

SU Ph.D Entrance Test Syllabus

Section 1: Engineering Mathematics

Discrete Mathematics: Propositional and first order logic. Sets, relations, functions, partial orders and lattices. Monoids, Groups. Graphs: connectivity, matching, colouring. Combinatorics: counting, recurrence relations, generating functions.

Linear Algebra: Matrices, determinants, system of linear equations, eigenvalues and eigenvectors, LU decomposition.

Calculus: Limits, continuity and differentiability, Maxima and minima, Mean value theorem, Integration.

Probability and Statistics: Random variables, Uniform, normal, exponential, Poisson and binomial distributions. Mean, median, mode and standard deviation. Conditional probability and Bayes theorem.

Section 2: Electric circuits

Network Elements: Ideal voltage and current sources, dependent sources, R, L, C, M elements; Network solution methods: KCL, KVL, Node and Mesh analysis; Network Theorems: Thevenin's, Norton's, Superposition and Maximum Power Transfer theorem; Transient response of DC and AC networks, sinusoidal steady-state analysis, resonance, two port networks, balanced three phase circuits, star-delta transformation, complex power and power factor in AC circuits.

Section 3: Electromagnetic Fields

Coulomb's Law, Electric Field Intensity, Electric Flux Density, Gauss's Law, Divergence, Electric field and potential due to point, line, plane and spherical charge distributions, Effect of dielectric medium, Capacitance of simple configurations, Biot-Savart's law, Ampere's law, Curl, Faraday's law, Lorentz force, Inductance, Magnetomotive force, Reluctance, Magnetic circuits, Self and Mutual inductance of simple configurations.

Section 4: Signals and Systems

Representation of continuous and discrete time signals, shifting and scaling properties, linear time invariant and causal systems, Fourier series representation of continuous and discrete time periodic signals, sampling theorem, Applications of Fourier Transform for continuous and discrete time signals, Laplace Transform and Z transform. R.M.S. value, average value calculation for any general periodic waveform.

Section 5: Electrical Machines

Single phase transformer: equivalent circuit, phasor diagram, open circuit and short circuit tests, regulation and efficiency; Three-phase transformers: connections, vector groups, parallel operation; Auto-transformer, Electromechanical energy conversion principles; DC machines: separately excited, series and shunt, motoring and generating mode of operation and their characteristics, speed control of dc motors; Three-phase induction machines: principle of operation, types, performance, torque-speed characteristics, no-load and blocked-rotor tests, equivalent circuit, starting and speed control; Operating principle of single-phase induction motors; Synchronous machines: performance and characteristics, regulation and parallel operation of generators, Types of losses and efficiency calculations of electric machines.

Section 6: Electrical Drives

Fundamentals of Electric Drives, Controlled Converter fed DC Motor Drives, Chopper fed DC drive, Scalar control (constant V/f control) of induction motor and Control of slip ring induction motor

Section 7: Power Systems

AC and DC transmission concepts, Models and performance of transmission lines and cables, Series and shunt compensation, Electric field distribution and insulators, Distribution systems, Per-unit quantities, Power factor correction, Symmetrical components, Symmetrical and unsymmetrical fault analysis, Principles of over-current, differential, directional and distance protection; Circuit breakers, Primitive Network, Y-bus formation methods, Singular transformation method, Direct inspection method, Static Load Flow Equations, Bus Classifications, Approximate method, Gauss-Seidel Method, Newton Raphson Method, Fast Decoupled Load Flow Method, Comparison of different methods, Generator operating cost, Economic operation of generators within thermal plant, Optimal operation by co-ordination equation, Penalty factor, transmission loss formula (Kron's method), Unit commitment, Frequency and voltage control methods: Speed governing mechanism, Mathematical modeling, Adjustment of Governor characteristics, Single area control, Flat frequency control, Selective frequency control, Classification of stability studies, concept of load angle and infinite bus, Dynamics of a Synchronous Machine, Swing equation, Power angle curve, Node Elimination Technique, Steady state stability analysis, Methods of improving Steady state stability, Transient stability analysis, Equal area criteria, Single Machine infinite bus stability studies, Methods of improving Transient stability, Renewable Energy source and grid integration

Section 8: Control Systems

Mathematical modeling and representation of systems, Feedback principle, transfer function, Block diagrams and Signal flow graphs, Transient and Steady-state analysis of linear time invariant systems, Stability analysis using Routh-Hurwitz and Nyquist criteria, Bode plots, Root loci, Lag, Lead and Lead-Lag compensators; P, PI and PID controllers; State space model, Solution of state equations of LTI systems.

Section 9: Electrical and Electronic Measurements

Bridges and Potentiometers, Measurement of voltage, current, power, energy and power factor; Instrument transformers, Digital voltmeters and multi-meters, Phase, Time and Frequency measurement; Oscilloscopes, Error analysis.

Section 10: Power Quality Issues and Mitigation Techniques

Power Quality definition, Classification of Power Quality Problems, Causes of Power Quality Problems, Effects of Power Quality Problems on Users, Power Quality Standards and Monitoring, Causes of Power Quality Issues, Passive Power Filters, Active Power Filters, Compensation Techniques- Active Shunt Compensation, Active Series Compensation

Section 10: Power Electronics

Static V-I characteristics and firing/gating circuits for Thyristor, MOSFET, IGBT; DC to DC conversion: Buck, Boost and Buck-Boost Converters; Single and three-phase configuration of uncontrolled rectifiers; Voltage and Current commutated Thyristor based converters; Bidirectional ac to dc voltage source converters; Magnitude and Phase of line current harmonics for uncontrolled and thyristor based converters; Power factor and Distortion Factor of AC to DC converters; Single-phase and three-phase voltage and current source inverters, sinusoidal pulse width modulation.

Section 11: Energy management, Conservation and Audit

Fundamentals of Energy management and objectives of energy audit, scope of energy management and opportunities in electrical and thermal utilities, economic analysis, monitoring instruments and data analysis.

 SARVAJANIK UNIVERSITY INCLUSIVE INTEGRATED INNOVATIVE	SARVAJANIK UNIVERSITY Sarvajani College of Engineering and Technology	
--	--	---

PhD, Semester 1/2
(CO / IT Engineering)

Subject Name: Data Science for Engineers

Subject Code: PTCO13104

Type of course: PhD Credit Course

Prerequisites (if any): - Statistics

Rationale: This course introduces the mathematical foundations required for data science. As part of this course, students will learn the framework for solving problems requiring data analytics. This course also introduces 'R' programming language. Students will be able to solve predictive problems on real time data after learning this course.

Teaching and Examination Scheme:

Teaching Scheme				Theory Marks			Practical Marks		Total
L	T	P	C	TEE	CA1	CA2	TEP	CA3	
4	0	0	4	50	30	20	0	0	100

CA1: Continuous Assessment (assignments/projects/open book tests/closed book tests) CA2: Sincerity in attending classes/class tests/ timely submissions of assignments/self-learning attitude/solving advanced problems TEE: Term End Examination TEP: Term End Practical Exam (Performance and viva on practical skills learned in course) CA3: Regular submission of Lab work/Quality of work submitted/Active participation in lab sessions/viva on practical skills learned in course

Contents

Sr No	Description	No. of Hours
1.	Course philosophy and expectation, Introduction to R, Variables and data types in R, Data frames, Recasting and joining of data frames, Arithmetic, Logical and Matrix operations in R, Advanced programming in R : Functions, Control structures, Data visualization in R Basic graphics	8
2.	Linear Algebra for Data science, Solving Linear Equations, Linear Algebra - Distance, Hyperplanes and Halfspaces, Eigenvalues, Eigenvectors	6
3.	Statistical Modelling, Random Variables and Probability Mass/Density	6

 SARVAJANIK UNIVERSITY INCLUSIVE INTEGRATED INNOVATIVE	SARVAJANIK UNIVERSITY Sarvajani College of Engineering and Technology	
--	--	---

	Functions, Sample Statistics, Hypotheses Testing	
4.	Optimization for Data Science, Unconstrained Multivariate Optimization, Gradient Descent, Learning Rule	6
5.	Multivariate Optimization With Equality Constraints, Multivariate Optimization With Inequality Constraints, Introduction to Data Science, Solving Data Analysis Problems - A Guided Thought Process	6
6.	Module: Predictive Modelling, Linear Regression, Model Assessment, Diagnostics to Improve Linear Model Fit, Simple Linear Regression Model Building, Simple Linear Regression Model Assessment, Multiple Linear Regression	6
7.	Cross Validation, Multiple Linear Regression Modelling Building and Selection, Classification, Logistic Regression, Performance Measures, Logistic Regression Implementation in R	6
8.	K - Nearest Neighbors (kNN), K - Nearest Neighbors implementation in R, K - means Clustering, K - means implementation in R	6
9.	Applications of Data Science, Challenges reported in contemporary literature, Case Studies	10

Course Outcomes

Sr. No	CO Statement	Marks % Weightage
1.	Describe a flow process for data science problems	20%
2.	Classify data science problems into standard typology	20%
3.	Develop R codes for data science solutions	20%
4.	Correlate results to the solution approach	15%

 SARVAJANIK UNIVERSITY INCLUSIVE INTEGRATED INNOVATIVE	SARVAJANIK UNIVERSITY Sarvajani College of Engineering and Technology	
--	--	---

5.	Assess the solution approach	15%
6.	Construct use cases to validate approach and identify modifications required	10%

Reference Books:

Sr no	Title of book /article	Author(s)	Publisher	Year of publication	Publication Edition
1	Introduction To Linear Algebra	Gilbert Strang	Wellesley Publishers	2016	Fifth Edition
2	Applied Statistics And Probability For Engineers	Douglas Montgomery	Wiley	2016	Sixth Edition
3	Practical Statistics for Data Scientists	Peter Bruce and Andrew Bruce	Publisher(s): O'Reilly Media, Inc. ISBN: 9781491952962	2017	2nd Edition
4	Think Stats: Probability and Statistics for Programmers	Allen B. Downey	Green Tea Press Needham, Massachusetts	2014	2nd Edition
5	Data Science for Dummies	John Muller	Wiley	2017	2nd Edition
6	Statistics for Data Science	James D. Miller	PACKT	2017	-

List of Online Learning Resources:

- NPTEL course on: Data Science for Engineers
(https://onlinecourses.nptel.ac.in/noc23_cs17/preview)

DULLABH RAMJI BHANABHAI PATEL (DRB)

Department Of Civil Engineering

Syllabus For Ph.D Civil Engineering Semester II

DULLABH RAMJI BHANABHAI PATEL (DRB)

Department Of Civil Engineering

Subject : 3 (Year I - Semester II)

Sr. No.	Domain in Civil Engineering	Subject No 3
1	Structural Engineering	Soil Improvement and Dynamic Response of Structure (PTCL13210) 04 Credits (4-0-0).
2	Water Resource Engineering	Issues and Sustainability of Water Resources (PTCL13208) 04 Credits (4-0-0).
3	Town Planning	Land Management Techniques (PTCL13203) 04 Credits (4-0-0)

Subject : 4 (Year I - Semester II)

Sr. No.	Domain in Civil Engineering	Subject No 4
1	All Domains of Civil Engineering	Seminar (PTCL16201) - Domain Specific 02 Credits (2-0-0)

Ph.D.	1	Semester	II	Teaching Scheme				Evaluation Scheme	
Subject Name	Land Management Techniques			L	T	P	Credits	CCE	SEE
Subject Code	PTCL13203			4	0	0	4	50	50
Type of course	PhD Credit Course								
Prerequisite	Understanding on housing, social aspects, urbanization, traffic planning, building bylaws also understanding on survey techniques, coordinate systems, statistics, geographic features, operations using CAD tools and worksheets.								
Rationale	To amalgamate planning techniques on the basis of qualitative & quantitative analysis of availed data for proper management & performance of urban planning. Subject helps orienting students to a very emerging, useful and important field of geo-spatial world wherein scopes for professional career are endless.								

Course Outcomes (COs): At the end of the course, students will be able to	
CO – 1	Understand and attempt practicing management principle.
CO – 2	Understand process of analysis and predict future population by using different statistical methods.
CO – 3	Scopes, functions, limitations of new town development were made known, various policies and land development schemes pertaining to urban planning.
CO – 4	Sensitization towards certain importance and use of geo spatial techniques and implementation in urban as well as regional planning.

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weight
1	Land use activities: Introduction, Population forecasting methods. Analysis and prediction of important land use activities.	10	30%
2	Urban Infrastructure: Elements of Infrastructure, Basic definitions, concepts, significance and importance, Data required for provision and planning of urban networks and services; Resource analysis, provision of infrastructure; Principles of resource distribution in space; Hierarchical distribution of facilities, Access to facilities, provision and location criteria, Norms and standards, etc.	15	20%

3	Land Management Practices: Land value and density pattern, Principal of Town Planning schemes, Land Acquisition, Rehabilitation and resettlement act 2013, TDR, Guidelines of URDPFI, GDCR and GTPUD Act. Zoning, Smart metropolitan planning. A case study of development plan, master plan, preparation, Formulation and implementation, Global Trends.	15	20%
4	Geospatial Techniques and Planning: Cartography, Geographic mapping process, transformations, map projections, Geographic Data Representation, Storage, Quality and Standards, database management systems, Raster data representation, Vector data representation, Assessment of data quality, Managing data errors, Geographic data standards.	20	30%

Recommended Reference Books

- 1 Das, A. K. (2007). *Urban Planning In India*. Rawat Publishers. ISBN: 8131600947.
- 2 Roberts, M. (n.d.). *Town Planning Techniques*. Hutchinson Educational Publication.
- 3 Lall, S. V. (2009). *Urban Land Markets: Improving Land Management for Successful Urbanization*. Springer.
- 4 Randolph, J. (2009). *Environmental Land Use Planning and Management*. Island Press.
- 5 Berke, P. R. (2009). *Urban Land Use Planning*. University of Illinois Press.
- 6 Lo, C. P., & Yeung, A. K. W. (2002). *Concepts and Techniques of Geographic Information Systems*. Prentice Hall of India.
- 7 Reddy, A. M. (2001). *Remote Sensing and Geographical Information Systems*. B.S. Publications.
- 8 Burrough, P. A. (1998). *Principles of Geographical Information Systems*. Oxford Publication.
- 9 Clarke, K. (2001). *Getting Started with Geographic Information Systems*. Prentice Hall.
- 10 De Mers, M. N. (2000). *Fundamentals of Geographic Information Systems*. John Wiley & Sons.

List of Open Source/learning website:

- CAD Drafting tools; word processing tools, calculation sheets
- Google Sketch-Up Pro
- ESRI City Engine (Transforms 2D GIS Data into 3D city models)
- Remote Sensing & Geographic Information System (<http://gis.nic.in/>)
- National Remote Sensing Centre (<http://www.nrsc.gov.in/>)
- Indian Space Research Organisation (<http://www.isro.org/>)

- Indian institute of Remote Sensing (<http://www.iirs.gov.in/>)
- List of geographic information systems software
(http://en.wikipedia.org/wiki/List_of_geographic_information_systems_software)
- Google books on GIS and Remote Sensing
([https://www.google.co.in/search?q=Urban+Planning+Techniques&btnG=Search+Books&tbm=bks
& tbo=1&gws_rd=ssl#q=GIS+Remote+Sensing&tbm=bks](https://www.google.co.in/search?q=Urban+Planning+Techniques&btnG=Search+Books&tbm=bks&tbo=1&gws_rd=ssl#q=GIS+Remote+Sensing&tbm=bks)) .

Ph. D.	I	Semester	II	Teaching Scheme				Evaluation Scheme	
Subject Name	Issues and Sustainability of Water Resources			L	T	P	Credits	CCE	SEE
Subject Code	PTCL13208			4	-	-	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	1st year of Ph. D.								
Rationale	The subject of water resources and sustainability is important because water is a vital natural resource that is essential for human survival, economic development, and the health of the planet. It essential for creating a balance approach to managing one of the planet’s most critical resources. Through this study, students can develop the knowledge, skill and awareness needed to contribute to sustainable water management practices.								

Course Outcomes (COs): At the end of the course, students will be able to		Marks % Weightage
CO – 1	Understand the environmental issues pertaining to water and its usage, its effects on food pattern and society.	25
CO – 2	Appreciate the remedies and protective measures for maintaining the quality and quantity of water.	25
CO – 3	Apply sustainability principles to real-world scenarios	25
CO – 4	Gain the skills to take up research activities in environmental sustainability.	25

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1.	Environmental issues Water crisis and Climate Change, conservation of water, Green-House Effect , Green House Gases GHGs) and their Emission, famine and drought scenario, heat island formation and its consequences, Sea Level rise, effects on wetlands and estuaries	14	25%
2.	Assessment of Contamination Industrial Pollution, Quantification of contamination, Global Warming Potential (GWP) of flux emission from treatment facilities, agricultural pollution, ground water contamination	15	25%
3.	Sustainability of Environment History and Need of the concept of Sustainable Development, basic	15	25%

	terms, Environmental issues and crisis, Resource degradation, green house gases, deforestation, food insecurity, Industrialization, Globalization and Environment, substitutes for usage of pesticides and fertilisers.		
4.	Roles and Techniques Alternatives of Carbon Sequestration, Conventional and non-conventional techniques, Role of Countries and Citizens in Controlling Global Warming, Integrated approach for resource protection and management.	12	25%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15	25	25	15	10	10

Legends: R: Remembrance, **U:** Understanding; **A:** Application, **N:** Analyze, **E:** Evaluate **C:** Create and above Levels (**Revised Bloom's Taxonomy**)

Recommended Reference Books

- 1 Basant Yadav Mohit Prakash Mohanty Ashish Pandey Vijay P. Singh, R. D. Singh ,” Sustainability of Water Resources: Impacts and Management”, Springer International Publishing ISBN-13: 978-3031134692; 1st edition, 2022.
- 2 Sarda Ganguly Gangadhar Banerjee, “Water Resources and Environmental Sustainability”, MV Learning ISBN-13: 978-9387692855, 1st edition, 2018.
- 3 Ritu Singh, Sanjeev Kumar, “Green Technologies and Environmental Sustainability”, Springer International Publishing, ISBN 978-3-319-50654-8, ebook, 2017.
- 4 Dr. D K Asthana Dr. Meera Asthana, “Environmental Studies”, S Chand ISBN-13 978-8121927642, 2nd edition, 2015.
- 5 Sudha Sambyal Malik , “Environmental Issues”, Bio-Green Books ISBN-13 978-9388982962, 1st edition, 2020.

Ph. D	I	Semester	II	Teaching Scheme				Evaluation Scheme	
Subject Name	Soil Improvement and Dynamic Responses of Structure			L	T	P	Credits	CCE	SEE
Subject Code	PTCL13210			4	0	0	4	50	50
Type of course	Ph. D – Credit Subject			CCE: Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Soil Mechanics, Foundation Engineering, Strength of Materials, Structural Analysis & Repair& Rehabilitation of Structure								
Rationale	When a project encounters difficult foundation conditions, possible alternate solutions are: Avoid the particular site or Design the planned structure accordingly. The choice of a method of ground improvement for a particular object will depend on: Type and degree of improvement required, type of soil, cost, possible damage to adjacent structures or pollution of ground water resources, reliability of method of analysis and design etc.. Though earthquakes can produce devastating damages to life and property, modern technologies of seismic vibration control such as building elevation control, elevated building foundations, and the use of dampers and springs can assist in minimizing earthquake damage. Wind-induced vibration has become one of the main design challenges regarding modern high-rise buildings. High-rise buildings are naturally more sensitive for dynamic responses due to their low fundamental frequencies than low-rise buildings. At the same time, different wind conditions such as vortex effects intensify at higher levels and create more vibration prone structures. The main problem regarding wind-induced vibration is occupants’ respond to the fluctuation of a building and it has proven to cause various negative effects, such as sleepiness and motion sickness. For this reason, different criterion and methods to evaluate dynamic responses of structures are required.								

Course Outcomes (COs): At the end of the course, students will be able to			Marks % Weightage
CO – 1	Identify the mineral composition responsible for the weak soil deposits and problems associated with it. (R, U, A – Cognitive Level)		25
CO – 2	Analyze various index/strength properties of soil and suggest suitable ground improvement method. (R, U, A, – Cognitive Level)		15
CO – 3	Classify and identify the distress in structure (R, U, A, N, E, – Cognitive Level)		10
CO – 4	Identify Understand the Basics of Earthquake Engineering (R, U, A, N, E, C– Cognitive Level)		35
CO – 5	Conceptualize vibrating body for free and forced vibration (R, U, A, N, E, C – Cognitive Level)		15

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage

1.	Ground Improvement: Definition, Objectives of soil improvement, Classification of ground improvement techniques, Factors to be considered in the selection of the best soil improvement technique. Weak Deposits – Identification – Problems associated with weak deposits – Mitchel chart of applicability of treatment methods – Principles – Suitable methods. Mechanical Modification, Principle of modification for various types of soils	14	20%
2.	Geosynthetics and Reinforced Soil: Types of Geosynthetics like geotextiles, Geogrid, geonets, geocells, geo-composites, their functions, applications and manufacturing methods. Index properties and Strength properties of Geosynthetics. Historical background of reinforced soil, Principles of reinforced soil. Concept of MSE wall and Reinforced Soil slopes.	12	15%
3.	Structural Health Monitoring: Concepts, Various measures, Structural Safety in alteration, Factors Affecting health of structures, causes of distress, regular maintenance	12	20%
4.	Fundamentals of Earthquake Vibrations of buildings Static load v/s Dynamic load, simplified single degree of freedom system, mathematical modelling of buildings, natural frequency, resonance v/s increased response, responses of buildings to different types of vibrations like free and forced, damped and un-damped vibration, response of building to earthquake ground motion, Response to multi degree (maximum three) of freedom systems up to mode shapes.	14	35%
5.	Wind Induced Vibrations of Tall Buildings: Types of Flow Induced Excitation, Vortex Induced Phenomenon, Buffeting and Ovaling, Galloping and Flutter.	08	10%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10	20	30	15	15	10

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (**Revised Bloom's Taxonomy**)

Recommended Reference Books	
1	A. K. Chopra, "Dynamics of structures", Pearson Education India, 2014.
2	Daniel Balageas, Claus-Peter Fritzen, Alfredo Güemes, "Structural Health Monitoring", John Wiley & Sons., 2010.
3	Douglas E Adams, "Health Monitoring of structural Materials and components -- Methods with applications", John Wiley & Sons, 2007.
4	Jie H, "Principles and Practice of Ground Improvement", Wiley India, 2018.
5	Koerner R. M., "Designing with Geosynthetics", Prentice Hall, New Jersey, USA, 2012.
6	L. Meirovitch, "Elements of Vibration Analysis", Tata Mc Graw-Hill, Singapore., 1986.
7	Manish Shrikhande & Pankaj Agrawal, "Earthquake Resistant Design of Structures", PHI Publication, New Delhi, 2014.
8	P. Purushothama Raj, "Ground Improvement Techniques", Laxmi Publications, 2016.

Ph.D	EC	Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Generative AI and Autonomous Agent Architectures			L	T	P	Credits	CCE	SEE
Subject Code				4	0	0	4	50	50
Type of course	PhD Paper 3			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Machine learning , Deep Learning								
Rationale	Artificial Intelligence (AI) and Machine Learning (ML) are crucial due to the rapid emergence of Generative AI, Large Language Models (LLMs), and Autonomous Agentic Systems. This course prepares individuals to design, deploy, and operate intelligent systems using modern practices (MLOps) and address critical concerns related to Responsible AI, fairness, and explainability. It is essential for individuals, businesses, and society at large to harness the benefits of these technologies responsibly, stay competitive, and navigate the evolving landscape of artificial intelligence.								

Course Outcomes (COs): At the end of the course, students will be able to		Marks % Weightage
CO – 1	Understand and implement Generative AI models (GANs, VAEs, Diffusion Models) for creating synthetic content and media.	25%
CO – 2	Apply advanced NLP and LLM concepts like Prompt Engineering and RAG for complex, real-world conversational systems.	25%
CO – 3	Analyze and design Autonomous AI Agent systems capable of planning, reasoning, and tool utilization.	20%
CO – 4	Organize and apply XAI techniques (LIME, SHAP) to ensure transparency and evaluate models for Ethical and Responsible AI practices.	20%
CO – 5	Create deployable real-time applications by utilizing MLOps principles and modern deployment strategies.	10%

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Generative AI: Architectures and Synthetic Media Introduction to Generative AI. Variational Autoencoders (VAEs). Generative Adversarial Networks (GANs): Architecture, Training stability, Deepfake generation. Diffusion Models (DMs): Core concepts of forward and reverse process, conditional generation (Text-to-Image).	10	25%
2	Large Language Models (LLMs) and Agentic AI LLM Architectures: Transformer, Encoder-Decoder vs. Decoder-Only models. Parameter-Efficient Fine-Tuning (PEFT), LoRA. Prompt Engineering: Chain-of-Thought, Tree-of-Thought, RAG (Retrieval Augmented Generation). AI Agents: Agent architectures, Planning, Tool-Use, and Multi-Agent Systems.	12	25%
3	Trustworthy AI: Explainability (XAI) & Ethics Explainable AI (XAI): Black Box vs. Glass Box, Model-Agnostic vs. Model-Specific. Local Explanations: LIME and SHAP. Ethical AI: Concepts of Fairness, Accountability, Transparency, and Privacy (F.A.T.P). Bias mitigation, Data Provenance. Soft Computing for Optimization: Genetic Algorithm, PSO, ACO for hyper-parameter tuning	08	15%
4	AI Deployment and Operations (MLOps) MLOps Lifecycle: Continuous Integration, Continuous Delivery, and Continuous Training (CI/CD/CT). Model Versioning and Registry. Deployment Strategies: Containerization (Docker), Serverless deployment. Model Monitoring: Data Drift, Concept Drift, Outlier detection. Edge AI & TinyML: Model compression, On-device inference.	10	25%
5	Special Applications/Case Studies Case studies in AI for Sustainability/Climate, AI in Finance (Algorithmic Trading), Autonomous Vehicles (Decision-making and Perception), Robot Learning from Demonstration (LfD).	05	10%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15	20	25	25	10	5

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Recommended Reference Books

Sr. No.	Book Title	Author(s)	Publisher & Year (Approx.)
1.	Hands-On Generative AI with Transformers and Diffusion Models	Omar Sanseviero, et al.	O'Reilly (2024)
2.	The LLM Engineering Handbook	Paul Iusztin, Maxime Labonne	Packt (2024)
3.	Practical MLOps: How to Get Models into Production	Noah Gift, Alfredo Deza	O'Reilly (2021)
4.	Explainable AI for Practitioners: Design, Testing, and Governance	Ajay Thampi, Animesh Singh	Apress (2022)
5.	Dive into Deep Learning	Aston Zhang, et al.	Cambridge University

List of Open Source/learning website/Other Details if any:

NPTEL / Swayam Course Links

These NPTEL courses cover the theoretical and implementation details for the LLMs, Generative AI, and Agentic AI modules.

1. Introduction to Large Language Models (LLMs)
Link: https://onlinecourses.nptel.ac.in/noc25_cs45/preview
2. Generative AI Fundamentals, Transformers, RAG, Diffusion Models, LangChain, Responsible AI.
Link: https://onlinecourses.swayam2.ac.in/imb24_mg116/preview
3. Intelligent Agents, Evolutionary Algorithms (Soft Computing), Multi-agent Systems, Ethics in AI.
Link: https://onlinecourses.nptel.ac.in/noc25_cs159/preview



Ph.D	EC	Semester	2nd	Teaching Scheme				Evaluation Scheme	
Subject Name	Advanced VLSI Architectures			L	T	P	Credits	CCE	SEE
Subject Code				4	-	-	4	50	50
Type of course	Paper 3			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Basic understanding of Digital Electronics, VLSI Design, CMOS Technology, and Semiconductor Devices.								
Rationale	This course provides an in-depth understanding of state-of-the-art VLSI architectures used in high-performance computing, SoC design, embedded systems, and semiconductor technologies. It enables research scholars to explore design challenges, optimization techniques, and emerging architecture trends in modern VLSI systems.								

Course Outcomes (COs): At the end of the course, students will be able to		Marks % Weightage
CO – 1	Understand fundamentals of advanced VLSI system architectures	20%
CO – 2	Analyze performance and design trade-offs in arithmetic and memory architectures	20%
CO – 3	Apply principles of low-power and high-performance VLSI design	20%
CO – 4	Evaluate emerging semiconductor trends and 3D IC integration	20%
CO – 5	Demonstrate analytical and research skills in VLSI architectural optimization	20%

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Unit 1: Fundamentals of VLSI Architectures Evolution of VLSI Architectures: From ASICs to SoCs, Overview of design abstraction levels (system, architecture, logic, circuit), Architecture modeling techniques, Processor-level architectures: RISC, CISC, DSP architectures, Design metrics: performance, power, area, cost, scalability	6	20%
2	Unit 2: Arithmetic and Logic Architectures High-speed adder and multiplier architectures, Parallel-prefix adders: Kogge-Stone, Brent-Kung, Booth multipliers, Wallace and	8	20%



	Dadda trees, ALU design optimization, Pipelining and parallelism in arithmetic units		
3	Unit 3: Memory and Interconnect Architectures SRAM, DRAM, Flash memory architectures, Cache design: mapping, replacement policies, coherence, Multiported and embedded memory design, Interconnects: global vs. local, crosstalk, delay modeling, NoC (Network-on-Chip) architectures	8	20%
4	Unit 4: Low-Power & High-Performance VLSI Techniques Power dissipation: dynamic, static, short-circuit, Power optimization techniques: clock gating, power gating, DVFS, High-performance design: pipelining, retiming, logic restructuring, Physical design considerations: floorplanning, placement, routing	8	20%
5	Unit 5: Emerging Trends in VLSI & Semiconductor Architectures 3D ICs, TSV technology, FinFET, GAAFET, and nanoscale device architectures, AI/ML-enabled chip design, SoC & heterogeneous integration, Quantum and neuromorphic architecture introduction	8	20%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10%	20%	20%	20%	15%	15%

Legends: R: Remembrance, **U:** Understanding; **A:** Application, **N:** Analyze, **E:** Evaluate **C:** Create and above Levels (**Revised Bloom's Taxonomy**)

Recommended Reference Books

1. Jan M. Rabaey – Digital Integrated Circuits
2. Neil Weste & David Harris – CMOS VLSI Design
3. Keshab Parhi – VLSI Digital Signal Processing Systems
4. Wayne Wolf – Modern VLSI Design
5. John P. Uyemura – Introduction to VLSI Circuits and Systems
6. M. Morris Mano – Computer System Architecture



List of Open Source/learning website/Other Details if any:

- NPTEL Online Courses – VLSI Design, Digital IC Design
- Coursera – VLSI CAD, Semiconductor Physics
- edX – Advanced VLSI Systems
- IEEE Xplore Digital Library

Ph.D		Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Modelling, Planning and Optimal Energy Management of Microgrid			L	T	P	Credits	CCE	SEE
Subject Code				4	0	0	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	knowledge of Power Systems and renewable energy sources								
Rationale	This subject aims to benefit the research scholar wishing to work in any area of Distributed Generation and Microgrid. The subject covers wide spectrum of recent developments in the field of Microgrid from planning to optimal operation and energy management using conventional and intelligent techniques.								

Course Outcomes (COs): At the end of the course, students will be able to		Marks % Weightage
CO – 1	Describe significance of Distributed Generation, sources and economic aspects.	25
CO – 2	Illustrate issues pertaining to integration of energy sources with grid.	15
CO – 3	Apply concepts of distributed generation in Microgrid.	15
CO – 4	Apply and analyse optimal control and energy management strategies for microgrid.	30
CO – 5	Apply Intelligent techniques in micro-grid for real-world problems.	15

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Introduction Conventional power generation methods and sources, advantages and disadvantages, energy crisis, non-conventional energy sources, renewable energy potential, world energy scenario, Indian energy scenario, renewable energy policies of India.	5	10
2	Decentralized Generation Decentralized versus centralized station generation, traditional power systems, load curves and load curve analysis, demand scheduling, optimal design of hybrid energy systems, energy economics and cost optimization of integrating energy system and case study.	6	10
3	Distributed Generation (DG)	8	10



	Introduction to Distributed Generation (DG), Non - Conventional Energy (NCE) Resources, Solar Photovoltaic Generation, Wind Energy - Wind Power Plants, Micro-turbines, Fuel Cell, Energy Storage Systems: Batteries, Fly-Wheels, Ultra-capacitors, Unit Sizing of DGs.		
4	DG integration with Grid Requirements for grid interconnection, IEEE 1547 standard for interconnection and interoperability of distributed energy resources electric power systems interfaces, grid interconnection issues, constraints on operational parameters, response to grid abnormal operating conditions, LVRT and synthetic inertia emulation, islanding, stability, power quality issues and reliability.	7	15
5	Microgrid (MG) Concept and definition of micro grid, types and structure of micro-grids, autonomous and non-autonomous grids, microgrid drivers and benefits, review of sources of micro grids, typical structure and configuration of a micro grid, AC and DC micro grids, power electronics interfaces in DC and AC micro grids, decision making tools.	8	15
6	Energy Management Systems (EMS) in MG Definitions and significance, objectives, monitoring and control system, centralized and decentralized EMS, decision making, role of EMS in MG scheduling, mathematical modeling of different MG's components, role of energy storage systems in Microgrid operation	7	10
7	Planning, Operation and control of micro grid Planning of DGs sizing of DGs, sizing of micro-grids, modes of operation and control of micro grid: grid connected and islanded mode, active and reactive power control, protection issues, economic demand management strategy for passive consumers and microgrid operation, conventional droop methods for Microgrid, distributed control approaches for Microgrid, control of energy storage systems in Microgrid, fault ride through and fault current management for Microgrid, microgrid protection	12	20
8	Intelligent techniques Optimization techniques, genetic algorithm, fuzzy logic, artificial neural networks and multi-agent system, applications of intelligent techniques for microgrid.	7	10

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10%	15%	25%	20%	15%	15%

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Reference Books:

Sr. No.	Title of book /article	Author(s)	Publisher and details	Year of publication
1	Renewable Energy Resources	John Twidell and Tony Weir	Taylor and Francis	2006
2	Distributed Power Generation – Planning and Evaluation	H. Lee Willis, Walter G. Scott	Taylor & Francis	2000
3	Integration of Distributed Generation in the Power System	Bollen M. H. and Hassan F	Wiley-IEEE Press	2011
4	Microgrids	Sanjeevikumar Padmanaban, K. Nithiyananthan, S. Prabhakar Karthikeyan, Jens Bo Holm-Nielsen	CRC Press	2020
5	Microgrid: Operation, Control, Monitoring and Protection	Monalisa Biswal, Papia Ray	Springer Singapore	2020
6	Modeling, planning and optimal energy management of combined cooling, heating and power microgrid: A review	Wei Gu, Zhi Wu, Rui Bo, Wei Liu, Gan Zhou, Wu Chen, Zaijun Wu	Elsevier	2014
7	Microgrids: Advances in Operation, Control, and Protection	Amjad Anvari-Moghaddam, Behnam Mohammadi-Ivatloo, Hamdi Abdi, Nikos Hatziargyriou	Springer International Publishing	2021
8	Demand response and smart grids—a survey	Pierluigi Siano	Elsevier Journal of Renewable and Sustainable Energy Reviews	Volume 30, 2014, pp. 461-478.
9	Artificial Intelligence (2nd Edition)	Elaine Rich and Kevin Knight	Tata McGraw- Hill	
10	Artificial Intelligence: A Modern Approach (2nd edition)	Stuart Russel, Peter Norvig	Prentice Hall	

Ph.D		Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Recent Advancements in Electrical Engineering			L	T	P	Credits	CCE	SEE
Subject Code				4	0	0	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	knowledge of Electrical Engineering-power systems, electrical machines and drives.								
Rationale	This subject aims to benefit the research scholar wishing to work in any area of Electrical Engineering domain. The subject covers wide spectrum of recent developments in the field of electrical and multidisciplinary areas and its impact on environment, society and economy.								

Course Outcomes (COs): At the end of the course, students will be able to			Marks % Weightage
CO – 1	Explore and identify various recent developments in the field of distributed energy sources and impact on power systems.		25
CO – 2	Explore and identify applications of modern efficient electrical drives.		20
CO – 3	Identify power quality issues in modern power systems and microgrid.		20
CO – 4	Identify various components of electric vehicle and configurations.		20
CO – 5	Explore various intelligent techniques and their applications in electrical engineering		15

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Modern Electrical Power Systems and Devices Optimal Load Flow solution of a modern power system, Transient and steady state stability of a Power System and soft-simulation tools, protection and control of modern power systems, modelling of FACTS Devices and HVDC Systems	7	12
2	Electrical Machines & Drives Special purpose and industrial electrical motors, advanced drives and modelling of control techniques, special purpose motors and applications, like traction, electrical vehicles, etc.	7	10
3	Applications of Power Electronics	7	13

	Switch Mode Power Supplies, Power Electronic Converters for Renewable Energy System, Power Electronic converters for EV, Power Electronics for Drives, Advanced Power Converters and Applications		
4	Renewable Energy Systems Solar and solar-thermal energy systems, grid interactive and isolated solar photovoltaic systems, wind energy and wind turbine- generators and power electronics interfaces, fuel-cell and converters, benefits over conventional energy source based generation	7	10
5	Power Quality Management Power Quality Standards and recommended practices, transient system modelling, harmonics and mitigation, reduction techniques, passive and active filters, power factor correcting techniques, power quality monitoring and instruments.	8	15
6	Electric Vehicle Motion and dynamic equations of the electric vehicles and various forces acting on it, Power flow control and drive train topologies, Energy management strategies, Types of Storage systems, Battery charging techniques and standards	8	10
7	Smart and Microgrids Concepts, definition, and classifications, operation management of Microgrid clusters, Energy Management Systems(EMS) for Microgrids, role of Energy Storage Systems(ESS)	8	15
8	Artificial Intelligence and Machine Learning Introduction to Artificial Intelligence, Fuzzy Logic and Fuzzy set theory, Artificial Neural networks, Genetic Algorithms, Introduction to machine learning	8	15

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15	15	20	20	15	15

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Reference Books:

Sr. No.	Title of book /article	Author(s)	Publisher and details	Year of publication
1	Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems	Narain G. Hingorani, Laszlo Gyugyi	Wiley-IEEE Press; 1st edition	1999
2	HVDC/FACTS for Grid Services in Electric Power Systems	José M Maza-Ortega, Antonio Gómez-Expósito	MDPI AG	2020
3	Control of Power Electronic Converters and Systems: Volume 1	Frede Blaabjerg	Elsevier Science	2018
4	Renewable Energy Systems: Simulation with Simulink and Sim-power systems	Viktor Perelmuter	Taylor and Francis	2016
5	Power quality	C. Sankaran	CRC Press	2002
6	Electric Vehicle Technology Explained	James Larminie, J. Lowry	John Wiley & Sons Ltd.	2003
7	Electric and Hybrid Vehicles: Design Fundamentals	Iqbal Hussein	CRC Press,	2003
8	Microgrids	Sanjeevikumar P.a, K. Nithiyananthan, S. Prabhakar K. and Jens	CRC Press	2020
9	Microgrid: Operation, Control, Monitoring and Protection	Monalisa Biswal, Papia Ray	Springer Singapore	2020
10	Artificial Intelligence (2 nd Edition)	Elaine Rich and Kevin Knight	Tata McGraw-Hill	2018
11	Artificial Intelligence: A Modern Approach (2 nd edition)	Stuart Russel, Peter Norvig	Prentice Hall	2002



**SARVAJANIK
UNIVERSITY**

INCLUSIVE | INTEGRATED | INNOVATIVE

creating an enlightened society...

SARVAJANIK UNIVERSITY

SARVAJANIK COLLEGE OF ENGINEERING AND TECHNOLOGY

DOCTOR OF PHILOSOPHY



264

Ph.D.	MECH	Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Numerical Methods for Mechanical Engineers			L	T	P	Credits	CCE	SEE
Subject Code				4	0	0	4	50	50
Type of course	Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Fundamental concepts of Mathematics								
Rationale	This course will help to understand the basics of numerical algorithms and skills to implement algorithms to solve research problems.								

Course Outcomes (COs): At the end of the course, students will be able to			Marks % Weightage
CO-1	Apply interpolation and numerical integration techniques for mathematical and engineering problems.		20
CO-2	Apply Laplace transform techniques for solving differential equations and integral equations.		15
CO-3	Solve linear & nonlinear algebraic equations using classical and iterative numerical approaches.		15
CO-4	Formulate and solve ordinary differential equations using analytical & numerical methods.		20
CO-5	Apply probability and statistical tools for data analysis, inference and hypothesis testing.		15
CO-6	Select and implement suitable numerical algorithms using software tools for solving real-time mechanical engineering / research problems.		15

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1.	Numerical Analysis: Introduction, Solution of Equations by Iteration, Finite Differences, Forward, Backward and Central operators, Interpolation by polynomials: Newton's forward, Backward interpolation formulae, Newton's divided	14	25 %

Credit Course

w.e.f. AY-2025-26

Ph.D.



**SARVAJANIK
UNIVERSITY**

INCLUSIVE | INTEGRATED | INNOVATIVE
creating an enlightened society...

SARVAJANIK UNIVERSITY

SARVAJANIK COLLEGE OF ENGINEERING AND TECHNOLOGY

DOCTOR OF PHILOSOPHY



265

Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
	Gauss & Stirling's central difference formulae and Lagrange's interpolation formulae for unequal intervals, Coefficients of an Interpolating Polynomial, Inverse Interpolation; Spline Interpolation. Numerical Integration: Newton-Cotes formula, Trapezoidal and Simpson's formulae, error formulae, Gaussian quadrature formulae.		
2.	Laplace Transforms: Laplace Transform, Linearity, First Shifting Theorem (s-Shifting); Transforms of Derivatives and Integrals, ODE; Unit Step Function (Heaviside Function), Second Shifting Theorem (t-Shifting); Short Impulses, Dirac's Delta Function, Partial Fractions; Convolution, Integral Equations; Differentiation and Integration of Transforms, ODEs with Variable Coefficients; Systems of ODEs.	10	15%
3.	Linear and non-linear algebraic equation: Solution of a System of Linear Equations: Gauss elimination, partial pivoting, Gauss-Jacobi method and Gauss-Seidel method. Roots of Algebraic and Transcendental Equations: Bisection, false position, Secant and Newton-Raphson methods, Rate of convergence, Eigen values by Power and Jacobi methods.	12	20%
4.	Ordinary Differential Equations: Basic Concepts: Modelling, Differential Equations, Ordinary and Partial differentiation, Order of the equation, Solution, Existence and Uniqueness of Solution, Initial Value problem, Boundary Value Problem, Linear and Non-Linear Equation. 1st Order ODE: Geometric Meaning of $y' = f(x, y)$, Direction Fields, Euler's Method; Separable ODEs; Exact ODEs (Integrating Factors Method, Existence and Uniqueness of Solution); Linear ODEs (Homogeneous and Non Homogeneous, Reduction to Linear problems); Orthogonal Trajectories. 2nd Order ODE: Linear Dependence and Linear Independence; Homogeneous Linear ODEs of Second Order (Principal of Superposition, Initial Value Problem, Boundary Value Problem); Homogeneous Linear ODEs with Constant Coefficients (Euler's formula and review of the circular and hyperbolic function, Exponential Solutions, Repeated Roots	12	20%



Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
	and Stability)); Differential Operator; Modelling of Free Oscillations of Spring-Mass System; Homogeneous Linear ODEs with Non-constant Coefficient (Cauchy-Euler Equation, Existence and Uniqueness of Solutions).		
5.	Probability and Statistics: Data Representation, Average, Spread; Experiments, Outcomes, Events; Probability, Permutations and Combinations; Random Variables. Probability Distributions; Mean and Variance of a Distribution; Binomial, Poisson, and Hypergeometric Distributions; Normal Distribution, Random Sampling; Point Estimation of Parameter, Confidence Intervals; Testing Hypotheses, Decisions; Goodness of Fit, X ² -Test, Nonparametric Tests, Regression, Linear Regression, Polynomial Regression, General Linear Regression, Nonlinear Regression, Correlation.	12	20%

Suggested Specification Table of Marks as per Revised Bloom's Taxonomy

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10	20	25	20	15	10

Legends: R: Remembrance, U: Understanding, A: Application, N: Analyze, E: Evaluate, C: Create and above Levels

Recommended Reference Books

1. S. C. Chapra and R. P. Canale. (2015). *Numerical Methods for Engineers*, Tata McGraw Hill, New Delhi.
2. E. Kreyszig. (2011). *Advanced Engineering Mathematics*, John Wiley & Sons, Inc.
3. S. C. Chapra. (2018). *Applied Numerical Methods with MATLAB for Engineers & Scientists*, Tata McGraw Hill, New Delhi.
4. C.F. Gerald and P.O. Wheatley. (1998). *Applied Numerical Analysis*, Pearson (Addison-Wesley).
5. M.K. Jain, S.R.K. Iyengar and R. K. Jain. (2003). *Numerical Methods: For Scientific And Engineering Computation*. New Age Pvt. Pub, New Delhi.



6. Kiusalaas, J. (2010). *Numerical Methods in Engineering with Python*. Cambridge University Press.

List of Open Source/learning website/Other Details if any

1. Indian Institute of Technology Roorkee. (n.d.). Numerical methods [Online course]. NPTEL. https://onlinecourses.nptel.ac.in/noc19_ma21/preview
2. Numerical Analysis: <https://www.scilab.org>
3. Coursera: <https://www.coursera.org/learn/numerical-methods-engineers>
4. MATLAB Tutorials: <https://www.mathworks.com/help>

List of Open Source Software

1. Scilab
2. MATLAB
3. Python
4. Wolfram Alpha



**SARVAJANIK
UNIVERSITY**

INCLUSIVE | INTEGRATED | INNOVATIVE
creating an enlightened society...

SARVAJANIK UNIVERSITY

SARVAJANIK COLLEGE OF ENGINEERING AND TECHNOLOGY

DOCTOR OF PHILOSOPHY



Ph.D.	MECH	Semester	2	Teaching Scheme				Evaluation Scheme		
Subject Name	Advance Dynamics	Thermal	and	Fluid	L	T	P	Credits	CCE	SEE
Subject Code					4	0	0	4	50	50
Type of course	Credit Course				CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Subjects of Fluid mechanics, Thermodynamics and Heat Transfer									
Rationale	The course is prepared to provide the detailed understating of fundamental of thermodynamics and various modes of heat transfer and its applications. This course also provides the in depth of fluid dynamics and its effects.									

Course Outcomes (COs): At the end of the course, students will be able to		Marks % Weightage
CO – 1	Apply the governing laws of fluid flow and obtain analytical approximate and exact solutions of Navier–Stokes equations.	20
CO – 2	Analyze laminar boundary layer characteristics over external surfaces using governing equations and integral methods.	15
CO – 3	Evaluate and solve practical problems related to potential flow and turbulent flow models for internal and external flows.	15
CO – 4	Evaluate thermodynamic systems using exergy analysis and second-law efficiency concepts.	15
CO – 5	Formulate and solve conduction, convection and radiation heat-transfer problems involving steady, unsteady and multi-dimensional systems.	20
CO – 6	Select and implement advanced thermal–fluid computational tools for research-based mechanical engineering problems.	15

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1.	Introduction and Governing Equations of Fluid Flow: Definition of fluid and concept of continuum; Properties of fluids; Flow field, streamlines, path lines and streak lines; Kinematics of fluid	15	30%

Credit Course

w.e.f. AY-2025-26

Ph.D.



	motion; Eulerian and Lagrangian formulations. General equations of fluid motion: Reynolds transport theorem; Mass and momentum in cartesian, polar and cylindrical coordinates, Exact Solutions of Navier-Stokes Equations: Fully developed flows, parallel flow in straight channel, Couette flow, Creeping flows.		
2.	Boundary Layer Theory: Concept of boundary layer; Derivation of boundary layer equations; Boundary layer flow over a flat plate; Boundary layer flow with non-zero pressure gradient; Flow separation and drag; Karman's momentum integral equations, Karman-Pohlhausen approximate solution.	10	20%
3.	Potential & Turbulent Flow: Potential Flow-Introduction to inviscid flow, Uniform flow, Source and Sink, Free vortex flow, Flow around a Rankine Half-Body, Dipole, Doublet, Magnus Effect. Turbulent Flow-Characteristics of turbulent flows, Concept of averaging, Reynolds equations of motion, semi-empirical theories of turbulence, Turbulent internal flows; Turbulent external flows, velocity profiles for inner, outer and overlap layers, equilibrium boundary layers.	15	20%
4.	Thermodynamics: Fundamental laws of thermodynamics, availability and irreversibility, second-law efficiency, exergy change of a system, exergy transfer by heat, work, and mass flow, exergy balance for closed systems and control volumes.	05	10%
5.	Heat Transfer: Modes of heat transfer; general heat conduction equation in Cartesian, cylindrical, and spherical coordinates, steady-state heat conduction considering multiple dimensions, numerical methods of analysis, unsteady state heat conduction, heat flow in a semi-infinite solid; empirical and practical relations for forced convection heat transfer, natural convection in internal and external configurations, combined free and forced convection; radiation heat transfer, black and gray body radiation, intensity of radiation and Lambert's cosine law, radiative transport equation for bulk radiation; boiling and condensation heat transfer, heat pipe; methods to improve the performance of heat exchangers.	15	20%

Suggested Specification Table of Marks as per Revised Bloom's Taxonomy

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10	20	25	20	15	10

Legends: R: Remembrance, U: Understanding, A: Application, N: Analyze, E: Evaluate, C: Create and above Levels

Recommended Reference Books

1. White, F.M. (1979). *Fluid Mechanics*. McGraw-Hill Education.
2. Schlichting, H. (1979). *Boundary Layer Theory*. McGraw-Hill Education.
3. Garde, R.J. (1994). *Turbulent Flow*. Wiley Eastern Limited.
4. Ojha, C.S.P., Berndtsson, R. and Chandaramouli, P.N.(2010). *Fluid Mechanics*. Oxford University Press.
5. Y. A. Cengel, M. A. Boles, and M. Kanoglu. (2018). *Thermodynamics - An Engineering Approach*. McGraw-Hill Education.
6. R. K. Rajput.(2020). *Thermal Engineering*. Laxmi Publications.

List of Open Source/learning website/Other Details if any

1. Indian Institute of Technology Kharagpur. *Advanced Concepts in Fluid Mechanics*. [Online course]. NPTEL. <http://digimat.in/nptel/courses/video/112105287/L01.html>
2. Advanced Thermal-Fluid Simulations: <https://www.ansys.com/student>
3. Fluid Mechanics Research: <https://www.cfd-online.com/>

List of Open Source Software

1. MATLAB / Octave
2. OpenFOAM
3. ParaView

Ph.D.	MECH	Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	SEMINAR			L	T	P	Credits	CCE	SEE
Subject Code				0	0	4	2	25	25
Type of course				CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Knowledge of Fundamental subject of Mechanical Engineering								
Rationale	---								

Seminar Outcomes

1. Review literature for the given topic.
2. Comprehend the data from literature review.
3. Present the selected topic based on the recent development in the field of mechanical Engineering.
4. Generate the detail report on given topic.

Recommended References

1. Refer the Reference books, Journals, Encyclopaedia etc.
2. Journals on Recent advancements in the field of mechanical Engineering
3. Handbook of mechanical Engineering

List of Open Source/learning website/Other Details if any:

1. www.sciencedirect.com
2. www.acs.com
3. <https://pubs.acs.org/>
4. <https://www.springer.com/in>
5. <https://onlinelibrary.wiley.com/>

Ph.D		Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	SEMINAR			L	T	P	Credits	CCE	SEE
Subject Code	Code will be provided by SU			0	0	4	2	25	25
Type of course	Professional Core Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Knowledge of Fundamental subject of Chemical Engineering								
Rationale	---								

Seminar Outcomes	
1	Review literature for the given topic.
2	Comprehend the data from literature review.
3	Present the selected topic based on the recent development in the field of Chemical Engineering.
4	Generate the detail report on given topic.

Recommended References	
1	Refer the Reference books, Journals, Encyclopaedia etc.
2	Journals on Recent advancements in the field of Chemical Engineering
3	Handbook of Chemical Engineering

List of Open Source/learning website/Other Details if any:

- www.sciencedirect.com
- www.acs.com
- <https://pubs.acs.org/>
- <https://www.springer.com/in>
- <https://onlinelibrary.wiley.com/>



Ph.D		Semester	3	Teaching Scheme				Evaluation Scheme	
Subject Name	Advanced Chemical Reaction Engineering			L	T	P	Credits	CCE	SEE
Subject Code				4	0	0	4	50	50
Type of course	Professional Elective Core Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Chemical Reaction Engineering-I & II and Advanced applications , Reaction kinetics, Mathematical concepts to solve ordinary and partial differential equations, Concepts of plug flow and continuous stirred tank reactor & multiphase reactors								
Rationale	The objective of this course is to enable students to design, analyze and modify the reaction system to apply green concepts.								

Course Outcomes (COs): At the end of the course, students will be able to		Marks % Weightage
CO – 1	Apply the basic principles of reaction kinetics to various types of reactors	20
CO – 2	Estimate reaction rate parameters and their limitations based on given reaction scheme	20
CO – 3	Design various components of reactors used in industrial practice for multiphase flow reactors	20
CO – 4	Synthesize the solid catalyst and apply it for process intensification	20
CO – 5	Simulate the reaction scheme using advanced softwares and flow chemistry principles	20

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Basics of Reactor design: Basic design of ideal reactors with energy effects, product yield, selectivity, multiphase steady state flow system, stability and sensitivity studies	10	16%
2	Non-ideal Reactors: Non-ideal flow reactors , Continuous reactors, Unsteady state PFR & MFR, Non-Isothermal reactors Non-isothermal Batch reactor, PFR & MFR, RTD, Analysis of flow distribution, dispersed plug flow and tanks in series model, design of macro-micro reactors, application of flow chemistry with efficient	10	17%



	product synthesis		
3	Kinetics of solid-catalysed fluid phase reactions: Mechanisms of Catalytic Reactions, Development of rate equations for solid catalysed fluid phase reactions, Diffusion mechanism through porous catalyst, Kinetic estimation by different model, LHHW model; Mass and Heat Transfer Limitations and Other Aspects of the Use of Large Scale Catalytic Reactors, Design & modeling aspects of solid catalyzed reactions	10	16%
4	Fluid – Fluid Reactions: Mass transfer with chemical reaction, model contactors, design & modelling aspects of fluid – fluid reactors	10	17%
5	Catalyst : Intra & Interparticle diffusion, External Internal mass transfer/heat transfer effects; Effectiveness analysis of catalyst, Regeneration methods, Advanced Catalyst synthesis methods, Catalyst characterization techniques, Inhibition and Selectivity rates, Industrial catalyst design & development towards the sustainable process.	10	16%
6	Case studies and application of multiphase reaction engineering with Process Intensification using Industrial Catalyst Synthesis	10	16%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10	10	15	25	20	20

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (**Revised Bloom's Taxonomy**)

Recommended Reference Books

- Levenspiel O, Chemical Reaction Engineering, Wiley & Sons, Inc., Singapore, 3rd ed., 1999.
- Fogler H S, Elements of Chemical Reaction Engineering, Prentice-Hall, 4th ed., 2006.
- Rawlings J B , Ekerdt J G, Chemical Reactor Analysis and Design Nob Hill Publishing ISBN-10 097593774X, 2nded., 2020.
- Astarita G, Mass Transfer with Chemical Reaction, Amsterdam, London, Elsevier, 1st ed., 1967.
- Carberry J J, Chemical and catalytic reaction engineering Dover Publications, Inc. New York, 1st ed. 2001.
- Hill Jr C G, Root T W, Introduction to chemical engineering kinetics and reactor design, Wiley, 2nd ed., 2014.
- Froment G F, Bischoff K B, De Wilde J, Chemical reactor analysis and design, John Wiley & Sons,



Inc. 3rd ed., 2011.

- 8 Missen R W, Mims C A, Saville B A, Introduction to chemical reaction engineering and kinetics, John Wiley & Sons Inc., New York, 1st ed., 1999.
- 9 Perry, Dale L. Materials Synthesis and Characterization, ISBN 978-1-4899-0145-3, 1st, 1997.

List of Open Source/learning website/Other Details if any:

- <https://nptel.ac.in/courses/103/101/103101001/>
 - Chapter 1 to 6.

List of Open Source Software: --

- <https://www.comsol.co.in/chemical-reaction-engineering-module>
- <https://www.mathworks.com/>
- www.aspentech.com

Ph.D	2	Semester	3	Teaching Scheme				Evaluation Scheme	
Subject Name	Wastewater engineering			L	T	P	Credits	CCE	SEE
Subject Code				3	1	-	4	50	50
Type of course	Paper 3			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Interest and concern for the conservation and protection of the environment								
Rationale	The objective of this course is to help the students to develop an ability to apply the basic understanding of physical, chemical and biological phenomena for wastewater treatment. Additionally, students will learn about the implementation of intelligent systems in wastewater treatment and management.								

Course Outcomes (COs): At the end of the course, students will be able to			Marks % Weightage
CO – 1	Understand the need for wastewater treatment and identify the target pollutants		15
CO – 2	Evaluate the conventional and advanced strategies in wastewater treatment		30
CO – 3	Apply the principles of wastewater treatment for successful operation and maintenance of ETPs		25
CO – 4	Interpret the need for compliance of laws and environmental audit.		20
CO – 5	Provide customised solutions to wastewater treatment problems		10

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Introduction Industrial waste, types of industrial waste, sources of industrial Waste, Characterisation, Effects of waste on sewage treatment plants.	03	8
2	Basics of Wastewater treatment Types of wastewater, Significance of wastewater contaminants, Discharge limit of wastewater, handling and storage of wastewater.	02	5
3	Treatment of wastewater Preliminary or primary treatment of wastewater-Different physical and chemical treatments, Secondary treatment:-Aerobic and	15	30



	anaerobic treatment, BOD, COD, MLSS MLVSS, Attached growth, Suspended growth.		
4	Sludge Treatment Introduction, sludge treatment and disposal. Activated sludge process, Up flow anaerobic sludge blanket reactor (UASB), trickling filter, Rotating biological contactor (RBC) Advanced oxidation processes.	05	11
5	Post treatment strategies Lagoon, stabilizing pond, facultative pond etc. Tertiary treatment or advanced treatment:-Membrane separation process, membrane bioreactor (MBR), nitrogen removal process, phosphorus removal process, Disinfection.	05	12
6	Case studies Typical case studies from industrial sectors viz. Petrochemicals, Polymers, Chlor-alkali, Dyes, Pharmaceuticals, Pesticides, Food processing, Textile and Specialty Chemicals with due focus on Environment Pollution control and health.	05	12
7	Rules and regulations Common effluent treatment plant (CETP) State norms and compliance, pertaining to wastewater treatment and disposal.	03	11
8	Sustainable development and Waste minimization Need and benefits, Methodology, Techniques and barriers for waste reduction and alternative solutions in Industrial wastewater treatment. Scope of conventional processes and operations, Environmental audit aspects. Use of Advanced strategies in wastewater treatment. Use of AI & ML strategies in wastewater treatment and management.	07	11

LIST OF TUTORIALS:

Sr No	Description	No of Hours (15)
A	Study of Standard methods in wastewater treatment for the following: APHA/AWWA	
1	Study of methods for determination of Phenol content /Chlorine content in wastewater sample	2
2	Characterization of a given sample of wastewater. Study of sampling protocol and preservation techniques of wastewater.	2
3	Study of important parameters for Characterization of any given sample of wastewater	2
B	EA aspects of selected industries. (Report to be submitted)	2
C	Study of MSDS of selected chemicals used in your laboratory.	2
D	Case study: Study of Industry groups (Eg Dyeing/pharma) adapting advanced treatment strategies for wastewater treatment and provide alternative suggestions. (Report to be submitted)	2
E	Visit to nearby CETP. (Report to be submitted)	1
F	Study of AI/ML applications in wastewater treatment and management. Case studies	2



Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15	15	25	25	20	00

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (**Revised Bloom's Taxonomy**)

Recommended Reference Books	
1	Rao, C.S Environmental pollution control engineering New Age International 2011 2 nd Edition
2	Metcalf & Eddy Wastewater Engineering: Treatment Disposal Reuse McGraw-Hill, 1979 3 rd Edition
3	Raju B.S.N Water Supply and Wastewater Engineering Tata McGraw-Hill, New Delhi 1995 2 nd Edition
4	APHA (American Public Health Association Standard methods for examination of water and waste water (2003). 23 rd Ed. Washington DC, USA.

List of Open Source/learning website/Other Details if any:

- <https://nptel.ac.in/courses/105/107/105107207/>
wastewater treatment-review of fundamentals
- <https://nptel.ac.in/courses/105/105/105105178/>
Pollutants, Issues, challenges
- <https://nptel.ac.in/courses/105/105/105105048/>
wastewater management

Ph.D		Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Smart Grid			L	T	P	Credits	CCE	SEE
Subject Code				4	0	0	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	In-depth knowledge of Power electronics, Power Systems and Energy Sources.								
Rationale	This course helps research scholar in understanding concept of smart grid and developments on smart grid. The subject covers the smart grid technologies and application of smart grid concept in hybrid electric vehicles etc. The course also explores monitoring and protection for micro grids and distributed energy systems, and significance of power quality aspects in smart grid.								

Course Outcomes (COs): At the end of the course, students will be able to			Marks % Weightage
CO – 1	Compare Smart-grids with conventional network grids, review smart grid challenges, policies and developments.		20
CO – 2	Identify components/technologies employed and their significance in Smart grid.		25
CO – 3	Assess renewable energy sources and illustrate Micro-grids		25
CO – 4	Investigate power quality issues and communication technologies for Smart-grid.		20
CO – 5	Illustrate infrastructure requirements and examine impact of integration of electrical vehicles (EV) into Smart-grid.		10

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Introduction to Smart Grid Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Architecture of Smart Grid System, Opportunities & Barriers of Smart Grid, Difference between Conventional & Smart grid, Concept of Resilient & Self-Healing Grid, Present Development & International policies on Smart Grid, Case study of Smart Grid.	09	15%
2	Distributed Energy Resources Introduction - Combined heat and power (CHP) systems - Solar photovoltaic (PV) systems – Wind energy conversion systems (WECS) - Small-scale hydroelectric power generation - Storage devices:	10	17%

	Penetration and Variability Issues Associated with Sustainable Energy Technology, Demand Response Issues, Electric Vehicles and Plug-in Hybrids.		
3	Smart Grid Technologies Introduction to Smart Meters, Signal conditioning, Analog to Digital conversion, Computation, Communications Infrastructure and Protocols for Smart Metering, Real Time Pricing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Smart Sensors, Home & Building Automation, Phase Shifting Transformers, Smart Substations, Substation Automation, Feeder Automation. Geographic Information System(GIS), Intelligent Electronic Devices(IED) & their Application for Monitoring & Protection, Wide Area Measurement System(WAMS), Phasor Estimation, Phase Measurement Unit(PMU), Demand-side integration, Smart Storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage.	14	23%
4	Micro grids and Distributed Energy Resources Concept of Micro Grid, Need & Applications of Microgrid, Formation of Microgrid, Issues of Interconnection, Protection & Control of Microgrid, Islanding Detection Techniques, Smart Grid Protection.	10	17%
5	Power Quality Management in Smart Grid EMC in smart grid, equipment required for grid connected systems, grid connection requirements from power provider, addressing safety and power quality for grid connection, metering and rate arrangement for grid connected systems, web based power quality monitoring. Information and Communication Technology for Smart Grid, Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN), Zig-Bee, GPS, Wi-Fi, Wi-Max based communication, Wireless Mesh Network, Broadband over Power line (BPL)	10	17%
6	Electric Vehicles & Smart grid Integration Smart grid and smart charging, Smart Grid and Plug-in Vehicles, Electric vehicles and smart grid interaction, vehicle to grid and renewable energy sources integration	07	11%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15%	20%	25%	15%	15%	10%

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Recommended Reference Books

- 1 Ali Keyhani, Mohammad N. Marwali, Min Dai, Integration of Green and Renewable Energy in Electric Power Systems, Wiley, 2009



- 2 Clark W. Gellings, The Smart Grid: Enabling Energy Efficiency and Demand Response, CRC Press 2009
- 3 Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama Smart Grid: Technology and Applications, Wiley, 2012
- 4 Jean Claude, Sabonnadière, Nouredine Hadjsaïd, Smart Grids, Wiley Blackwell, 2012
- 5 Peter S. Fox Penner , Smart Power: Climate Changes, the Smart Grid, and the Future of Electric Utilities Island Press 2010 First edition
- 6 S. Chowdhury, S. P. Chowdhury, P. Crossley ; Microgrids and Active Distribution Networks; Institution of Engineering and Technology 2009
- 7 Stuart Borlase ; Smart Grids (Power Engineering); CRC Press 2012
- 8 Yang Xiao; Communication and Networking in Smart Grids; CRC Press 2012 First edition
- 9 MladenKezunovic, Mark G. Adamiak, Alexander P. Apostolov, Jeffrey George Gilbert; Substation Automation (Power Electronics and Power Systems); Springer 2010

List of Open Source/learning website/Other Details if any:

1. https://onlinecourses.nptel.ac.in/noc22_ee82/preview

Ph.D		Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Modelling, Planning and Optimal Energy Management of Microgrid			L	T	P	Credits	CCE	SEE
Subject Code				4	0	0	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	knowledge of Power Systems and renewable energy sources								
Rationale	This subject aims to benefit the research scholar wishing to work in any area of Distributed Generation and Microgrid. The subject covers wide spectrum of recent developments in the field of Microgrid from planning to optimal operation and energy management using conventional and intelligent techniques.								

Course Outcomes (COs): At the end of the course, students will be able to		Marks % Weightage
CO – 1	Describe significance of Distributed Generation, sources and economic aspects.	25
CO – 2	Illustrate issues pertaining to integration of energy sources with grid.	15
CO – 3	Apply concepts of distributed generation in Microgrid.	15
CO – 4	Apply and analyse optimal control and energy management strategies for microgrid.	30
CO – 5	Apply Intelligent techniques in micro-grid for real-world problems.	15

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Introduction Conventional power generation methods and sources, advantages and disadvantages, energy crisis, non-conventional energy sources, renewable energy potential, world energy scenario, Indian energy scenario, renewable energy policies of India.	5	10
2	Decentralized Generation Decentralized versus centralized station generation, traditional power systems, load curves and load curve analysis, demand scheduling, optimal design of hybrid energy systems, energy economics and cost optimization of integrating energy system and case study.	6	10
3	Distributed Generation (DG)	8	10

	Introduction to Distributed Generation (DG), Non - Conventional Energy (NCE) Resources, Solar Photovoltaic Generation, Wind Energy - Wind Power Plants, Micro-turbines, Fuel Cell, Energy Storage Systems: Batteries, Fly-Wheels, Ultra-capacitors, Unit Sizing of DGs.		
4	DG integration with Grid Requirements for grid interconnection, IEEE 1547 standard for interconnection and interoperability of distributed energy resources electric power systems interfaces, grid interconnection issues, constraints on operational parameters, response to grid abnormal operating conditions, LVRT and synthetic inertia emulation, islanding, stability, power quality issues and reliability.	7	15
5	Microgrid (MG) Concept and definition of micro grid, types and structure of micro-grids, autonomous and non-autonomous grids, microgrid drivers and benefits, review of sources of micro grids, typical structure and configuration of a micro grid, AC and DC micro grids, power electronics interfaces in DC and AC micro grids, decision making tools.	8	15
6	Energy Management Systems (EMS) in MG Definitions and significance, objectives, monitoring and control system, centralized and decentralized EMS, decision making, role of EMS in MG scheduling, mathematical modeling of different MG's components, role of energy storage systems in Microgrid operation	7	10
7	Planning, Operation and control of micro grid Planning of DGs sizing of DGs, sizing of micro-grids, modes of operation and control of micro grid: grid connected and islanded mode, active and reactive power control, protection issues, economic demand management strategy for passive consumers and microgrid operation, conventional droop methods for Microgrid, distributed control approaches for Microgrid, control of energy storage systems in Microgrid, fault ride through and fault current management for Microgrid, microgrid protection	12	20
8	Intelligent techniques Optimization techniques, genetic algorithm, fuzzy logic, artificial neural networks and multi-agent system, applications of intelligent techniques for microgrid.	7	10

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10%	15%	25%	20%	15%	15%

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Reference Books:

Sr. No.	Title of book /article	Author(s)	Publisher and details	Year of publication
1	Renewable Energy Resources	John Twidell and Tony Weir	Taylor and Francis	2006
2	Distributed Power Generation – Planning and Evaluation	H. Lee Willis, Walter G. Scott	Taylor & Francis	2000
3	Integration of Distributed Generation in the Power System	Bollen M. H. and Hassan F	Wiley-IEEE Press	2011
4	Microgrids	Sanjeevikumar Padmanaban, K. Nithiyananthan, S. Prabhakar Karthikeyan, Jens Bo Holm-Nielsen	CRC Press	2020
5	Microgrid: Operation, Control, Monitoring and Protection	Monalisa Biswal, Papia Ray	Springer Singapore	2020
6	Modeling, planning and optimal energy management of combined cooling, heating and power microgrid: A review	Wei Gu, Zhi Wu, Rui Bo, Wei Liu, Gan Zhou, Wu Chen, Zaijun Wu	Elsevier	2014
7	Microgrids: Advances in Operation, Control, and Protection	Amjad Anvari-Moghaddam, Behnam Mohammadi-Ivatloo, Hamdi Abdi, Nikos Hatziargyriou	Springer International Publishing	2021
8	Demand response and smart grids—a survey	Pierluigi Siano	Elsevier Journal of Renewable and Sustainable Energy Reviews	Volume 30, 2014, pp. 461-478.
9	Artificial Intelligence (2nd Edition)	Elaine Rich and Kevin Knight	Tata McGraw- Hill	
10	Artificial Intelligence: A Modern Approach (2nd edition)	Stuart Russel, Peter Norvig	Prentice Hall	

Ph.D		Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Smart Grid			L	T	P	Credits	CCE	SEE
Subject Code				4	0	0	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	In-depth knowledge of Power electronics, Power Systems and Energy Sources.								
Rationale	This course helps research scholar in understanding concept of smart grid and developments on smart grid. The subject covers the smart grid technologies and application of smart grid concept in hybrid electric vehicles etc. The course also explores monitoring and protection for micro grids and distributed energy systems, and significance of power quality aspects in smart grid.								

Course Outcomes (COs): At the end of the course, students will be able to			Marks % Weightage
CO – 1	Compare Smart-grids with conventional network grids, review smart grid challenges, policies and developments.		20
CO – 2	Identify components/technologies employed and their significance in Smart grid.		25
CO – 3	Assess renewable energy sources and illustrate Micro-grids		25
CO – 4	Investigate power quality issues and communication technologies for Smart-grid.		20
CO – 5	Illustrate infrastructure requirements and examine impact of integration of electrical vehicles (EV) into Smart-grid.		10

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Introduction to Smart Grid Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Architecture of Smart Grid System, Opportunities & Barriers of Smart Grid, Difference between Conventional & Smart grid, Concept of Resilient & Self-Healing Grid, Present Development & International policies on Smart Grid, Case study of Smart Grid.	09	15%
2	Distributed Energy Resources Introduction - Combined heat and power (CHP) systems - Solar photovoltaic (PV) systems – Wind energy conversion systems (WECS) - Small-scale hydroelectric power generation - Storage devices:	10	17%



	Penetration and Variability Issues Associated with Sustainable Energy Technology, Demand Response Issues, Electric Vehicles and Plug-in Hybrids.		
3	Smart Grid Technologies Introduction to Smart Meters, Signal conditioning, Analog to Digital conversion, Computation, Communications Infrastructure and Protocols for Smart Metering, Real Time Pricing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Smart Sensors, Home & Building Automation, Phase Shifting Transformers, Smart Substations, Substation Automation, Feeder Automation. Geographic Information System(GIS), Intelligent Electronic Devices(IED) & their Application for Monitoring & Protection, Wide Area Measurement System(WAMS), Phasor Estimation, Phase Measurement Unit(PMU), Demand-side integration, Smart Storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage.	14	23%
4	Micro grids and Distributed Energy Resources Concept of Micro Grid, Need & Applications of Microgrid, Formation of Microgrid, Issues of Interconnection, Protection & Control of Microgrid, Islanding Detection Techniques, Smart Grid Protection.	10	17%
5	Power Quality Management in Smart Grid EMC in smart grid, equipment required for grid connected systems, grid connection requirements from power provider, addressing safety and power quality for grid connection, metering and rate arrangement for grid connected systems, web based power quality monitoring. Information and Communication Technology for Smart Grid, Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN), Zig-Bee, GPS, Wi-Fi, Wi-Max based communication, Wireless Mesh Network, Broadband over Power line (BPL)	10	17%
6	Electric Vehicles & Smart grid integration Smart grid and smart charging, Smart Grid and Plug-in Vehicles, Electric vehicles and smart grid interaction, vehicle to grid and renewable energy sources integration	07	11%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15%	20%	25%	15%	15%	10%

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Recommended Reference Books

- 1 Ali Keyhani, Mohammad N. Marwali, Min Dai, Integration of Green and Renewable Energy in Electric Power Systems, Wiley, 2009



- 2 Clark W. Gellings, The Smart Grid: Enabling Energy Efficiency and Demand Response, CRC Press 2009
- 3 Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama Smart Grid: Technology and Applications, Wiley, 2012
- 4 Jean Claude, Sabonnadière, Nouredine Hadjsaid, Smart Grids, Wiley Blackwell, 2012
- 5 Peter S. Fox Penner , Smart Power: Climate Changes, the Smart Grid, and the Future of Electric Utilities Island Press 2010 First edition
- 6 S. Chowdhury, S. P. Chowdhury, P. Crossley ; Microgrids and Active Distribution Networks; Institution of Engineering and Technology 2009
- 7 Stuart Borlase ; Smart Grids (Power Engineering); CRC Press 2012
- 8 Yang Xiao; Communication and Networking in Smart Grids; CRC Press 2012 First edition
- 9 MladenKezunovic, Mark G. Adamiak, Alexander P. Apostolov, Jeffrey George Gilbert; Substation Automation (Power Electronics and Power Systems); Springer 2010

List of Open Source/learning website/Other Details if any:

1. https://onlinecourses.nptel.ac.in/noc22_ee82/preview

Ph.D		Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Recent Advancements in Electrical Engineering			L	T	P	Credits	CCE	SEE
Subject Code				4	0	0	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	knowledge of Electrical Engineering-power systems, electrical machines and drives.								
Rationale	This subject aims to benefit the research scholar wishing to work in any area of Electrical Engineering domain. The subject covers wide spectrum of recent developments in the field of electrical and multidisciplinary areas and its impact on environment, society and economy.								

Course Outcomes (COs): At the end of the course, students will be able to		Marks % Weightage
CO – 1	Explore and identify various recent developments in the field of distributed energy sources and impact on power systems.	25
CO – 2	Explore and identify applications of modern efficient electrical drives.	20
CO – 3	Identify power quality issues in modern power systems and microgrid.	20
CO – 4	Identify various components of electric vehicle and configurations.	20
CO – 5	Explore various intelligent techniques and their applications in electrical engineering	15

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Modern Electrical Power Systems and Devices Optimal Load Flow solution of a modern power system, Transient and steady state stability of a Power System and soft-simulation tools, protection and control of modern power systems, modelling of FACTS Devices and HVDC Systems	7	12
2	Electrical Machines & Drives Special purpose and industrial electrical motors, advanced drives and modelling of control techniques, special purpose motors and applications, like traction, electrical vehicles, etc.	7	10
3	Applications of Power Electronics	7	13

	Switch Mode Power Supplies, Power Electronic Converters for Renewable Energy System, Power Electronic converters for EV, Power Electronics for Drives, Advanced Power Converters and Applications		
4	Renewable Energy Systems Solar and solar-thermal energy systems, grid interactive and isolated solar photovoltaic systems, wind energy and wind turbine- generators and power electronics interfaces, fuel-cell and converters, benefits over conventional energy source based generation	7	10
5	Power Quality Management Power Quality Standards and recommended practices, transient system modelling, harmonics and mitigation, reduction techniques, passive and active filters, power factor correcting techniques, power quality monitoring and instruments.	8	15
6	Electric Vehicle Motion and dynamic equations of the electric vehicles and various forces acting on it, Power flow control and drive train topologies, Energy management strategies, Types of Storage systems, Battery charging techniques and standards	8	10
7	Smart and Microgrids Concepts, definition, and classifications, operation management of Microgrid clusters, Energy Management Systems(EMS) for Microgrids, role of Energy Storage Systems(ESS)	8	15
8	Artificial Intelligence and Machine Learning Introduction to Artificial Intelligence, Fuzzy Logic and Fuzzy set theory, Artificial Neural networks, Genetic Algorithms, Introduction to machine learning	8	15

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15	15	20	20	15	15

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Reference Books:

Sr. No.	Title of book /article	Author(s)	Publisher and details	Year of publication
1	Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems	Narain G. Hingorani, Laszlo Gyugyi	Wiley-IEEE Press; 1st edition	1999
2	HVDC/FACTS for Grid Services in Electric Power Systems	José M Maza-Ortega, Antonio Gómez-Expósito	MDPI AG	2020
3	Control of Power Electronic Converters and Systems: Volume 1	Frede Blaabjerg	Elsevier Science	2018
4	Renewable Energy Systems: Simulation with Simulink and Sim-power systems	Viktor Perelmuter	Taylor and Francis	2016
5	Power quality	C. Sankaran	CRC Press	2002
6	Electric Vehicle Technology Explained	James Larminie, J. Lowry	John Wiley & Sons Ltd.	2003
7	Electric and Hybrid Vehicles: Design Fundamentals	Iqbal Hussein	CRC Press,	2003
8	Microgrids	Sanjeevikumar P.a, K. Nithiyananthan, S. Prabhakar K. and Jens	CRC Press	2020
9	Microgrid: Operation, Control, Monitoring and Protection	Monalisa Biswal, Papia Ray	Springer Singapore	2020
10	Artificial Intelligence (2 nd Edition)	Elaine Rich and Kevin Knight	Tata McGraw-Hill	2018
11	Artificial Intelligence: A Modern Approach (2 nd edition)	Stuart Russel, Peter Norvig	Prentice Hall	2002

Ph.D		Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Modelling, Planning and Optimal Energy Management of Microgrid			L	T	P	Credits	CCE	SEE
Subject Code				4	0	0	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	knowledge of Power Systems and renewable energy sources								
Rationale	This subject aims to benefit the research scholar wishing to work in any area of Distributed Generation and Microgrid. The subject covers wide spectrum of recent developments in the field of Microgrid from planning to optimal operation and energy management using conventional and intelligent techniques.								

Course Outcomes (COs): At the end of the course, students will be able to		Marks % Weightage
CO – 1	Describe significance of Distributed Generation, sources and economic aspects.	25
CO – 2	Illustrate issues pertaining to integration of energy sources with grid.	15
CO – 3	Apply concepts of distributed generation in Microgrid.	15
CO – 4	Apply and analyse optimal control and energy management strategies for microgrid.	30
CO – 5	Apply Intelligent techniques in micro-grid for real-wold problems.	15

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Introduction Conventional power generation methods and sources, advantages and disadvantages, energy crisis, non-conventional energy sources, renewable energy potential, world energy scenario, Indian energy scenario, renewable energy polices of India.	5	10
2	Decentralized Generation Decentralized versus centralized station generation, traditional power systems, load curves and load curve analysis, demand scheduling, optimal design of hybrid energy systems, energy economics and cost optimization of integrating energy system and case study.	6	10
3	Distributed Generation (DG)	8	10

	Introduction to Distributed Generation (DG), Non - Conventional Energy (NCE) Resources, Solar Photovoltaic Generation, Wind Energy - Wind Power Plants, Micro-turbines, Fuel Cell, Energy Storage Systems: Batteries, Fly-Wheels, Ultra-capacitors, Unit Sizing of DGs.		
4	DG integration with Grid Requirements for grid interconnection, IEEE 1547 standard for interconnection and interoperability of distributed energy resources electric power systems interfaces, grid interconnection issues, constraints on operational parameters, response to grid abnormal operating conditions, LVRT and synthetic inertia emulation, islanding, stability, power quality issues and reliability.	7	15
5	Microgrid (MG) Concept and definition of micro grid, types and structure of micro-grids, autonomous and non-autonomous grids, microgrid drivers and benefits, review of sources of micro grids, typical structure and configuration of a micro grid, AC and DC micro grids, power electronics interfaces in DC and AC micro grids, decision making tools.	8	15
6	Energy Management Systems (EMS) in MG Definitions and significance, objectives, monitoring and control system, centralized and decentralized EMS, decision making, role of EMS in MG scheduling, mathematical modeling of different MG's components, role of energy storage systems in Microgrid operation	7	10
7	Planning, Operation and control of micro grid Planning of DGs sizing of DGs, sizing of micro-grids, modes of operation and control of micro grid: grid connected and islanded mode, active and reactive power control, protection issues, economic demand management strategy for passive consumers and microgrid operation, conventional droop methods for Microgrid, distributed control approaches for Microgrid, control of energy storage systems in Microgrid, fault ride through and fault current management for Microgrid, microgrid protection	12	20
8	Intelligent techniques Optimization techniques, genetic algorithm, fuzzy logic, artificial neural networks and multi-agent system, applications of intelligent techniques for microgrid.	7	10

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10%	15%	25%	20%	15%	15%

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Reference Books:

Sr. No.	Title of book /article	Author(s)	Publisher and details	Year of publication
1	Renewable Energy Resources	John Twidell and Tony Weir	Taylor and Francis	2006
2	Distributed Power Generation – Planning and Evaluation	H. Lee Willis, Walter G. Scott	Taylor & Francis	2000
3	Integration of Distributed Generation in the Power System	Bollen M. H. and Hassan F	Wiley-IEEE Press	2011
4	Microgrids	Sanjeevikumar Padmanaban, K. Nithiyananthan, S. Prabhakar Karthikeyan, Jens Bo Holm-Nielsen	CRC Press	2020
5	Microgrid: Operation, Control, Monitoring and Protection	Monalisa Biswal, Papia Ray	Springer Singapore	2020
6	Modeling, planning and optimal energy management of combined cooling, heating and power microgrid: A review	Wei Gu, Zhi Wu, Rui Bo, Wei Liu, Gan Zhou, Wu Chen, Zaijun Wu	Elsevier	2014
7	Microgrids: Advances in Operation, Control, and Protection	Amjad Anvari-Moghaddam, Behnam Mohammadi-Ivatloo, Hamdi Abdi, Nikos Hatziargyriou	Springer International Publishing	2021
8	Demand response and smart grids—a survey	Pierluigi Siano	Elsevier Journal of Renewable and Sustainable Energy Reviews	Volume 30, 2014, pp. 461-478.
9	Artificial Intelligence (2nd Edition)	Elaine Rich and Kevin Knight	Tata McGraw- Hill	
10	Artificial Intelligence: A Modern Approach (2nd edition)	Stuart Russel, Peter Norvig	Prentice Hall	



Ph.D		Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Smart Grid			L	T	P	Credits	CCE	SEE
Subject Code				4	0	0	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	In-depth knowledge of Power electronics, Power Systems and Energy Sources.								
Rationale	This course helps research scholar in understanding concept of smart grid and developments on smart grid. The subject covers the smart grid technologies and application of smart grid concept in hybrid electric vehicles etc. The course also explores monitoring and protection for micro grids and distributed energy systems, and significance of power quality aspects in smart grid.								

Course Outcomes (COs): At the end of the course, students will be able to		Marks % Weightage
CO – 1	Compare Smart-grids with conventional network grids, review smart grid challenges, policies and developments.	20
CO – 2	Identify components/technologies employed and their significance in Smart grid.	25
CO – 3	Assess renewable energy sources and illustrate Micro-grids	25
CO – 4	Investigate power quality issues and communication technologies for Smart-grid.	20
CO – 5	Illustrate infrastructure requirements and examine impact of integration of electrical vehicles (EV) into Smart-grid.	10

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Introduction to Smart Grid Evolution of Electric Grid, Concept of Smart Grid, Definitions, Need of Smart Grid, Functions of Smart Grid, Architecture of Smart Grid System, Opportunities & Barriers of Smart Grid, Difference between Conventional & Smart grid, Concept of Resilient & Self-Healing Grid, Present Development & International policies on Smart Grid, Case study of Smart Grid.	09	15%
2	Distributed Energy Resources Introduction - Combined heat and power (CHP) systems - Solar photovoltaic (PV) systems – Wind energy conversion systems (WECS) - Small-scale hydroelectric power generation - Storage devices:	10	17%



	Penetration and Variability Issues Associated with Sustainable Energy Technology, Demand Response Issues, Electric Vehicles and Plug-in Hybrids.		
3	Smart Grid Technologies Introduction to Smart Meters, Signal conditioning, Analog to Digital conversion, Computation, Communications Infrastructure and Protocols for Smart Metering, Real Time Pricing, Smart Appliances, Automatic Meter Reading(AMR), Outage Management System(OMS), Smart Sensors, Home & Building Automation, Phase Shifting Transformers, Smart Substations, Substation Automation, Feeder Automation. Geographic Information System(GIS), Intelligent Electronic Devices(IED) & their Application for Monitoring & Protection, Wide Area Measurement System(WAMS), Phasor Estimation, Phase Measurement Unit(PMU), Demand-side integration, Smart Storage like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage.	14	23%
4	Micro grids and Distributed Energy Resources Concept of Micro Grid, Need & Applications of Microgrid, Formation of Microgrid, Issues of Interconnection, Protection & Control of Microgrid, Islanding Detection Techniques, Smart Grid Protection.	10	17%
5	Power Quality Management in Smart Grid EMC in smart grid, equipment required for grid connected systems, grid connection requirements from power provider, addressing safety and power quality for grid connection, metering and rate arrangement for grid connected systems, web based power quality monitoring. Information and Communication Technology for Smart Grid, Advanced Metering Infrastructure (AMI), Home Area Network (HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN), Zig-Bee, GPS, Wi-Fi, Wi-Max based communication, Wireless Mesh Network, Broadband over Power line (BPL)	10	17%
6	Electric Vehicles & Smart grid integration Smart grid and smart charging, Smart Grid and Plug-in Vehicles, Electric vehicles and smart grid interaction, vehicle to grid and renewable energy sources integration	07	11%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15%	20%	25%	15%	15%	10%

Legends: R: Remembrance, **U:** Understanding; **A:** Application, **N:** Analyze, **E:** Evaluate **C:** Create and above Levels (**Revised Bloom's Taxonomy**)

Recommended Reference Books

- 1 Ali Keyhani, Mohammad N. Marwali, Min Dai, Integration of Green and Renewable Energy in Electric Power Systems, Wiley, 2009



- 2 Clark W. Gellings, The Smart Grid: Enabling Energy Efficiency and Demand Response, CRC Press 2009
- 3 Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama Smart Grid: Technology and Applications, Wiley, 2012
- 4 Jean Claude, Sabonnadière, Nouredine Hadjsaïd, Smart Grids, Wiley Blackwell, 2012
- 5 Peter S. Fox Penner , Smart Power: Climate Changes, the Smart Grid, and the Future of Electric Utilities Island Press 2010 First edition
- 6 S. Chowdhury, S. P. Chowdhury, P. Crossley ; Microgrids and Active Distribution Networks; Institution of Engineering and Technology 2009
- 7 Stuart Borlase ; Smart Grids (Power Engineering); CRC Press 2012
- 8 Yang Xiao; Communication and Networking in Smart Grids; CRC Press 2012 First edition
- 9 MladenKezunovic, Mark G. Adamiak, Alexander P. Apostolov, Jeffrey George Gilbert; Substation Automation (Power Electronics and Power Systems); Springer 2010

List of Open Source/learning website/Other Details if any:

1. https://onlinecourses.nptel.ac.in/noc22_ee82/preview



Ph.D		Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Data Science for Engineers			L	T	P	Credits	CCE	SEE
Subject Code	PTCO11201			4	0	0	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Statistics								
Rationale	This course introduces the mathematical foundations required for data science. As part of this course, students will learn the framework for solving problems requiring data analytics. This course also introduces 'R' programming language. Students will be able to solve predictive problems on real time data after learning this course.								

Course Outcomes (COs): At the end of the course, students will be able to		Marks % Weightage
CO - 1	Describe a flow process for data science problems	20
CO - 2	Classify data science problems into standard typology	20
CO - 3	Develop R codes for data science solutions	20
CO - 4	Correlate results to the solution approach	15
CO - 5	Assess the solution approach	15
CO - 6	Construct use cases to validate approach and identify modifications required	10

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Course philosophy and expectation, Introduction to R, Variables and data types in R, Data frames, Recasting and joining of data frames, Arithmetic, Logical and Matrix operations in R, Advanced programming in R : Functions, Control structures, Data visualization in R Basic graphics	8	14%
2	Linear Algebra for Data science, Solving Linear Equations, Linear Algebra - Distance, Hyperplanes and Halfspaces, Eigenvalues, Eigenvectors	6	10%
3	Statistical Modelling, Random Variables and Probability Mass/Density Functions, Sample Statistics, Hypotheses Testing	6	10%
4	Optimization for Data Science, Unconstrained Multivariate Optimization, Gradient Descent, Learning Rule	6	10%
5	Multivariate Optimization With Equality Constraints, Multivariate Optimization With Inequality Constraints, Introduction to Data Science, Solving Data Analysis Problems - A Guided Thought Process	6	10%



6	Module: Predictive Modelling, Linear Regression, Model Assessment, Diagnostics to Improve Linear Model Fit, Simple Linear Regression Model Building, Simple Linear Regression Model Assessment, Multiple Linear Regression	6	10%
7	Cross Validation, Multiple Linear Regression Modelling Building and Selection, Classification, Logistic Regression, Performance Measures, Logistic Regression Implementation in R	6	10%
8	K - Nearest Neighbors (kNN), K - Nearest Neighbors implementation in R, K - means Clustering, K - means implementation in R	6	10%
9	Applications of Data Science, Challenges reported in contemporary literature, Case Studies	10	16%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20%	20%	20%	15%	15%	10%

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Recommended Reference Books

- 1 Gilbert Strang, *Introduction to Linear Algebra*, 5th Edition, Wellesley Publishers, 2016.
- 2 Douglas Montgomery, *Applied Statistics and Probability for Engineers*, 6th Edition, Wiley, 2016.
- 3 Peter Bruce and Andrew Bruce, *Practical Statistics for Data Scientists*, 2nd Edition, O'Reilly Media, 2017.
- 4 Allen B. Downey, *Think Stats: Probability and Statistics for Programmers*, 2nd Edition, Green Tea Press, Needham, Massachusetts, 2014.
- 5 John Muller, *Data Science for Dummies*, 2nd Edition, Wiley, 2017.
- 6 James D. Miller, *Statistics for Data Science*, Packt, 2017.

List of Open Source/learning website/Other Details if any:

1. NPTEL course on: Data Science for Engineers (https://onlinecourses.nptel.ac.in/noc23_cs17/preview)

Ph.D		Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Machine Learning			L	T	P	Credits	CCE	SEE
Subject Code	PTCO11202			4	0	0	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Artificial Intelligence, Probability Theory								
Rationale	Machine Learning is a branch of Artificial Intelligence that allows computers to learn and improve automatically with experience. There has been a huge increase in both scientific and e-commerce driven data generation in recent times. This has led to increased focus on disciplines like machine learning and data analytics. Machine learning can be used to solve real world problems that require classification, prediction, pattern mining and trend detection. This course aims to cover important aspects of problem representation, data pre-processing, hypothesis evaluation and modeling using machine learning algorithms which are useful to the student in research.								

Course Outcomes (COs): At the end of the course, students will be able to			Marks % Weightage
CO - 1	Explain machine learning methods useful for generating models from data		30
CO - 2	Describe various issues in machine learning		20
CO - 3	Apply various data pre-processing techniques to prepare datasets for learning.		20
CO - 4	Use the algorithms for a real world problem, optimize the model learned and estimate the accuracy that can be achieved by applying the model		30

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Introduction to Machine Learning, Defining a learning problem, Designing a machine learning system- Choosing training experience, Choosing and representing a target function, supervised and unsupervised learning, Model evaluation; Issues in Machine Learning reported in contemporary literature	12	20%
2	Data Pre-processing: Data Cleaning- removing noise, substitution of missing values, Data Normalization, Data Discretization	06	10%
3	The Inductive Learning Hypothesis, Inductive Bias, Sampling, Hypothesis Evaluation, Comparing learning algorithms	08	14%
4	Bayesian Learning- Probability and Bayes' theorem, Maximum Likelihood Estimation, naïve Bayesian classifier, Bayesian Networks;	12	20%



	Decision Tree Learning- Algorithms for generating Decision trees, Inductive bias in decision tree learning, stopping criterion, handling missing values, overfitting and pruning of decision trees		
5	Artificial Neural Networks- Perceptrons, activation function, multilayer network, network topology, parameter tuning, Backpropagation; Support Vector Machines- Linear discriminant, separating hyperplane, Maximum Margin Hyperplane, Support Vectors	12	20%
6	Applications of Machine Learning, Case Studies	10	16%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20%	20%	20%	10%	20%	10%

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Recommended Reference Books

- 1 Tom M. Mitchell, *Machine Learning*, McGraw Hill, 1997.
- 2 Christopher M. Bishop, *Pattern Recognition and Machine Learning*, Springer, 2006.
- 3 Jiawei Han and Micheline Kamber, *Data Mining: Concepts and Techniques*, 2nd Edition, Morgan Kaufmann Publishers, 2006.
- 4 Peter Flach, *Machine Learning: The Art and Science of Algorithms that Make Sense of Data*, Cambridge University Press, 2012.
- 5 John D. Kelleher, Brian Mac Namee, and Aoife D'Arcy, *Fundamentals of Machine Learning for Predictive Data Analytics*, 2nd Edition, MIT Press, 2020.

List of Open Source/learning website/Other Details if any:

1. NPTEL course on: Introduction to Machine Learning (<https://nptel.ac.in/courses/106106139>)
2. NPTEL course on: Machine Learning (<https://nptel.ac.in/courses/106106202>)

Ph.D		Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Deep Learning			L	T	P	Credits	CCE	SEE
Subject Code	PTCO11203			4	0	0	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Knowledge of Linear Algebra, Probability theory								
Rationale	Deep Learning has received a lot of attention over the past few years to solve a wide range of problems in Computer Vision. The availability of huge volume of Image and Video data over the internet has made the problem of data analysis and interpretation a really challenging task. Deep Learning has proved itself to be a possible solution to such Computer Vision tasks. This course covers learning approaches and then moves to the modern Deep Learning architectures like Convolutional Neural Networks, Autoencoders etc.								

Course Outcomes (COs): At the end of the course, students will be able to			Marks % Weightage
CO – 1	Explain Neural network architecture, key concepts and back propagation learning algorithm		15
CO – 2	Use building blocks of CNN for Deep neural network		25
CO – 3	Apply transfer learning concept for different applications using different CNN architectures.		15
CO – 4	Examine various optimization techniques to make Deep learning models efficient.		20
CO – 5	Design deep learning model for the real world application.		25

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Introduction to Neural Network: Expressing linear perceptron as neurons, Linear neurons and their limitations, Nonlinear functions, Multilayer Perceptron, Feed Forward Neural Networks, Loss function, Propagation Learning, Supervised and Unsupervised learning.	15	25%
2	Training Feed forward neural network: Gradient Descent, batch optimization, back propagation algorithm, Test set, Validation Set, Overfitting in deep neural network.	7	12%
3	Introduction to Deep Learning: Bayesian Learning, Decision Surfaces, Linear Classifiers, Feature descriptor, Discriminate function.	8	14%
4	Convolutional Neural Network (CNN): Shortcomings of feature selection, Filters and Feature Maps, Building blocks of CNN - Convolution layer, Max pooling, Visualizing learning in CNN.	20	33%

	Popular CNN architecture: LeNet, AlexNet, VGG16, GoogleNet, ResNet etc., Vanishing Gradient, Transfer Learning, Auto encoder.		
5	Effective training in Deep Net, L2 regularization, Early stopping, Dataset augmentation, Applications of Deep Learning.	10	16%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10%	20%	20%	10%	20%	20%

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Recommended Reference Books

- 1 B. Yegnanarayana, Artificial Neural Networks, Prentice-Hall of India, 2006.
- 2 Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer-Verlag, New York, 2013.
- 3 Nikhil Buduma, Fundamentals of Deep Learning, Shroff Publishers & Distributors Pvt. Ltd., 2017.

List of Open Source/learning website/Other Details if any:

1. NPTEL course on: Deep Learning (IIT Kharagpur, Prof. P. K. Biswas
(<https://nptel.ac.in/courses/106105215>)
2. NPTEL course on: Deep Learning- Part 1, IIT Ropar (<https://nptel.ac.in/courses/106106184>)

Syllabus
For
Doctor of Philosophy (Ph.D)
CIVIL ENGINEERING
Semester II

Subject – 3

YEAR – I, SEMESTER II											
Sr. No.	Category	Subject Code	Subject Name	Teaching Scheme (In Hours)			Total Credits	Total Hours	Evaluation Scheme (Marks)		
				L	T	P			CCE	SEE	Total
01.	Ph.D	PTCL11201	Land Management Techniques	4	0	0	4	4	50	50	100
02.	Ph.D		Legislation and Policies in Urban Planning	4	0	0	4	4	50	50	100
03.	Ph.D		Sustainable Planning & Development	4	0	0	4	4	50	50	100
04.	Ph.D		Urban Development and Management Governance	4	0	0	4	4	50	50	100
05.	Ph.D		Rehabilitation and Modernization of Water Projects	4	0	0	4	4	50	50	100
06.	Ph.D	PTCL11206	Issues and Sustainability of Water Resources	4	0	0	4	4	50	50	100
07.	Ph.D	PTCL11207	Soil Improvement and Dynamic Response of Structure	4	0	0	4	4	50	50	100

TEACHING SCHEME

L – Lecture

T – Tutorial

P – Practical

EVALUATION SCHEME

CCE – Continuous and Comprehensive Evaluation

SEE – Semester End Examination

Ph.D.	1	Semester	II	Teaching Scheme				Evaluation Scheme	
Subject Name	Land Management Techniques			L	T	P	Credits	CCE	SEE
Subject Code	PTCL11201			4	0	0	4	50	50
Type of course	PhD Credit Course								
Prerequisite	Understanding on housing, social aspects, urbanization, traffic planning, building bylaws also understanding on survey techniques, coordinate systems, statistics, geographic features, operations using CAD tools and worksheets.								
Rationale	To amalgamate planning techniques on the basis of qualitative & quantitative analysis of availed data for proper management & performance of urban planning. Subject helps orienting students to a very emerging, useful and important field of geo-spatial world wherein scopes for professional career are endless.								

Course Outcomes (COs): At the end of the course, students will be able to

- CO – 1 Understand and attempt practicing management principle.
- CO – 2 Understand process of analysis and predict future population by using different statistical methods.
- CO – 3 Scopes, functions, limitations of new town development were made known, various policies and land development schemes pertaining to urban planning.
- CO – 4 Sensitization towards certain importance and use of geo spatial techniques and implementation in urban as well as regional planning.

Course Contents

Unit	Content	Tentative Teaching Hours	Tentative Unit Weight
1	Land use activities: Introduction, Population forecasting methods. Analysis and prediction of important land use activities.	10	30%
2	Urban Infrastructure: Elements of Infrastructure, Basic definitions, concepts, significance and importance, Data required for provision and planning of urban networks and services; Resource analysis, provision of infrastructure; Principles of resource distribution in space; Hierarchical distribution of facilities, Access to facilities, provision and location criteria, Norms and standards, etc.	15	20%

3	Land Management Practices: Land value and density pattern, Principal of Town Planning schemes, Land Acquisition, Rehabilitation and resettlement act 2013, TDR, Guidelines of URDPFI, GDCR and GTPUD Act. Zoning, Smart metropolitan planning. A case study of development plan, master plan, preparation, Formulation and implementation, Global Trends.	15	20%
4	Geospatial Techniques and Planning: Cartography, Geographic mapping process, transformations, map projections, Geographic Data Representation, Storage, Quality and Standards, database management systems, Raster data representation, Vector data representation, Assessment of data quality, Managing data errors, Geographic data standards.	20	30%

Recommended Reference Books

- 1 Das, A. K. (2007). *Urban Planning In India*. Rawat Publishers. ISBN: 8131600947.
- 2 Roberts, M. (n.d.). *Town Planning Techniques*. Hutchinson Educational Publication.
- 3 Lall, S. V. (2009). *Urban Land Markets: Improving Land Management for Successful Urbanization*. Springer.
- 4 Randolph, J. (2009). *Environmental Land Use Planning and Management*. Island Press.
- 5 Berke, P. R. (2009). *Urban Land Use Planning*. University of Illinois Press.
- 6 Lo, C. P., & Yeung, A. K. W. (2002). *Concepts and Techniques of Geographic Information Systems*. Prentice Hall of India.
- 7 Reddy, A. M. (2001). *Remote Sensing and Geographical Information Systems*. B.S. Publications.
- 8 Burrough, P. A. (1998). *Principles of Geographical Information Systems*. Oxford Publication.
- 9 Clarke, K. (2001). *Getting Started with Geographic Information Systems*. Prentice Hall.
- 10 De Mers, M. N. (2000). *Fundamentals of Geographic Information Systems*. John Wiley & Sons.

List of Open Source/learning website:

- CAD Drafting tools; word processing tools, calculation sheets
- Google Sketch-Up Pro
- ESRI City Engine (Transforms 2D GIS Data into 3D city models)
- Remote Sensing & Geographic Information System (<http://gis.nic.in/>)
- National Remote Sensing Centre (<http://www.nrsc.gov.in/>)
- Indian Space Research Organisation (<http://www.isro.org/>)

- Indian institute of Remote Sensing (<http://www.iirs.gov.in/>)
- List of geographic information systems software
(http://en.wikipedia.org/wiki/List_of_geographic_information_systems_software)
- Google books on GIS and Remote Sensing
(https://www.google.co.in/search?q=Urban+Planning+Techniques&btnG=Search+Books&tbm=bks&tbo=1&gws_rd=ssl#q=GIS+Remote+Sensing&tbm=bks) .

Ph.D.	1	Semester	II	Teaching Scheme				Evaluation Scheme	
Subject Name	Legislation and Policies in Urban Planning			L	T	P	Credits	CCE	SEE
Subject Code				4	0	0	4	50	50
Type of course	PhD Credit Course								
Prerequisite	Fundamentals on building bylaws, planning terminology, urbanization, issues of urbanization, constitutional provisions								
Rationale	The course helps in grasping and learning about recent challenges and problems that arise in urban development and how to resolve them. Comprehending methods and procedures for National highway planning and town planning scheme. The training also emphasizes the professional principles and procedures that planners must adhere to.								

Course Outcomes (COs): At the end of the course, students will be able to

- CO – 1 Understand land market dynamics, the principles of land use, and legal aspects of land management.
- CO – 2 Understand the concepts of Smart City and its fundamentals.
- CO – 3 The problems and issues pertaining to smart and metropolitan planning shall be addressed.
- CO – 4 Understand and perform Mass Housing Planning Practice and Procedure as well as exposure regarding various Housing policies, DCR, Financial aspect and housing pattern according to climatic condition.

Course Contents

Unit	Content	Tentative Teaching Hours	Tentative Unit Weight
1.	Introduction: Legislation Bylaws, Concepts, procedure for compulsory acquisition of property and determination of compensation. Legal aspects of innovative techniques such as Transfer of Development Rights, Accommodation Reservation (AR), Legal framework.	10	30%
2.	Land policies and practices Understanding, Need, Objective, Significance, Factor influencing location decision, Analysis of location of specific land use like residential- industrial commercial and institutional in intra-regional development. Case studies of various land use policies and practices at state level, land pooling techniques, Economics and Principles of land use, Development of land and real properties, Land development charges and betterment levy PPP in urban land	15	20%

	development & case studies.		
3.	Habitat Laws and Land Development Regulations and Policies, Planning Tools, Enforcement Mechanisms, Land Development Practices, Habitat Restoration and Creation, Balancing Development and Conservation: Sustainable Development, National Wildlife Action Plan (India), UN-Habitat, Habitat fragmentation, Climate change- impacts of land development on habitats, Laws relating to Slum Clearance.	15	20%
4.	Housing policies & finance Housing Needs and Challenges, Role of Government, Housing: Process, Heterogeneity and Instrumentality, Legal and Policy Framework - National Housing Policies, RERAct, Land Policies, Building Codes and Regulations, Legal Framework for Housing Finance, Types of Housing Finance, Housing Finance Models, Housing Demand, Supply and Distortions in Housing market, Housing Affordability and Finance.	20	30%

Recommended Reference Books

1	Bhargava, G. (2002). <i>Development of India's Urban and Regional Planning in 21st Century: Policy Perspective</i> . Gyan Publishing House. ISBN: 9788121207140.
2	Blackhall, J. C. (2005). <i>Planning Law and Practice</i> (3rd ed.). Taylor & Francis Ltd. ISBN: 9781859417485.
3	Gupta, K. R., & Maiti, P. (2004). <i>Urban Development Debates in the New Millennium</i> . Atlantic Publishers. ISBN: 9788126903900.
4	Apte, P. M. (2013). <i>Urban Growth Strategies: Mumbai Lessons</i> . Leadstart Publications. ISBN: 9789381576335.
5	Kulshrestha, S. K. (2012). <i>Urban and Regional Planning in India: A Handbook for Professional Practice</i> . SAGE Publications Pvt. Ltd. ISBN-10: 8132106970.
6	Paul, S., Seetharam, S. K., & Reddy, A. V. (2012). <i>The State of Our Cities: Evidence from Karnataka</i> . Oxford University Press. ISBN-10: 0198080387.
7	Lall, S. V. (2009). <i>Urban Land Markets: Improving Land Management for Successful Urbanization</i> . Springer.
8	Abrahams, C. <i>Housing in the Modern World</i> . Faber and Faber, London.
9	Dwivedi, R. M. (2007). <i>Urban Development and Housing in India (1947–2007)</i> . New Century Publications.
10	Heggade, D., & Cherunilam, F. <i>Housing in India</i> . Himalaya Publishing House, Bombay.
11	Gibberd, F. <i>Town Design</i> . Architectural Press, London.
12	Brueckner, J. K. (2011). <i>Lectures on Urban Economics</i> . PHI Learning Pvt. Ltd. New Delhi. ISBN: 978-81-203-4752-6.
13	Narwade, P. (2014). <i>Land – Property: Practice & Law</i> . Global Publishers, Mumbai.
14	Madan, V. L. (2013). <i>Sale and Purchase of Properties: A Legal Guide</i> . Universal Law Publishing Company, New Delhi. ISBN: 978-93-5035-283-0.
15	Poulose, K. T. (2002). <i>Reading Material on Housing</i> . Institute of Town Planners, India, New Delhi.

List of Open Source/learning website:

1. Governance Knowledge Center (Department of Administrative Reforms and Public Grievances)
2. Ministry of Housing and Urban Poverty Alleviation
3. Gujarat Infrastructure Development Board
4. Other Ministries and State Government Department websites.



**SARVAJANIK
UNIVERSITY**

INCLUSIVE | INTEGRATED | INNOVATIVE
creating an enlightened society...

SARVAJANIK UNIVERSITY

SARVAJANIK COLLEGE OF ENGINEERING AND TECHNOLOGY

Doctor of Philosophy

Civil Engineering

311



Ph. D.	I	Semester	II	Teaching Scheme				Evaluation Scheme	
Subject Name	Sustainable Planning and Development			L	T	P	Credits	CCE	SEE
Subject Code				4	-	-	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	1st year of Ph. D.								
Rationale	The course helps the students for their research work in domain of Sustainable development aims to protect the planet by reducing pollution, conserving natural resources, and using less energy.								

Course Outcomes (COs): At the end of the course, students will be able to			Marks % Weightage
CO – 1	Understand of the carrying capacity of ecosystems as related to providing for human needs.		25
CO – 2	Understand three Pillars of Suitability; Balance environmental, social, and economic considerations.		25
CO – 3	Have knowledge about Ecological principles in planning can help create sustainable and resilient environments. These principles can help maintain the delivery of ecosystem services, which are the benefits that humans receive from ecosystems		15
CO – 4	Study on drought, storms, heat waves, rising sea levels, melting glaciers and warming oceans can directly harm animals, places and people too.		20
CO – 5	Understand the Urban environmental management outcomes include reducing greenhouse gas emissions, improving sustainability, and building climate resilience		15

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1.	Introduction to Sustainable Development: Sustainable Development- Definitions, concepts and Parameters; Eco- City Approach; Kyoto Protocol, Intergovernmental Panel on Climate Change (IPCC), united nations framework convention on climate change; Indian network of climate change assessment, global environment facility , and clean development mechanism; UNHABITAT policies, sustainable development goals, new urban agenda, sustainable cities programme.	6	25%
2.	Principle of Sustainable Planning : Concepts of sustainable planning, three pillars of sustainability and its implication in planning process; Environmental preservation;	10	25%



	commerce and liveability; Walk ability and Connectivity; Integration of diverse community features; Strong sense of place.		
3.	Climate Changes and its Impact Basic concepts and definitions of Climate Change; Urban Heat Islands; Climatic Change and Human History; Impacts of Climate Change; Climate as Forcing Variable, Locational Attributes, Sensitivity and Vulnerability of Different Sectors.	10	15%
4.	Urban Environmental Management: Urban Environment and Planning ; Human activities and energy in Cities; contribution to GHGs; Environmental Impact and Strategic Environmental assessment for Urban area; Ecological Footprint Analysis of Cities; Sustainable Lifestyle Assessment	10	20%
5.	Low Carbon Urban Development: Low carbon urban development strategies- concept of 3-Rs: "Recycle-Reuse and Recovery"; Low carbon transport modes and mobility options; Land Capability and Suitability Analysis; Compact City Concepts Use of Non-Conventional Energy Sources; Urban Water Treatment, Recycling, Recycling and Harvesting; Pollution Control Measures for Industrial Wastes, Hazardous Wastes, Biomedical Wastes, Domestic Waste Water, Air Pollutants and Noise.	12	15%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	20	20	15	15	10

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Recommended Reference Books

- 1 Ajay Ahlawat , " Sustainable Development Goals", Notion Press 978-1646785049; 1st edition, 2019.
- 2 Dr. Kajalbaran Jana, "The Sustainable Development Goals In India: Few Issues & Contexts", Redshine Publication, 1st edition, 2021
- 3 Margaret Robertson, "Sustainability Principles and Practic", Taylor & Francis Ltd, 1st edition, 2021.
- 4 Dr. Varun Cha-cha "Sustainable Development in India" VL Media Solutions, 1st edition, 2023.

Ph. D.	I	Semester	II	Teaching Scheme				Evaluation Scheme	
Subject Name	Urban Development Management and Governance			L	T	P	Credits	CCE	SEE
Subject Code				4	-	-	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	1st year of Ph. D.								
Rationale	Urban development management and governance are important for managing infrastructure, improving quality of life, and creating sustainable cities.								

Course Outcomes (COs): At the end of the course, students will be able to		Marks % Weightage
CO – 1	Apply management techniques in urban planning and development.	25
CO – 2	Understand sustainability of land use, urban planning, and environment.	15
CO – 3	Understand redevelopment of urban areas to improve quality of life, economic vitality, and land values with Urban redevelopment	15
CO – 4	Know Suitability, Accountability, Coordination, Social cohesion, Urban mobility.	15
CO – 5	Understand administrative reforms in local governance; Organisational Restructuring of Local Governments; capacity building; NGO's.	20

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1.	Introduction to Development Management Definition, objectives and scope of management; Role of management in developing economy; Decision making process and corporate activity in urban development; Application of management techniques in urban planning and development.	6	25%
2.	Land Economics and Real Estate Development Economic concepts of land, land pricing/ valuation; economic principles of land use; demand forecasting for land use: factors affecting land supply and demand; land development methods, supply management, Demand side management; real estate markets, type of property development and its impact on supply and demand, method of development, environmental considerations	10	15%

3.	Urban Redevelopment Strategies and evaluation of redevelopment; role of public sector agencies in redevelopment; Area based redevelopment Initiatives; Property led redevelopment policies; Investment and Funding of Urban Redevelopment Schemes; Role of private sector; Development Potential and Pricing; Plot reconstitution; Renewal through Housing and Mixed Use Development; Community Participation.	12	15%
4.	Urban Governance, Institutions and Organizations Urban Governance- Definition, concepts and components; hierarchy and structure, form of governance; Institutional and organizational framework, existing institutional and organizational setting for urban management in India; distribution of responsibilities ; special purpose vehicles (SPV's) in the urban sector; significance of organizational framework; Difference between institutions and organizations	10	15%
5.	Urban Local Governance and its Reform Urban local governance- type, organization, power , functions, resource, state supervision control and their working; improvement trust- organizations, scope of their powers and functions and their working; City development authorities: organizations, scope of their power and functions, resources, and their working; administrative reforms in local governance; Organisational Restructuring of Local Governments; capacity building; NGO's.	10	20%
6.	Participatory Process in Urban Governance Stakeholder participation- roles and responsibilities, access to governments; Citizen Participation in urban development and management; Inter-organizational relations and coordination at local level; role of digital engagement and social media	12	10%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20	20	20	15	15	10

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Recommended Reference Books

- 1 Jasmeet Sandhu & Gurpreet Bal," Urban Development and Governance: Issues, Concerns and Challenges", ISBN: 9788131605622; 1st edition, 2013.
- 2 John Rennie Short, "Urban Theory: A Critical Assessment", ISBN: 9788131613733, 2nd edition, 2024
- 3 Satish K. Sharma and Suman Lata Pathak, "Urbanization Population and Environment", ISBN: 9788131613528, 1st edition, 2024.

Ph. D.	I	Semester	II	Teaching Scheme				Evaluation Scheme	
Subject Name	Rehabilitation and Modernization of Water Projects			L	T	P	Credits	CCE	SEE
Subject Code				4	-	-	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	1st year of Ph. D.								
Rationale	The course helps the students for their research work in domain of irrigation project management which include understanding of maintenance of irrigation system, Diagnostic Analysis of Irrigation Systems and rehabilitation								

Course Outcomes (COs): At the end of the course, students will be able to		Marks % Weightage
CO – 1	Understanding the different types of maintenance problems with respect to technical and social aspects.	20
CO – 2	Solve different types of irrigation system maintenance issues for improving their performance based on service oriented approach	20
CO – 3	Plan various irrigation canal structures in the canal network as per the site situation and requirement.	25
CO – 4	Examine the irrigation system, identifying both its strengths and weaknesses, and suggesting solutions to remove constraints.	25
CO – 5	Develop critical thinking, problem solving, and collaboration skills by understand real-world situations and develop solutions to problems.	10

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1.	Irrigation Systems Historical evolution of irrigation systems in India; its importance to agricultural production, Irrigation system classification – Nature of system modernization and rehabilitation, Distinction between rehabilitation and modernization; Rehabilitation and modernization objectives – Theory and Practice	10	20%
2.	System Maintenance Maintenance: essential, catch up, preventive and normal – Diagnostic analysis of flow, seepage and other parameters through Participatory Rural Appraisal, Rapid Rural Appraisal and Walk-through Survey – Development and maintenance programme – Kudimaramath– Turnover – WUA.	10	20%



3.	Diagnostic Analysis of Irrigation Systems System performance: history of inflow, cropping pattern, system alterations, distribution performance – Operational constraints – Management constraints – Resources constraints.	14	25%
4.	Rehabilitation Baseline survey – Deferred maintenance – Causes – Criteria used for taking rehabilitation programmes –Service Delivery Concepts-Software and hardware improvements – Prioritization – Role of water users" association – Monitoring and evaluation.	14	25%
5.	Case Studies Rehabilitation and modernization programmes – Periyar Vaigai Project – Walawe Project – Tank Modernization Project – Water Resources Consolidation Project. IAM WARM Project - DRIP - Case study of Rehabilitation using Water Delivery Concept	8	10%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15	20	20	20	15	10

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Recommended Reference Books

- 1 S. K.Garg," Irrigation Engineering and Hydraulic Structures", Khanna Publishers; 38th edition, 2023.
- 2 G. L. Asawa, "Irrigation and Water Resources Engineering", Newage publishers, 1st edition, 2005.
- 3 Pankaj K. Thakur, "Irrigation Engineering", Researchgate.net, 1st edition, 2023.
- 4 Daniel Renault, RobinaWahaj, Stef Smits, "Multiple Uses of Water Services in Large Irrigation Systems: Auditing and Planning Modernization the MASSMUS Approach", Food & Agriculture Org, 1st edition, 2014.
- 5 Adrian Laycock, "Irrigation Systems: Design, Planning and Construction", Cabi Publishing, 1st edition, 2011.
- 6 D. Majumdar, "Irrigation Water Management: Principles & Practice", Prentice Hall India Publisher, 2nd edition, 2014.
- 7 Dr. B. C. Punmia, Dr. Pande B. B., "Irrigation and Water Power Engineering", Laxmi Publications, 2nd edition, 2018.

Ph. D.	I	Semester	II	Teaching Scheme				Evaluation Scheme	
Subject Name	Issues and Sustainability of Water Resources			L	T	P	Credits	CCE	SEE
Subject Code	PTCL11206			4	-	-	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	1st year of Ph. D.								
Rationale	The subject of water resources and sustainability is important because water is a vital natural resource that is essential for human survival, economic development, and the health of the planet. It essential for creating a balance approach to managing one of the planet's most critical resources. Through this study, students can develop the knowledge, skill and awareness needed to contribute to sustainable water management practices.								

Course Outcomes (COs): At the end of the course, students will be able to		Marks % Weightage
CO – 1	Understand the environmental issues pertaining to water and its usage, its effects on food pattern and society.	25
CO – 2	Appreciate the remedies and protective measures for maintaining the quality and quantity of water.	25
CO – 3	Apply sustainability principles to real-world scenarios	25
CO – 4	Gain the skills to take up research activities in environmental sustainability.	25

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1.	Environmental issues Water crisis and Climate Change, conservation of water, Green-House Effect , Green House Gases GHGs) and their Emission, famine and drought scenario, heat island formation and its consequences, Sea Level rise, effects on wetlands and estuaries	14	25%
2.	Assessment of Contamination Industrial Pollution, Quantification of contamination, Global Warming Potential (GWP) of flux emission from treatment facilities, agricultural pollution, ground water contamination	15	25%
3.	Sustainability of Environment History and Need of the concept of Sustainable	15	25%

	Development, basic terms, Environmental issues and crisis, Resource degradation, greenhouse gases, deforestation, food insecurity, Industrialization, Globalization and Environment, substitutes for usage of pesticides and fertilisers.		
4.	Roles and Techniques Alternatives of Carbon Sequestration, Conventional and non-conventional techniques, Role of Countries and Citizens in Controlling Global Warming, Integrated approach for resource protection and management.	12	25%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15	25	25	15	10	10

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (**Revised Bloom's Taxonomy**)

Recommended Reference Books

- 1 Basant Yadav Mohit Prakash Mohanty Ashish Pandey Vijay P. Singh, R. D. Singh, "Sustainability of Water Resources: Impacts and Management", Springer International Publishing ISBN-13: 978-3031134692; 1st edition, 2022.
- 2 Sarda Ganguly Gangadhar Banerjee, "Water Resources and Environmental Sustainability", MV Learning ISBN-13: 978-9387692855, 1st edition, 2018.
- 3 Ritu Singh, Sanjeev Kumar, "Green Technologies and Environmental Sustainability", Springer International Publishing, ISBN 978-3-319-50654-8, ebook, 2017.
- 4 Dr. D K Asthana Dr. Meera Asthana, "Environmental Studies", S Chand ISBN-13 978-8121927642, 2nd edition, 2015.
- 5 Sudha Sambyal Malik, "Environmental Issues", Bio-Green Books ISBN-13 978-9388982962, 1st edition, 2020.



Ph. D	I	Semester	II	Teaching Scheme				Evaluation Scheme	
Subject Name	Soil Improvement and Dynamic Responses of Structure			L	T	P	Credits	CCE	SEE
Subject Code	PTCL11207			4	0	0	4	50	50
Type of course	Ph. D – Credit Course			CCE: Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Soil Mechanics, Foundation Engineering, Strength of Materials, Structural Analysis & Repair& Rehabilitation of Structure								
Rationale	When a project encounters difficult foundation conditions, possible alternate solutions are: Avoid the particular site or Design the planned structure accordingly. The choice of a method of ground improvement for a particular object will depend on: Type and degree of improvement required, type of soil, cost, possible damage to adjacent structures or pollution of ground water resources, reliability of method of analysis and design etc.. Though earthquakes can produce devastating damages to life and property, modern technologies of seismic vibration control such as building elevation control, elevated building foundations, and the use of dampers and springs can assist in minimizing earthquake damage. Wind-induced vibration has become one of the main design challenges regarding modern high-rise buildings. High-rise buildings are naturally more sensitive for dynamic responses due to their low fundamental frequencies than low-rise buildings. At the same time, different wind conditions such as vortex effects intensify at higher levels and create more vibration prone structures. The main problem regarding wind-induced vibration is occupants' respond to the fluctuation of a building and it has proven to cause various negative effects, such as sleepiness and motion sickness. For this reason, different criterion and methods to evaluate dynamic responses of structures are required.								

Course Outcomes (COs): At the end of the course, students will be able to			Marks % Weightage
CO – 1	Identify the mineral composition responsible for the weak soil deposits and problems associated with it. (R, U, A – Cognitive Level)		25
CO – 2	Analyze various index/strength properties of soil and suggest suitable ground improvement method. (R, U, A, – Cognitive Level)		15
CO – 3	Classify and identify the distress in structure (R, U, A, N, E, – Cognitive Level)		10
CO – 4	Identify Understand the Basics of Earthquake Engineering (R, U, A, N, E, C– Cognitive Level)		35
CO – 5	Conceptualize vibrating body for free and forced vibration (R, U, A, N, E, C – Cognitive Level)		15



Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1.	Ground Improvement: Definition, Objectives of soil improvement, Classification of ground improvement techniques, Factors to be considered in the selection of the best soil improvement technique. Weak Deposits – Identification – Problems associated with weak deposits – Mitchel chart of applicability of treatment methods – Principles – Suitable methods. Mechanical Modification, Principle of modification for various types of soils	14	20%
2.	Geosynthetics and Reinforced Soil: Types of Geosynthetics like geotextiles, Geogrid, geonets, geocells, geo-composites, their functions, applications and manufacturing methods. Index properties and Strength properties of Geosynthetics. Historical background of reinforced soil, Principles of reinforced soil. Concept of MSE wall and Reinforced Soil slopes.	12	15%
3.	Structural Health Monitoring: Concepts, Various measures, Structural Safety in alteration, Factors Affecting health of structures, causes of distress, regular maintenance	12	20%
4.	Fundamentals of Earthquake Vibrations of buildings Static load v/s Dynamic load, simplified single degree of freedom system, mathematical modelling of buildings, natural frequency, resonance v/s increased response, responses of buildings to different types of vibrations like free and forced, damped and un-damped vibration, response of building to earthquake ground motion, Response to multi degree (maximum three) of freedom systems up to mode shapes.	14	35%
5.	Wind Induced Vibrations of Tall Buildings: Types of Flow Induced Excitation, Vortex Induced Phenomenon, Buffeting and Ovaling, Galloping and Flutter.	08	10%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10	20	30	15	15	10

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Recommended Reference Books	
1	A. K. Chopra, "Dynamics of structures", Pearson Education India, 2014.
2	Daniel Balageas, Claus-Peter Fritzen, Alfredo Güemes, "Structural Health Monitoring", John Wiley & Sons., 2010.
3	Douglas E Adams, "Health Monitoring of structural Materials and components -- Methods with applications", John Wiley & Sons, 2007.
4	Jie H, "Principles and Practice of Ground Improvement", Wiley India, 2018.
5	Koerner R. M., "Designing with Geosynthetics", Prentice Hall, New Jersey, USA, 2012.
6	L. Meirovitch, "Elements of Vibration Analysis", Tata Mc Graw-Hill, Singapore., 1986.
7	Manish Shrikhande & Pankaj Agrawal, "Earthquake Resistant Design of Structures", PHI Publication, New Delhi, 2014.
8	P. Purushothama Raj, "Ground Improvement Techniques", Laxmi Publications, 2016.

SARVAJANIK UNIVERSITY
FACULTY OF ENGINEERING AND TECHNOLOGY
DOCTOR OF PHILOSOPHY

Ph.D		Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Deep Learning			L	T	P	Credits	CCE	SEE
Subject Code	Code will be provided by SU			4	0	0	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Knowledge of Linear Algebra, Probability theory								
Rationale	Deep Learning has received a lot of attention over the past few years to solve a wide range of problems in Computer Vision. The availability of huge volume of Image and Video data over the internet has made the problem of data analysis and interpretation a really challenging task. Deep Learning has proved itself to be a possible solution to such Computer Vision tasks. This course covers learning approaches and then moves to the modern Deep Learning architectures like Convolutional Neural Networks, Autoencoders etc.								

Course Outcomes (COs): At the end of the course, students will be able to			Marks % Weightage
CO – 1	Explain Neural network architecture, key concepts and back propagation learning algorithm		15
CO – 2	Use building blocks of CNN for Deep neural network		25
CO – 3	Apply transfer learning concept for different applications using different CNN architectures.		15
CO – 4	Examine various optimization techniques to make Deep learning models efficient.		20
CO – 5	Design deep learning model for the real world application.		25

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Introduction to Neural Network: Expressing linear perceptron as neurons, Linear neurons and their limitations, Nonlinear functions, Multilayer Perceptron, Feed Forward Neural Networks, Loss function, Propagation Learning, Supervised and Unsupervised learning.	15	25%
2	Training Feed forward neural network: Gradient Descent, batch optimization, back propagation algorithm, Test set, Validation Set, Overfitting in deep neural network.	7	12%
3	Introduction to Deep Learning: Bayesian Learning, Decision Surfaces, Linear Classifiers, Feature descriptor, Discriminate function.	8	14%
4	Convolutional Neural Network (CNN): Shortcomings of feature selection, Filters and Feature Maps, Building blocks of CNN - Convolution layer, Max pooling, Visualizing learning in CNN.	20	33%

SARVAJANIK UNIVERSITY
FACULTY OF ENGINEERING AND TECHNOLOGY
DOCTOR OF PHILOSOPHY

	Popular CNN architecture: LeNet, AlexNet, VGG16, GoogleNet, ResNet etc., Vanishing Gradient, Transfer Learning, Auto encoder.		
5	Effective training in Deep Net, L2 regularization, Early stopping, Dataset augmentation, Applications of Deep Learning.	10	16%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10%	20%	20%	10%	20%	20%

Legends: **R:** Remembrance, **U:** Understanding; **A:** Application, **N:** Analyze, **E:** Evaluate **C:** Create and above Levels (**Revised Bloom's Taxonomy**)

Recommended Reference Books

- 1 B. Yegnanarayana, Artificial Neural Networks, Prentice-Hall of India, 2006.
- 2 Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer-Verlag, New York, 2013.
- 3 Nikhil Buduma, Fundamentals of Deep Learning, Shroff Publishers & Distributors Pvt. Ltd., 2017.

CO-PO-Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO – 1	✓	✓										
CO – 2	✓	✓										
CO – 3	✓	✓										
CO – 4	✓	✓		✓								
CO – 5	✓	✓	✓		✓						✓	✓

List of Open Source/learning website/Other Details if any:

1. NPTEL course on: Deep Learning (IIT Kharagpur, Prof. P. K. Biswas
(<https://nptel.ac.in/courses/106105215>)
2. NPTEL course on: Deep Learning- Part 1, IIT Ropar (<https://nptel.ac.in/courses/106106184>)

SARVAJANIK UNIVERSITY
FACULTY OF ENGINEERING AND TECHNOLOGY
DOCTOR OF PHILOSOPHY

Ph.D		Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Machine Learning			L	T	P	Credits	CCE	SEE
Subject Code	Code will be provided by SU			4	0	0	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Artificial Intelligence, Probability Theory								
Rationale	Machine Learning is a branch of Artificial Intelligence that allows computers to learn and improve automatically with experience. There has been a huge increase in both scientific and e-commerce driven data generation in recent times. This has led to increased focus on disciplines like machine learning and data analytics. Machine learning can be used to solve real world problems that require classification, prediction, pattern mining and trend detection. This course aims to cover important aspects of problem representation, data pre-processing, hypothesis evaluation and modeling using machine learning algorithms which are useful to the student in research.								

Course Outcomes (COs): At the end of the course, students will be able to			Marks % Weightage
CO – 1	Explain machine learning methods useful for generating models from data		30
CO – 2	Describe various issues in machine learning		20
CO – 3	Apply various data pre-processing techniques to prepare datasets for learning.		20
CO – 4	Use the algorithms for a real world problem, optimize the model learned and estimate the accuracy that can be achieved by applying the model		30

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Introduction to Machine Learning, Defining a learning problem, Designing a machine learning system- Choosing training experience, Choosing and representing a target function, supervised and unsupervised learning, Model evaluation; Issues in Machine Learning reported in contemporary literature	12	20%
2	Data Pre-processing: Data Cleaning- removing noise, substitution of missing values, Data Normalization, Data Discretization	06	10%
3	The Inductive Learning Hypothesis, Inductive Bias, Sampling, Hypothesis Evaluation, Comparing learning algorithms	08	14%
4	Bayesian Learning- Probability and Bayes' theorem, Maximum Likelihood Estimation, naïve Bayesian classifier, Bayesian Networks;	12	20%

SARVAJANIK UNIVERSITY
FACULTY OF ENGINEERING AND TECHNOLOGY
DOCTOR OF PHILOSOPHY

	Decision Tree Learning- Algorithms for generating Decision trees, Inductive bias in decision tree learning, stopping criterion, handling missing values, overfitting and pruning of decision trees		
5	Artificial Neural Networks- Perceptrons, activation function, multilayer network, network topology, parameter tuning, Backpropagation; Support Vector Machines- Linear discriminant, separating hyperplane, Maximum Margin Hyperplane, Support Vectors	12	20%
6	Applications of Machine Learning, Case Studies	10	16%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20%	20%	20%	10%	20%	10%

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels **(Revised Bloom's Taxonomy)**

Recommended Reference Books

- 1 Tom M. Mitchell, *Machine Learning*, McGraw Hill, 1997.
- 2 Christopher M. Bishop, *Pattern Recognition and Machine Learning*, Springer, 2006.
- 3 Jiawei Han and Micheline Kamber, *Data Mining: Concepts and Techniques*, 2nd Edition, Morgan Kaufmann Publishers, 2006.
- 4 Peter Flach, *Machine Learning: The Art and Science of Algorithms that Make Sense of Data*, Cambridge University Press, 2012.
- 5 John D. Kelleher, Brian Mac Namee, and Aoife D'Arcy, *Fundamentals of Machine Learning for Predictive Data Analytics*, 2nd Edition, MIT Press, 2020.

CO-PO-Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO – 1	✓	✓	✓								✓	✓
CO – 2	✓	✓	✓								✓	✓
CO – 3	✓	✓	✓								✓	✓
CO – 4	✓	✓	✓	✓	✓	✓	✓				✓	✓

List of Open Source/learning website/Other Details if any:

1. NPTEL course on: Introduction to Machine Learning (<https://nptel.ac.in/courses/106106139>)
2. NPTEL course on: Machine Learning (<https://nptel.ac.in/courses/106106202>)

SARVAJANIK UNIVERSITY
FACULTY OF ENGINEERING AND TECHNOLOGY
DOCTOR OF PHILOSOPHY

Ph.D		Semester	2	Teaching Scheme				Evaluation Scheme	
Subject Name	Data Science for Engineers			L	T	P	Credits	CCE	SEE
Subject Code	Code will be provided by SU			4	0	0	4	50	50
Type of course	PhD Credit Course			CCE : Continuous and Comprehensive Evaluation SEE : Semester End Evaluation					
Prerequisite	Statistics								
Rationale	This course introduces the mathematical foundations required for data science. As part of this course, students will learn the framework for solving problems requiring data analytics. This course also introduces ‘R’ programming language. Students will be able to solve predictive problems on real time data after learning this course.								

Course Outcomes (COs): At the end of the course, students will be able to		Marks % Weightage
CO – 1	Describe a flow process for data science problems	20
CO – 2	Classify data science problems into standard typology	20
CO – 3	Develop R codes for data science solutions	20
CO – 4	Correlate results to the solution approach	15
CO – 5	Assess the solution approach	15
CO – 6	Construct use cases to validate approach and identify modifications required	10

Course Contents			
Unit	Content	Tentative Teaching Hours	Tentative Unit Weightage
1	Course philosophy and expectation, Introduction to R, Variables and data types in R, Data frames, Recasting and joining of data frames, Arithmetic, Logical and Matrix operations in R, Advanced programming in R : Functions, Control structures, Data visualization in R Basic graphics	8	14%
2	Linear Algebra for Data science, Solving Linear Equations, Linear Algebra - Distance, Hyperplanes and Halfspaces, Eigenvalues, Eigenvectors	6	10%
3	Statistical Modelling, Random Variables and Probability Mass/Density Functions, Sample Statistics, Hypotheses Testing	6	10%
4	Optimization for Data Science, Unconstrained Multivariate Optimization, Gradient Descent, Learning Rule	6	10%
5	Multivariate Optimization With Equality Constraints, Multivariate Optimization With Inequality Constraints, Introduction to Data Science, Solving Data Analysis Problems - A Guided Thought Process	6	10%

SARVAJANIK UNIVERSITY
FACULTY OF ENGINEERING AND TECHNOLOGY
DOCTOR OF PHILOSOPHY

6	Module: Predictive Modelling, Linear Regression, Model Assessment, Diagnostics to Improve Linear Model Fit, Simple Linear Regression Model Building, Simple Linear Regression Model Assessment, Multiple Linear Regression	6	10%
7	Cross Validation, Multiple Linear Regression Modelling Building and Selection, Classification, Logistic Regression, Performance Measures, Logistic Regression Implementation in R	6	10%
8	K - Nearest Neighbors (kNN), K - Nearest Neighbors implementation in R, K - means Clustering, K - means implementation in R	6	10%
9	Applications of Data Science, Challenges reported in contemporary literature, Case Studies	10	16%

Suggested Specification table with Marks

% Distribution of Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20%	20%	20%	15%	15%	10%

Legends: R: Remembrance, U: Understanding; A: Application, N: Analyze, E: Evaluate C: Create and above Levels (**Revised Bloom's Taxonomy**)

Recommended Reference Books

- 1 Gilbert Strang, *Introduction to Linear Algebra*, 5th Edition, Wellesley Publishers, 2016.
- 2 Douglas Montgomery, *Applied Statistics and Probability for Engineers*, 6th Edition, Wiley, 2016.
- 3 Peter Bruce and Andrew Bruce, *Practical Statistics for Data Scientists*, 2nd Edition, O'Reilly Media, 2017.
- 4 Allen B. Downey, *Think Stats: Probability and Statistics for Programmers*, 2nd Edition, Green Tea Press, Needham, Massachusetts, 2014.
- 5 John Muller, *Data Science for Dummies*, 2nd Edition, Wiley, 2017.
- 6 James D. Miller, *Statistics for Data Science*, Packt, 2017.

CO-PO-Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO – 1	✓	✓										
CO – 2	✓	✓	✓									
CO – 3			✓	✓	✓							
CO – 4			✓	✓	✓							✓
CO – 5			✓	✓	✓	✓	✓					✓
CO – 6		✓	✓	✓	✓	✓	✓					✓

List of Open Source/learning website/Other Details if any:

1. NPTEL course on: Data Science for Engineers (https://onlinecourses.nptel.ac.in/noc23_cs17/preview)