian Discriminant Analysis ● **MIMO OFDM** ○ Detection in MIMO/ OFDM Systems ○ Bit-Error Rate (BER) ● **Bayesian Detection** ○ Bayesian detection for random signals ○ Energy Detector and Performance ○ Chi-squared random variables ● **Generalized Likelihood Ratio Test (GLRT)** ○ Detection with unknown parameters ○ Generalized Likelihood Ratio Test (GLRT) and performance ● **Distributed Detection** ○ Principles of Distributed Detection ○ Applications in Sensor Networks and IoT
EE931	Advanced Wireless Transceiver Processing Techniques	5	The goal of the module is to present various advanced techniques for transceiver design in 4G/5G wireless systems. Several algorithms will be presented such as the Kalman filter and Adaptive LMS filter for scalar/vector channels. The Orthogonal Matching Pursuit (OMP) and Simultaneous OMP	● **Kalman Filter** ○ Principle of Kalman filter,Application of Kalman filter for time selective 4G/ 5G channel estimation ● **Compressive Sensing** ○ Sparse estimation and sparse signal recovery, Orthogonal Matching Pursuit (OMP) and

			will be presented for sparse parameter and channel estimation in MIMO OFDM systems. The Expectation-Maximization (EM) algorithm will also be described, which is a cutting edge algorithm with several applications in Machine Learning Channel Estimation and Bayesian Learning. Block Diagonalization and Successive Optimization (SO) will be described for MU-MIMO Transmission. This will be followed by other state-of-the-art techniques, such as MUSIC for DoA estimation, Optimal pilot construction in MIMO systems and Robust transceiver design techniques.	Simultaneous Orthogonal Matching Pursuit (SOMP) algorithms for Sparse Estimation in MIMO OFDM ● **Adaptive Signal Processing** ○ Introduction to adaptive signal processing, applications in wireless, Steepest Descent, Least Mean Squares algorithm,Convergence in mean, MSE ● **Expectation-Maximization (EM) algorithm** ○ Applications of EM: Unsupervised learning – Probabilistic clustering,Blind channel estimation, Sparse Bayesian Learning for sparse channel estimation ● **Multiuser MIMO Techniques** ○ Multi-user MIMO Uplink Transmission, MU MIMO Downlink with Zero-Forcing, MU MIMO Block Diagonalization and Successive Optimization ● **MUSIC Algorithm for Direction of arrival estimation** ○ Introduction to array processing,Signal covariance matrix, Multiple Signal Classification for Direction of Arrival (DoA) estimation algorithm ● **Optimal Pilot Design** ○ Pilot-based MIMO channel estimation, optimal pilot design, pilot design with prior information ● **Robust transceiver Design** ○ Channel uncertainty models,Robust beamformer design
EE932	Introduction to Reinforcem	5	Reinforcement learning (RL) is a type of machine learning paradigm where an agent learns how to behave in an	● **Introduction** ○ Basic terminology of an RL framework: States, Actions, Reward, Environment, etc.

	ent Learning		environment by performing actions and receiving feedback in the form of rewards or penalties. RL algorithms have proven effective in solving intricate problems across diverse domains such as robotics, gaming, finance, and communication networks. This course aims to provide students with a solid understanding of the various RL algorithms, enabling them to apply this knowledge to their specific research areas.	• **Multi-armed Bandits**
				  ○ n-Armed Bandit problem, UCB algorithm, Contextual bandits
				• **Finite Markov Decision Processes and Dynamic Programming**
				  ○ Markov Decision Process, Value functions, Bellman expectation equation, Bellman optimality equation, Policy Iteration, Value iteration
				• **Monte-Carlo and Temporal-Difference based Tabular methods**
				  ○ Monte Carlo prediction and control, TD prediction, SARSA, Q-Learning
				• **Function approximation-based methods**
				  ○ Q-learning with function approximation, Policy gradient methods: REINFORCE, Actor-critic methods
				• **Applications**
				  ○ Discussion of RL applications

EE999	Project Module	5	The goal of this module is to have the students do an industrial-relevant project on a topic related to modern communication systems. The project topic may include any topics in the general area of Advance Communication Systems.	Capstone Project

Department of Management Sciences (DoMS)

***Initially [Industrial and Management Engineering (IME)]**

Programme Name: Data Science and Business Analytics (DSBA)

Module ID	Module Title	Credit	Description	Content

MBA931	Stochastic Elements of Business	5	This course provides the foundation required for the analysis of stochastic elements of business. It aims to develop basic understanding about data and their analysis for solving business problems, through the study of the underlying principles of probability and statistics.	• **Data-driven decision making**
				  ○ Some examples involving stochastic elements.
				• **Probability**
				  ○ Basic concepts of probability, Conditional probability and independence.
				• **Random variables**
				  ○ Mass, distribution and density functions, Common random variables, Functions of a random variable, Mean, variance and quantiles.
				• **Random vectors**
				  ○ Joint distribution, Conditional distribution and independence, Sum of random variables, Covariance and correlation, Limit theorems.
				• **Statistical estimation**
				  ○ Population and sample, Point estimation, Goodness properties of point estimators, Interval estimation, Confidence intervals.
				• **Hypothesis testing**
				  ○ Introduction to hypothesis testing, Some hypothesis tests.

MBA932	Linear and Non-Linear Modeling	5	The purpose of this module is to understand regression tools that allow the students to explore causal relationships between different factors within a business environment. It is expected that students taking this module will gain skills and experiences in data analysis, economic modeling and interpretation of results.	• Economic Data and Insights Review of Probability • Review of Statistics, Hypothesis testing, Confidence Intervals • Linear Regression with one regressor, Classical linear Model, Assumptions, OLS estimator • Hypothesis testing for linear Regression with one regressor, measures of fit, dummy variables,heteroskedas- ticity • Linear Regression with many variables, Omitted variable Bias • Multiple Regression, Multicollinearity, Control Variables, Measures of fit • Common Pitfalls in Regression Analysis, Non Linear Models • Regression with Binary Dependent variables, Logit, Probit
MBA933	Data Mining Tools & Techniques	5	The module introduces the fundamental approaches to knowledge discovery and data mining (DM) and its main theoretical foundations. Starting with exploratory data analysis, the module will present fundamental algorithms for data preprocessing, classification and prediction problems. Emphasis will be to demonstrate these techniques to analyze real-life problems. There is significant importance to interpret the result/ knowledge obtained from these algorithms.	• Introduction to DM, DM Tools, DM functionalities and applications • Basic Data Understanding • Data Preparation for DM • Supervised and Unsupervised Learning • Decision Trees • Artificial Neural Network • Naive Bayes Classifier • Classifier Evaluation and Improvement Techniques
MBA934	Applied Machine Learning	5	Organizations are making more and more data-driven decisions for improving their processes, identifying opportunities and trends and launching new products. With the advent of machine learning	• **ML for Data Science** ○ Introduction and Fundamentals of ML, Supervised and Unsupervised Learning Algorithms, Fundamentals of R programming, Statistical modeling,

			techniques and the availability of data and high computing capabilities, data driven decision-making has transformed considerably. This module aims to understand popular machine learning (ML) algorithms (Regression, Classification and Clustering) and their business applications to appreciate these algorithms .Emphasis will be on ML applications with real-world decision making.The course allows hands-on experience in implementing the most widely employed algorithms in business domains using machine learning libraries, mainly in Python.	inferential statistics, confidence interval estimation, hypothesis testing ● **Exploratory Data Analytics** ○ Data cleaning and data visualization, generating insights from data ● **Predictive Analytics with Linear Regression modeling** ○ Simple and multiple linear regression, residual diagnostics, multicollinearity, heteroscedasticity etc. ● **Time Series Analytics** ○ ARIMA models, Time series stationarity, Unit roots, Modelling short-term and long-term relationships ● **Panel Data models** ○ Fixed effects and Random effects models, Least Square Dummy Variable models ● **Non-Linear models** ○ Logistic Regression, Quantile Regression, Model Building, and Estimation issues ● **Big Data Text Analytics** ○ Natural Language Processing, Text Mining, Sentiment Analysis, Text corpus visualization, Case study example
MBA935	Optimization Methods for Analytics	5	The course aims to prepare the candidates in optimization models and techniques to solve business problems.	● Introduction to operations research: Linear programming— formulation. ● Linear programming: Solution procedures-graphical and simplex methods. ● Linear programming: Duality and sensitivity analysis. ● Linear programming formulations: Transportation and assignment problems ● Multi-objective optimization: Modeling, solution approaches, applications ● Integer programming: Modeling and applications

				• Nonlinear programming—Unconstrained optimization technique, applications • Nonlinear programming—Constrained optimization techniques, applications
MBA936	Temporal and Cross-Sectional Modeling	5	The aim of this course is to introduce the principles of forecasting and time series analysis to business students. It is an applied course with focus on building models using time-series data.The main aim of the course is to equip students with forecasting tools in business settings.	• Introduction to time-series data - time-series graphics • Forecaster's toolbox • Time-series Decomposition • Moving Average and Exponential Smoothing • Time-series regression • ARIMA models • Dynamic regression models • Advanced forecasting methods – VAR, Neural Network
MBA937	Causal Inference Models	5	The module introduces a set of econometric tools to draw causal inferences in a social/organization setting. A critical objective of the module is to emphasize the importance of conducting cause and effect analysis in policy-related decision-making, the problems that occur while conducting such analysis in a managerial context and then to learn the relevant methods that can help overcome these constraints .Emphasis of the module will be on applying these tools/methods to various managerial/policy-related decision problems.	• Introduction • Refresher on multivariate regression,focusing on dummy variable regression and interpretation of results. Interpretation of interaction effect. • From correlation to causality. True Experiments and Quasi- experiments. • Matching methods. • Fixed effects and Event studies • Difference-in-Differences method (DID). • Regression Discontinuity Design (RDD). • Instrumental Variable Regression (IV). • Project Presentations
MBA938	Multivariate Data Analysis	5	The main aim of this course is to recognize the patterns within multivariate data. This course will focus on interdependence relationships rather than	• Introduction to R-packages,Introduction to Model Building with Multivariate Data • Visualizing and Preparing MV Data for Analysis • Principal Component Analysis; Factor Analysis

			dependence relationships.These techniques may be useful for categorizing individual entities into consumer segments, or uncovering latent variables that cannot be measured directly.	• Association, Canonical Correlation Analysis • Conjoint Analysis • Cluster Analysis; Discriminant Analysis • Multidimensional Scaling; Correspondence Analysis • Structural Equation Modeling

MBA939	Financial Analytics	5	This course aims to provide the students with the technical knowledge of building financial models and doing financial analytics in Excel/R/Python in corporate finance and financial markets. The aim is to bridge the gap between financial theory and practice. The course includes topics covering the application of data analytics in the financial markets: equity markets, fixed-income markets and derivative markets. The module has a dedicated focus on portfolio analytics and risk management.	• **Course introduction and Excel preliminaries**
				• **Analytics in Equity Markets**
				  ○ Time Value of Money
				  ○ Dividend discount model
				  ○ Discounted Cash Flow approach
				  ○ Incorporating assumptions in the Valuation Model using Excel
				• **Analytics and report generation for Equity Research and Investment banking**
				• **Analytics of Fixed income markets**
				  ○ Pricing of bonds
				  ○ Term structure modeling in Excel/R/Python
				  ○ Fixed-income risk measurement and management: Duration, convexity
				  ○ Fixed-income portfolio analytics
				• **Portfolio Management**
				  ○ Building Basic Portfolio Model using Excel/R/Python
				  ○ Performance measurement analytics using Excel/ R/ Python
				  ○ Portfolio analytics and dashboards using R, Python, R- Shiny
				• **Analytics of Derivative markets**
				  ○ Derivative Pricing Models: Forwards, Futures, Options, and Swaps
				  ○ Derivatives trading strategy and performance analytics
				  ○ Derivative and risk management using R, Python, R-Shiny

MBA940	Marketing Analytics	5	Given the availability of large amounts of retail data related to individual's shopping and online browsing behavior, today's marketing strategies are completely data-driven. The aim of this course is to understand the use of statistical tools to improve marketing decisions and return on marketing investment. Students will learn: (i) The advantages of quantitative marketing, (ii) Apply metrics-driven techniques to improve marketing decisions (iii) Learn by doing through computer based models.	• Introduction to Marketing Analytics, Summarizing marketing data • Understanding customer requirement – conjoint analysis, logistic regression, discrete choice analysis • Pricing – estimating demand curve, optimizing price, price bundling, non-linear pricing, price skimming and sales, revenue management • Customer lifetime value (CLV) – calculating CLV, using CLV to value a business, Monte Carlo simulation, optimizing customer acquisition and retention • Market segmentation – cluster analysis • Retailing – market basket analysis, RFM analysis, optimizing direct mail campaigns,allocating retail space and sales resources • Advertising – measuring the effectiveness of advertising, media selection models, pay per click online advertising • Online Business, Recommender Systems
MBA941	Supply Chain Analytics	5	To provide an understanding of the design and management of a supply chain.To will enable one to critically analyze the performance of a supply chain and will give exposure to the techniques for improving the performance of a supply chain.	• **Supply chain network design** ○ mixed integer linear programming models on network design • **Supply chain inventory optimization** • **Supply chain dynamics** ○ strategies to mitigate information distortion and bullwhip effect • **Modeling and analysis of the waiting lines** • **Contract design in the supply chain** ○ achieving supply chain coordination through contracts using stochastic non-linear optimization models • **Supply chain resilience and role of technology in supply chain management**

MBA942	HR Analytics	5	This course aims to impart necessary skills for quantification of human attributes and efforts and measurement of its efficiency and effectiveness in producing desirable organizational outcomes. It also provides modalities for analyzing and drawing data driven insights for determination of developmental needs of employees and designing total reward system.	• Introduction to key OB and HRM processes • Challenges in quantification of amorphous human attributes • HR analytics: From benchmarking to predictive analytics • HR metrics: Design, reliability and validity, concept of RoIHR • HR analytics approach: Identification, measurement, analysis and interpretation • Alignment of business and HR objectives through analytics • Talent Management through HR Analytics: Audits and competency repository • HR analytics amid emerging work arrangements (WFH and digitalization)
MBA943	Social Media Analytics	5	The access to social media has changed the way individuals live, buy, interact with each other and consume products, services and information.Individuals are more connected with each other than ever before and this interconnectivity leads to large consequences of small events known as the “butterfly effect”. The aim of this Module is to understand the complexity of network effects and to be able to use online data about social media use to enable companies to drive their strategies and make profitable decisions.	• Challenges in social media: Online experiments, Customer decision journey, recommendation and personalization, analysis of text and network data • Application of social data, basics of network analysis, network visualization, hands on with Gephi • Representing and measuring networks: strength of weak ties, centrality-degree, diameter, path lengths • Prestige, influence: Betweenness, PageRank, Eigenvector, Bonacich, decay, closeness, centrality • Analysis of real world networks • Recommendations in social media
MBA944	Elective Project	5	To allow the students to apply the learnings from the modules to address data analytics and business problems.The students are expected to work for a quarter on this project and	Capstone Project

			derive meaningful insights from its execution. The Projects are expected to showcase the problem-solving capabilities and skills of the students.	
MBA945	Elective Project	5	To allow the students to apply the learnings from the modules to address data analytics and business problems.The students are expected to work for a quarter on this project and derive meaningful insights from its execution. The Projects are expected to showcase the problem-solving capabilities and skills of the students.	Capstone Project

Programme Name: Financial Technology & Management(FTM)

Module ID	Module Title	Credit	Description	Content

MBA971	Banks and Financial Institutions	5	This compulsory module will provide participants with an understanding of how the Banking and Financial Institutions operate and their role in enabling global and domestic economies. Coverage will include the evolution and role of financial institutions and the regulatory system governing them. The module will also cover the basics of fiscal policy, the global economy, and foreign trade. Broad coverage of the Indian financial institutions and their roles will also be provided.	• **Banking & its History**
				  ○ Evolution, Nationalization, Types, New Banks, Deposit Services, Non-deposit Liabilities, Capital, Liquidity of Reserves Management, Risk Management, Analysis of Asset & Liability, ALM Mismatch
				• **Banking as Intermediation**
				  ○ An Overview, Components of Financial Intermediation, Sources and Applications of Funds, Lending Function, Financial Intermediation: Non-Fund Based Services, Measuring, Managing, Monitoring Credit Risk
				• **Financial Institutions & its Functions**

				○ Bank Regulations and Policies, Impact of Government Policies and Regulations, RBI, SEBI, NHB, MPC, Fiscal Policy, LAF ● **Regulations** ○ Managing Solvency and Capital Adequacy, Regulation and Monetary Policy for Banks, Need for Independence of Central Banks, Capital Adequacy
MBA972	Capital Market and Financial Products	5	Capital and Money Markets: An introduction to the financial system, its functions. Briefly cover various assets and contracts that are commonly traded, which include fixed income securities, equities, pooled investments, currencies, contracts, commodities and real assets. This module will also familiarize the students with various financial intermediaries Brokers, exchanges, investment banks, dealers, securitizers, depository institutions, insurance companies. The module will also discuss how issuers first trade in primary security markets and how trading happens in secondary markets.	● **Equity** ○ An introduction to equities and types. Difference between private and public equities. Discuss risk and return characteristics, and based on that valuation of equities. Also, familiarize you with commonly used equity valuation models- present value, multiplier, and asset based. ● **Fixed Income Securities** ○ Introduce you to the debt market, and the different kinds of bonds that are issued. Briefly discuss the different provisions that bondholders or issuers of bonds may be granted. Discuss various risks that bondholders take on. Understanding and calculation of valuation of bonds How change in interest rate affects bond price. ● **Derivatives and Alternative Investments** ○ Introduce you to the derivatives market, and commonly traded derivatives, which include forwards, futures, options, and swaps. Will understand the pricing of these derivatives. Finally, familiarize to the alternative investments, which include hedge funds, private equity, real estate and commodities.
MBA973	Financial	5	Organizations of all kinds need data-driven	● **Big Data Analytics**

	Big Data Analytics		decision-making to help students to improve their processes, identify opportunities and trends, launch new products, and make thoughtful decisions. In this module students will be introduced to the world of data analytics through a hands-on curriculum. This module is designed to equip the learners with the skills needed to become eligible for mid to senior-level data analyst/ scientist/ engineer jobs. In this module, Students will learn about the programming language known as R, and find out how to use R-Studio, the environment that allows students to work with R. This module will also cover the software applications and tools that are unique to R, such as ggplot (grammar of graphics). Students will discover how R lets them clean, organize, analyze, visualize, and report financial big data in new and more powerful ways.	○ Fundamentals of R programming, Statistical modeling, inferential statistics, confidence interval estimation, hypothesis testing ● **Exploratory Data Analytics** ○ Data cleaning and data visualization, generating insights from data ● **Predictive Analytics with Linear Regression modeling** ○ Simple and multiple linear regression, residual diagnostics, multicollinearity, heteroscedasticity etc. ● **Time Series Analytics** ○ ARIMA models, Time series stationarity, Unit roots, Modeling short-term and long-term relationships ● **Panel Data models** ○ Fixed effects and Random effects models, Least Square Dummy Variable models ● **Non-Linear models** ○ Logistic Regression, Quantile Regression, Model Building and Estimation issues ● **Big Data Text Analytics** ○ Natural Language Processing, Text Mining, Sentiment Analysis, Text corpus visualization, Case study example.
MBA974	Investment Banking	5	This module aims to prepare students for an Analyst role in the Capital Markets and Advisory divisions of an Investment Bank. This module will emphasize on the practical aspects of an investment banking job and the finance theory required for the same. The module will be taught in four modules. The first part of the module will focus on the analytical skills required for an investment banker. This module will cover	● **Introduction and Basic Tools** ○ Introduction to Primary Capital Markets: Structure of an Investment Bank, Different types of financial instruments and their uses from firms' perspective, Capital Structure Decision ○ Basics of Valuation and Financial Statement Analysis: DCF Models, Price Multiples, EV Multiples, Industry Specific Multiples, Accounting Ratio Analysis

			financial statement analysis and various valuation methods in the second module, the students will gain an in-depth understanding of the Equity Capital Markets Division of an investment bank. The third module will focus on the Debt Capital Markets Division of an Investment Bank. Finally, the fourth module focuses on the Advisory Division of an Investment Bank.	• **Equity Capital Markets**
				  ○ Initial Public Offering 1: Strategic motivation for going public, IPO process, role and fee structure of an investment bank in an IPO
				  ○ Initial Public Offering 2: Underwriting, Green Shoe Options, IPO underpricing
				  ○ Follow-on Public Offerings, Rights Issues and Private Placement: Strategic Motives, Legal and Procedural Aspects
				  ○ Share Buy-Backs and Delisting: Strategic Motives, Legal and Procedural Aspects
				• **Debt Capital Markets**
				  ○ Bonds: Strategic, Procedural, Legal and Accounting Aspects of Bond Issues, Different types of bonds and their uses
				  ○ Loan Syndication and Project Finance: Strategic Motives, Risk Mitigation through Project Finance, Covenants, Cash Trap, Cash Sweep, Debt Sculpting
				• **Mergers and Acquisitions**
				  ○ Mergers and Acquisitions: Strategic Motives, Mode of payment, Synergy, Valuation, M&A Analysis

MBA975	AI, Machine Learning and Deep Learning	5	This compulsory module will help learners understand the intricacies of ML and DL models used to solve business problems. The students will also learn the concepts of NLP and Reinforcement Learning from scratch.	• **ML techniques**
				  ○ Various learning paradigms: Supervised learning, Unsupervised learning, Representation learning, Semi-supervised learning, Regularization, Naïve Bayes, SVM, Decision Trees, Random Forest, Multilayer perceptron, Gradient Boosting, XG Boost
				• **Deep learning**
				  ○ Restricted Boltzmann Machine, Deep Belief Network, CNN, Long short-term memory (LSTM), GAN.
				• **Natural language processing**

				○ Bag of words model, Topic Modeling, Latent Dirichlet allocation, Word2vec, natural language understanding and generation. ● **Reinforcement learning** ○ Introduction, Models and applications to banking. ● **Case Studies and demos of deep learning and NLP** ○ Chatbot development, Cyber fraud detection including phishing/ spam/malware detection; Credit card fraud detection, Financial forecasting using ML and sentiment analysis.
MBA976	Blockchain and Distributed Ledger Technologies	5	Blockchains and Distributed Ledger Technologies have brought about changes that could mean more transparency, efficiency and resilience to fraud in a distributed system.This module aims to introduce mechanisms underlying Blockchain and Distributed Ledgers, their origins and key characteristics. On successful completion of this module the students will be able to differentiate between decentralized applications based on 'public' and 'private' blockchains.This module will also focus on the roles and risks associated with cryptocurrencies. Examples of distributed ledger technology based applications will be used throughout the module.	● Introduction: Blockchain and distributed ledger technology, Bitcoin blockchain,Transactions, Digital signature, Consensus mechanism and Proof of Work (PoW). ● Bitcoin Blockchain Stability, Second Generation Blockchain, Ethereum Blockchain, Smart Contracts, Blockchain as a platform. ● Alternatives to Proof of Work, Proof of stake, Proof of Authority and other consensus mechanisms for different blockchain architectures. ● Transaction ledgers in blockchain networks, Public and private ledgers, Permissionless and permissioned blockchain, Enterprise level blockchains and distributed ledgers. ● More on Enterprise level blockchains – Hyperledger Fabric and Ethereum Enterprise blockchains. ● Secure multiparty computation techniques and their application in blockchain networks. ● Privacy and Scalability Issues, Anonymity, Pseudonymity, Unlinkability. Zero Knowledge Proofs, Byzantine agreement protocols. ● Cryptocurrencies, Roles and risks associated with cryptocurrencies, Policy issues related with

				blockchain.

MBA977	IT Platforms, Cloud Computing & IoT	5	This compulsory module will help learners understand cloud computing and IoT architectures. They will learn about virtualization and its role in cloud computing. The module will focus on delivery and deployment models of cloud computing and various private and public cloud platforms.Students will be taught how to determine the right sensors and communication protocols to use in a particular IoT system, understand the data generated from an IoT device and migrated to the cloud and the security features required to protect data stored in the cloud.	• **Introduction to Cloud and IoT**
				  ○ Cloud Computing: NIST definition of cloud computing Evolution of cloud computing, Cloud essential Characteristics, Cloud computing architecture, Benefits and challenges of cloud computing. IoT: IoT architecture, devices, sensors and applications.
				• **Virtualization and Virtual data centers**
				  ○ What is Virtualization, Benefits of virtualization, Virtualization structures/hypervisors, Approaches to virtualization, Types of resource Virtualization, Virtual Data Centers and role of virtualization in cloud computing.
				• **Hands-on Virtualization**
				  ○ Creating and managing Virtual machines, Migration VMs and creating virtual data centers using KVM and Xen hypervisors.
				• **Cloud Delivery and Deployment Models**
				  ○ Cloud services: Software as a Service(SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). Cloud types: Public cloud, private cloud, community cloud and hybrid cloud.
				• **Hands-on Cloud Computing**
				  ○ Hands-on creating private cloud and management using Openstack.
				• **IoT Communication and protocols**
				  ○ Message Queuing Telemetry Transport (MQTT), Secure Message Queuing Telemetry Transport (MQTT), Constrained Application Protocol (CoAP), Extensible Messaging and Presence Protocol (XMPP), Advanced

				Message Queuing Protocol (AMQP). ● **Cloud of Things(CoT)** ○ IoT and cloud integration, The Cloud of Things architecture, Edge/fog computing and mobile cloud computing. ● **Cloud Security and Privacy** ○ Cloud security fundamentals, Cloud security threats, Data security and storage, Privacy, Application Security,Identity and access management (IAM), Audit and compliance management,and Secure data management in IoT.
MBA978	Cyber Security	5	The primary objective of this module is to equip students with various cyber- attack tactics,techniques and procedures along with hands-on training in different cyber security tools.Through this module, students will develop an ability to identify, detect, analyze and prevent popular cyber-attacks.	● **Introduction to Cryptography** ○ Symmetric and asymmetric encryption algorithms,Digital signatures, Digital certificate, SSL and TLS,IPSec. ● **Introduction to Cyber Security** ○ Different types of cyber-attacks: Malware, phishing, SQL injection, DoS/DDoS, spoofing, compromise password, Cross-site scripting, Cross-site request forgery, OWASP top 10. ● **Vulnerability Analysis and Penetration Testing** ○ Application vulnerabilities and mitigations strategies, Information gathering techniques, target enumeration and post scanning techniques, vulnerability assessment, network sniffing, remote exploitation, client-side exploitation. Application and Network VAPT Tools -hands-on exercises.Organizational security, Security policy, administration of security , monitoring security. ● **Network Security Tools** ○ Firewalls, VPN, Intrusion detection/prevention , WAF, Packet capturing using Wireshark,

				NAC, NBAD.

MBA980	Open Banking in Mobile-First, Cloud-First world	5	This module will teach students the platforms and tools driving the neo-banking ecosystem. This will also be exposed to the operational aspects of such platforms. Students will develop the ability to analyze and extend such platforms at a conceptual level.	• **Introduction**
				  ○ The technical elements of Open/Neo Banking stack and a brief overview of digital banking channels.
				• **Software architecture patterns**
				  ○ Brief overview of architectural patterns, client-server/ controller/ middleware/ multi-tier/ front-end/ back-end etc.
				• **Open APIs**
				  ○ Overview of PSD2 and India Stack. A basic demo of REST API calls.
				• **Cloud and Virtualization**
				  ○ Basics of virtualization as a pillar to enable Open Banking.
				• **App project management basics**
				  ○ Planned vs. iterative software development
				• **Mobility and banking**
				  ○ Mobile banking and enablement by edge-computing etc. Includes an overview of financial inclusion through business correspondents AEPS etc.
				• **Security perspectives**
				  ○ Benefits and challenges with cloud and mobile ecosystem for security.
				• **Recent innovations**
				  ○ AR/VR/MR in fin-tech space.5G and beyond – a convergence of cloud + mobile.

MBA981	Extreme Automation	5	This compulsory module will cover various aspects of RPA / DPA and its use cases, e.g. customer onboarding, KYC Compliance, Report Generation, AML and doubtful transaction identification etc. Exposure will be given to popular RPA /	• **RPA - UIPath** ○ RPA Basics,Benefits, Impacts, Types,Introduction to UIPath,Variables & Arguments, Selectors,COntrol Flow, Data Manipulation, Orchestrator, UiPath Features, Studio, StudioX, Reading & Writing

			DPA platform(s) such as UIPath, Pega, Automation Anywhere and Blue Prism. The module will focus on how RPA and DPA assist in processing the work that is repetitive in nature, help banks & financial institutions increase productivity by engaging customers in real-time and leverage the power of bots.	• **PEGA**
				  ○ Introduction to Pega, Situational LayerCake, Navigation, Application development studios, Roles, Designing a case life cycle, Service level, Controlling the workflow,Routing work to user,Configure a case hierarchy, Adding fields to a case type,Data in Memory, Manipulating, Validating Integration with UI, Styling, Report Creation and optimization
				• **Blue Prism**
				  ○ Introduction,value, technology ,Automation Scenario, Application Model, Actions,Process Flow, Object Studio, Exception Handling, Other Capabilities, Focus Points

MBA979	Core Project 1	5	This component will cover various aspects of topics that would range from Digital Banking. Decentralised Finance, Digital Transactions Optimization, Digital Risk Management and Digital Customer Experience and more.	Capstone Project
MBA982	Core Project 2	5	This component will cover various aspects of topics that would range from Digital Banking.Decentralised Finance, Digital Transactions Optimization, Digital Risk Management and Digital Customer Experience and more.	Capstone Project

Programme Name: Power Sector Regulation, Economics and Management (PSRM)

Module ID	Module Title		Description	Content
MBA951	Fundamentals of Economics, Accounting and Finance	5	To provide an overview of the fundamentals of economics and data analysis, providing a basis for understanding other modules in the program. To understand financial statements and their relevance in regulatory accounting.	• Demand, Supply, Cost Concepts and Perfect Competition • Monopoly- Entry Barrier, Profit Maximization and Welfare Impact • Understanding Market Structure - Oligopoly and Monopolistic Competition • Introduction to Macroeconomic Measures • Understanding Statistical Concepts and Regression Analysis • Demand Estimation and Forecasting • Production Economics • Pricing: Theory and Practice • Accounting Principles: Profit-Loss and Balance Sheet Statement • Depreciation, Working Capital, Interest Cost and Loan Repayment • Free Cash Flow and Investment Valuation • Fundamentals of Project Financing • Evaluating Projects under Project Financing • Differentiating Financial and Regulatory Accounting
MBA952	Power Sector Reform and Regulation: Economic Principles and Evolution	5	To understand the economic rationale for regulation, and the evolution of the regulatory and policy changes in the power sector.	• Introduction to the Indian Power Sector • Progress towards Power Sector Reforms - Electricity Act, 2003 and Beyond • Fundamentals of Economic Regulation • Market Failure and Regulation of Natural Monopoly • Theories of Regulation • Cost-of-Service Regulation - I • Cost-of-Service Regulation - II

				• Distribution Reforms and Programs – APDRP, R-APDRP, DDUGVY, UDAY • Incentive Regulation: Theory • Incentive Regulation in Practice: International Experience • Electricity Act, 2003 • National Electricity Policy and Tariff Policy • Unbundling, Privatization and Franchisee Development - Experience across States • Current Developments in Policy and Regulatory Framework in the Indian Power Sector
MBA953	Power System Operation and Ancillary Services	5	To provide an overview of the key aspects of a power system covering Generation, Transmission and Distribution. To identify the roles of ancillary services and examine the cost drivers for ancillary services, regulation and reserve products.	• Understanding Power System – Generation, Transmission & Distribution • Functioning of Electric Bulk Power System • Integrated Operation of Grid -Reliability, Stability and Security • Indian Electricity Grid Code • Power System Operation in Practice: Scheduling and Despatch • Transfer Capability Assessment and Congestion Management • Deviation Settlement Mechanism • Demand Response and Demand side management • Assessment of Power System Stability • Ancillary Services – RRAS and Beyond • Understanding Power System Data and its Processing • Governance in the Power Sector and Independence of Regulatory Institutions • Analytics of Power System Data • Power System Simulation Lab
MBA954	Power Sector Regulation in	5	To understand Multi-Year Tariff Framework for generation,	• Regulatory Framework for Multi-Year Tariff (MYT) • Tariff Determination Framework: Electricity Act,

	Practice: MYT Framework for Generation, Transmission & Distribution		transmission and distribution. To understand the process of ARR approval and tariff determination. Hands-on exercises to understand the above.	2003 and Tariff Policy, 2016 • Rate of Return Regulation and Performance Based Regulation • Regulated Tariff Framework for Thermal Generation • Determining Tariff for Thermal Generation: Hands-on Exercise • Regulated Tariff Framework for Hydro Generation • Determining Tariff for Hydro Generation: Hands-on Exercise • Fundamentals of Transmission Tariff Design • Evolution of Transmission Tariff - PoC and Sharing of Transmission charges • Regulated Tariff Framework for Distribution • Determining Tariff for Distribution - I: Hands-on Exercise • Determining Tariff for Distribution - II: Hands-on Exercise • Estimating Category-wise Cost-of-Service: Hands-on Exercise • Return on Equity and Return on Capital Employed: Estimation and Implementation • Benchmarking Norms for Tariff Determination – Generation, Transmission and Distribution
MBA955	Competition and Power Market Development	5	To understand the evolution of the Power Market in India. To understand the regulatory and policy framework for Power Market Operation. To understand various market segments. To understand the operation of power exchanges. Retail Competition and International Experiences in Power Market Development.	• Principles of Electricity Market Design - I • Indian Power Market Structure: Role of Trading and Power Exchanges • Power Market Regulation, Transmission Allocation, DSM Regulation, Grid code and Licensing • Network Access (STOA, MTOA & LTA) and Cross-subsidy Surcharge • Principles of Electricity Market Design -II • Electricity Contracts and Operation of Power Exchanges

				• Short-term power market – Bilateral, DEEP, Banking/ Barter • Resource Adequacy and Capacity Market • SCED and MBED • Market Monitoring, Market Share, Market Power and its estimation • International Experiences in Power Market Development • Derivatives and Risk Management in Power Market • Retail Competition • Evolution of Power Market: Next Steps
MBA956	Smart Grid Technologies and Implementation	5	To understand the implementation and technologies involved to integrate and optimize distributed energy resources to achieve a more efficient and reliable grid.	• History of Power System and Power System Automation • Smart Grid Definition • Smart Grid Domains & Building Blocks • Smart Grid Architecture • Smart Grid Measurement Technology • Smart Grid Measurement & Communication Technologies • Energy Storage and Demand Response • Active Distribution System Management • National Smart Grid Mission and Pilot Projects • Peer-to-Peer Market and Blockchain • Regulatory Aspects related to Smart Grid • Microgrids - Regulatory and Policy Framework
MBA957	Power Procurement: Principles and Practice	5	To understand economic and financial concepts related to the decision-making for power procurement. To provide an understanding of the process of LT and ST power procurement in the power sector. To understand the regulatory and policy framework governing the	• Power Procurement – PPA under Regulated Tariff, Competitive Bidding and Markets • Power Purchase Agreement - Contracting & Transitioning • Short-term Power Procurement in Practice • Estimating and Understanding Levelized Tariff • Economic Approach to Power Procurement – Merit-order Dispatch

			same. Hands-on exercises/projects to understand the above.	• Resource Adequacy: Long-term Demand Forecasting and Power Procurement Planning • Long-term Demand Forecasting: Electric Power Survey • Competitive Bidding – Principles and Guidelines • Power Procurement Portfolio Management - Multiple Sessions • Short-term Load Forecasting in Practice • Mini-project (live)
MBA958	Renewable Energy Policy, Regulation and Market	5	To provide an overview on the Renewable Energy Policy, Regulation and Market. To understand the process of RE procurement through regulated and competitive bidding Mechanisms. To understand various aspects of policy and regulatory instruments to promote RE. To understand challenges to RE development. To understand the development of the market for REC and other market-based products. To understand factors influencing framework for behind the meter generation by domestic, industrial and agricultural consumers.	• Evolution of Renewable Energy Development – India and the World • Understanding Solar, Wind, Small Hydro, Biomass and other RE Resources • Policy and Regulatory Framework for Renewable Energy Development: RPO, FiT, RECs • Regulated Tariff Determination for Renewable Energy • Competitive Bidding for RE procurement • Developing a Market for Renewable Energy Certificates (RECs) • Designing and Implementing a Rooftop SPV Program: Net Metering vs Gross Metering • Solarisation of Agricultural Pumps • RE Procurement in Practice: GTAM, GDAM and Beyond • Challenges to RE integration - Role of Flexibility and Storage (Hydro, Pumped Storage and Battery) • Renewable Energy Scheduling, Forecasting, Dispatch and Deviation Settlement Regulations • PAT Mechanism and ESCerts • Mini Project
MBA959	Regulatory Capstone	5	To allow the students to demonstrate their understanding, abilities and skills	A student registered for a project module will choose a project topic in consultation with the course

	Project - I		required to formulate a relevant question, gather relevant data, undertake analysis and present the outcome. Students, in consultation with the supervisor, may choose a topic of their interest in the relevant area of the program.	coordinator/main supervisor. Topics should be relevant to the program. Industry-relevant topics would be preferable.
MBA960	Regulatory Capstone Project - II	5	To allow the students to demonstrate their understanding, abilities and skills required to formulate a relevant question, gather relevant data, undertake analysis and present the outcome. Students, in consultation with the supervisor, may choose a topic of their interest in the relevant area of the program.	A candidate registered for a project module will choose a project topic in consultation with the course coordinator/main supervisor. Topics should be relevant to the program. Industry-relevant topics would be preferable.
MBA961	Designing Retail Electricity Tariff	5	To understand economic and financial concepts related to the electricity retail tariff. To understand the regulatory and policy framework governing the same. Hands-on exercises/project to understand the above.	• Economics of Retail Tariff Design: Concepts of Elasticity and Price Discrimination • Principles of Retail Tariff Design - Single Part vs. Multi-part Tariffs, Telescopic vs non-telescopic Tariff and Two-part Tariff vs. Minimum charges • Mini Project (Part A) - Evolution of Retail Tariff in a state • Estimating Cost of Service – Category-wise and Voltage-wise - I • Estimating Cost of Service – Category-wise and Voltage-wise - II • Estimating Cost of Service – Hand on exe3rcise • Mini Project (Part B) - Redesigning Retail Tariff in a state • Designing a demand response program and ToU Tariff • Cross-subsidy, Subsidy and Financial gap: The Indian Conundrum

				• Consumer electricity pricing under retail competition • Implementation of Retail Competition in India: Sectoral Legacy and Tariff Unbundling • Mini Project - Final Presentation • Consumer Services - Supply Code and Standard of Performance • Consumer Rights, Grievance Redressal and Ombudsman
MBA962	Power Sector Regulation: Emerging Issues and International Perspectives	5	To learn from international experience from power sector reform. To understand the role of the power sector in India's climate policy commitments. To understand the impact of RE, EV and Green Hydrogen adoption on the Indian power market with respect to decarbonization targets. To understand the institutional framework, processes and adjudication of disputes in the power sector and learning from recent judgements of APTEL and Supreme Court.	• Cross Border Energy Trade and Regional power market • Electric Vehicle Charging Infrastructure • Green Hydrogen: Technology and Economics • Green Hydrogen: Mission, Standards and Policy • Energy Storage: Economics and Supply Chain • Electricity Act Amendment: Developments and Future Prospects - I • Electricity Act Amendment: Developments and Future Prospects - II • India's Climate Policy Commitments and the Role of Power Sector • Challenges to Harnessing India's PV Potential: Technology, Supply Chain and Policy Environment • International Experience of Power Sector Regulation: Market Evolution and Regulatory Governance • Learning from recent judgements of APTEL and Supreme Court - I • Learning from recent judgements of APTEL and Supreme Court - II • Clean Energy Transition for the Power Sector: International Perspective
MBA963	Project Financing for	5	Project Financing, being distinct from corporate finance, pertains to fundings	• **Project Finance for Energy and Infrastructure Projects**

	Energy and Infrastructure Sectors		of projects under an SPV framework which assures debt servicing through the project cash flows. Energy and infrastructure sector projects require large investment and have a long-gestation period. The stakeholder in a project financial deal in such sectors face a variety of risks that are hedged through a variety of contractual arrangements. The course would provide an exposure to the conceptual and applied understanding while evaluating a project financing deal. The course would also help understand the contractual linkages that identify, manage and allocate various risks in a Project Financing, particularly in the energy and infrastructure sectors.	○ Understanding Project Financing, Project Financing Vs Corporate Financing, Financing Energy and Infrastructure Projects ● **Understanding financial concepts** ○ Time value of money, discount rate and investment valuation ● **Understanding Financial Structuring,statements and ratios** ○ Understanding Financial Structuring, Financial statements and ratios ● **Evaluating Free Cash Flows** ○ Free cash flow to project and free cashflow to equity, Interest During Construction (IDC) ● **Project Evaluation Concepts** ○ NPV, IRR, MIRR, Cost-benefit Analysis, Payback period etc.Viability vs financeability of projects ● **Evaluating Public/Social Projects** ○ Social Cost-benefit Analysis,Financial Vs Economic IRR ● **Project Appraisal and Documentation** ○ Project Appraisal, Financial Ratios and Documentation ● **Sources of Finance for Energy and Infrastructure Projects** ○ Financing Infrastructure Projects, Sources of Finance, Consortium Financing, Domestic and International sources of project finance, Green Financing, Role of Multilateral Agencies (MLAs) ● **Risk Identification and Mitigation** ○ Identify project risks, understand mitigation strategies and contractual linkages

				• **Term sheet, covenants and loan documentation**
				  ○ Project financeterm sheet, covenants and loan documentation
				• **Case study based financial modelling of projects**
				  ○ Hands on Case Discussion and Financial modelling for identified cases.

Programme Name: Quantitative Finance and Risk Management (QFRM)

Module ID	Module Title	Credit	Description	Content
MBA901	Foundations of Economics and Finance	5	This module will provide the foundational understanding of economic terms and their application in equity and derivatives markets investment. At the same time, to introduce the students to the basics of financial concepts and develop a firm theoretical understanding.	• Introduction to macroeconomic indicators and financial instruments. • Monetary and Fiscal policies - models and dynamics • Exchange rate determination, forex risk management practices, trade: current and capital accounts, trade policy. • Future and Present Values, annuities, perpetuities, compounding and measuring returns. • Basics of portfolio construction, mean-variance framework, Optimal portfolio analysis with riskless asset, capital allocation framework, optional portfolios with multiple assets. • Bond and its types, valuations, yield curve and duration
MBA902	Introduction to Derivatives	5	This module introduces the students to the pricing and valuation of derivative	• Basics of Derivatives Markets and Derivatives Markets in India.

			contracts, primarily focusing on contracts traded in the market. It also elaborates on the various theoretical frameworks linked to different types of commodities and financial instruments.	• Mechanics of Futures Markets -Forwards Contracts, Valuation. • Margining and Mark-to-market in Futures markets. • Hedging and Risk Management with Futures Contracts - Minimum Variance Hedging Strategy. • Futures Markets in India: Instruments and Specifics (Demonstration). • Options: Payoff structure, Basic trading strategies using Options.
MBA903	Quantitative Methods in R and Python	5	The primary objective of this module is to equip the students with various tools and techniques and their applications for better understanding and investment decisions. Through this module, the students will develop an ability to analyze the data by applying appropriate quantitative methods.	• Overview of financial econometrics, statistical foundations: data, Visualizing and describing the data, descriptive statistics and data summary. • Role of linear regression in financial data modelling, assumptions, violations, diagnostics, and two-stage procedures. • Introduction to time series, autocorrelation and forecasting techniques. • Fixed effects and random effects and instrumentation process. • Logit, Probit, Tobit and other variants and their applications. • Monte Carlo simulations, Variance reduction techniques, bootstrapping and random number generation.
MBA904	Security Analysis and Portfolio Management	5	The module offers comprehensive learnings about security analysis and portfolio and exposes the practical side of security analysis and portfolio management.	• Introduction to financial markets, investment alternatives, risk and return. • Optimal portfolio analysis with the riskless asset, capital allocation framework, optional port-folios with multiple assets, single index formulations. • CAPM, APT models, Factor models. • Return anomalies and market efficiency. • Security Analysis and Valuation. • Fundamental analysis, investment strategies.

MBA905	Treasury and Credit Risk Management	5	This module trains the students with different types of risks faced by firms. The module will focus on the advanced treatments of different risk management practices and provide exposure to regulatory norms.	• Introduction to treasury risk management, its underlying usefulness in risk management: role and scope. • Cash forecasts, short-term finance, cash budgets, working capital management. • Long-term finance, cost of capital, capital investment appraisal, capital rationing. • Financial and non-financial risk measures: volatility, VaR; credit and counterparty risk management. • Credit risk in swaps, FRAs, and options. • Settlement risk, netting requirements, capital treatment, and margin and collateral requirements.
MBA906	ML in Financial Modeling	5	This module aims to understand the big data problems in finance. This module focuses on the various models for applying machine learning in quantitative finance, such as quantitative risk modeling with kernel learning and derivatives markets and risk management.	• Basics of Machine Learning and difference between ML and Statistical Modelling: USE Case of ML in finance. Why ML Proliferation i.e. Use of Data, Computation Power; Use Case of SPAM Filtering. • Generalization and Regularization and Basics of Python Libraries. • Understanding Model Fit: Variance and BIAS, Use of Decision Trees, K Means Clustering. • Ensemble Methods: Boosting and Bagging Techniques, LSTM and Karas Modelling. • ML in Active Management. • ML in Risk Management.
MBA907	Advanced Derivative Contracts and Pricing	5	The module provides an in-depth understanding of derivatives contracts with a balanced exposure to futures and options initially, and then it introduces to the new dynamics of commodity derivatives. The valuations of forwards and futures are crucial from	• **Pricing and valuations of commodity futures** ○ Pricing of forwards and futures, spot and forward relationship under no-arbitrage, the market value of futures positions, cost of carry model (seasonal and non-seasonal), convenience yield, pricing of precious metals: Gold and Silver,

			the perspectives of price discovery and risk management.	spread arbitrage, pricing of forwards for storable consumption commodities. ● **Pricing and valuations of non-storable commodities** ○ Valuations of non-storable commodities,electricity derivatives, DAM, DAC, TAM, Daily Term Ahead Market, RECs, Nord Pool, valuations of gas storage facility, swing options. ● **Pricing and Valuations of Weather Derivatives** ○ Weather risk and Weather derivatives, valuations of temperature-based derivatives contracts, contract size, wind speed derivatives, rainfall futures and options. ● **Pricing and Valuations of Carbon Derivatives** ○ Rules and regulations, Emission trading standards, CDM, Mechanism of Carbon Credits, Pricing of Carbon Units: Allowance Units, CER and ERU, switching price and Carbon Credits. ● **Pricing and Valuations of Freight, Property, and Payroll** ○ Functioning of Freight exchanges, freight indexes, REITs, Payroll and Water derivatives valuations, Pricing and the Baltic Freight market, forward freight agreements and Options. ● **Hedging and speculation with futures** ○ Types of hedges, profit margin hedging, inverse hedging, enhancements, speculation and investment process, cross-hedge, tailing the hedge.
MBA908	Blockchain	5	This module provides an overview of	● Introduction

	Applications in Finance		blockchain technology and its applications, supported by illustrations and use cases for effective learning.	• Evolution and Genesis • Blockchain in Finance • Blockchain in Finance Application – 1 • Application – 2 • Wholesale P2P Trading

MBA909	Technical Analysis in Finance	5	This module helps to learn about various methods of detecting and identifying trends and develop trading strategies.	• **Introduction**
				  ○ Introduction to Technical Analysis, importance , basic rules and terminology, philosophy, price, volume and time , pattern
				• **Trend Recognition**
				  ○ Real time chart,understanding various types of charts-moving averages, Bars, Candles, Hollow candles, Heikin Ashi, Penko, Kagi etc
				• **Chart**
				  ○ Chart and Candlestick patterns, Bullish and Bearish pattern
				• **Technical Indicators**
				  ○ Introduction to technical indicators, leading indicators, lagging indicators, pivot point, Oscillators, Advantages and disadvantages.
				• **Technical Indicators - Oscillators**
				  ○ Types of Oscillators (Momentum,Centered, Banded, Stochastics), Gap analysis
				• **Commodity Trading Strategies**
				  ○ Commodity market, products, Types of investors and indices

MBA910	Advanced Financial Modeling	5	This module helps students get an overview of financial modelling in the equity and derivatives markets and explore the tools and techniques	• **Introduction to Financial Modelling for equity and derivatives** ○ Mathematical Foundation, Time -Series properties, Introduction to Stationarity,

			required for analysing the financial data of different frequencies.	ARIMA models, AIC/BIC Criteria, MLE; Recap of OLS, Panel data, Quantile, and Logistic regressions
				• **Multivariate time-series models**
				  ○ Simultaneous Equation approach, Vector Auto Regressions, Impulse response functions, Variance decomposition, Granger Causality test. Case study based application in derivative markets.
				• **Modelling short-term and long-term relationships**
				  ○ Non-stationarity and unit root testing, Error correction models and cointegration. Case study based application in commodity Markets.
				• **Dynamic volatility models**
				  ○ Conditional Volatility Models, Standard and Non-standard GARCH model, BEKK GARCH, DCC GARCH, Conditional Quantile and Time-varying Spillover models, Dynamic Conditional correlations, Dynamic hedge ratios and portfolio rebalancing
				• **Regime Switching Models**
				  ○ Seasonality and cycles in financial markets, forecasting with regime switching models, Markov Regime Switching Models, model estimation and residual diagnostics, state-space models. Case study applications in energy markets.
				• **Events Study Analysis**
				  ○ Econometrics of event study approach, estimating normal and abnormal returns, application to carbon markets.
				• **Price discovery across equity and derivative**

				markets ○ Lead-lag relationships, information share and component share methods, structural breaks in relationships, price discovery with time-varying approaches, Applications to equity-derivatives.
MBA911	Project-I	5	Project-I	Capstone Project
MBA912	Project-II	5	Project-II	Capstone Project

Department of Sustainable Energy Engineering (SEE)

Programme Name: Renewable Energy and E-Mobility (REEM)

Module ID	Module Title	Credit	Description	Content

SEE901	Energy Sustainability : An Overview	5	The objective of this course is to make working professionals understand the importance of energy in the context of human development and its consequences in a broader sense. The course will cover the evolution and types of energy technologies, the role of materials, mining, and manufacturing. It will also teach the issues created by the increasing energy demand coupled with increasing population and changing lifestyles, environmental issues caused by growing energy demand and global warming, carbon emissions, and sequestration and finally, the possible decarbonization pathways for a sustainable future.	• **Climate change and role of energy**
				  ○ Understanding Climate Change: Science, Impacts and Mitigation Options Energy Overview in Global and Indian context and its impact on environment
				• **Fundamental concepts of energy**
				  ○ Definitions Basic thermodynamics Measuring efficiency of energy systems and units
				  ○ Energy balance table and Sankey diagram
				• **Energy Demand -**
				  ○ Demand rise – and impact on carbon generation
				  ○ **Industrial**
				  ▪ Role of industrial emissions
				  ▪ Major sectors and trends
				  ▪ Energy Efficiency pathways
				  • Steel sector and other hard to abate sectors
				  ○ **Transport**
				  ▪ Contribution to overall emissions Mitigation plans for controlling

				emissions Role of technologies and standards ○ **Buildings** ▪ Contribution to overall emissions The need for energy efficiency Initiatives and Schemes by Government and Utilities: Opportunities and Barriers. • **Supply** ○ Major sources of energy generation and related emissions Expected scenarios – global and Indian ○ Solar ▪ Solar as an energy source: various technologies and Relative Costs Global Projections and India's potential Expected challenges and barriers ○ Others ▪ Wind ▪ Hydro ▪ Nuclear ○ Storage and integration challenges ▪ Role of storage including duck curve Storage technologies Renewable energy integration challenges in the grid ○ Alternate Mitigation Strategies ▪ The need for CCUS (carbon capture utilization and storage) and technology update

				• **Carbon calculations and NetZero**
				  ○ General understanding of LCA analysis and role in carbon calculations
				  ○ Net Zero and Global Climate Discussions
				  ▪ What do we mean by Net Zero? • Definition as per some standards • COP commitments.

SEE902	Energy Storage Materials and Devices	5	This course intends to provide an understanding of the working mechanisms of different energy technologies e.g., batteries, supercapacitors, fuel cells, thermal energy storage, pumped-hydro storage, and identify the limitations of these storage technologies/systems electrochemical systems. The study includes thermodynamics, kinetics pertaining to the electrochemical reactions, electrodes, electrolytes, and design of thermal and pumped-hydro storage, as well as some experimental techniques.	• **Introduction to Energy Conversion & Storage Systems**
				  ○ Scope of energy systems
				  ○ Needs and opportunities
				  ○ Technology overview and applications
				• **Introduction to Batteries**
				  ○ Primary & Secondary Batteries
				  ○ Primary & Secondary Batteries
				  ○ Battery Electrode Reactions
				  ○ Important Parameters viz. Operating Voltage
				  ○ Charge Capacity
				  ○ Maximum Theoretical Specific Energy (MTSE)
				  ○ Coulombic Efficiency
				  ○ Cycling Behavior
				  ○ Transference Number
				  ○ Types of Battery Electrode Reactions
				  ○ Discharge Curves and the Gibbs Phase Rule
				  ○ Binary and Ternary Electrodes
				  ○ Phase Diagrams and Discharge Curves
				  ○ Cases: Li-Bi, Li-I2, Li-Sb, Li-Cu-Cl
				• **Components of Batteries**
				  ○ Insertion and convertible electrode reactions in batteries

				○ Positive electrodes for Li-ion batteries: (Olivine (LiMPO4), LiMO2, Spinel (LiMn2O4), Sulfur and other materials ○ Negative electrodes for Li-ion batteries based on insertion, alloying, conversion and alloying-conversion reactions ○ Graphite, Sn, Si, and other metal oxides ○ Electrolytes for Li-ion Batteries: Requirements, Organic liquid electrolyte, Dry polymer electrolyte, gel polymer electrolyte, solid electrolytes based on Sulfides and Oxides • **Battery Configuration & Fabrication** ○ Conventional batteries with liquid electrolyte ○ Passive Components ○ All-Solid-State Batteries and other types ○ Batteries Based on Other Chemistries: Sodium-Ion, Zinc-Air, Pb-Acid, Ni-Metal Hydride Batteries, etc. • **Supercapacitors** ○ Supercapacitors and its working principle ○ Types of supercapacitors ○ Criteria of materials selection for electrodes ○ Cycling and performance characteristics ○ Difference between battery and supercapacitors ○ Hybrid battery/supercapacitor energy storage system ○ Prospects and challenges • **Thermal Energy Storage** ○ Solar pond ○ Sensible thermal energy storage ○ Phase change thermal energy storage, ○ Thermal analyses of the storages

				○ Integration with solar thermal systems • **Pumped-hydro Energy Storage** ○ Basic concepts ○ Design and preliminary analyses of pumped-hydro energy storage ○ System efficiency calculation
SEE903	Solar Photovoltaics	5	• How do solar cells function? • Underlying physics and optoelectronic processes • Techniques used for photovoltaic characterization. • Various type of solar cells • Designing of PV system	• **Introduction to solar cells** ○ History of solar cells, economics, current status, emerging technologies, and recent developments ○ Solar spectrum, the concept of air mass • **Basics of semiconductors** ○ What are semiconductors? ○ Origin of bandgap ○ Direct and indirect bandgap semiconductors ○ Intrinsic and extrinsic semiconductors and their properties • **Optoelectronic processes in solar cells** ○ Optical absorption, generation, and recombination in semiconductors ○ Charge transport, charge extraction, contacts, continuity equation • **P-N junction** ○ Basics of PN Junction and Band Diagram ○ Operation of p-n junction in forward and reverse bias, depletion width ○ Drift-diffusion currents, I-V characteristics of P-N junction in Dark and Light • **Device characterization of solar cells** ○ Open circuit voltage, short circuit current, fill factor, efficiency, quantum efficiency, an equivalent circuit of a solar cell, series and

				shunt resistance, diffusion length, and the effect of recombination processes o Characterization (I-V testing, solar simulators, EQE, IQE, IPCE, EL, PL imaging etc.) o Hands-on exposure • **Brief overview of different types of solar cells** o First-generation technologies: Primarily Si-based and GaAs + Multijunction o Second-generation technologies (low cost):thin films (a Si, CdTe, CIGS) o Third generation (high efficiency and low cost): Organic and perovskite solar cells o Multi-junction Cells, BIPV • **PV Module Design** o Migration from solar cells to modules to systems, o BIPV: present status and outlook • **PV system design** o Overview of designing a PV system
SEE904	Wind and Hydro Energy	5	This course will equip participants with the basics of green energy technologies like wind and hydro energy. The course will address the potential of such energy harvesting methods in India and worldwide, along with the possible solutions available and future directions. An overview of the challenges associated with the existing technologies will be discussed. Laboratory demonstrations of scaled models of horizontal as well as vertical axis wind turbines will be conducted. The basics of computations will be presented.	• **Introduction to wind and hydro energy** o Advantages of green energy o Potential of green energy worldwide and in India • **Fundamentals of wind power** o Overview of wind meteorology o Wind Data measurements and correlations o Wind power capture and efficiency in extracting wind power • **Wind Turbine Technologies** o Aerodynamics of wind turbines o Types of wind turbines and applications o Transmission and power generation systems

				• **Horizontal Axis and Vertical Axis Wind Turbines**
				  ○ Aerodynamics of HAWT: Momentum methods
				  ○ Working principle: Lift Vs Drag based VAWT, Power coefficient
				  ○ VAWT Design: Aerofoil choice, geometric, kinematic and dynamic design parameters
				  ○ Experimental methods for design and power estimations
				• **Offshore Wind Turbines**
				  ○ Off-shore Wind Turbines
				  ○ Challenges and benefits
				• **Hydro turbines**
				  ○ Hydrodynamics of hydro turbines
				  ○ Safety and Environmental impact
				  ○ Mini hydro turbines
				• **Numerical Methodology**
				  ○ Introduction to Computational Fluid Dynamics
				  ○ Numerical Simulation of Wind/Hydro Turbines
				  ○ Impact of atmosphere on turbine performances

SEE905	Hydrogen Energy: Generation, Storage, and Utilization	5	• Hydrogen economy, eco-system, mission
			• Basics of hydrogen generation, storage, transportation, and utilization
			• Design of technological devices for hydrogen generation, storage, transportation, and utilization
				• **Introduction**
				  ○ Overview of a hydrogen-based economy/eco-system and hydrogen energy
				  ○ Role of hydrogen in decarbonization
				  ○ Essential components of the hydrogen energy ecosystem: production, storage, transportation, and conversion
				  ○ National hydrogen mission and other initiatives
				• **Hydrogen Production**

				○ Electrochemical methods(5 lectures): ○ Electrolysis, basic electrochemistry, device/system design ○ Electrolysis of water/ammonia for hydrogen production ○ Thermochemical methods(3 lectures): ○ Pyrolysis and gasification processes from renewable sources. Thermodynamics and design. ○ Thermochemical splitting of water/ammonia Photochemical ○ Photochemical Water splitting(2 lectures) ● **Hydrogen Storage and Transportation** ○ Fundamentals of methods for hydrogen storage ○ Materials, devices, and protocols for hydrogen storage ○ Materials, devices, and protocols for hydrogen transportation ● **Applications/ Utilization of Hydrogen** ○ Electrical/Electrochemical(lectures): Fuel cells, co-generation, combined heat, and power ○ Thermal(3 lectures): Heating, cooling, hydrogen-based power generation cycles ○ Chemical(1 lecture): As a chemical reagent in metal refining and other reactions
SEE906	Manufacturing Technologies for Solar Photovoltaics	5	Energy harvesting using solar photovoltaic systems is rapidly becoming ubiquitous and constitutes an essential element for realizing the vision of reliable and economically sustainable energy generation. It is imperative to develop these systems, which will not only assist	● **Introduction** ○ Introduction to energy harvesting systems such as solar PV ○ Introduction to thin films, vacuum science and technologies ● **Raw Material Processing**

			in the efficient utilization of renewable energy but also in achieving energy security. The proposed course intends to provide an understanding of the manufacturing of these energy harvesting solutions.	○ Refining, processing, and manufacturing of silicon and glass • **General Processing Techniques** ○ Lithography ○ Dry etching ○ Wet etching ○ Vapor deposition (physical and chemical) ○ Electroplating ○ Oxide growth ○ Large-area coatings • **Solar Cell Manufacturing** ○ Crystalline Si ingot growth, slicing of ingots ○ Wafer processing ○ Diffusion/Ion implantation ○ Screen printing of contacts ○ Wiring of contacts ○ Encapsulation ○ Glass cover ○ Al frame incorporation ○ **PV Module Manufacturing** ○ Module circuit design ○ Cell packaging ○ Heat dissipation ○ Module degradation and failure modes • **Process Development** ○ Design of experiments methodologies ○ Process monitoring, and control
SEE907	Manufacturing of Batteries and Hydrogen Systems	5	Energy conversion and storage systems such as fuel cells, batteries and supercapacitors constitute an essential element for realizing the vision of reliable and economic sustainable energy. It is imperative to develop these systems,	• **Introduction** ○ Introduction to energy conversion and storage systems such as fuel cells, hydrogen systems, batteries, and supercapacitors ○ Introduction to thin films, vacuum science and technologies

			which will not only assist in the efficient utilization of renewable energy but also in the successful transition to electric vehicles. The proposed course intends to provide an understanding of the manufacturing of these aforementioned energy conversion and storage solutions.	• **Raw Material Processing**
				  ○ Refining, processing, and manufacturing
				• **General Processing Techniques**
				  ○ Vapor deposition (physical and chemical)
				  ○ Electroplating
				  ○ Large-area coatings
				• **Battery Manufacturing**
				  ○ Batteries: Types, working principle, basic concepts, components
				  ○ Devices: Current Trends in Battery Manufacturing, Coin Cells, Pouch Cells and Cylindrical Cells, Conventional Rechargeable Batteries with Liquid Electrolyte, Active & Passive Electrode Components, Electrode Coating, Calendaring and Assembly of Prototype Coin Cell, Assembly of pouch cells, Solid-State Batteries and Metal Air Batteries
				• **Fuel Cell Manufacturing**
				  ○ Fuel cells: Types, working principle, basic concepts, component
				  ○ Proton exchange membrane
				  ○ Fuel Cells: Configurations, Fabrication of Electrolyte-supported anode, cathode, membrane
				• **Hydrogen Systems**
				  ○ Electrolyzers: Working principle, basic concepts, components
				• **Process Development**
				  ○ Design of experiments methodologies, process monitoring, and control

SEE908	Characterization of Materials	5	The main objective of this course is to make the students learn different structural and compositional	• **Essentials of materials: structure and composition** ○ Materials tetrahedron: basic principles

			characterization methods, including fundamental principles, how to analyze the data and how to avoid making common mistakes that can lead to erroneous interpretations.	○ Basics of crystal structures ○ Bonding in materials and materials classes ○ Defects in Materials ○ Structural forms: Single crystals, polycrystals and amorphous ○ Phases and phase equilibrium ○ Effect of composition on phases and correlation with key properties ● **Structure Determination using X-ray Diffraction** ○ Fundamentals of diffraction ○ X-rays generation ○ X-ray diffraction: powder diffraction, phase identification, Scherrer formula, strain, and grain size determination, texture determination ● **Microstructural and Compositional Characterization** ○ Fundamentals of Imaging: magnification, resolution, depth of field and depth of focus, aberration, and astigmatism ○ Optical microscopy ○ Fundamentals of SEM: imaging modes, image contrast, illustrative applications ○ Imaging with TEM: Contrast mechanisms, BF, DF, Weak beam DF images ○ X-ray spectroscopy (Energy and wavelength dispersive spectroscopy (EDS and WDS), Electron probe microanalysis (EPMA) ○ Surface probe microscopy (AFM, STM, and other modes) ● **Vibrational and Optical Spectroscopic Techniques** ○ Vibrational Spectroscopy (Raman and FTIR spectroscopy)

				○ Optical spectroscopy: UV-Vis-NIR and ellipsometer spectroscopy ● **Thermal Analysis Techniques** ○ Differential scanning calorimetry (DSC) ○ Differential Thermal Analysis (DTA) ○ Thermogravimetric Analysis ○ Dilatometry
SEE909	Energy Systems: Modelling and Analysis	5	The broad aim of this course is to acquaint with various energy systems through their modelling, design and techno-economic analysis aspects.	● **Solar Photovoltaic System** ○ Introduction ○ I-V characteristics and maximum power point ○ Modelling and system design: stand-alone & grid-connected systems ○ Applications: power generation, water pumping, and irrigation ● **Solar Thermal System** ○ Introduction ○ Basics thermodynamics ○ Conservation of mass, momentum, and energy ○ Non-concentrating and concentrating systems ○ Design of heat exchangers e.g. receiver, condenser, thermal energy storage ○ Applications: heating, cooling, and power generation ● **Wind Energy-based Systems** ○ Introduction ○ Types of wind turbines and generators ○ Power in the wind ○ Maximum rotor efficiency ○ Average power with wind statistics ○ Energy generation

				• **Fuel Cells System**
				  ○ Introduction
				  ○ Overview
				  ○ Types of fuel cells
				  ○ Energy balance in fuel cells
				  ○ Integration of fuel cells with co-generation and combined heat and power plants

SEE910	Smart Grid	5	This course will equip students with the basics of renewable energy technologies, grid integration studies, Concepts on Microgrids operation and controls, Smart Grid Technologies and communications along with exposure to real time simulations and hardware in the loop case studies.	• **Smart Grid Technologies**
				  ○ Smart Grid overview
				  ○ Smart Grid architecture & design
				  ○ Smart Grid measurement technology
				  ○ Smart Grid communication technology
				  ○ Smart Grid standards and protocols
				  ○ Interoperability & associated standards
				• **Renewable Energy Integration and Electricity Markets**
				  ○ Maximum power point operation of Solar and wind renewable technologies
				  ○ Grid Integration challenges of renewables
				  ○ Short term Electricity market
				  ○ Power exchanges
				  ○ Renewable energy certificates
				  ○ Cross border energy trading
				• **Microgrids**
				  ○ Fundamentals and architecture of microgrids
				  ○ Types of microgrids
				  ○ Hierarchical control of microgrids
				  ○ Grid-connected and isolated operation of microgrids
				  ○ Challenges with Microgrids and Solutions
				  ○ Demand Response, ADMS Features,
				  ○ Real Time Simulation and Hardware in the loop Case Studies

SEE911	Electric Vehicle Technologies	5	This course will equip students with the basics of electric vehicles (EV), battery storage technologies and charging algorithms, EV charging technologies with detailed converter analysis and EV drives.	• **Basics of Electric Vehicles**
				  ○ Introduction
				  ○ Comparison between EV & ICEV
				  ○ Types of EVs, vehicle fundamentals
				  ○ Plug-in hybrid electric vehicles (PHEV),
				  ○ Range extended EVs (REEVs),
				  ○ Configurations of EVs,
				  ○ Motor drive technologies
				  ○ Battery technologies
				  ○ Vehicle to grid technologi es, and charging technologies
				• **Energy Storage Systems**
				• **EV Charging**
				  ○ Classification of EV chargers
				  ○ Charger topologies
				  ○ Single phase boost PFC – analysis, design, and control Three phase on-board charger
				  ○ Bidirectional dual active bridge converter (DAB)
				  ○ Fast charging stations
				  ○ Vehicle to grid charging
				• **EV Motor Drives**
				  ○ Induction motor drive
				  ○ Brushless DC motor drive
				  ○ Permanent magnet synchronous motor drive
				  ○ Switched reluctance motor drive
				  ○ Synchronous reluctance motor drive
				  ○ DC motor drive

SEE912	Autonomous Driving & Industrial Automation	5	This course provides an in-depth exploration of the principles, technologies and applications of autonomous driving and industrial automation. It covers the fundamentals of autonomous vehicle,	• **AI, Autonomous driving and Automation**
				  ○ AI and autonomous driving
				  ○ Introduction to autonomous driving
				  ○ Historical overview and current state of the field

			sensor fusion, perceptual sensors, motion planning, and industrial automation processes. The course emphasizes both theoretical concepts and practical implementation aspects through hands-on projects and case studies.	○ Applications and impact on various industries ○ Taxonomy of driving ○ Driving decisions and actions ○ Computing hardware ○ Software ○ Basics of programming ● **Sensor Fusion for Perception** ○ Sensors and computing hardware ○ LIDAR sensor ○ Sensor data processing and filtering techniques ○ Multi- integration and data fusion ○ Kalman filtering and estimation ○ AI and deep learning methods for perceptual inference in autonomous driving ● **Motion Planning and Decision Making** ○ Trajectory generation and path planning ○ Collision avoidance and obstacle detection ○ Decision-making algorithms ○ Rule-based systems ○ Path search algorithms ○ V2X communication ● **Industrial Automation Processes** ○ Overview of industrial automation systems ○ Use of perceptual systems ○ Robotic manipulators ○ Robotic systems for automation