VIT®

Vellore Institute of Technology

(Deemed to be University under section 3 of UGC Act, 1956)

SCHOOL OF ADVANCED SCIENCES

DEPARTMENT OF MATHEMATICS

Integrated M.Sc. in Mathematics

Curriculum & Syllabi

(2021–2022 Admitted Students)

VISION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

Transforming life through excellence in education and research.

MISSION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

- **World class Education**: Excellence in education, grounded in ethics and critical thinking, for improvement of life.
- **Cutting edge Research**: An innovation ecosystem to extend knowledge and solve critical problems.
- **Impactful People**: Happy, accountable, caring and effective workforce and students.
- **Rewarding Co-creations**: Active collaboration with national & international industries & universities for productivity and economic development.
- **Service to Society**: Service to the region and world through knowledge and compassion.

VISION STATEMENT OF SCHOOL OF ADVANCED SCIENCES

To be an internationally renowned science school in research and innovation by imparting futuristic education relevant to the society.

MISSION STATEMENT OF SCHOOL OF ADVANCED SCIENCES

- To nurture students from India and abroad by providing quality education and training to become scientists, technologists, entrepreneurs and global leaders with ethical values for a sustainable future.

- To enrich knowledge through innovative research in niche areas.

- To ignite passion for science and provide solutions for national and global challenges.

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Integrated M.Sc. in Mathematics

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

PEO_01: Graduates will be practitioners and leaders in their chosen field.

PEO_02: Graduates will function in their profession with social awareness and responsibility.

PEO_03: Graduates will interact with their peers in other disciplines in their work place and society and contribute to the economic growth of the country.

PEO_04: Graduates will be successful in pursuing higher studies in their chosen field.

PEO_05: Graduates will pursue career paths in teaching or research.

Integrated M.Sc. in Mathematics

PROGRAMME OUTCOMES (POs)

PO_01: Having a clear understanding of the subject related concepts and of contemporary issues.

PO_02: Having an ability to design and conduct experiments, as well as to analyse and interpret data.

PO_03: Having an ability to use techniques, skills and modern tools necessary for solving scientific problems.

PO_04: Having problem solving ability- solving social issues and societal problems Having cross cultural competency exhibited by working in teams.

PO_05: Having adaptive thinking and adaptability.

PO_06: Having a clear understanding of professional and ethical responsibility.

PO_07: Having cross cultural competency exhibited by working in teams.

PO_08: Having a good working knowledge of communicating in English.

PO_09: Having a good cognitive load management [discriminate and filter the available data] skills.

PO_10: Having interest in lifelong learning.

Integrated M.Sc. in Mathematics

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion Integrated M.Sc. Mathematics (5yr.) Programme, graduates will be able to

PSO_01. Develop a multi-disciplinary approach for solving real life problems through various Foundational Core courses.

PSO_02. Use advanced knowledge on mathematics to pursue higher degrees at reputed academic institutions around the world.

PSO_03. Pursue research or careers in industry in mathematical sciences and allied fields.

PSO_04. Interact with international researchers and developing collaborations.

Category Credit Detail			
Sl.No.	**Description**	**Credit**	**Maximum Credit**
1	FC - Foundation Core	50	50
2	DC - Discipline Core	68	68
3	DE - Discipline Elective	45	45
4	PI - Projects and Internship	14	14
5	OE - Open Elective	6	6
6	AE - Ability Enhancement	9	9
7	SE - Skill Enhancement	8	8
Total Credits		200	

Foundation Core									
sl.no	**Course Code**	**Course Title**	**Course Type**	**Version**	**L**	**T**	**P**	**J**	**Credit**
1	TBIT101L	Biological Science	Theory Only	1.0	3	0	0	0	3.0
2	TBIT101P	Biological Science Lab	Lab Only	1.0	0	0	2	0	1.0
3	TCHY102L	Inorganic and Organic Chemistry	Theory Only	1.0	3	0	0	0	3.0
4	TCHY102P	Inorganic and Organic Chemistry Lab	Lab Only	1.0	0	0	2	0	1.0
5	TCHY103L	Physical and Analytical Chemistry	Theory Only	1.0	3	0	0	0	3.0
6	TCHY103P	Physical and Analytical Chemistry Lab	Lab Only	1.0	0	0	2	0	1.0
7	TCSE103L	Programming in Python	Theory Only	1.0	2	0	0	0	2.0
8	TCSE103P	Programming in Python Lab	Lab Only	1.0	0	0	4	0	2.0
9	TCSE104L	Structured and Object Oriented Programming	Theory Only	1.0	2	0	0	0	2.0
10	TCSE104P	Structured and Object Oriented Programming Lab	Lab Only	1.0	0	0	4	0	2.0
11	TFLE200L	M.Sc. (5 Year Integrated Programme) - Foreign Language - 2021	Basket	1.0	0	0	0	0	2.0
12	THUM101L	Ethics and Values	Theory Only	1.0	2	0	0	0	2.0
13	TMAT103L	Calculus and Analytical Geometry	Theory Only	1.0	3	0	0	0	3.0
14	TMAT103P	Calculus and Analytical Geometry Lab	Lab Only	1.0	0	0	2	0	1.0
15	TMAT104L	Ordinary and Partial Differential Equations	Theory Only	1.0	3	1	0	0	4.0
16	TMGT401L	Principles of Management	Theory Only	1.0	3	0	0	0	3.0
17	TPHY102L	Physics of Waves	Theory Only	1.0	3	0	0	0	3.0
18	TPHY102P	Physics of Waves Lab	Lab Only	1.0	0	0	2	0	1.0
19	TPHY103L	Modern Physics	Theory Only	1.0	3	0	0	0	3.0
20	TPHY103P	Modern Physics Lab	Lab Only	1.0	0	0	2	0	1.0
21	TRES101L	Research Methodology	Theory Only	1.0	3	0	0	0	3.0
22	TSSC201L	Critical Thinking	Theory Only	1.0	2	0	0	0	2.0
23	TSSC202L	Intra and Interpersonal Skills	Theory Only	1.0	2	0	0	0	2.0

Discipline Core									
sl.no	Course Code	Course Title	Course Type	Version	L	T	P	J	Credit
1	TMAT201L	Probability and Statistics	Theory Only	1.0	3	0	0	0	3.0
2	TMAT201P	Probability and Statistics Lab	Lab Only	1.0	0	0	2	0	1.0
3	TMAT202L	Linear Algebra	Theory Only	1.0	3	1	0	0	4.0
4	TMAT203L	Real Analysis	Theory Only	1.0	3	1	0	0	4.0
5	TMAT204L	Ordinary Differential Equations	Theory Only	1.0	3	1	0	0	4.0
6	TMAT205L	Complex Analysis	Theory Only	1.0	3	1	0	0	4.0
7	TMAT301L	Numerical Analysis	Theory Only	1.0	3	0	0	0	3.0
8	TMAT301P	Numerical Analysis Lab	Lab Only	1.0	0	0	2	0	1.0
9	TMAT302L	Abstract Algebra	Theory Only	1.0	3	1	0	0	4.0
10	TMAT303L	Discrete Mathematical Structures	Theory Only	1.0	3	1	0	0	4.0
11	TMAT304L	Topology	Theory Only	1.0	3	1	0	0	4.0
12	TMAT305L	Operations Research	Theory Only	1.0	3	1	0	0	4.0
13	TMAT401L	Calculus of Variations and Integral Equations	Theory Only	1.0	3	1	0	0	4.0
14	TMAT402L	Graph Theory	Theory Only	1.0	3	1	0	0	4.0
15	TMAT403L	Functional Analysis	Theory Only	1.0	3	1	0	0	4.0
16	TMAT404L	Partial Differential Equations	Theory Only	1.0	3	1	0	0	4.0
17	TMAT405L	Transform Techniques	Theory Only	1.0	3	1	0	0	4.0
18	TMAT406L	Measure and Integration	Theory Only	1.0	3	1	0	0	4.0
19	TMAT407L	Statistical Inference	Theory Only	1.0	3	0	0	0	3.0
20	TMAT407P	Statistical Inference Lab	Lab Only	1.0	0	0	2	0	1.0

Discipline Elective									
sl.no	Course Code	Course Title	Course Type	Version	L	T	P	J	Credit
1	TCSE204L	Data Structures	Theory Only	1.0	3	1	0	0	4.0
2	TCSE205L	Database Management	Theory Only	1.0	3	1	0	0	4.0
3	TMAT306L	Number Theory	Theory Only	1.0	3	0	0	0	3.0
4	TMAT307L	Fuzzy Set Theory and its Applications	Theory Only	1.0	3	0	0	0	3.0
5	TMAT308L	Mathematical Statistics	Theory Only	1.0	3	1	0	0	4.0
6	TMAT309L	Engineering Optimization	Theory Only	1.0	3	1	0	0	4.0
7	TMAT310L	Tensors and Differential Geometry	Theory Only	1.0	3	0	0	0	3.0
8	TMAT311L	Classical Mechanics	Theory Only	1.0	3	1	0	0	4.0
9	TMAT312L	Mathematical Ecology	Theory Only	1.0	3	0	0	0	3.0
10	TMAT313L	Mathematical Finance	Theory Only	1.0	3	0	0	0	3.0
11	TMAT314L	Fluid Dynamics	Theory Only	1.0	3	1	0	0	4.0
12	TMAT315L	Difference Equations and its Applications	Theory Only	1.0	3	0	0	0	3.0
13	TMAT390J	Study Project	Project	1.0	0	0	0	0	3.0
14	TMAT392J	Design Project	Project	1.0	0	0	0	0	3.0
15	TMAT393J	Laboratory Project	Project	1.0	0	0	0	0	3.0

Discipline Elective									
16	TMAT397J	Special Project	Project	1.0	0	0	0	0	3.0
17	TMAT408L	Advanced Abstract Algebra	Theory Only	1.0	3	0	0	0	3.0
18	TMAT409L	Advanced Complex Analysis	Theory Only	1.0	3	0	0	0	3.0
19	TMAT410L	Numerical Solution of Partial Differential Equations	Theory Only	1.0	3	0	0	0	3.0
20	TMAT411L	Stochastic Processes	Theory Only	1.0	3	0	0	0	3.0
21	TMAT412L	Magnetohydrodynamics	Theory Only	1.0	3	0	0	0	3.0
22	TMAT413L	Fractional Calculus	Theory Only	1.0	3	0	0	0	3.0
23	TMAT414L	Finite Element Methods	Theory Only	1.0	3	0	0	0	3.0
24	TMAT415L	Sobolev Spaces	Theory Only	1.0	3	0	0	0	3.0
25	TMAT416L	Computational Fluid Dynamics	Theory Only	1.0	3	0	0	0	3.0
26	TMAT417L	Mathematical Modelling and Simulation	Theory Only	1.0	3	0	0	0	3.0
27	TMAT418L	Infinite Dimensional Optimization and Control Theory	Theory Only	1.0	3	0	0	0	3.0

Projects and Internship									
sl.no	Course Code	Course Title	Course Type	Version	L	T	P	J	Credit
1	TMAT497J	Project	Project	1.0	0	0	0	0	2.0
2	TMAT498J	Research Project I	Project	1.0	0	0	0	0	4.0
3	TMAT499J	Research Project II / Internship	Project	1.0	0	0	0	0	8.0

Open Elective									
sl.no	Course Code	Course Title	Course Type	Version	L	T	P	J	Credit
1	TMAT419L	Exploratory Data Analysis and Visualisation	Theory Only	1.0	3	0	0	0	3.0
2	TMAT420L	Artificial Intelligence	Theory Only	1.0	3	0	0	0	3.0
3	TMAT421L	Neural Networks	Theory Only	1.0	3	0	0	0	3.0
4	TMAT422L	Machine Learning	Theory Only	1.0	3	0	0	0	3.0
5	TMAT423L	Quantum Computing	Theory Only	1.0	3	0	0	0	3.0
6	TMAT424L	Deep Learning	Theory Only	1.0	3	0	0	0	3.0
7	TMAT425L	Data Analytics	Theory Only	1.0	3	0	0	0	3.0

Ability Enhancement									
sl.no	Course Code	Course Title	Course Type	Version	L	T	P	J	Credit
1	TCHY140L	Environmental Studies	Theory Only	1.0	3	0	0	0	3.0
2	TENG101L	Effective English Communication	Theory Only	1.0	2	0	0	0	2.0
3	TENG102L	Technical English Communication	Theory Only	1.0	2	0	0	0	2.0
4	TENG102P	Technical English Communication Lab	Lab Only	1.0	0	0	2	0	1.0
5	TENG103P	Technical Report Writing	Lab Only	1.0	0	0	2	0	1.0

Skill Enhancement									
sl.no	**Course Code**	**Course Title**	**Course Type**	**Version**	**L**	**T**	**P**	**J**	**Credit**
1	TCSE201E	Programming in Java	Embedded Theory and Lab	1.0	3	0	2	0	4.0
2	TCSE202P	Scientific Computing Lab	Lab Only	1.0	0	0	4	0	2.0
3	TCSE203P	Data Analysis Lab	Lab Only	1.0	0	0	4	0	2.0

Foundation Core

TBIT101L	Biological Science	L	T	P	C
		3	0	0	3
Pre-requisite	**Nil**	**Syllabus version**			
		1.0			

Course Objectives

1. Recall the understanding of origin and diversity of biological beings
2. Contrast the fundamental concepts of organization and principles of living systems
3. Illustrate the basic concepts of heredity

Course Outcomes

1. Relate the basic concepts of biology including diversity, evolution and ecology
2. Demonstrate the structural and functional organization of the cell
3. Analyze the biological flow of information at the molecular level
4. Outline the metabolic pathways governing cellular function
5. Distinguish the organismal complexities in animals and plants
6. Interpret the genetic basis of hereditary traits and diseases

Module:1	**Origin and Diversity of Living Systems**	**7 hours**

Basis of life – diversification of life including viruses, Chemical basis of life – early origin of life experiments, Concept of evolution and natural selection, Levels of ecological study, Biotic and abiotic factors in ecosystem

Module:2	**The Cellular System**	**6 hours**

Cell as fundamental unit of life, Structure of a prokaryotic cell, Structure of a eukaryotic cell, Cell division – mitosis and meiosis

Module:3	**Molecules of Life**	**6 hours**

Structures and functions of biomolecules – carbohydrates, lipids, nucleic acids, and proteins

Module:4	**Metabolic Systems**	**6 hours**

Redox reactions, ATP energy coupling, Glycolysis, TCA cycle, Electron transport chain and ATP-synthesis

Module:5	**Molecular Information**	**6 hours**

Central dogma of molecular biology, DNA and genetic code, Replication, Transcription, Translation

Module:6	**Overview of Plant and Animal Systems**	**6 hours**

Plant forms and functions, Plant cells and tissue systems, Animal forms and functions, Animal tissues, organs, and systems, Animal homeostasis

Module:7	**Genetics and Heredity**	**6 hours**

Mendel's experiment – monohybrid cross and dihybrid cross, Linkage and crossing over, Mendel's laws of inheritance, Genetics of human diseases

Module:8	**Contemporary issues**	**2 hours**

Lecture by Industry Experts

	Total Lecture hours:	**45 hours**

Text Book

1. Freeman S, Quillin K, Allison L, Black M, Taylor E, Biological Science, 2017, 6th edition Prentice Hall, USA

Reference Books

1. Urry LA, Cain ML, Wasserman SA, Minorsky PV, Orr R, Campbell Biology, 2021, 12th edition,. Pearson Publisher, USA
2. Enger ED, Ross FC, Bailey DB, Concepts in Biology, 2017, 14th edition, Tata McGraw-Hill Publishing Co Ltd, India

Mode of Evaluation: CAT, Assignment, Quiz, and FAT

Recommended by Board of Studies	30-06-2021		
Approved by Academic Council	No. 63	Date	23.09.2021

TBIT101P	Biological Science Lab	L	T	P	C
		0	0	2	1
Pre-requisite	**Nil**	**Syllabus version**			
		1.0			

Course Objectives

1. To develop a basic understanding and practical knowledge of biological beings, their constituents and their functionalities.

Course Outcome

1. Able to interprete the structure-function relationships in biological beings and their constituents.

Indicative Experiments

1.	Principles and handling of microscope and studying the diversity of cells using permanent slides (morphology of bacteria, fungi and algae)	2-4 hours each experiments
2.	Identifying bacteria through Gram's staining	--do--
3.	Study of mitotic stages in onion roots	--do--
4.	Extraction of eukaryotic DNA	--do--
5.	Quantitative estimation of protein	--do--
6	Qualitative assay of salivary amylase	--do--
7	Rate of photosynthesis in plant	--do--
8	Tissue and organ structures in animal and plant from permanent slides	--do--
9	Testing Mendelian ratio by Chi square test	--do--
10	Human genetic variation study in facial feature in the class group	--do--
	Total Laboratory Hours	**30**

Mode of assessment: Continuous assessment, FAT and Oral examination

Recommended by Board of Studies	30-06-2021		
Approved by Academic Council	No. 63	Date	23.09.2021

TCHY102L	Inorganic and Organic Chemistry	L	T	P	C
		3	0	0	3
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

The course is aimed at

1. Imparting the knowledge on the structure, bonding and reaction mechanisms of inorganic and organic compounds.
2. Making the students to understand stereochemistry and conformational aspects in molecular level with three dimensional perspective which enables to understand reaction mechanism

Course Outcome:

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

1. Understand the basics of atomic structure and the periodic properties.
2. Discuss bonding characteristics of inorganic compounds.
3. Analyse various theories to understand bonding in inorganic compounds.
4. Examine the electronic effects of organic compounds.
5. Relate the concepts of bonding isomerism and stereochemistry.
6. Utilize the concepts of hybridization in different hydrocarbons.

Module:1	**Atomic Structure and periodic properties**	**6 hours**

Electronic configuration - filling of orbitals - stability of filled and semi filled orbitals - shapes and energy of atomic orbitals. Quantum numbers - Bohr's model of atom-Heisenberg uncertainty principle-Pauli's exclusion principle, Hund's rules maximum multiplicity- Aufbau principle. Periodic Properties-Atomic radii, ionic radii, covalent radii-ionisation potential-electronegativity and electron affinity.

Module:2	**Chemical Bonding**	**6 hours**

Types of bonding, Ionic Bond-conditions for bond formation-energetics of NaCl formation-Born-Haber cycle, hydration and lattice energies, Fajan's rule. Covalent bond-Conditions for bond formation-bond polarity-overlap of orbitals-bond length and energies-hybridisation-sigma and pi bond- coordinate – covalent bond.

Module:3	**Bonding in Inorganic Molecules**	**8 hours**

VSEPR theory - $BeCl_2$, BF_3, XeF_4, PCl_5, SF_6 and IF_7. Sidgwick's Theory - EAN rule - Theory of Bonding - Valence Bond Theory, MO theory. Relative order of Energies of molecular orbitals - MO diagram of H_2, He_2, O_2, O^{2+}, O^{2-}, N_2 and CO - Bond Order.

Module:4	**Basic Concepts of Organic Chemistry**	**6 hours**

Electronic Effects: Inductive, Inductomeric and Electromeric effects, resonance, hyperconjugation, steric effect (Hammett and Taft equation). Cleavage of bonds: homolytic and heterolytic C-C bond fission- Reaction Intermediates and their structure, stability and reactivity of intermediates: carbocations, carbanions and free radicals, carbenes and nitrenes.

Module:5	**Bonding and Hybridisation in Organic Molecules**	**6 hours**

Bonding in organic molecules-hybridisation-geometry of molecules-alkanes, alkenes, alkyne and benzene, benzyne; pKa, pKb, pH, polarity of molecules-organic acids and bases: Factors affecting the strength of acids and bases.

Module:6	**Stereochemistry**	**6 hours**

Concept of Isomerism, Classification of Stereoisomers- configurational (cis, trans or E, Z-alkenes, cycloalkanes) Wedge formula, Fischer projection, Newman projection and its interconversion. Application of Newman Projection to understand reaction mechanism.

Optical isomerism, Chirality & elements of symmetry- Chiral, achiral, prochiral, enantiomers, meso form, diastereoisomerism, akamp isomerism and atropisomerism.		
Module:7	**Alkanes, Alkenes and Alkynes**	**5 hours**
Alkanes, Alkenes and Alkynes: Synthesis (any three methods), Physical, Chemical properties and industrially important molecules and its applications.		
Module:8	**Contemporary issues**	**2 hours**
Guest lectures by industry and R & D organizations		
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Morrison R. T., Boyd R. N. and Bhattacharjee S. K., Organic Chemistry, Seventh Edition, Pearson Prentice Hall, 2011.
2. J.D. Lee, Concise Inorganic Chemistry, Oxford University Press, 5th Edition, 2014.

Reference Books

1. Peter K., Vollhardt, C., and Schore N. E., Organic Chemistry, W. H. Freeman and Company, 2010.
2. Pine S. H., Organic Chemistry, Tata McGraw Hill, 5th edition, 2008.
3. T. Overton, F. Armstron, J. Rourke and M. Weller. Inorganic Chemistry, 6th Edition, Oxford University Press, 2015.
4. J.E. Huheey, E.A. Keiter, R.L.. Keiter and O.K. Medhi Inorganic Chemistry: Principles of Structure and Reactivity, 4th Edition, Pearson Education, 2006.

Mode of Evaluation: CAT, Quiz , Assignments, FAT

Recommended by Board of Studies	28.06.2021		
Approved by Academic Council	No. 63	Date	23.09.2021

TCHY102P	Inorganic and Organic Chemistry Lab	L	T	P	C
		0	0	2	1
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives:

The course is aimed at
1. Imparting the knowledge on qualitative analysis of inorganic and organic compounds.
2. Understanding the principles of quantitative chemical analysis and synthetic methods of simple organic compounds.

Course Outcome

At the end of the course, the student should be able to
1. Understand the concepts of qualitative and quantitative analyses.
2. Estimate different components in given analytes.
3. Develop synthetic and experimental skills for real time sample analysis

Indicative Experiments	
1	Acid-base titration: Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture
2	Redox titration: Estimation of Fe(II) and oxalic acid using standardized KMnO4 solution.
3	Redox titration: Estimation of ferrous and ferric ions in a mixture
4	Iodometry – Estimation of copper
5	Precipitation Titration: Determination of chloride
6	Acid-Base titrations: Estimation of free alkali present in different soaps/detergents
7	Systematic Qualitative organic analysis -1
8	Systematic Qualitative organic analysis -2
9	Determination of optical rotation for the hydrolysis of sucrose into glucose and fructose using Polari meter
10	Synthesis of *tert.* butyl chloride from *tert.* Butanol
11.	Single step synthesis : Synthesis of benzoic acid from benzaldehyde by oxidation method

Total Laboratory Hours	**30 hours**
Mode of assessment: Lab assessments, Viva-Voce, FAT	
Recommended by Board of Studies	28.06.2021
Approved by Academic Council	No. 63 Date 23.09.2021

TCHY103L	Physical and Analytical Chemistry	L	T	P	C
		3	0	0	3
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

The Course is aimed at

1. To make the student understand the concepts of equilibrium, Thermodynamics, chemical Kinetics and surface chemistry.
2. To impart knowledge on analysis of errors and evaluation of determinate and indeterminate errors which can be applied in volumetric methods of analysis and acid-base, redox systems concepts.

Course Outcomes

1. Apply the concepts in chemical equilibrium reaction calculations.
2. Analyse the thermodynamics of chemical reactions.
3. Evaluate the rate of chemical reactions and factors influencing them.
4. Utilise adsorption isotherms for understanding surface reactions.
5. Introduce concepts of errors and deviations in volumetric analysis.
6. Use electrochemical concepts in study of redox reactions by conductivity and EMF measurements.

Module:1	**Chemical and Ionic Equilibria**	**6 hours**

Chemical equilibrium: law of mass action; Kp, Kc and Kx; LeChatelier's principle, solubility product; Concepts of a strong, weak acids and bases; pH scale; Henderson-Hasselbach equations;

Buffer solutions: Acid-base indicators; Ionic equilibrium: monoprotic, diprotic, and triprotic acids; pH, pOH: measurements and significance, solubility products.

Module:2	**Thermodynamics**	**6 hours**

Thermodynamic processes – Cyclic, Reversible, Irreversible, Isothermal, Isobaric, Adiabatic; Exact and Inexact Differentials - Heat and Work - Zeroth Law of Thermodynamics. Zeroth law of thermodynamics, First law of Thermodynamics - Cp and Cv Relationship - calculation of w, q, ΔE and ΔH for expansion of Ideal Gases under reversible, Isothermal and adiabatic Conditions.

Module:3	**Chemical Kinetics**	**7 hours**

Rate of a chemical reaction. Order and molecularity of chemical reactions, Factors influencing rates of chemical reactions; Rate equations for zero-, first- and second-order reactions - equal and unequal concentrations of reactants. Half-life period; Determination of order of reaction- differential method, method of integration, half-life period method, isolation method.

Module:4	**Surface Chemistry**	**6 hours**

Difference between adsorption and absorption. Physical and chemical adsorption--desorption. Adsorption isotherms: Gibbs, Langmuir, BET, other isotherms - measurement of surface area using adsorption isotherms, Freundlich adsorption isotherm and its experimental verification. Adsorption indicators.

Module:5	**Errors in Chemical Analysis**	**7 hours**

Classification of analytical methods- classical and instrumental, basis of their classification with examples. Classification - systematic or Determinate errors – additive, proportional; Types – instrumental, operative, errors of method; Random errors – Gaussian distribution; Accuracy-absolute error and relative error; Precision – uncertainty; Propagation of systematic and random errors. Standard deviation, relative standard deviation- related numerical.

Module:6	**Acid -Base concept and redox systems**	**6 hours**

Arrhenius concept, Brønsted-Lowry acids and bases, Lewis acids and bases, Acid and base

strength. Theory of electron transfer- redox reactions-electrochemical concepts in the study of redox systems – study of acid base and redox reactions by pH,conductivity and emf measurements		
Module:7	**Volumetric analysis**	**5 hours**
Principles of Volumetric analysis-molarity-molality-normality-mole fraction-calculations-primary and secondary standards-equivalent weight of acid, base, salt, oxidising agent and reducing agents. Theories of Acid-Base, redox, precipitation, complexometric, iodometric and iodimetric titrations-Theories of indicators-acid base, redox.		
Module:8	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Skoog and West Fundamentals of Analytical Chemistry by F. James Holler, Donald M. West, Stanley R. Crouch. Cengage Learning EMEA; 9th edition (2013)
2.	Atkins Physical Chemistry,11th Edition By Peter Atkins, Julio De Paula, James Keeler, Oxford University press, 2018.
Reference Books	
1.	Analytical Chemistry, Gary Christian, 6th Edition, John Wiley & Sons, New York, 2004.
2.	Chemical Kinetics, Keith James Laidler, J. Keith, Professor Emeritus of Chemistry Keith J Laidler Harper & Row, 1987.
3.	Principles Of Physical Chemistry, by B.R. Puri, L.R. Sharma, M.S. Pathania. 47th edition (2016), Vishal Publishing Co, India.
4.	Vogel's Text book of Quantitative Chemical Analysis, G. H. Jeffery j. Bassett J. Mendham R C. Denney, 5th Edition, Longman Scientific and Technical and John Wiley & Sons, New York, 1989.
Mode of Evaluation: CAT, Quiz, Assignments, FAT	

Recommended by Board of Studies	28-06-2021		
Approved by Academic Council	No. 64	Date	16-12-2011

TCHY103P	Physical and Analytical Chemistry Lab	L	T	P	C
		0	0	2	1
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

The course is aimed at

1. Understand the principles and methods of Conductivity, monitoring redox reactions using electrochemical methods.
2. Impart the concepts of monitoring the kinetics of chemical reactions.

Course Outcomes

1. Apply the concepts of electrochemical measurements in redox titrations.
2. Design experiments for monitoring rates of chemical reactions including surface reactions.
3. Evaluate the dissociation constant and partition coefficient of chemical reactions.

Indicative Experiments	
1.	Estimation of Chloride by Conductometry
2.	Determination of concentration of an acid using pH measurement method
3	Thermodynamics functions from EMF measurements : Zinc – silver chloride system
4	Determination of partition coefficient of iodine in CCl_4 and water
5.	Adsorption of acetic acid on charcoal
6.	Estimation of Ferrous ion by potassium permanganate using potentiometry
7.	Acid catalyzed hydrolysis of an ester- Determination of rate constant
8.	Ionization constant of a weak acid
9.	Kinetics of persulphate and iodide second order reaction
10.	Dissociation constant of methyl red

Total Laboratory Hours	30 hours
Mode of assessment: Lab assessment, Viva-Voce and FAT	

Recommended by Board of Studies	28-06-2021		
Approved by Academic Council	No. 64	Date	16-12-2011

TCSE103L	Programming in Python	L	T	P	C
		2	0	0	2
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives:

1. To introduce core programming basics required for science using Python language
2. To read and write simple Python programs
3. To develop Python programs with conditionals and loops
4. To use Python data structures – lists, tuples, dictionaries
5. To introduce the important science modules SymPy, NumPy, SciPy, Pandas and Matplotlib
6. To introduce the input/output with files in Python and statistical processing of a data

Course Outcome:

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

1. Read, write, execute simple Python programs
2. Decompose a Python program into functions
3. Manipulate with 1-d,2-d and multidimensional data using Python
4. Data Visualization using Python
5. Read and write data from/to files in Python programs
6. Develop algorithmic solutions to science related problems

Module:1	**Algorithmic Problem Solving**	**3 hours**

Algorithms, building blocks of algorithms (statements, state, control flow, functions); algorithmic problem solving; iteration, recursion. Illustrative problems: flow chart, finding minimum in a list, factorial of a number.

Module:2	**Data, Expressions, Statements in Python**	**4 hours**

Python Strengths and Weakness; Installing Python; IDLE - Spyder – Jupyter; Mutable and Immutable Data Types, Naming Conventions; String Values; String Operations; String Slices; String Operators; String functions. Numeric Data Types; Arithmetic Operators and Expressions; Comments in the Program;

Module:3	**Data Collection and Language Component of Python**	**4 hours**

List; Tuples; Sets; Dictionaries; Operations on List, Tuple , Set, Dictionary; Control Flow and Syntax; Indenting; The if statement; Relational Operators; Logical Operators; Bit-wise Operators; The while Loop – break and continue statements; The for Loop; List Comprehension

Module:4	**Functions in Python**	**4 hours**

Functions - Introduction; Defining your own functions; parameters; local and global scope; passing collections to a function; variable number of arguments; passing functions to a function; Lambda function; map; filter.

Module:5	**Modules for Science**	**3 hours**

Modules: Introduction; Standard Modules – sys, math, time, sympy, random.

Module:6	**Handling Scientific Data in Python**	**5 hours**

NumPy arrays – 1-d, multidimensional arrays and matrices; Mathematical operations with arrays; Slicing and addressing arrays; Boolean masks; Difference between lists and arrays SciPy – Scientific Computing library of Python – Introduction, Basic functions, Special functions, scipy.integrate, scipy.optimize, scipy.interpolate

Module:7	**Data Visualization and Analysis of Data in Python**	**5 hours**

Python Plotting: PyPlot – Basic Plotting; Logarithmic Plots; Plots with multiple axes; Matplotlib – interactive functions 3d plotting; Pandas – Introduction, Data Frame, Reading

and writing CSV, XLS files, Working with missing data, categorical data, data visualization with pandas		
Module:8	**Contemporary issues: (**Industry Expert Lecture**)**	**2 hours**
Research and Development problems related to Scientific Domains		
Total Lecture Hours		**30 hours**

Text Book(s)	
1.	David J. Pine, Introduction to Python for Science and Engineering, CRC Press, 2019.
2.	Robert Johansson, Numerical Python – Scientific Computing and Data Science Applications with NumPy, SciPy and Matplotlib, Apress, 2019
Reference Book(s)	
1.	Robert Sedgewick, Kevin Wayne, Robert Dondero, Introduction to Programming in Python: An Inter-disciplinary Approach, Pearson India Education Services Pvt. Ltd., 2016
2.	Nelli, F., Python Data Analytics: with Pandas, NumPy and Matplotlib, Apress, 2018.
3.	Jake vander Plas, Python Data Science Handbook – Essential Tools for Working with Data, O'Really Media, 2017

Mode of Evaluation: CAT, Quiz, Digital Assignment and FAT.			
Recommended by Board of Studies	12-07-2021		
Approved by Academic Council	63	Date	23.09.2021

TCSE103P	Programming in Python Lab	L	T	P	C
		0	0	4	2
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives:

1. To introduce core programming basics required for data science using Python language
2. To read and write simple Python programs
3. To develop Python programs with conditionals and loops
4. To use Python data structures – lists, tuples, dictionaries
5. To introduce the important science modules SymPy, NumPy, SciPy, Pandas and Matplotlib
6. To introduce the input/output with files in Python and statistical processing of a data

Course Outcome:

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

1. Read, write, execute simple Python programs
2. Decompose a Python program into functions
3. Manipulate with 1-d,2-d and multidimensional data using Python
4. Read and write data from/to files in Python programs
5. Develop algorithmic solutions to science related problems

List of Challenging Experiments (Indicative)

1. *First Basic Experiment(s):* (i) "Hello World!" Program in IDLE, Jupyter, Spyder Environments. (ii) Program(s) to demonstrate the Python data types
2. Python Operators, Expressions and Flow Controls
3. Python Lists, Tuples, Dictionaries & Sets
4. Python Functions, Modules and Packages
5. Python Symbolic Computation and Random Number generation
6. Array and Matrix Manipulation in Python
7. Data Manipulation – SciPy Module
8. Data Visualization in Python – PyPlot Module
9. Data Manipulation using Pandas
10. Descriptive Statistical Analysis – Evaluation, Plotting and Interpretation
11. Evaluation of Probability using various Distributions Functions
12. Linear and Nonlinear Regression in Python

	Total Laboratory Hours	**60 hours**	
Mode of assessment: CAT / Written Assignment / Quiz / FAT / Project.			
Recommended by Board of Studies	12-07-2021		
Approved by Academic Council	No. 63	Date	23.09.2021

TCSE104L	Structured and Object Oriented Programming	L	T	P	C
		2	0	0	2

Pre-requisite	NIL	Syllabus version
		1.0

Course Objectives

1. To impart the basic constructs in structured programming and object-oriented programming paradigms.
2. To inculcate the insights and benefits in accessing memory locations by implementing real world problems.
3. To help solving real world problems through appropriate programming paradigms.

Course Outcome

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

1. Understand different programming language constructs and decision-making statements; manipulate data as a group.
2. Recognize the application of modular programming approach; create user defined data types and idealize the role of pointers.
3. Comprehend various elements of object-oriented programing paradigm; propose solutions through inheritance and polymorphism; identify the appropriate data structure for the given problem and devise solution using generic programming techniques.

Module:1	C Programming Fundamentals	3 hours

Variables - Reserved words – Data Types – Operators – Operator Precedence - Expressions - Type Conversions - I/O statements - Branching and Looping: if, if-else, nested if, if-else ladder, switch statement, goto statement - Loops: for, while and do…while – break and continue statements.

Module:2	Arrays, Functions	4 hours

Arrays: One Dimensional array - Two-Dimensional Array – Strings and its operations. User Defined Functions: Declaration – Definition – call by value and call by reference - Types of Functions - Recursive functions - Storage Classes - Scope, Visibility and Lifetime of Variables.

Module:3	Pointers	4 hours

Declaration and Access of Pointer Variables, Pointer arithmetic – Dynamic memory allocation – Pointers and arrays - Pointers and functions.

Module:4	Structure and Union	3 hours

Declaration, Initialization, Access of Structure Variables - Arrays of Structure - Arrays within Structure - Structure within Structures - Structures and Functions – Pointers to Structure – Union – Linked list

Module:5	Overview of Object-Oriented Programming	4 hours

Features of OOP - Classes and Objects - “this” pointer - Constructors and Destructors - Static Data Members, Static Member Functions and Objects - Inline Functions – Call by reference - Functions with default Arguments - Functions with Objects as Arguments - Friend Class and Friend Functions

Module:6	Inheritance	4 hours

Inheritance - Types of Inheritance: Single inheritance, Multiple Inheritance, Multi-level Inheritance, Hierarchical Inheritance - Multipath Inheritance - Inheritance and constructors.

Module:7	**Polymorphism and Generic Programming**	**6 hours**
Function Overloading - Operator Overloading – Dynamic Polymorphism - Virtual Functions - Pure virtual Functions - Abstract Classes - Function templates and class templates, Standard Template Library		
Module:8	**Contemporary issues**: (Industry Expert Lecture)	**2 hours**
Research and Development problems related to Scientific Domains		
	Total Lecture hours:	**30 hours**

Text Book(s)	
1.	Herbert Schildt, C: The Complete Reference, 4th Edition, McGraw Hill Education, 2017
2.	Herbert Schildt, C++: The Complete Reference, 4th Edition, McGraw Hill Education, 2017.
Reference Books	
1.	Yashavant Kanetkar, Let Us C: 17th Edition, BPB Publicaitons, 2020.
2.	Stanley Lippman and Josee Lajoie, C++ Primer, 5th Edition, Addison-Wesley publishers, 2012.

Mode of Evaluation: CAT / Written Assignment / Quiz / FAT / Project.			
Recommended by Board of Studies	12-07-2021		
Approved by Academic Council	No. 63	Date	23.09.2021

TCSE104P	Structured and Object Oriented Programming Lab	L	T	P	C
		0	0	4	2
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To impart the basic constructs in structured programming and object-oriented programming paradigms.
2. To inculcate the insights and benefits in accessing memory locations by implementing real world problems.
3. To solve real world problems through appropriate programming paradigms.

Course Outcome

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

1. Understand different programming language constructs and decision-making statements; manipulate data as a group.
2. Recognize the application of modular programming approach; create user defined data types and idealize the role of pointers.
3. Comprehend various elements of object-oriented programing paradigm; propose solutions through inheritance and polymorphism; identify the appropriate data structure for the given problem and devise solution using generic programming techniques.

	Indicative Experiments
1.	Programs using basic control structures, branching and looping
2.	Experiment the use of 1-D, 2-D arrays and strings and Functions
3.	Demonstrate the application of pointers
4.	Experiment structures and unions
5.	Programs on basic Object-Oriented Programming constructs.
6.	Demonstrate various categories of inheritance
7.	Program to apply kinds of polymorphism.
8.	Develop generic templates and Standard Template Libraries.
	Total Laboratory Hours | **60 hours**

Mode of assessment: CAT / Written Assignment / Quiz / FAT / Project.			
Recommended by Board of Studies	12-07-2021		
Approved by Academic Council	No. 63	Date	23.09.2021

THUM101L	Ethics and Values	L	T	P	C
		2	0	0	2
Pre-requisite	**Nil**	**Syllabus version**			
		1.0			

Course Objectives:

1. To understand and appreciate the ethical issues faced by an individual in profession, society and polity.
2. To understand the negative health impacts of certain unhealthy behavior.
3. To appreciate the need and importance of physical, emotional health and social health.

Course Outcomes:

Students will be able to:

1. Follow sound morals and ethical values scrupulously to prove as good citizens.
2. Understand various social problems and learn to act ethically.
3. Understand the concept of addiction and how it will affect the physical and mental health.
4. Identify ethical concerns in research and intellectual contexts, including academic integrity, use and citation of sources, the objective presentation of data, and the treatment of human subjects.
5. Identify the main typologies, characteristics, activities, actors and forms of cybercrime.

Module:1	**Being Good and Responsible**	**5 hours**
Gandhian values such as truth and non-violence – Comparative analysis on leaders of past and present – Society's interests versus self-interests - Personal Social Responsibility: Helping the needy, charity and serving the society.		
Module:2	**Social Issues 1**	**4 hours**
Harassment – Types - Prevention of harassment, Violence and Terrorism.		
Module:3	**Social Issues 2**	**4 hours**
Corruption: Ethical values, causes, impact, laws, prevention – Electoral malpractices; White collar crimes - Tax evasions – Unfair trade practices.		
Module:4	**Addiction and Health**	**5 hours**
Peer pressure - Alcoholism: Ethical values, causes, impact, laws, prevention – Ill effects of smoking - Prevention of Suicides; Sexual Health: Prevention and impact of pre-marital pregnancy and Sexually Transmitted Diseases.		
Module:5	**Drug Abuse**	**3 hours**
Abuse of different types of legal and illegal drugs: Ethical values, causes, impact, laws and prevention.		
Module:6	**Personal and Professional Ethics**	**4 hours**
Dishonesty - Stealing - Malpractices in Examinations – Plagiarism.		
Module:7	**Abuse of Technologies**	**3 hours**
Hacking and other cyber crimes, Addiction to mobile phone usage, Video games and Social networking websites.		
Module 8	**Contemporary Issues**	**2 hours**
	Total Lecture Hours:	**30 hours**

Text Books :

1. R R Gaur, R Asthana, G P Bagaria, "A Foundation Course in Human Values and Professional Ethics", 2019, 2nd Revised Edition, Excel Books, New Delhi.

2.	Hartmann, N., "Moral Values" , 2017, United Kingdom: Taylor & Francis.
Reference Books :	
1.	Rachels, James & Stuart Rachels, "The Elements of Moral Philosophy", 9th edition, 2019, New York: McGraw-Hill Education.
2.	Blackburn, S. "Ethics: A Very Short Introduction", 2001, Oxford University Press.
3.	Dhaliwal, K.K , "Gandhian Philosophy of Ethics: A Study of Relationship between his Presupposition and Precepts", 2016, Writers Choice, New Delhi, India.
4	Ministry of Social Justice and Empowerment, "Magnitude of Substance Use in India", 2019, Government of India.
5.	Ministry of Home Affairs, "Accidental Deaths and Suicides in India", 2019, Government of India.
6.	Ministry of Home Affairs, "A Handbook for Adolescents/ Students on Cyber Safety", 2018, Government of India.
Mode of Evaluation: Poster making, Quiz, Assignment, CAT and Term End Examination	

Recommended by Board of Studies	27-10-2021		
Approved by Academic Council	No. 64	Date	16-12-2011

TMAT103L	Calculus and Analytical Geometry	L	T	P	C
		3	0	0	3
Pre-requisite	**Nil**	**Syllabus version**			
		1. 0			

Course Objectives

1. To reinforces calculus to give a better understanding of the mathematical concepts underlying them and to prepare students for more advanced mathematics.
2. To Learn to analyze and solve problems relating analytical geometry and vector calculus.
3. To consider problems that could be solved by applying appropriate theories, principles and concepts relevant to functions, continuity, derivatives, analytic geometry and vectors.

Course Outcome

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

1. To Apply single variable differentiation and integration to solve applied problems in engineering and find the maxima and minima of functions.
2. Evaluate partial derivatives, limits, total differentials, Jacobians, Taylor series and optimization problems involving several variables with or without constraints.
3. Apply integrals to find area and volume and to find masses, moments, force, work and energy.
4. Study the equations of lines, planes and spheres and the role of direction cosines and direction ratio.
5. Evaluate the line, surface and volume integral of a scalar and vector fields and apply Green's, Gauss' and Stoke's theorems.

Module:1	**Differential calculus and its geometrical applications**	**7 hours**

Review of continuity and differentiability, Successive differentiation, Leibnitz's rule, Taylor's and Maclaurin's expansions, Indeterminate forms, Tangent and Normal, Curvature, Evolutes and envelopes

Module:2	**Functions of several variables**	**6 hours**

Limit and continuity, Partial Differentiation-Euler's Theorem, Chain rule, Total differentiation, Differentiation of implicit functions, Taylor's series expansion, Jacobians-Change of variables, Maxima and minima, Lagrange multiplier method

Module:3	**Integral calculus**	**6 hours**

Integration-Definite integral, Average value, Length of a plane curve, Areas, Volumes-washer method, disk method, Area of a surface of revolution, Fundamental theorem of Calculus and its consequences, Improper integral, Differentiation under Integral sign-Leibnitz rule

Module:4	**Multiple integrals and their applications**	**5 hours**

Double and triple integrals, Change of order of integration, Change of variables, Areas and volumes, Masses, moments, Force, Work and energy

Module:5	**Analytical solid geometry**	**7 hours**

Coordinate systems and their interrelation, Direction cosines and direction ratios, Projection on a straight line, Angle between straight lines, Equation of plane, Shortest distance between the skew-lines, length of perpendicular from a given point to a given plane, Bisectors of the angles between two planes, Orthogonal projection on a plane, Sphere.

Module:6	**Vector differentiation**	**6 hours**

Scalar, vector fields and level Surfaces, Differentiation-Gradient, Tangent plane and normal, Directional derivative, Divergence and curl

Module:7	**Vector integration**	**6 hours**

Vector Integration, Line integrals, Surface integrals, Green's theorem in plane, Stokes's theorem, volume integrals, Divergence theorem			
Module:8	**Contemporary issues**		**2 hours**
Guest Lecture from industry and R&D organisations			
	Total Lecture hours:		**45 hours**
Text Book(s)			
1. George B. Thomas, Joel Hass, Christopher Heil, Maurice D. Weir, Thomas' Calculus, 2018, 14th edition, Pearson, India 2. Shanti Narayan, P. K. Mittal, Analytical Solid Geometry, 2007, 17th edition, S. Chand & Co., India			
Reference Books:			
1. Karl J. Smith, Monty J. Strauss, Magdalena D. Toda, Calculus, 2017, 7th edition, Kendall Hunt Publishing Company, USA 2. Saturnino L. Salas, Garret J. Etgen, Einar Hille, Calculus One and Several Variables, 2021, 10th edition, Wiley, India			
Mode of Evaluation: CAT, Written assignment , Quiz , FAT			
Recommended by Board of Studies	24.06.2021		
Approved by Academic Council	No. 63	Date	23.09.2021

TMAT103P	Calculus and Analytical Geometry Lab	L	T	P	C
		0	0	2	1
Pre-requisite	**Nil**	**Syllabus version**			
		1.0			

Course Objectives

1. To familiarize with the basic syntax, semantics and library functions of MATLAB which serves as a tool not only in calculus but also many courses in engineering and sciences.
2. To visualize mathematical functions and its related properties.
3. To evaluate single and multiple integrals and understand it graphically.

Course Outcome

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

1. Demonstrate MATLAB code for challenging problems in engineering
2. Using plots/displays, interpret and illustrate elementary mathematical functions and procedures.

Indicative Experiments (Any 10 experiments to be performed)

1.	To plot and visualize curves and surfaces in MATLAB – Symbolic computations using MATLAB
2.	To evaluate limits and Derivatives of functions
3.	To investigate applications of differentiation and study maxima and minima of a function of single variable
4.	To analyze maxima and minima of a function of two variables
5.	To write Taylor's and Maclaurin's series up to finite terms
6.	To evaluate integrals and find area, volume of solid of revolution
7.	To calculate double and triple integrals
8.	To find equation of line and angle between two planes
9.	To study divergence, curl and gradient and visualize vector fields
10.	To evaluate line integral and work done
	Total Laboratory Hours **30 hours**

Text Book(s)

1. Cesar Lopez, MATLAB Differential and Integral Calculus, 2014, 1st Edition, Apress
2. Ronald L. Lipsman, Jonathan M. Rosenberg, Multivariable Calculus with MATLAB: With Applications to Geometry and Physics, 2018, 1st edition Springer

Mode of assessment: Continuous assessments, Oral, FAT

Recommended by Board of Studies	24.06.2021		
Approved by Academic Council	No. 63	Date	23.09.2021

TMAT104L	Ordinary and Partial Differential Equations	L	T	P	C
		3	1	0	4
Pre-requisite	**TMAT103L, TMAT103P**	**Syllabus version**			
		1.0			

Course Objectives

1. To develop mathematical skills so that students can apply mathematical methods & principals in solving problems arising in real life.
2. To understand how real-life problems can give rise to differential equations.
3. To solve the problems choosing the most suitable method.
4. To utilise Laplace and Fourier transform techniques to solve the differential equations.

Course Outcome

1. Recognize the order and degree of differential equations and solve first order differential equations by different methods.
2. Understand the role of complementary functions and particular integrals in finding solution and should be able to apply variation of parameters and method of undetermined coefficients in solving differential equations.
3. Apply Frobenius' method to obtain series solution of second order differential equations.
4. Utilize the method of characteristics in handling partial differential equations of first order and should be able to solve partial differential equations of second and higher order.
5. Apply Laplace and Fourier Transform to solve differential equations.

Module:1	**Differential equations of first order**	**7 hours**

Differential equation of first order-exact and linear differential equations, First order equations of higher degree, Clairaut's form, singular solutions. Orthogonal trajectories, Applications in geometrical and mechanical problems.

Module:2	**Differential equations of higher order**	**6 hours**

Linear equations, linearity, linear independence and Wronskian, Reduction of order, Homogeneous linear equations with constant coefficients, Nonhomogenous equation-Cauchy-Euler Equation, Solution by method of Undetermined Coefficients and Variation of Parameters.

Module:3	**Series solution**	**4 hours**

Power Series representation of functions, Power Series method, Method of Frobenius, Series solution of Legendre and Bessel differential equations.

Module:4	**First order partial differential equations**	**8 hours**

Formation of Partial Differential equations, Solution of first order PDE (Standard forms), Complete integral, General Solution, Singular Solution, Lagrange's Equation, Nonlinear Equation-Charpit's method.

Module:5	**Higher order partial differential equations**	**6 hours**

Homogeneous linear equation with constant co-efficient, Nonhomogenous linear equations of any order, Non-linear equations of second order-Monge's method.

Module:6	**Laplace transform**	**6 hours**

Laplace Transform, Sufficient conditions for existence, Translation theorems, Operational properties, Periodic functions, Inverse Laplace Transform, Convolution, Application to the solution of Differential Equations, Heaviside Functions and Pulses, Impulses and Delta Function.

Module:7	**Fourier transform**	**6 hours**
Fourier Series, Convergence, Fourier Sine and Cosine series, Complex Fourier Series, Fourier Transform and its properties, Fourier Cosine and Sine Transform, Parseval's theorem.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours Lecture** **15 hours Tutorial**

Text Book(s)

1. G. F. Simmons, Differential Equations with Applications and Historical Notes, 2017, 3rd edition, CRC Press, USA
2. B. S. Grewal, Higher Engineering Mathematics, 2018, 44th edition, Khanna Publishers, India

Reference Books

1. Shepley L. Ross, Differential Equations, 2007, 3rd edition, Wiley, India
2. Ian N. Sneddon, Elements of Partial differential equations, 2006, 1st edition, Dover, USA
3. Murray R. Spiegel, Schaum's outline of Theory and Problems of Laplace Transform, McGraw Hill, 1965, USA

Mode of Evaluation: CAT , Written assignment , Quiz , FAT			
Recommended by Board of Studies	24-06-2021		
Approved by Academic Council	No. 64	Date	16-12-2011

Course code	Course Title	L	T	P	C
TMGT401L	Principles of Management	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

1. To provide knowledge on management key concepts, evaluation of management thoughts and theories.
2. To understand the various functions of management and framework.
3. To gain a holistic understanding of multidisciplinary nature of management for effective functioning.

Course Outcomes

At the end of the course, the students will be able to

1. Understand the basic concepts of management.
2. Analyse the environmental factors that affect the organization and its growth.
3. Identify and apply appropriate techniques to manage an organisation.
4. Critically analyse the challenges in each function of the management.
5. Ascertain the role of technologies in management.

Module:1	Management Basics	6 hours

Management - nature and purpose, evolution of management concept, approaches to management process, functions and roles of management, influence of external and internal environment on decision making, factors affecting social responsibility and sustainability, and ethical business management.

Module:2	Planning	6 hours

Types of plans, steps in planning, strategic planning process, SWOT matrix, portfolio matrix, Porter's industry analysis and generic competitive strategies, decision making - importance of decision making, development of alternatives and evaluation of alternatives, and decision making under certainty, uncertainty and risk.

Module:3	Organizing	7 hours

Formal and informal organization, organizational levels and span of management, organization reengineering, structure and process of organizing, departmentation, matrix organization, strategic business units, virtual organization, line and staff authority, decentralization and delegation of authority, and organization culture.

Module:4	Staffing	6 hours

Overview to staffing functions, factors affecting staffing, position requirements, job design, job description, selection process and techniques, orientating new employees, performance appraisal and career strategy - appraisal criteria, team evaluation, rewards, and formulating career strategy, managerial training and development, conflict management, managing change, and learning organization.

Module:5	Leading	6 hours

Understanding motivation, motivation theories, leadership traits, styles, and types, committees, groups, and team decision making, communication purpose, communication process, and barriers to effective communication.

Module:6	Controlling	6 hours

Basic control process, critical control points, standards and bench marking, real-time information and control, feedforward or preventive control, control of overall performance, profit and loss control, control through ROI, management audits - balanced scorecard, bureaucratic and clan control, and control techniques and information technology.

Module:7	Managing Operations and Technology	6 hours

Operations management and corporate strategy, value chain management, role of technology in modern management practices, virtual organization and its structure, online business management, applications of digital technology, e-commerce, m-commerce, social media, and artificial intelligence in business management, and challenges to modern management practices.		
Module:8	**Contemporary Topics**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Harold Koontz and Heinz Weihrich, Essentials of Management: An International and Leadership Perspective, 2020, 11th edition, McGraw-Hill, India.
Reference Books	
1.	Stephen P. Robbins, Mary Coulter and Agna Fernandez, Fundamentals of Management, 2019, 14th Edition, Pearson Education, India.
2.	Robert N. Lussier, Management Fundamentals: Concepts, Applications, & Skill Development, 9th Edition, 2020, Sage Publications, USA
3.	Pravin Durai, Principles of Management – Texts and Cases, 2019, 2nd Edition, Pearson Education, India.
Mode of Evaluation: CAT, Written Assignment, Quiz, and FAT	

Recommended by Board of Studies			
Approved by Academic Council		Date	

TPHY102L	Physics of Waves	L	T	P	C
		3	0	0	3
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To develop deeper insights to cut through various fields of Physics.
2. To provide expertise for solving the differential equations which arise in simple mathematical models for oscillations and waves.
3. To hone the foundation of various Physics courses such as pre-quantum theory, optics, acoustics etc.

Course Outcome

At the end of the course the student will be able to

1. Comprehend the simple harmonic motion in various physical systems.
2. Explain the damped as well as forced oscillations in realistic physical systems.
3. Recall the theoretical ideas of complex vibrations using Fourier series.
4. Understand the ideas of transverse, longitudinal and standing waves in various physical systems.
5. Apply the knowledge of various types of oscillations and vibrations for designing simple machines.

Module:1	**Simple harmonic motion**	**5 hours**
Oscillations in physical systems, Spring-mass system- Time period and frequency, Harmonic oscillator in one-dimension and its solutions, Superposition of simple harmonic oscillations, Lissajous figures.		
Module:2	**Damped oscillations**	**6 hours**
Damped harmonic oscillator, solution of the differential equation of damped oscillator. Energy considerations, relaxation time, quality factor		
Module:3	**Forced oscillations**	**6 hours**
Differential equation of forced oscillator and its solution, amplitude resonance and velocity resonance.		
Module:4	**Complex vibrations**	**8 hours**
Fourier theorem and evaluation of the Fourier coefficients, analysis of periodic wave functions-square wave, triangular wave, saw tooth wave.		
Module:5	**Transverse waves: Vibrating strings**	**6 hours**
Transverse wave propagation along a stretched string, general solution of wave equation and its significance, modes of vibration of stretched string clamped at ends, overtones, energy transport and transverse impedance. Hertz's experiment.		
Module:6	**Longitudinal waves: Vibration of bars**	**6 hours**
Longitudinal vibrations in bars-wave equation and its general solution. Special cases i) bar fixed at both ends ii) bar fixed at the mid point iii) bar free at both ends iv) bar fixed at one end. Tuning fork.		
Module:7	**Standing waves**	**6 hours**
Standing waves, Reflection and transmission of waves at a boundary, Impedance matching, Wave packet, Phase velocity and group velocity. Tuning fork (revisited).		
Module:8	**Contemporary issues**	**2 hours**
Guest lectures by industry and R & D organizations		
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	H. J. Pain, The Physics of Vibrations and Waves, Sixth Edition, 2013, Wiley Publications, USA.

Reference Books			
1. 2. 3. 4	N. Bajaj, The Physics of Waves and Oscillations, 2017, Tata McGraw Hill, India. Walter Fox Smith, Waves and Oscillations, 2010, Oxford University Press, New York, USA. Arnt Inge Vistnes, Physics of Oscillations and Waves-with use of MATLAB and PYTHON, 2016, Springer, Switzerland. Howard Georgi, The Physics of Waves, 2015, Prentice Hall, New Jersey, USA.		
	Authors, book title, year of publication, edition number, press, place		
Mode of Evaluation: CAT, Written assignment, Quiz and FAT			
Recommended by Board of Studies	26.06.2021		
Approved by Academic Council	No. 63	Date	23.09.2021

TPHY102P	Physics of Waves Lab	L	T	P	C
		0	0	2	1
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To gain hands on experience with spring-mass system for understanding various types of motions.
2. To learn the basics of waves by doing various types of experiments in different fields of Physics such as quantum theory, optics, acoustics etc.

Course Outcome

At the end of the course the student will be able to
1. Comprehend the various types of motions/oscillations and the behaviour of waves in ideal and real physical systems.
2. Apply the knowledge of various types of oscillations and vibrations for performing experiments in different fields of Physics such as quantum theory, optics, acoustics etc.
3. Analyze the theoretical modelling of harmonic oscillation experiments using software packages.

Indicative List of Experiments	
1.	To demonstrate the simple harmonic motion –spring mass system
2.	To demonstrate the standing waves on a string
3.	To demonstrate the Lissajous figures using CRO
4.	To determine the frequency of the alternating current using a sonometer
5.	To determine the frequency and velocity of ultrasonic wave
6.	To generate electromagnetic wave using Hertz's experiment
7.	To determine the wavelength of sodium light using Newton's ring method
8.	To determine the wavelength of a He-Ne laser source using an optical grating
9.	To determine the refractive index of a given prism
10.	To determine the frequency of the alternating current using a sonometer
	Total Laboratory Hours **30 hours**

Mode of assessment: Continuous assessment, Oral examination and FAT			
Recommended by Board of Studies	26.06.2021		
Approved by Academic Council	No. 63	Date	23.09.2021

TPHY103L	Modern Physics	L	T	P	C
		3	0	0	3
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To understand the dual nature of matter and radiation.
2. To apply Schrödinger equations to solve finite and infinite potential problems and apply quantum ideas at the nanoscale.
3. To model the atomic and nuclear structure.

Course Outcomes

At the end of the course the student will be able to

1. Compare and contrast the properties of waves and particles.
2. Apply uncertainty principle to estimate position and energy.
3. Model matter waves using tools of quantum mechanics.
4. Apply Schrödinger equation to confined particles and predict tunnelling probability.
5. Demonstrate knowledge on atomic and nuclear structure and appreciate nuclear reactions.

Module:1	**Particle properties of waves**	**7 hours**
Blackbody radiation, Planck's quantum theory of light, idea of quantization (Planck and Einstein), Photoelectric effect, Compton scattering.		
Module:2	**Wave properties of particle**	**7 hours**
Double slit experiment with electrons, de Broglie waves, Davisson Germer experiment, wave function and probability interpretation, construction of wave packets (phase velocity and group velocity).		
Module:3	**Measurement of position and energy**	**6 hours**
Heisenberg uncertainty principle, Heisenberg's microscope (Gedanken experiment), application to virtual particles and range of an interaction.		
Module:4	**Wave mechanics**	**5 hours**
Linear superposition principle, probability and normalization, operators, expectation values: position, momentum, energy, Schrödinger equation for non-relativistic particles.		
Module:5	**Application of wave mechanics**	**6 hours**
Eigenvalues and eigenfunction of particle confined in one- dimensional box - 3 dimensional box (qualitative), quantum confinement and quantum dots.		
Module:6	**Atomic structure**	**6 hours**
Bohr atom model, energy levels and spectra, optical spectra, special terms and notations, selection rule, fine structure of sodium D lines, Zeeman effect- theory and experiment, Stark effect.		
Module:7	**Nuclear structure**	**6 hours**
Nuclear composition, stable nuclei, Liquid drop model (qualitative), Shell model (qualitative), radioactive decay, half-life, alpha, beta, gamma decay, nuclear fission and fusion.		
Module:8	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1. A. Beiser, S. Mahajan, S. R. Choudhury, Concepts of Modern Physics, 7th edition, 2017, McGraw- Hill., India.
2. H. D. Young and R. A. Freedman, University Physics with Modern Physics, 15th edition, 2019, Pearson, UK.

Reference Books			
1.	K. Krane, Modern Physics, 4th Edition, 2016, Wiley Indian Edition.		
2.	D. J. Griffiths, D. F. Schroeter, Introduction to Quantum Mechanics, 3rd Edition, 2019, Cambridge University Press, UK.		
3.	B. R. Martin, G. Shaw, Nuclear and Particle Physics: An Introduction, 3rd Edition, 2019, Wiley, USA.		
Mode of Evaluation: CAT, Written assignment, Quiz and FAT			
Recommended by Board of Studies	26-06-2021		
Approved by Academic Council	No. 64	Date	16-12-2011

TPHY103P	Modern Physics Lab	L	T	P	C
		0	0	2	1
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To apply theoretical knowledge gained in the theory course and get hands-on experience of the topics.

Course Outcomes

At the end of the course the student will be able to:

1. Comprehend the dual nature of radiation and matter by means of experiments.
2. Get hands-on experience on the topics of quantum mechanical ideas in the laboratory.
3. Apply quantum mechanical ideas to atomic physics experiment.

Indicative Experiments

1.	Determination of Planck's constant using LED.
2.	Determination of work function of a metal using Photoelectric effect.
3.	Demonstration of Black body spectrum of light intensity for a given light source.
4.	Determination of phase velocity and group velocity of EM waves.
5.	Demonstration of wave nature of electrons through electron diffraction.
6.	Demonstration of tunnelling effect in tunnel diode using I-V characteristics.
7	Demonstration of Heisenberg Uncertainty Principle.
8	Determination of wavelength of Sodium D1 and D2 lines.
9	Determination of the ionization potential of mercury.
10	Numerical solutions of Schrödinger equation (e.g., particle in a box problem).

Total Laboratory Hours	**30 hours**

Mode of assessment: Continuous assessment, FAT and Oral examination

Recommended by Board of Studies	26-06-2021		
Approved by Academic Council	No. 64	Date	16-12-2011

TRES101L	Research Methodology	L	T	P	C
		3	0	0	3
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

The course is aimed at students to

1. Identify the societal lead hypothesis and ability to design the research framework.
2. Understand the value of Research ethics.
3. Scrutinize the raw data and derive to the conclusion.
4. Compose and present the research investigation report.

Course Outcomes:

At the end of the course the students will be able to

1. Understand the basic concepts of research and values of research ethics.
2. Sketch out the research problems and carryout the literature review.
3. Articulate the research design and execute the sampling method.
4. Fetch, Organize, Investigate and Interpret the data.
5. Perform the statistical analysis and identify the significance of research.
6. Use of search engines and various research tools judiciously for research purposes.

Module:1	**Introduction to Research**	**5 hours**

Research- Definition, objectives, motivation and its importance. Concepts of theory: empiricism, deductive and inductive theory. Scientific method- definition, characteristics. The language of research- definition-theory, hypothesis, conceptualization, variables- dependent and independent variables, sample, population, validity, reliability, data.

Module:2	**Identification and Formulation of Research Problem**	**5 hours**

Research Problem- Need, definition, components, characteristics and formulating the research problem. Literature review- research articles, review articles, case studies and their importance. Hypothesis- null and alternative.

Module:3	**Research Ethics and Intellectual Property Rights**	**7 hours**

Introduction to research ethics, moral issues in research. Different types of animal models and human model used in research, basics to animal ethical guidelines. Introduction to Intellectual Property Rights (IPR), basics of patent rights, copy right, trademark. Common authorship issues in publications.

Module:4	**Research Design and Sampling**	**7 hours**

Research Design- Importance, features and their concepts. The research process basics. Types of Research Design- Historical, descriptive, exploratory and experimental design. Sampling methods- types, advantages and disadvantages. Criteria to determine the sample method and size.

Module:5	**Data Collection and Statistical Analysis**	**7 hours**

Introduction to primary data and secondary data, importance of data collection, open sources reliability. Statistical analysis- basics, univariate, bivariate, and multivariate analysis. Error analysis.

Module:6	**Report and Proposal Writing**	**6 hours**

Report Writing- Importance, types of report, precautions. Layout of research report. Interpreting the research results, infographic interpretation and its report writing. Oral presentations. Proposal writing.

Module:7	**Use of Encyclopaedias, Tools/Techniques for Research**	**6 hours**

Introduction to research, guides and handbooks. Academic databases for chemistry and biological science discipline. Software for detection of plagiarism. Software used for paper formatting and reference management.

Module:8	**Contemporary Issues**	**2 hours**

	Total Lecture hours:	**45 hours**
Text Book(s)		
1.	C. R. Kothari, 2019. Research methodology- Methods & Techniques, (Second Revision Edition), New Age International Publishers.	
2.	Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani, 2017. An Introduction to Statistical Learning with Applications in R, Springer.	
Reference Books		
1.	Carlos, C.M., 2000. Intellectual property rights, the WTO and developing countries: the TRIPS agreement and policy options. Zed Books, New York.	
2.	Coley, S.M. and Scheinberg, C. A., 1990, “Proposal Writing”, Sage Publications.	
3.	Catherine Dawson, Introduction to research methods : a practical guide for anyone undertaking a research project, Oxford : How To Books, Reprint 2010	
Mode of Evaluation: Quiz/Digital Assignment/CAT/Seminar/Project		
Recommended by Board of Studies	14-02-2022	
Approved by Academic Council	No. 65	Date 17-03-2022

TSSC201L	Critical Thinking	L	T	P	C
		2	0	0	2
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives:

1. To understand the importance of critical thinking.
2. To diagnose need analysis as well as to identify ways of improving them.
3. To describe and apply the nuances of decision making and problem-solving.

Course Outcomes:

1. Execute the basic tools of critical and lateral thinking in solving real life issues.
2. Develop coherent and critical thinking required for academic and corporate environments.
3. Integrate leadership, decision making and motivational strategies for the professional milieu.
4. Apply informal logical concepts to contemporary scenarios.

Module:1	**Introduction to Critical Thinking in Academic Contexts**	**4 hours**
History of Critical Thinking- - Basic Tools for Critical thinking - Strategies to be adopted for lateral thinking.		
Module:2	**Critical Thinking in Reading and Argumentation**	**4 hours**
Finding and evaluating the line of reasoning in a text - Identifying false premises and flawed reasoning - Recognizing good and bad arguments.		
Module:3	**Skills & Procedure**	**4 hours**
Socratic questioning in a professional environment - Differentiating between different types of statements - Grammar for Critical Thinking.		
Module:4	**Purpose of adopting Critical Thinking**	**4 hours**
Necessity - Professional Excellence - Personality Development - Qualities of a Critical Thinker.		
Module:5	**Decision-Making Skills**	**4 hours**
Cost-Benefit - Narrow Down the Options - Evaluate Significance –Prioritisation.		
Module:6	**Critical Thinking in Corporate Contexts**	**4 hours**
Importance of Critical Thinking in the Workplace - Critical Thinking and Leadership Skills - Critical Thinking for Evaluating Information - Critical thinking skill development & Motivational strategies.		
Module:7	**Informal Fallacies**	**4 hours**
Ad Hominem - Appeal to the Emotions - Bandwagon fallacy - False Dilemma - Appeal to Unqualified Authority - Begging the question - Appeal to tradition - Strawman Fallacy.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**30 hours**

Text Book(s)

1. Galen A. Foresman, Peter S. Fosl, and Jamie Carlin Watson (2017), *The Critical Thinking Toolkit.* New Sussex: Wiley Blackwell
2. Caroselli, M. (2011). *The Critical Thinking Toolkit: Spark Your Team's Creativity with 35 Problem Solving Activities*. AMACOM

Reference Books

1. Nevid, J. S., &Rathus, S.A. (2009). *Psychology and the challenges of life* (11th edition). New York: John Wiley & Sons.

2	Hanscomb, S. (2017). Critical thinking: The basics. Taylor & Francis.
3	https://courses.lumenlearning.com/austincc-learningframeworks/chapter/chapter-7-critical-thinking-and-evaluating-information/.
4.	Cottrell, Stella (2017). *Critical Thinking Skills: Effective Analysis, Argument and Reflection*. London: Palgrave Macmillan.
5.	Manika Ghosh (2013) Positivity – A way of life: Orient Blackswan Private Limited - New Delhi.

Mode of Evaluation: CAT / Assignment / Quiz / FAT / Case Study / Seminar			
Recommended by Board of Studies	28-06-2021		
Approved by Academic Council	No. 65	Date	17-03-2022

TSSC202L	Intra and Interpersonal Skills	L	T	P	C
		2	0	0	2
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To understand the core concepts of interpersonal and intrapersonal skills.
2. To enrich expertise to evaluate oneself, one's sentiments and to ascertain means of sharing opinions constructively.
3. To classify one's talents and imperfections and improve aptitudes to accomplish constructive relationships.

Course Outcome

1. Exemplify the concepts of interpersonal and intrapersonal skills in all scenarios.
2. Describe the concepts of self, emotions and communication in relationships.
3. Assess features of healthy relationships and develop skills to handle and respond to criticism.
4. Translate what is learned into strategies for use in educational and professional settings.

Module:1	**Introduction to Intrapersonal and Interpersonal Skills**	**4 hours**
Nature and Process - Interpersonal Communication – Models - Perception and communication		
Module:2	**Knowing and valuing Yourself**	**4 hours**
Concept of self, Self-Awareness, Self-Esteem - Attachment styles: Dismissive-Avoidant, Fearful-Avoidant, Anxious Attachment and Secure Attachment - Self-presentation and Self-disclosure		
Module:3	**Understanding yourself throughout your life span**	**4 hours**
Influences on personality - Personality types and development - The Myers Brigg personality test. Genetics and personality: Gender and personality & Culture and Personality		
Module:4	**Exploring values and making wise choices**	**4 hours**
Understanding values and choices - Define wellness and ways of promoting wellness - Exploring and prioritizing - Cultivate skills to make prudent decisions		
Module:5	**Experiencing and expressing emotion**	**4 hours**
Emotional Behaviour - Understanding emotions& adoption of ways to express emotions - Developing effective listening - Positive listening		
Module:6	**Communication in Constructive Criticism**	**4 hours**
Need of criticism - Making constructive criticism - Handling negative comments & Responding to criticism - Giving and receiving criticism		
Module:7	**Building Positive Relationships**	**4 hours**
Ways of achieving happiness and satisfaction - Types of relationships - Define conflict styles and conflict management		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**30 hours**

Text Book(s)

1.	Wood, J. T. (2015). *Interpersonal communication: Everyday encounters*. Cengage Learning. UK
Reference Books	
1.	DeVito, J. A. (2019). The interpersonal communication. *Instructor*, *1*, 18. Pearson Education India; 13th edition
2.	Ury, W. (2007). *Getting past no: Negotiating in difficult situations*. Bantam Books. US
3.	Corey, G., & Corey, M. S. (2017). *I never knew I had a choice: Explorations in personal growth*. Cengage Learning. US.
4.	Pavord, E., & Donnelly, E. (2015). *Communication and interpersonal skills*. Lantern Publishing. UK
5.	Adler, R. B., & Proctor II, R. F. (2016). *Looking out, looking in*. Cengage Learning. US
6.	Goldsmith, D. J. (2008). Politeness theory. *Engaging theories in interpersonal communication: Multiple perspectives*, 255-267. Thousand Oaks. Sage Publishers. CA
7.	Diener, E., Lucas, R. E., &Oishi, S. (2021). Subjective well-being: The science of happiness and life satisfaction. *Handbook of positive psychology*, *2*, 63-73. Oxford University Press. USA
8.	Gibson, T. (2020). *Attachment theory: A guide to strengthening the relationships in your life*. Bottom of Form. Rockridge Press. US
Mode of Evaluation: CAT / written assignment / Quiz / FAT / group discussion/Case Study	

Recommended by Board of Studies	28-06-2021		
Approved by Academic Council	No. 65	Date	17-03-2022

Discipline Core

TMAT201L	Probability and Statistics	L	T	P	C
		3	0	0	3
Pre-requisite	**TMAT103L, TMAT103P**	**Syllabus Version**			
		1.0			

Course Objectives

1. To motivate the students to address the relevance of Probability and Statistical Theory to various data analysis situations.
2. To analyse distributions and relationship of real-time data.
3. To apply estimation and testing methods to make inference and modelling techniques for decision making.

Course Outcomes

At the end of this course, students will be able to

1. To understand the basic probability concepts using real time problems.
2. Understand the basic concepts of random variables and find an appropriate distribution for analysing data specific to an experiment.
3. Apply statistical methods like correlation, regression analysis in analysing, interpreting experimental data.
4. Make appropriate decisions using statistical inference that is the central to experimental research.
5. Use statistical methodology and tools in reliability engineering problems.

Module:1	**Probability**	**6hours**
Probability –axioms of probability– Addition Rule– Conditional probability – Multiplication rule-total probability- Baye's formula– Independence of events.		
Module:2	**Random Variables**	**7 hours**
Discrete and continuous random variables – probability mass, probability density and cumulative distribution functions- Mathematical expectation - Joint Probability distributions – Marginal and conditional distributions- Covariance.		
Module:3	**Correlation and Regression**	**6 hours**
Moments – Moment generating functions – Characteristic function, Correlation and linear regression – Partial correlation- Multiple correlation - Multiple linear regression.		
Module:4	**Distributions**	**6 hours**
Binomial-Poisson – Normal – Exponential – Gamma - Weibull – Distributions- Applications.		
Module:5	**Testing of Hypothesis**	**8 hours**
Sampling distributions – Estimation of parameters – Statistical hypothesis – Large sample tests based on Normal distribution for single mean and difference of means -Tests based on t, F distributions for mean, variance and proportion – Chi-square test - Contingency table – Goodness of fit.		
Module:6	**Design of experiments**	**5 hours**
Principles of Experimental Design-replication, randomization and local control-Completely randomized design – Randomized block design – Latin square design		
Module:7	**Reliability**	**5 hours**
Basic concepts- Hazard function-Reliabilities of series and parallel systems- System Reliability - Maintainability-Preventive and repair maintenance.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Books

1. Probability and Statistics for engineers and scientists, R.E.Walpole, R.H.Myers,

<table>
<tr><td colspan="4">S.L.Mayers and K.Ye, 9th Edition, Pearson Education (2012).
2. Probability, Statistics and Reliability for Engineers and Scientists, Bilal M. Ayyub and Richard H. McCuen, 3rd edition, CRC press (2011).</td></tr>
<tr><td colspan="4">Reference Books</td></tr>
<tr><td colspan="4">1. John E. Freund’s Mathematical Statistics with Applications, Irwin Miller, Marylees Miller, 8th edition, Pearson (2014).
2. Probability and Statistics for Engineers, R.A.Johnson, Miller Freund’s, 8th edition, Prentice Hall India (2011).
3. Applied Statistics and Probability for Engineers, Douglas C. Montgomery, George C. Runger, 6th Edition, John Wiley & Sons (2016).
4. Reliability Engineering, E.Balagurusamy, Tata McGraw Hill, Tenth reprint 2017
5. Introduction to Mathematical Statistics (Seventh Edition), Robert V. Hogg, J.W. McKean, and Allen T. Craig, Pearson Education, Asia (2012).</td></tr>
<tr><td colspan="4">Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes</td></tr>
<tr><td>Recommended by Board of Studies</td><td colspan="3">15-02-2022</td></tr>
<tr><td>Approved by Academic Council</td><td>No. 65</td><td>Date</td><td>17-03-2022</td></tr>
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TMAT201P	Probability and Statistics Lab	L	T	P	C
		0	0	2	1
Pre-requisite	**TMAT103L, TMAT103P**	**Syllabus version**			
		1.0			

Course Objectives

1. To enable the students for having experimental knowledge of basic concepts of statistics using R programming.
2. To study the relationship of real-time data and decision making through R.
3. To make students capable to do experimental research using statistics in various engineering problems.

Course Outcomes

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

1. Demonstrate R programming for statistical data.
2. Carry out appropriate analysis of statistical methods through experimental techniques using R.

Indicative Experiments		
1.	Introduction: Understanding Data types; importing/exporting data.	Total Laboratory hours: 30
2.	Plotting and visualizing data using Graphical Representations – Bar, Multiple Bar diagrams -	
3.	Fitting of Binomial distribution, Poisson distribution	
4.	Fitting of exponential distribution, gamma distribution, Weibull distribution, Normal distribution.	
5.	Correlation and simple linear regression model	
6.	Multiple linear regression	
7.	Testing of hypothesis for One sample mean and proportion.	
8.	Testing of hypothesis for Two sample means and proportion.	
9.	Applying the t test for independent and dependent samples	
10.	Applying Chi-square test for goodness of fit test and Contingency test	
11.	Performing ANOVA for real dataset for Completely randomized design, Randomized Block design, Latin square Design	

Text Book

1. Statistical analysis with R, Joseph Schmuller, John wiley and sons Inc., New Jersey 2017.

Reference Books

1. The Book of R: A First course in Programming and Statistics, Tilman M Davies, William Pollock, 2016.
2. R for Data Science, Hadley Wickham and Garrett Grolemund, O' Reilly Media Inc., 2017

Mode of assessment: Weekly Assessment, FAT and Oral examination

Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT202L	Linear Algebra	L	T	P	C
		3	1	0	4
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. Improving the computational techniques and algebraic skills essential for the study of systems of linear equations, matrix algebra, vector spaces, eigenvalues and eigenvectors, orthogonality and diagonalization.
2. Interpret and Critically analyse and construct mathematical arguments that relate to the study of introductory linear algebra.
3. Imparting the knowledge of real time applications of linear algebra in other branches of sciences, engineering, and economics.

Course Outcomes

1. Demonstrate an understanding of vector spaces and subspaces
2. Demonstrate an understanding of linear transformations.
3. Compute and interpretthe eigenvalues and eigenvectors.
4. Identify and understand the characteristics of matrix, the notion of an inner product space in a general setting and how the notion of inner products can be used to define orthogonal vectors. Develop the ability to use the Gram-Schmidt process to generate an orthonormal set of vectors.
5. Demonstrate an understanding of structure of linear transformations and to compute and interpret different types of canonical forms.

Module:1	**Vector Spaces**	**5 hours**

Vector Space, Subspaces, Intersection, Sum & Direct sums of subspaces, Linear combination & spans, Linear dependence & independence.

Module:2	**Basis & Dimension**	**8 hours**

Basis, Dimension, Co-ordinates and Quotient space, Null, Row & Column spaces, Dimension Theorem.

Module:3	**Linear Transformation**	**7 hours**

Linear Transformation, Properties of linear transformation, Kernel & Range, singular & non-singular transformations, Isomorphism Theorems, Matrix representation, Change of basis & similarity.

Module:4	**Eigenvalues & Eigenvectors**	**6 hours**

Definition, Characteristics polynomial, Cayley-Hamilton theorem, diagonalization, Similarity transformation.

Module:5	**Inner product Spaces**	**6 hours**

Inner product, Norms, Orthogonality & Orthonormality, Orthogonal sets, Projections, Orthonormal sets, Gram-Schmidt algorithm, QR-Factorization, Least squares method.

Module:6	**Structure of Linear Transformations**	**5 hours**

Annihilating & Minimum polynomial, Invariant Direct Sum Decomposition, Quotient Subspaces, Relation between Characteristics and Minimum polynomials, Nilpotent Operators & Matrices, Cyclic Subspaces.

Module:7	**Canonical Forms**	**6 hours**

Reduction to triangular form, Jordan Blocks & Jordan Matrices, Existence & uniqueness of Jordan form, Jordan Canonical forms, Rational Canonical forms.

Module:8	**Contemporary Issues**	**2 hours**

Total Lecture hours:	**45 hours**
Total Tutorial hours:	**15 hours**

Text Books

1. Linear Algebra, Friedberg, Insel, Spence, 5th Edition, Pearson, 2019. 2. Linear Algebra, K. Hoffman & R. Kunze, 2nd Edition, Pearson, 2015.			
Reference Books			
1. Matrix Computations, Gene H. Golub, Charles F. Van Loan, Hindustan Book Agency, 2015. 2. Linear Algebra and Its Applications, Gilbert Strang, 4th Edition, Cengage Learning India Pvt. Ltd, 2014. 3. Matrix Analysis, Roger A. Horn, Charles R. Johnson, 2ndEdition, Cambridge University Press, 2016. 4. Matrix Analysis and Applied Linear Algebra, Carl D. Meyer, SIAM, 2000.			
Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes			
Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT203L	Real Analysis	L	T	P	C
		3	1	0	4
Pre-requisite	**TMAT103L, TMAT103P**	**Syllabus version**			
		1.0			

Course Objectives

1. Understand the meaning of limits and Continuity and it's role in Analysis
2. Apply the Concept of Differentiation in finding
3. Evaluate Riemann Integral and know the various properties
4. Can demonstrate the properties which are preserved under uniform convergence and understand term by term Differentiation and Integration.
5. Aware of basic results on analysis.

Course Outcomes

At the end of the course the student should be able to

1. Describe the fundamental properties of the real numbers that underpin the formal development of real analysis;
2. Demonstrate an understanding of the theory of sequences and series, continuity, differentiation and integration;
3. Demonstrate skills in constructing rigorous mathematical arguments;
4. Apply the theory in the course to solve a variety of problems at an appropriate level of difficulty;
5. Develop skills in communicating mathematics.

Module:1	**Limits and Continuity**	**5 hours**

Limits of functions, Algebra of limits, one sided limits, Infinite limits and limits at infinity, Characterization of limit at a point in terms of sequences, Continuous functions, Continuity on closed interval, Uniform Continuity.

Module:2	**Differentiation**	**5 hours**

Derivative of a real function, Mean value theorems, continuity of derivatives, L'Hospital's rule, Derivatives of higher Order, Taylor' s theorem, Differentiation of vector valued functions.

Module:3	**Riemann Integral**	**6 hours**

Partition, Refinement of a partition, Norm of a partition, Definition and Existence of Riemann Integral, Properties of the Integral, Fundamental theorem, Integration by parts.

Module:4	**Sequences and series of functions**	**6 hours**

Sequences of functions, Pointwise convergence, Uniform convergence, Uniform convergence and Continuity, Uniform convergence and Integration, Term by Term Differentiation.

Module:5	**Equicontinuity**	**6 hours**

Equicontinuous families of functions, Stone-Weierstrass Theorem and Stone's generalization.

Module:6	**Some Special Functions**	**7 hours**

Power series, Exponential and logarithmic functions, Trigonometric functions, Fourier Series, Gamma function.

Module:7	**Functions of several variables**	**8 hours**

Linear Transformations, Differentiation , Contraction principle, Inverse function theorem, Implicit function theorem, determinants, derivatives of higher order and differentiation of integrals.

Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**
	Total Tutorial hours:	**15 hours**

Text Books

1. Principles of Mathematical Analysis, Walter Rudin, 3rd edition, McGraw Hill, 1976
2. Introduction to Real Analysis, Robert G. Bartle and Donald R. Sherbert, Wiley, 2014

Reference Books			
1. Mathematical Analysis, S. C. Malik, Savita Arora, 6th edition, New Age, 2022 2. Real Analysis, Shanti Narayan, S. Chand and Company, 2013 3. Real Analysis, N. L. Carothers, Cambridge, 2000 4. Mathematical Analysis, Tom M. Apostol, Narosa, 1996			
Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes			
Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT204L	Ordinary Differential Equations	L	T	P	C
		3	1	0	4
Pre-requisite	**TMAT202L**	**Syllabus version**			
		1.0			

Course Objectives

1. To provide the students with sufficient exposure to basic mathematical methods and tools that are relevant to engineering research.
2. Improving the computational skills of students by giving sufficient knowledge of analytical techniques useful for solving problems arising in Science and Engineering.
3. Imparting the knowledge of eigenvalues and eigenvectors of matrices and the matrix techniquesto solve linear systems, that arise in sciences and engineering
4. Enriching the skills in solving initial and boundary value problems
5. Imparting the knowledge of real time applications of Linear Autonomous systems of ordinary differential equations.

Course Outcomes

1. Understanding the basic phenomenon of differential equations and connect with real word problems.
2. To know finite and infinite form of higher order differential equation and application to scientific and engineering problems.
3. Apply the concepts of eigenvalues, eigenvectors and diagonalisation in linear systems
4. Distinguish and analyse a variety of tools for solving linear systems and finding eigenvalues of the systems and application to scientific models.
5. Finding eigenvalues, eigenfunctions of Strum-Liouville's problem so as to apply in physical world problems.

Module:1	**Existence and Uniqueness**	**6 hours**

Existence and Uniqueness of Initial Value Problems: Picard's and Peano's Theorems, Gronwall's inequality, Continuous dependence on initial data and dynamics, continuation of solutions to larger interval, maximal interval of existence.

Module:2	**ODE**	**6 hours**

Direction fields, Autonomous equations, Equilibria and the phase line, classification of equilibrium points, Bifurcations, Exponential and Logistic Models, Simple electric circuits,Cooling problem, Radioactive decay, Radiocarbon dating, Chemical Reactions.

Module: 3	**Linear Systems**	**6 hours**

Solutions of linear systems, Homogeneous Linear System, Non homogeneous linear systems– Undermined coefficients & Variation of Parameters, Fundamental Matrix Solutions, Solving systems by Laplace transform, Qualitative Analysis.

Module:4	**Sturm-Liouville Boundary Value Problems**	**6 hours**

Sturm-Liouville System, Sturm-Liouville series, Physical Interpretation, Singular System, Sturm Comparison Theorem, Sturm Oscillation Theorem.

Module:5	**Nonlinear Differential Equations**	**6 hours**

Phase Plane, Paths, and Critical Points, Critical Points and Paths of Linear Systems, Critical Points and Paths of Nonlinear Systems , Limit Cycles and Periodic Solutions.

Module:6	**Expansions**	**6 hours**

Fourier Series, Expansion of a Function in a Series of Orthonormal Functions, Trigonometric Fourier Series, Eigenfunction expansions.

Module:7	**Green's Function**	**7 hours**

Inverse operator and Dirac-Delta Function, Adjoint and self-adjoint Operators, Green's Function and the adjoint operator.

Module:8	**Contemporary Issues**	**2 hours**

Total Lecture hours:	**45 hours**
Total Tutorial hours:	**15 hours**

Text Books

1. Differential Equations, Sheply L. Ross, 3rd edition, Wiley, 2007
2. Differential Equations with Applications and Historical notes, George F. Simmons, 3rd edition, CRC Press, 2017

Reference Books

1. Differential equations with boundary value problems, Dennis G. Zill, Michael R. Cullen, 9th Edition, Cengage, 2018.
2. Differential Equations Theory, Technique and Practice with Boundary Value Problems, Steven G. Krantz, CRC Press, 2015
3. Textbook of Ordinary Differential Equations, S. G. Deo, V. Raghavendra, Rasmita Kar, McGraw Hill, 2017
4. Elementary Differential Equations and Boundary Value Problems, William E. Boyce, Richard C. Diprima, Douglas B. Meade, John Wiley & Sons, 2017(11th Edison)
5. Ordinary Differential Equations: Principles and Applications, A. K. Nandakumaran, P.S. Datti, Raju K. George, Cambridge, 2017

Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes

Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT205L	Complex Analysis	L	T	P	C
		3	1	0	4
Pre-requisite	**NIL**	**Syllabus Version**			
		1.0			

Course Objectives

1. The objective of this course is to introduce the fundamental ideas of the functions of complex variables.
2. Acquiring the required knowledge for developing a clear understanding of the basic concepts of Analytic functions, Harmonic and Meromorphic functions.
3. Motivating the learners for understanding the fundamental concepts and basic Theorems in Complex Analysis.

Course Outcomes

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

1. Explore the basic concepts of limits, continuity and derivative for complex functions as well as consequences of continuity.
2. Familiarize with the concept of conformal Mapping and also implement the learned techniques to realistic problems.
3. Express analytic functions in power series.
4. Apply the concept and consequences of complex integration in different field of research.
5. Cognizant the basic principles of Singularities for solving various practical problems.
6. Gain knowledge of Meromorphic functions and also grasp a deeper understanding of different techniques involved in proving the Theorems.
7. Understand the importance of Harmonic functions in various field.

Module: 1	**Analytic Functions**	**6 hours**

Functions of complex variables-Mappings-Limits-Continuity-Derivatives-Cauchy-Reimann Equations-Sufficient conditions for differentiability-Polar Coordinates- Analyticity -Laplace equation and Harmonic functions- Construction of Harmonic conjugate and analytic functions.

Module:2	**Conformal Mappings**	**6 hours**

Conformal mapping - Linear mapping and inversion-Linear fractional transformations-Exponential and logarithmic mappings-Mapping by trigonometric functions- Normal Families-Riemann Mapping Theorem.

Module:3	**Complex Integration**	**6 hours**

Integration of a complex function-Cauchy-Goursat theorem-Cauchy's Theorem-Simply connected and Multiconnected domains-Cauchy's integral formula-Morera's Theorem, Liouville's theorem-Maximum modulus Principle.

Module:4	**Power Series**	**6 hours**

Convergence of Sequences-Convergence of Series-Taylor Series-Laurent's Series-Absolute and Uniform convergence of Power series-Continuity of sums of Power Series-Integration and differentiation of Power Series-Uniqueness of Series Representation-Multiplication and division of Power Series.

Module:5	**Residues and Poles**	**7 hours**

Zeros of analytic functions- singularity and types of singularity -Residues-Cauchy's Residue Theorem-Residue at infinity- Residue at poles- Weierstrass' Theorem-Jordan's Lemma-Argument Theorem, Rouche's Theorem.

Module:6	**Entire and Meromorphic Functions**	**6 hours**

Infinite Products-Entire Functions-Jensens formula-Hadamard's Theorem- Meromorphic functions- Weierstrass' Product Theorem - Mittag-Leffler Theorem.

Module:7	**More on Harmonic functions**	**6 hours**

Basic Properties- mean value property-Poisson integral formula-Positive Harmonic functions-Dirichlet problem for the disc- Harnack's inequality- Harnack's principle.

Module:8	**Contemporary Issues**	**2 hours**

Total Lecture hours:	**45 hours**
Total Tutorial hours :	**15 hours**

Text Books

1. Complex variables and applications, R.V. Churchill and J.W. Brown, McGraw Hill Education, 9th edition, 2021.
2. Complex Analysis for Mathematics and Engineering, J. H. Mathews and R. W. Howell, 6th Edition, John and Bartlett, 2012.

Reference Books

1. Complex Analysis, L. V. Ahlfors, 3rd Edn., McGraw Hill, 2017.
2. Functions of One Complex Variable, J.B. Conway, 2nd Edn.,Narosa, 1996.
3. Complex Analysis in One Variable, Narasimhan, R., 2nd ed., Birkhauser, 2001.
4. Basic complex analysis, J. E. Marsden and M. J. Hoffman, 3rd Edn., W. H. Freeman, 1999.
5. Complex variables with applications, S. Ponnusamy and H. Silverman, Birkhauser, 2006.

Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes			
Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT301L	Numerical Analysis	L	T	P	C
		3	0	0	3
Pre-requisite	TMAT104L	Syllabus Version			
		1.0			

Course Objectives

The aim of this course is to

1. Understand the fundamental principles of digital computing, including number representation and arithmetic operations.
2. Understand the linkage between accuracy, stability and convergence.
3. Perform error analysis for arithmetic operations.
4. Understand the propagation of errors through complex numerical algorithms.
5. Perform numerical stability analysis.

Course Outcomes

At the end of the course the student should be able to

1. Develop stable algorithms for solving linear systems of equations.
2. Develop efficient and stable algorithms for finding roots of non-linear equations.
3. Implement numerically stable recursion algorithms for evaluating mathematical functions.
4. Understand the use of interpolation for numerical differentiation and integration.
5. Develop stable solution algorithms for ordinary differential equations.

Module:1	Mathematical Preliminaries and Error Analysis	4 hours

Significant digits of Precision, Errors: absolute and relative-Loss of Significance, Rounding and chopping and Computer Arithmetic, Algorithms and Convergence.

Module:2	Solutions of Equations in One Variable	6 hours

Bisection Method, Fixed-Point Iteration, Newton-Raphson Method and Its Extensions, Error Analysis for Iterative Methods, Accelerating Convergence, Zeros of Polynomials and Muller's Method.

Module:3	Interpolation and Polynomial Approximation	6 hours

Interpolation and the Lagrange Polynomial, Data Approximation and Neville's Method, Divided Differences, Hermite Interpolation, Cubic Spline Interpolation.

Module:4	Numerical Differentiation and Integration	7 hours

Numerical Differentiation, Richardson's Extrapolation, Elements of Numerical Integration, Composite Numerical Integration, Romberg Integration, Adaptive Quadrature Methods, Gaussian Quadrature.

Module:5	Initial-Value Problems for Ordinary Differential Equations	7 hours

Theory of Initial-Value Problems, Euler's Method, Higher-Order Taylor Methods, Runge-Kutta Methods, Error Control and Runge-Kutta-Fehlberg Method, Multistep Methods, Variable Step-Size Multistep Methods.

Module:6	Iterative Techniques in Matrix Algebra	6 hours

Norms of Vectors and Matrices, Eigenvalues and Eigenvectors, The Jacobi and Gauss-Siedel Iterative Techniques, Relaxation Techniques for Solving Linear Systems, Error Bounds and Iterative Refinement.

Module:7	Boundary-Value Problems For Ordinary Differential Equations	7 hours

Linear Shooting Method, Shooting Method for Nonlinear Problems, Finite-Difference Methods for Linear Problems, Finite-Difference Methods for Nonlinear Problems, Rayleigh-Ritz Method.

Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Books

1. Numerical Analysis, J. Douglas Faires, Richard L. Burden, Cengage, 10th Ed., 2016
2. Applied Numerical Methods With MATLAB, Steven C. Chapra, 4th Edition, McGraw Hill, 2019.

Reference Books

1. Introductory Methods of Numerical Analysis, S. S. Sastry, PHI Pvt. Ltd., 5th Edition, New Delhi, 2012.
2. Applied Numerical Methods Using MATLAB, W. Y. Yang, W. Cao, T. S. Chung and J. Morris, Wiley, 2020.
3. Applied Numerical Analysis, C. F. Gerald and P. V. Wheatley, Pearson, 7th Edition, 2007.
4. An Introduction to Numerical Analysis, Kendall E. Atkinson, Wiley, 2008

Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes			
Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT301P	Numerical Analysis Lab	L	T	P	C
		0	0	2	1
Pre-requisite	**TMAT104L**	**Syllabus version**			
		1.0			

Course Objectives

1. Learn the basics of MATLAB programming.
2. To be able to use MATLAB to solve computational problems.
3. Demonstrate numerical methods to solve engineering problems.

Course Outcomes

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

1. Use MATLAB to solve and nonlinear equations.
2. Understand curve fitting.
3. Find the integrals of given functions with the help of MATLAB.
4. Solve the ordinary differential equations.

Indicative Experiments

1.	Introduction to MATLAB	Total Laboratory hours: 30
2.	To find the roots of nonlinear equations using Newton Method	
3.	Curve fitting by least squares method	
4.	To solve the equation using Gauss-Seidel method	
5.	To solve the equation using Gauss-Jordan method	
6.	To find the largest Eigenvalue by Power method	
7.	To Integrate numerically using Trapezoidal Rule	
8.	To Integrate numerically using Simpson's Rule	
9.	To find the numerical solution of ODE by Runge-Kutta method	
10.	To find the numerical solution of ODE by Milne's method	

Text Books

1. Applied Numerical methods using MATLAB, Morris Yang, Cao Chung, Wiley, 2007
2. Numerical methods in Engineering with MATLAB, Jaan Kiusalaas, 3rd edition, Cambridge University Press, 2015

Mode of assessment: Weekly Assessment, FAT and Oral examination

Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT302L	Abstract Algebra	L	T	P	C
		3	1	0	4
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To provide the students with sufficient exposure to advanced mathematical theory such as group theory and ring theory.
2. Ability to apply algebraic ways of thinking.

Course Outcomes

1. Solving problems using the powerful concept of group action.
2. Demonstrate knowledge and understanding of fundamental concepts including groups, subgroups, normal subgroups, homomorphisms and isomorphisms.
3. Facility in understanding the structure of a problem where the problem involves a permutation group, for instance, Rubik's cube.
4. Ability to understand a large class of commutative rings by regarding them as quotients of polynomial rings by suitable ideals
5. Ability to understand basic field theory and apply it on basic concepts of error correcting codes and cryptography.

Module:1	**Group Theory**	**6 hours**
Definition and examples of groups and subgroups, a counting principle, normal subgroups and quotient groups andLagrange's theorem.		
Module:2	**Cyclic Groups and Isomorphisms**	**7 hours**
Generating sets, Cyclic Groups, Homomorphism and Isomorphism theorems, Automorphisms.		
Module:3	**Finite Groups**	**8 hours**
Permutation groups, alternating groups, Simplicity of A_5, Cayley's theorem, Direct Products: External and Internal. Fundamental theorem of finitely generated Abelian groups (Statement only) and applications, Structure of finite Abelian groups.		
Module:4	**Solvability**	**6 hours**
Conjugate elements, class equation with applications, Cauchy's Theorem, Sylow's theorems and their simple applications, Solvable Groups, Composition Series, and Jordan Holder Theorem.		
Module:5	**Ring Theory**	**8 hours**
Definition and examples of Rings, some special classes of Rings, homomorphisms, Ideal and Quotient rings, Maximal Ideal, Integral domain, Principal Ideal Domain, Unique Factorization Domain.		
Module:6	**Field Theory**	**5 hours**
Definition of field and some examples, the field of Quotients of an Integral domain, Euclidean rings, polynomial rings.		
Module:7	**Application to Algebraic Coding theory**	**3 hours**
Error Correcting Codes: Linear codes, Generator and parity check matrices, decoding: coset and syndrome, Classical Cryptosystems –Plain Text, Cipher Text, Encryption		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**
	Total Tutorial hours:	**15 hours**

Text Books

1. Topics in Algebra, Herstein, I. N., 2nd Ed., John Wiley & Sons, 2006.
2. Abstract Algebra, Dummit, D. S. and Foote, R. M., 3rd Ed., John Wiley & Sons, 2003.

Reference Books

1. Contemporary Abstract Algebra, Gallian J. A., 10th Ed., CRC Press, 2021. 2. Algebra, Thomas W. Hungerford, Springer, 2003. 3. Algebra, Artin M. 2nd Ed., Pearson, 2017. 4.Basic Abstract Algebra, P.B Bhattacharya, S.K. Jain and S.R. Nagpaul, 2nd Ed., Cambridge University Press, 1999. 5. A First Course in Abstract Algebra, John B. Fraleigh, 8th Ed., Pearson, 2020.			
Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes			
Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT303L	Discrete Mathematical Structures	L	T	P	C
		3	1	0	4
Pre-requisite	**NIL**	**Syllabus Version**			
		1.0			

Course Objectives

1. To understand the Mathematical structures required for building logical and computational tools.
2. To use Counting techniques, in particular recurrence relations to solve discrete time problems.
3. To understand the concepts of graph theory and formal languages.

Course Outcomes

At the end of this course, students will be able to

1. Apply proof techniques and concepts of inference theory.
2. Use Counting techniques in discrete time problems.
3. Use lattice and Boolean algebra properties in digital circuits.
4. Solve network optimization problems using Graph theory.
5. Design grammar and finite automata to generate and accept languages.

Module:1	**Mathematical Logic**	**6 hours**

Statements and Notation-Connectives–Tautologies-Equivalence - Implications–Normal forms - The Theory of Inference for the Statement Calculus - Predicate Calculus - Inference Theory of the Predicate Calculus

Module:2	**Counting Techniques**	**6 hours**

Basics of counting-Pigeonhole principle- Permutations and combinations-Inclusion-exclusion principle-Recurrence relations-Solving recurrence relations-Generating functions-Solution to recurrence relations by generating function

Module:3	**Lattices and Boolean algebra**	**7 hours**

Partially Ordered Relations -Lattices as Posets – Hasse Diagram – Properties of Lattices – Boolean algebra-Properties of Boolean Algebra-Boolean functions

Module:4	**Fundamentals of Graphs**	**6 hours**

Basic Concepts of Graph Theory – Planar and Complete graph - Matrix representation of Graphs – Graph Isomorphism – Connectivity–Cut sets-Euler and Hamilton Paths–Shortest Path algorithms

Module:5	**Trees, Fundamental circuits , Cut sets**	**6 hours**

Trees – properties of trees – distance and centres in tree –Spanning trees – Spanning tree algorithms- Tree traversals- Fundamental circuits and cut-sets

Module:6	**Graph colouring, covering, Partitioning**	**6 hours**

Bipartite graphs - Chromatic number – Chromatic partitioning – Chromatic polynomial - matching – Covering– Four Colour problem

Module:7	**Grammars and Automata**	**6 hours**

Alphabets- Strings- Free monoids – Formal Languages- Grammars- Context Free Grammar- Derivation trees- Regular Grammar- Deterministic finite automaton- Non-Deterministic finite automaton-Pushdown Automaton- Turing Machine

Module:8	**Contemporary Issues**	**2 hours**

Total Lecture hours:	**45 hours**
Total Tutorials hours:	**15 hours**

Text Books

1. Discrete Mathematical Structures with Applications to Computer Science, J .P. Trembley and R. Manohar, Tata McGraw Hill-35th reprint, 2017.
2. Graph theory with application to Engineering and Computer Science, Narasing Deo, Dover, 2016.

Reference Books

1. Discrete Mathematics and its applications, Kenneth H. Rosen, 8th Edition, Tata McGraw Hill, 2021.
2. Discrete Mathematical Structures, Kolman, R.C.Busby and S.C.Ross, 6th Edition, Pearson, 2015.
3. Discrete Mathematics, Richard Johnsonbaugh, 8th Edition, Pearson, 2017.
4. Discrete Mathematics, S. Lipschutz and M. Lipson, McGraw Hill Education (India) 2017.
5. Elements of Discrete Mathematics–A Computer Oriented Approach, C.L.Liu, 4th Edition, McGraw Hill, Special Indian Edition, 2017.
6. Introduction to Graph Theory, D. B. West, 2nd Edition, Pearson, 2015.

Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes

Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT304L	Topology	L	T	P	C
		3	1	0	4
Pre-requisites	**TMAT203L**	**Syllabus Version**			
		1.0			

Course Objectives

1. Providing the basic notions of Topology that helps to study about the abstractness in weird higher dimensional spaces.
2. Applying the concepts of Identification spaces, connectedness and compactness to study the Algebraic Topology.
3. Imparting the knowledge of Topology in the field of computer science.

Course Outcomes

1. Educate various spaces with examples using the concepts of Topology.
2. Learn the concepts of connectedness and its applications.
3. Construction of the geometric objects with the help of Identification Topology.
4. Establishment of the applications of compactness.
5. Analyze the properties of separation axioms with the help of Normal spaces.

Module 1	**Topological spaces**	**7 hours**

Metric and Topological spaces, Accumulation points, Closed sets, Closure of a set, Interior, exterior, boundary, Neighborhoods and neighborhood systems, Convergent sequences, Coarser and finer topologies.

Module 2	**Subspaces**	**6 hours**

Subspaces, relative topologies. Equivalent definitions of topologies, Base for a topology, Subbases, Topologies generated by classes of sets, Local bases.

Module 3	**Continuous functions**	**6 hours**

Continuous functions, arbitrary closeness, Continuity at a point, Sequential continuity at a point, Open and closed functions, Homeomorphic spaces, Topologies induced by functions, Metric topologies, Metrization problem, Convergence and continuity in metric spaces.

Module 4	**Countability and Separation**	**6 hours**

First and Second countable spaces, Lindelöf's theorems, Separable spaces, Hereditary properties, T_1-spaces. Hausdorff spaces. Regular spaces. Normal spaces, Urysohn's lemma and metrization theorem, Functions that separate points, Completely regular spaces.

Module 5	**Compactness**	**6 hours**

Covers. Compact sets, Subsets of compact spaces, Finite intersection property, Compactness and Hausdorff spaces, Sequentially compact sets, Countably compact sets, Locally compact spaces, Compactification, Compactness in metric spaces, Totally bounded sets, Lebesgue numbers for covers.

Module 6	**Connectedness**	**6 hours**

Separated sets, Connected sets, Connected spaces, Connectedness on the real line, Components, Locally connected spaces, Paths, Arcwise connected sets, Homotopic paths, Simply connected spaces.

Module 7	**Product topology and Completeness**	**6 hours**

Product topology, Base for a finite product topology, Defining subbase and defining base for the product topology, Tychonoff product theorem, Cauchy sequences. Complete metric spaces, Principle of nested closed sets, Completeness and contracting mappings,

Completions, Baire's category theorem, Completeness and compactness.		
Module 8	**Contemporary Issues**	**2 hours**
	Total Lecture hours :	**45 hours**
	Total Tutorial hours:	**15 hours**

Text Books:

1. James R. Munkres, Topology, Pearson, 2nd Edition, Pearson, 2022.
2. G. F. Simmons, Introduction to Topology and Modern Analysis, 1st Edition, McGraw-Hill Education, 2015.

Reference Books:

1. James Dugundji, Topology, Universal Book Stall, New Delhi, 1999.
2. S. Kumaresan, Topology of Metric spaces, Narosa Publishing House, 2018.
3. M. A. Armstrong, Basic Topology, Springer-Verlag, 2005.
4. J. L. Kelly, General Topology, Springer-Verlag, 2005.
5. R. Vaidyanathaswamy, Set Topology, Courier Corporation (Dover), 1960.

Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes			
Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT305L	Operations Research	L	T	P	C
		3	1	0	4
Pre-requisite	**NIL**	**Syllabus Version**			
		1.0			

Course Objectives

1. Understand the meaning, purpose, and tools of Operations Research.
2. The students will use operations research techniques to enhance systems and to manage scarce resources using current tools, frameworks and reusable resources.

Course Outcomes :

At the end of this course, students will be able to

1. Model the real problems into LP and solves using graphical and simplex methods.
2. Understand the concept of duality in linear programming and Integer programming.
3. Classify and handle different types of transportations problems and assignment problems.
4. Apply the sequencing techniques to execute a series of jobs in a sequential order.
5. Develop mathematical models that associated with network flows, Construct the project activity network diagram and critically analyse the projects with deterministic and probabilistic activity times.

Module:1	**Linear Programming**	**7 hours**

Introduction to linear Programming (LP) – Formulation – Graphical solution to LP – Types of solutions – Standard and canonical forms of LP – The Simplex method – Big M-Method – Two-phase Method – Special cases in simplex method and its applications.

Module:2	**Duality in Linear Programming**	**6 hours**

Dual and Primal Problems – Duality theorems –Dual Simplex method – Post-optimal sensitivity analysis.

Module:3	**Integer Programming**	**6 hours**

Integer Programming – Formulation – Branch and Bound algorithm – Cutting Plane algorithm.

Module:4	**Transportation Problems**	**6 hours**

Transportation problem (TP)– various methods to find Initial basic feasible solution, methods – MODI method – Degeneracy in TP – Stepping stone method – Transhipment problem – maximization in a transportation problem.

Module:5	**Assignment Problems**	**6 hours**

Assignment problem – Unbalanced assignment problem – Hungarian method–Crew assignment,Travelling salesman Problem.

Module:6	**Sequencing Problems**	**6 hours**

Sequencing problem – Processing jobs 2 machines – Processing 2 jobs k machines- Processing jobs k machines– Maintenance crew scheduling.

Module:7	**Network Models**	**6 hours**

Minimal Spanning Tree Algorithm – Shortest Route Problem – Maximal Flow Model – Minimum cost capacitated flow problems – CPM and PERT.

Module:8	**Contemporary Issues**	**2 hours**

Total Lecture hours:	**45 hours**
Total Tutorials hours:	**15 hours**

Text Books

1. Operations Research an Introduction, H. A. Taha, Pearson, 11th Edition, 2022.
2. Operations Research, Kanti Swarup, P.K. Gupta, and Manmohan, S. Chand, 2019.

Reference Books

1. Operations Research, Hiller and Lieberman, 11th Ed, McGraw Hill, 2021
2. Operations Research, Winston, 4th ed, Thomson Learning, 2007.

3. Optimization in Operations Research, Ronald L. Rardin, 2nd Ed, Pearson, 2019. 4. Linear Programming, S.I. Gass, 5rd Edition, McGraw Hill, New York, 2003.			
Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes			
Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

Course code	Course Title	L	T	P	C
TMAT401L	Calculus of Variations and Integral Equations	3	1	0	4
Pre-requisite	TMAT204L - Ordinary Differential Equations	Syllabus Version			

Course Objectives

1. To introduce the necessity of calculus of variations in various physical phenomena.
2. To introduce different types of Integral equations arising in several engineering sectors, and methods/tools for solving different types of integral equations
3. To introduce the concept of resolvent kernels, Eigenvalues and eigenvectors of Fredholm integral equations, Green's function for a boundary value problem.

Course Outcomes

1. Formulate and solve Euler problems and justify several aspects of the solution.
2. Solve differential equation with several dependent variables.
3. Conceptual understanding of relationship between linear differential equations and integral equations, and solutions.
4. Construct Green's function for a boundary value problem.
5. Solve integral equations using Fourier transform.

Module:1	Calculus of Variations	7 hours

The problem of minimum surface of revolution - Minimum energy problem – Brachistochrone problem - Variational problems involving several functions – Isoperimetric problem - Variational problems in parametric form Euler Poisson equation - Application of Calculus of Variation - Hamilton's principle - Lagrange's and Hamilton's equations.

Module:2	Variational problems with moving boundaries	5 hours

Variational problems with moving boundaries - Variational problem with a moving boundary for a functional dependent on two functions – One sided variations.

Module 3	Sufficient conditions for extrema	6 hours

Proper field, central field and field of extremals – Jacobi condition – Weierstrass function – Legendre's condition – Nature of extremal of functionals, Direct methods of Ritz and Kantorovich methods and applications.

Module 4	Fundamentals of Integral Equations	7 hours

Definition and classification of linear integral equations - Relation between differential and integral equations - Conversion of initial and boundary value problems into integral equations - Conversion of integral equations into differential equations and Integro-differential equations - Solution of Integro-Differential Equations through Laplace Transform.

Module 5	Solution of Integral Equations	7 hours

Fredholm integral equation with separable kernel: Theory and Examples, Solution of integral equations by successive substitution, Solution of integral equations by successive approximations: Resolvent kernel - Direct computation, Adomian decomposition - Solution of integral equations with symmetric kernels.

Module 6	**Eigenvalues and Eigen functions of Integral Equations**	**5 hours**
Eigenvalues and Eigen functions - Neumann series - Hilbert-Schmidt theorem, construction of Green's function for BVP, singular integral equations.		
Module 7	**Fredholm Theory and Applications of Integral Equations**	**6 hours**
Fredholm method of solution and Fredholm theorems - Solution of integral equations using Fourier transform, Solution of a boundary value problem - Green's function approach for converting an initial value problem into an integral equation.		
Module 8	**Contemporary Issues**	**2 hours**
Industry Expert Lecture		

	Total Lecture hours:	**45 hours**	
	Total Tutorial hours:	**15 hours**	

Text Book(s)	
1	Filip Rindler, Calculus of variations, 2018, First Edition, Springer Cham, New York.
Reference Books	
1	Weinstock Robert, Calculus of Variations With Applications to Physics and Engineering, 1974, Dover Publications INC, New York.
2	Jerry, Abdul J., Introduction to Integral Equations with applications, 1999, 4th Edition, Wiley.
3	M.D. Raisinghania, Integral equations and boundary value problems, S. Chand & Company Pvt. Ltd., New Delhi.
4	David Porter, and David S.G. Stirling, Integral Equations: A Practical Treatment, from Spectral Theory to Applications, 1990, Cambridge texts in Applied Mathematics.
5	Ram P. Kanwal, Linear Integral Equations: Theory and Technique, 1997, Springer.
Mode of Evaluation: Continuous Assessment Tests, Final Assessment Test, Digital Assignments, Quizzes.	

Recommended by Board of Studies			
Approved by Academic Council		Date	

Course Code	Graph Theory	L	T	P	C
TMAT402L		3	1	0	4
Pre-requisite	TMAT303L Discrete Mathematical Structures	Syllabus version			

Course Objectives

1. To introduce the fundamental concepts of graph theory
2. To introduce how to apply graph theoretical tools in solving practical problems
3. To introduce the proof writing skills and Model problems using graphs

Course Outcomes

1. Learn the concepts of graph operations, trees and applications of trees
2. Apply the concepts of graph colouring, matching and covering in different engineering disciplines
3. Analyse the concepts of domination and spectra of graphs
4. Understand the applications of Ramsey theory in real life problems.
5. Know the basics of directed graph and its properties

Module:1	Graphs	5 hours

Basics of graphs - Incidence and adjacency matrices of graphs – Isomorphism – Euler and Hamiltonian graphs - Operations on Graphs - Graph products - Graphic Sequences.

Module:2	Trees and Graph Colouring	7 hours

Trees – Breadth First Search – Depth First Search - Chromatic number - Chromatic index - The greedy algorithm - The Five-Colour Theorem – Konig's Theorem for colouring - Brook's theorem - Vizing's theorem - Applications of graph colouring - Scheduling Problem.

Module:3	Matching and Factorization	7 hours

Matching - Maximum matching - Perfect matching - Hall's theorem - Tutte's theorem – Covering – Konig's Theorem for matching – Factorization: 1-factorable - Petersen's theorem -2-factorable – decomposition of graphs - Graceful labelling - Graceful graph.

Module:4	Domination and Independence Number	7 hours

Clique - Independence number - Perfect Graph Theorem - Dominating set - Domination number - Bounds on domination number - Conditions on domination set - Varieties of dominations.

Module:5	Networks and Spectra of Graphs	6 hours

Flows – Cuts - Max-flow - Min-cut theorem - Eigenvalues of a graph - Eigen vectors - Spectrum of a graph - Spectral radius - polynomial - Energy of a graph.

Module:6	Ramsey Theory and Enumerations	5 hours

Introduction to Ramsey theory - Ramsey numbers - Ramsey's theorem - Types of enumerations - Polya's theory of enumeration.

Module:7	Directed graphs	6 hours
Digraphs - Sub digraphs - Directed paths and cycles – in degree – out degree - Euler digraphs – Hamiltonian – Isomorphism - Orientations and Tournaments - Fundamental circuits and circuit matrix		
Module:8	**Contemporary Issues**	**2 hours**
Guest Lecture from Industry and R & D Organizations		
	Total Lecture hours: **Total Tutorial Hours:**	**45 hours** **15 hours**

Text Book(s)

1.	Douglas B. West., "Introduction to Graph Theory ", 2009, 2nd Edition, Prentice Hall India.
2.	R. Diestel, "Graph Theory", 2017, 5th Edition, Springer, Berlin.

Reference Books

1.	T. W. Haynes, S. T. Hedetniemi, P. J. Slater, Fundamentals of Domination in Graphs, 1998, CRC Press.
2.	Bondy J. A. and Murty U. S. R., "Graph Theory", 2011, Springer.
3.	Bela Bollobas, Modern Graph Theory, 2013, Springer.
4.	R. Balakrishnan, K. Ranganathan, A textbook of Graph Theory, 2012, 2nd Edition, Springer.

Mode of Evaluation: CAT, Written Assignment, Quiz, FAT and Seminar

Recommended by Board of Studies	DD-MM-YYYY	
Approved by Academic Council	No. xx	Date DD-MM-YYYY

TMAT403L	Functional Analysis	L	T	P	C
		3	1	0	4

Pre-requisite	TMAT203L Real Analysis TMAT202L Linear Algebra	Syllabus Version
		1.0

Course Objectives

1. To introduce infinite-dimensional vector spaces.
2. To introduce the ideas and some of the fundamental theorems of functional analysis.
3. To provide a working knowledge of the basic properties of Banach spaces, Hilbert spaces, bounded linear operators, compact linear operator and inner product spaces.

Course Outcomes

1. Understand how functional analysis uses and unifies ideas from vector spaces, the theory of metrics, and complex analysis.
2. Apply fundamental theorems from the theory of normed and Banach spaces, including the Hahn-Banach theorem, the open mapping theorem, the closed graph theorem, and the Uniform boundedness principle.
3. Appreciate the role of inner product spaces and apply ideas from the theory of Hilbert spaces to other areas.
4. Apply the projection theorem and spectrum of bounded operators.
5. Understand the fundamentals of spectral theory.

Module 1: Linear Spaces	**6 hours**
Linear spaces, Linear maps, Finite dimensional linear space, Holder's Inequality, Minkowski's Inequality, Separability, Completeness, Hyperspace	

Module 2: Normed Linear Spaces	**7 hours**
Normed Linear Space, Banach spaces and their examples - $K^n, M_{n\times n}, c_0, c_{00}, C[a,b], l^p, L^p,$ $p \geq 1,$ Quotient norm, Riesz Lemma, Equivalence of norms, Convexity.	

Module 3: Linear Operators	**6 hours**
Continuity and Boundedness of Linear operators, Hahn Banach separation and extension theorems, Dual spaces and their examples.	

Module 4: Fundamental Theorems	**6 hours**
Open Mapping Theorem, Closed Graph theorem, Uniform Boundedness theorem, Banach Steinhaus theorem, Resonance theorem.	

Module 5: Hilbert Spaces	**6 hours**
Inner product spaces – Cauchy Schwartz Inequality, Hilbert Space, orthonormal basis, Orthogonal Complement, Riesz-Fischer theorems, Riesz Representation theorem.	

Module 6: Basic Operator Theory	**6 hours**

Bounded operators and adjoint operator, Projections, Projection theorem, Normal, Unitary and self-adjoint operators, spectrum of a bounded operator.			
Module 7: Spectral Theory of Linear Operators			**6 hours**
Compact Operators, Spectral Theorem for the Compact Self-adjoint Operators.			
Module 8: Contemporary Issues			**2 hours**
		Total Lecture hours:	**45 hours**
		Total Tutorial hours:	**15 hours**
Text Books			
1. M. Thamban Nair, Functional analysis – A First Course, 2021, Second edition, PHI-Learning, India.			
Reference Books			
1. Erwin Kreyszig, Introductory Functional Analysis with Applications, 2007, John Wiley & Sons. 2. Kosaku Yosida, Functional Analysis, 1974, 4th Edition, Narosa Publishing House, India. 3. B.V. Limaye, Functional analysis, 2006, 2nd rev edition, New Age International. 4. John. B. Conway, A course in functional analysis, 2007, Springer.			
Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes			
Recommended by Board of Studies			
Approved by Academic Council			

Course Code	Partial Differential Equations	L	T	P	C
TMAT404L		3	1	0	4
Pre-requisite	TMAT204L–ORDINARY DIFFERENTIAL EQUATIONS	Syllabus version			

Course Objectives

1. To introduce the first and second order partial differential equations.
2. To introduce how to apply first and second order partial differential equations to different physical problems.
3. To introduce how to apply the transform methods and Green's function technique for solving partial differential equations.

Course Outcome

1. Show the application of partial differential equations in several physical problems
2. Familiarize the significance of elliptic, parabolic and hyperbolic partial differential equations
3. Explain the weak formulation of partial differential equations
4. Familiarize the associated mathematical techniques in several physical problems
5. Application of Fourier transform for solving second order partial differential equations

Module:1	First Order Partial Differential Equations	8 hours

Review of Multivariable Calculus: Inverse Function Theorem and Implicit Function Theorem, Integration-by-parts, Green's theorem, Integral Curves and Surfaces of Vector Fields, Formation and Classification of first order partial differential equations, Linear and quasi-linear first order partial differential equations, Cauchy's problem for first order partial differential equations, Cauchy-Kowalevski Theorem, Method of Characteristics, Charpit's Method, Jacobi's method for nonlinear partial differential equations.

Module:2	Second Order Partial Differential Equations	6 hours

Classification of second order partial differential equations, Canonical forms, Well-posed problems, Super- position principle, Method of separation of variables for elliptic, parabolic and hyperbolic partial differential equations.

Module:3	Elliptic Partial Differential Equations	6 hours

Laplace equation: Basic concepts, Types of Boundary value problems, Maximum and Minimum principle, Fundamental Solution, Mean Value Property, Poisson Integration Formula, Dirichlet problems for the rectangle, for annuli and for the disk, Exterior Dirichlet Problem.

Module:4	Parabolic and Hyperbolic Partial Differential Equations	6 hours

Heat Equation: Formulation of Heat Equation, Maximum Principle, Minimum Principle, Uniqueness and continuous dependence, Method of separation of variables, Duhamel's Principle.

Wave Equation: Formulation of wave Equation, Infinite String problem, D'Alembert's solution of wave

equation, Semi-Infinite String problem, Finite Vibrating String problem, Non-homogeneous wave equation.		
Module:5	**Fourier Transforms in Partial Differential Equations**	**6 hours**
Complex Fourier Transform, Fourier sine and cosine transforms, Heat flow problem in an infinite and semi infinite rods, infinite string problem, Laplace equation on half plane.		
Module:6	**Green's Function in Partial Differential Equations**	**5 hours**
Integral formulation, Green's identity, Green's theorem and its applications, method of Green's function for Laplace, Heat and Wave equations.		
Module:7	**Introduction to Weak Formulation of Partial Differential Equations**	**6 hours**
Introduction to Sobolev Spaces, Weak Formulation of partial differential equations: Laplace, Heat and Wave equations, Weak Solution of Conservation Laws, Entropy Solutions of Conservation Laws and its well-posed ness.		
Module:8	**Contemporary Issues**	**2 hours**
Guest Lecture from Industry and R & D Organizations		
	Total Lecture hours:	**45 hours**
	Total Tutorial hours:	**15 hours**

Textbook

1.	A. K. Nandakumaran, P. S. Datti, Partial Differential Equations, Classical Theory with a Modern Touch, 2020, Cambridge University Press.

Reference Books

1.	Yehuda Pinchover, Jacob Rubinstein, An Introduction to Partial Differential Equations, 2005, Cambridge University Press.
2.	Lawrence C. Evans, Partial Differential Equations, 2010, American Mathematical Society.

Mode of Evaluation: CAT, Digital Assignments, Quiz, FAT

Recommended by Board of Studies	DD-MM-YYYY	
Approved by Academic Council	No. xx	Date DD-MM-YYYY

Course Code	Transform Techniques	L	T	P	C
TMAT405L		3	1	0	4
Pre-requisite	TMAT104L – ORDINARY AND PARTIAL DIFFERENTIAL EQUATIONS	Syllabus version			

Course Objectives

1. To introduce and when to apply various transforms.
2. To introduce the definition and properties of various transforms and their inverse.
3. To be able to solve simple real world problem (ODE & PDE) using various transforms.

Course Outcomes

1. Acquire knowledge in integral transform- Hankel, Mellin and Legendre Transforms.
2. Acquire knowledge in Laguerre and Hermite Transforms.
3. Implement Fast Fourier Transform (FFT) and its application in real world problem.
4. Solve PDE using various transforms.
5. Apply various transforms on real world problem solving.

Module:1	Hankel Transforms	7 hours

Hankel Transform - Definition and Basic operational property of Hankel transform, Inversion theorem, transform of the derivative of functions, transform of elementary functions, Parseval's theorem, Relation between Laplace transform and Hankel transform.

Module:2	Mellin Transforms	6 hours

Mellin Transform - Definition and elementary properties, shifting and scaling properties, Mellin transform of derivative and integrals.

Module:3	Legendre Transforms	7 hours

Introduction – Definition of Legendre Transforms and Examples – Properties of Legendre Transforms – Applications of Legendre Transforms to Boundary Value Problems.

Module:4	Laguerre Transforms	6 hours

Introduction – Definition of the Laguerre Transform and Examples – Basic Operational Properties – Applications of Laguerre Transforms.

Module:5	Hermite Transforms	6 hours

Introduction – Definition of the Hermite Transform and Examples – Basic Operational Properties.

Module:6	Wavelets and Wavelet Transforms	6 hours

Brief Historical Remarks – Continuous Wavelet Transforms – The Discrete Wavelet Transform – Examples of Orthonormal Wavelets.

Module:7	Fast Fourier Transform	5 hours

Discrete Fourier transform in algorithmic format, Danielson-Lanczos lemma, Fourier Matrix, The Cooley-Tukey Algorithm, Fast Fourier Transform Algorithm and Applications in digital signal processing.		
Module:8	**Contemporary Issues**	**2 hours**
Guest Lecture from Industry and R & D Organizations.		
	Total Lecture hours: **Total Tutorial hours:**	**45 hours** **15 hours**

Text Book(s)

1. Debnath L., Bhatta D., Integral transforms and their Applications, 2015, 3rd Edition, CRC Press, Boca Raton.
2. K.R. Rao, Do Nyeon Kim, Jae Jeong Hwang, Fast Fourier Transform - Algorithms and Applications (Signals and Communication Technology), 2010, Springer.

Reference Books

1. B. Davis, Integral Transforms and Their Applications, 2002, Springer.
2. Patra B., An Introduction of Integral Transform, 2018, Taylor & Francis.
3. Drof R.C., Transform and Applications, 2010, 3rd Edition, Taylor & Francis.

Mode of Evaluation: CAT, Written Assignment, Quiz, FAT and Seminar		
Recommended by Board of Studies	DD-MM-YYYY	
Approved by Academic Council	No. xx	Date DD-MM-YYYY

Course code	Course Title	L	T	P	C
TMAT406L	Measure and Integration	3	1	0	4

Pre-requisite	TMAT203L - Real analysis	Syllabus Version

Course Objectives:

1.To introduce a new perspective on integration of functions.

2.To explain the importance of Measure theory for the development of functional analysis and probability theory.

3.To demonstrate the advancements of basic integration theory and the applications in various fields.

Course Outcome:

The students can expect

1. To familiarize the concept of Lebesgue measure, measurable sets and approximation of a measurable function by simple measurable function.

2. To familiarize the concept of Lebesgue integral and concepts related to them.

3. To use measure theory in Riemann integration and calculus

4. To classify the absolute continuous functions and functions of bounded variation.

5. To familiarize the decomposition of measures.

Module:1	Riemann Integration	4 hours

Riemann integration overview, Characterisation of Riemann integrable functions, Theoretical view of Riemann integral.

Module:2	Measure on the Real Line	7 hours

Lebesgue outer measure, Measurable sets, Measurable functions, General integration, Borel and Lebesgue measurability, Extension of a measure, Uniqueness of measure.

Module:3	Lebesgue Measure on $\mathbb{R}$ and its properties	7 hours

Lebesgue measurable sets, Lebesgue measure, Regularity, Measurable functions, Non-measurable sets, Lebesgue measurable functions, Borel Lebesgue measurability, Monotone convergence theorem, Fatou's lemma, Dominated convergence theorem.

Module:4	Integration of functions of a Real Variable	8 hours

Integration of non-negative functions, Integration of series, Integration of non-negative measurable functions, Integration of non-negative simple measurable functions, Improper Riemann integral and its relation with Lebesgue integral.

Module:5	Fundamental theorem of calculus for the Lebesgue integral	8 hours

Continuous non differentiable functions, Functions of bounded variation, Lebesgue's differentiation theorem, Absolute continuous functions, Statement of Vitali's lemma and almost everywhere differentiability of monotone increasing functions, Fundamental theorem of calculus and its applications.

Module:6	**Signed Measures and their Derivatives**	**4 hours**
Signed measures and Hahn decomposition, The Jordan decomposition, The Radon-Nikodym theorem and its applications.		
Module:7	**Inequalities and L^P Spaces**	**5 hours**
L^p -spaces, Jensen's inequality, Minkowski inequality, Hölder inequality, Convergence in L^p, Completeness of L^p, L^p (μ)spaces and their properties.		
Module:8	**Contemporary Issues**	**2 hours**
Industry Expert Lecture		
	Total Lecture hours:	**45 hours**
	Total Tutorial hours:	**15 hours**

Text Book(s)	
1	G. de Barra, Measure Theory and Integration, 2000, Third Edition, New Age International Pvt. Limited, New Delhi.
2	Ammar Khanfer, Measure Theory and Integration, 2023, First Edition, Springer, Singapore.
Reference Books	
1	Elias. M. Stein, Rami. Shakarchi. Real Analysis: Measure Theory, Integration, and Hilbert Spaces. Princeton University Press, 2005.
2	H.L. Royden, P.M. Fitzpatrick. Real Analysis, 4th ed., Pearson education, 2011.
3	S. Shirali. A Concise Introduction to Measure Theory, Springer, 2018.

Mode of Evaluation: Continuous Assessment Tests, Final Assessment Test, Digital Assignments, Quizzes.			
Recommended by Board of Studies			
Approved by Academic Council		Date	

Course code	Course title	L	T	P	C
TMAT407L	STATISTICAL INFERENCE	3	0	0	3
Pre-requisite	TMAT201L – Probability and Statistics				Syllabus version
					1.0

Course Objectives

1. To introduce the basic concepts of parametric estimation
2. To introduce the study properties and methods of statistical estimation theory and construct the confidence intervals
3. To draw inference about unknown population parameters based on random samples
4. To impart knowledge on statistical hypothesis
5. To inculcate various parametric and non-parametric test procedures

Course Outcome

At the end of the course the student will be able to

1. Understand the concepts and importance of properties of estimators.
2. Obtain the optimal estimator for a given parametric function
3. Construct confidence intervals for population parameters
4. Test statistical hypothesis by selecting suitable test procedure.
5. Determine the size of critical region and power of test function.
6. Solve real life problems by applying suitable parametric / nonparametric testing procedure

Module:1	**Introduction**	**6 hours**
Population, sample, parameter and statistic – Characteristics of good estimator – Unbiasedness – Consistency – Efficiency – Sufficiency – Minimum Variance Unbiased estimator – Uniformly Minimum Variance Unbiased estimator – Mean squared error.		
Module:2	**Point Estimation**	**6 hours**
Introduction to Point estimation - Methods of point estimation – Maximum Likelihood Estimation – Method of Moments – Method of Minimum Chi-Square – Method of modified Minimum Chi-Square.		
Module:3	**Interval Estimation**	**6 hours**
Interval Estimation: Confidence level and confidence coefficient – Confidence intervals for mean, variance of normal population, difference between mean and ratio of two normal populations.		
Module:4	**Exact Sampling Distributions**	**6 hours**
t-distribution, properties and applications, F-distribution, properties and applications, Chi-square distribution, properties and its applications.		
Module:5	**Testing of Hypothesis I**	**6 hours**
Testing of Hypothesis – Simple and composite – Null and Alternative hypothesis – Two kinds of errors – Level of significance – Size and power of a test.		
Module:6	**Testing of Hypothesis II**	**6 hours**
Most powerful test – Uniformly most powerful test – Neyman-Pearson Lemma – Example problems of NP Lemma – Likelihood ratio test – Properties.		
Module:7	**Non- Parametric Tests**	**7 hours**
Non-parametric tests – Kolmogorov-Smirnov test – Sign test – Wald-Wolfowitz run test – run test for randomness – Median test – Wilcoxon test – Mann-Whitney U test.		
Module:8	**Contemporary issues**	**2 hours**

Expert lectures, Seminars, Webinars			
	Total Lecture hours		**45hours**
Text Book(s)			
1.	Rajagopalan, M., and Dhanavanthan, P. Statistical Inference 2012, PHI Learning Pvt., Ltd., New Delhi, .		
2.	V. K. Rohatgi and A. K. Saleh, An Introduction to Probability and Statistics, 2015,3rd Edition, Wiley Publishers.		
Reference Books			
1.	Lehman, E. L., and Cassella, G. Theory of Point Estimation,1998, Second Edition, Springer,		
2.	Lehmann, E. L. Testing Statistical Hypotheses, Third Edition, Springer, 2010		
3.	Goon, A. M., Gupta, M. K., Das Gupta. B. An outline of Statistical Theory, 1973,Vol. II, World Press, Calcutta.		
4.	Rao, C.R. Linear Statistical Inference and Its Applications,1973, 2nd Edition,, Wiley Eastern Ltd.		
Mode of Evaluation: CAT / Written assignment / Quiz / FAT / Project / Seminar			
Mode of Evaluation: Continuous Assessment and FAT			
Recommended by Board of Studies			
Approved by Academic Council	No.	Date	

Course code	Course title	L	T	P	C
TMAT407P	STATISTICAL INFERENCE LAB	0	0	2	1
Pre-requisite	TMAT201P – Probability and Statistics Lab				Syllabus version
					1.0

Course Objectives

1. To introduce the basic concepts of parametric estimation
2. To introduce the study properties and methods of statistical estimation theory and construct the confidence intervals
3. To draw inference about unknown population parameters based on random samples
4. To impart knowledge on statistical hypothesis
5. To inculcate various parametric and non-parametric test procedures

Course Outcome

Students are able to

1. Understand the concepts and importance of properties of estimators.
2. Obtain the optimal estimator for a given parametric function
3. Construct confidence intervals for population parameters
4. Test statistical hypothesis by selecting suitable test procedure.
5. Determine the size of critical region and power of test function.
6. Solve real life problems by applying suitable parametric / nonparametric testing procedure

List of Challenging Experiments (Indicative)

1	Normality test, t test, Paired t test and independent t test	4 Hours
2	F Test,	2 Hours
3	Chi-square test	2 Hours
4	Maximum Likelihood estimation	2 Hours
5	Kolmogorov-Smirnov test	4 Hours
6	Wald-Wolfowitz run test – run test for randomness	4 Hours
7	Sign test — Median test	4 Hours
8	Wilcoxon test – Mann-Whitney U test.	4 Hours
9	Kruskal Wallis test	4 Hours
	Total	**30 Hours**

Text Books

1. Christian Heumann, Michael Schomaker and Shalabh. Introduction to Statistics and Data Analysis With Exercises, Solutions and Applications in R, 2017,Springer Cham.

Discipline Elective

TCSE204L	Data Structures	L	T	P	C
		3	1	0	4
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To understand the fundamentals of data structures and algorithms.
2. To determine the impact of data structures and algorithm design methodologies on programme performance.
3. To get understanding into the problem's fundamental nature and to create software systems of varying complexity.

Course Outcomes

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

1. Use basic features of Data Structures, evaluate and offer appropriate strategies for solving an issue and analyze algorithm performance using asymptotic notations.
2. Demonstrate many sorts of algorithmic problem-solving methodologies and evaluate the trade-offs involved.
3. Analyse basic graph algorithms, operations and applications through a structured (well-defined) algorithmic approach.
4. Use of several sorting technique in real life applications.
5. Apply some searching algorithm in real world problems.

Module:1	**Algorithms and Analysis of Algorithms**	**7 hours**

Definition, Structure and Properties of Algorithms, Development of an Algorithm, Data Structures and Algorithms, Data Structure – Definition and Classification, Efficiency of Algorithms, Apriory Analysis, Asymptotic Notations, Time Complexity of an Algorithm using O Notation, Polynomial Vs Exponential Algorithms, Average, Best and Worst case Complexities, Analyzing Recursive Programs.

Module:2	**Arrays, Stacks and Queues**	**5 hours**

Array Operations, Number of Elements in an Array, Representation of Arrays in Memory, Applications of Array, Stack-Introduction, Stack Operations, Applications of Stack, Queues-Introduction, Operations on Queues, Circular Queues, Other Types of Queues, Applications of Queues.

Module:3	**Linked List, Linked Stacks and Linked Queues**	**7 hours**

Singly Linked Lists, Circularly Linked Lists, Doubly Linked Lists, Multiply Linked Lists, Applications of Linked Lists, Introduction to Linked Stack and Linked Queues, Operations on Linked Stacks and Linked Queues, Dynamic Memory Management and Linked Stack, Implementations of Linked Representations, Applications of Linked Stacks and Linked Queues.

Module:4	**Trees, Binary Trees, BST, AVL Trees and B Trees**	**6 hours**

Trees: Definition and Basic Terminologies, Representation of Trees, Binary Trees: Basic Terminologies and Types, Representation of Binary Trees, Binary Tree Traversals, Threaded Binary Trees, Applications, BST & AVL Trees: Introduction, BST: Definition and Operations, AVL Trees: Definition and Operations, B Trees: Introduction, m-way search trees: Definition and Operations, B Trees: Definition and Operations, Heap.

Module:5	**Graphs**	**6 hours**

Introduction, Definitions and Basic Terminologies, Representations of Graphs, Graph Traversals, Single-Source Shortest-Path Problem, Minimum Cost Spanning Trees.

Module:6	**Sorting**	**6 hours**

Introduction, Shell Sort, Quick Sort, Heap Sort.

Module:7	**Searching**	**6 hours**

Introduction, Binary Search, Transpose Sequential Search, Interpolation Search.

Module:8	**Contemporary Issues**	**2 hours**

	Total Lecture hours: **Total Tutorial hours**	**45 hours** **15 hours**

Text Books				
1.	G A V Pai – Data Structures and Algorithms: Concepts, Techniques and Applications, 2nd Edn, Tata McGraw-Hill, 2008.			
2.	Horowitz E.Sahni, S., Susan A., Fundamentals of Data Structures in C, 2nd Edition, University Press, 2010.			
Reference Books				
1.	J. P. Tremblay , P. G. Sorenson – An Introduction to Data Structures With Applications, 2nd Edn, McGraw-Hill, Inc. New York, NY, USA, 2017.			
2.	Seymour Lipschutz – Data Structures, 6th Edition (9th Reprint), Tata McGraw-Hill, 2008,			
3.	Adam Drozdek – Data Structures and Algorithms in C++, Thomson Learning, ND– 2007.			
Mode of Evaluation: CAT, Digital Assignments, Quizzes and FAT				
Recommended by Board of Studies		15-02-2022		
Approved by Academic Council		No. 65	Date	17-03-2022

TCSE205L	Database Management	L	T	P	C
		3	1	0	4
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To explore advantages of using a DBMS rather than a file system and designing an Entity-Relationship model for a real-life application.
2. To evaluate relational schemas for design qualities and optimize a query.
3. To have basic concepts on transaction processing, concurrency control and to access database using various algorithms.

Course Outcomes

1. Describe the function of a database management system in an organization.
2. Describe the structure and operation of the relational data model.
3. Use Structured Query Language (SQL) to create database queries.
4. Design and implement a database project based on company needs while taking into account various design issues.
5. Implement the database transaction concept and related database features.

Module:1	**Introduction to Database Systems**	**7 hours**

Purpose of Database Systems, View of Data. Database Language, Transaction Management, Database Architecture, Database Users Administrator. Database Design and Entity- Relational Model: Overview of Design Process, E-R model, Constraints, E-R diagrams, Weak Entity Sets, Extended E-R Features.

Module:2	**Relational Model**	**6 hours**

Structure of relational databases, Fundamental Relational Algebra, Operation, Additional Operations, Tuple Relational, Calculus.

Module:3	**SQL and Advanced SQL**	**6 hours**

Data Definition, basic structure of SQL Operations, Set Operations, Aggregate Functions, NULL Values, Nested Sub-Queries, Complex Queries, views and modifications of database, SQL data Type and schemas, integrity constrains, Authorization, Embedded SQL.

Module:4	**Relational Database Design**	**6 hours**

Atomic domains and First Normal form, decompositions using Functional dependencies, decompositions using Multi-valued dependencies, More Normal forms.

Module:5	**Indexing and Hashing**	**6 hours**

Basic concepts, Ordered Indices, B+ tree index files, B tree index files, Multiple Key Access, Hashing, comparison of ordered Indexing and Hashing.

Module:6	**Query Processing**	**5 hours**

Overview, measures of Query cost, Selection operation, sorting join Operations.

Module:7	**Transaction and Concurrency Control**	**7 hours**

Transaction concepts and ACID properties, Transaction States, Concurrent executions, Serializability and its Testing, Recoverability, Introduction to Concurrency Control, Locked base Protocol and Deadlock handling, Timestamp- based Protocol, Validation-based Protocol. Multiple Granularity.

Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**
	Tutorial hours:	**15 hours**

Text Books

1. Abraham Silberschatz, Henry F. Korth and S. Sudarshan, Database System Concepts, McGraw-Hill Education (Asia), Fifth Edition, 2006.
2. C. J. Date, A. Kannan and S. Swamynathan, An Introduction to Database Systems, Pearson Education, Eighth Edition, 2009.

Reference Books

1. Ramez Elmasri and Shamkant B. Navathe, Fundamentals of Database Systems,

	Pearson Education, Seventh Edition, 2016.		
Mode of Evaluation:CAT, Quizzes, Digital Assignments and FAT			
Recommended by Board of Studies	15.02.2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT306L	Number Theory	L	T	P	C
		3	0	0	3
Pre-requisite	**NIL**	**Syllabus Version**			
		1.0			

Course Objectives

1. To provide the requisite and relevant background necessary to understand the other important number theoretical techniques offered for Engineers and Scientists.
2. To introduce important topics of applied mathematics, namely Congruencies, Diophantine equations and Arithmetical functions etc.
3. Enhance to use technology to model the physical situations into mathematical problems, experiment, interpret results, and verify conclusions.

Course Outcomes

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

1. Apply Euler, Fermat and Wilsons theorems to solve applied problems in engineering Scientific and research problems.
2. Evaluate solutions of congruence, studying properties arithmetic functions and Dirichlet multiplication.
3. Analyze Dirichlet's theorem for primes of the form *4n-1* and *4n+1*, distribution of primes in arithmetic progressions.
4. Explaining Quadratic residues and quadratic reciprocity law, applications of the reciprocity law, Gauss sums.
5. Understand and solving industrial issues using the above number theoretical tools.

Module:1	**Theory of Numbers**	**6 hours**

Divisibility; Greatest Common Divisor, Least Common Multiple, prime numbers, the fundamental theorem of arithmetic, Euclidean algorithm, greatest common divisor of more than two numbers.

Module:2	**Congruences**	**7 hours**

Definition and basic properties of congruences, Residue classes and complete residue systems, linear congruence, reduced residue system, Wilson, Euler and Fermat Theorems, Polynomial Congruences modulo *p*–Chinese remainder theorem and Applications.

Module:3	**Diophantine Equations**	**6 hours**

Some Diophantine equations: The equation ax+by = c - Positive solutions - Other linear equations - The equation $x^2 + y^2 = z^2$ - The Equation $x^4 + y^4 = z^4$ - The equation $4x^2 + y^2 = n$.

Module:4	**Arithmetical functions**	**6 hours**

Sigma Function, Tau Function, Dirichlet product, Dirichelet inverse, Mobius Function, Mobius inversion formula, Euler's Function, Euler's theorem.

Module:5	**Averages of Arithmetical Functions**	**6 hours**

Asymptotic Equality of functions, Euler Summation formula, Some Elementary asymptotic formulas, The average order of divisor, Mobious, Mangoldt and other functions.

Module:6	**Primitive roots and Indices**	**6 hours**

The order of a positive integer, Primality Tests, Primitive roots for primes, composite numbers having primitive roots, Algebra of Indices.

Module:7	**Quadratic Residues and Quadratic Reciprocity Law**	**6 hours**

Euler's criterion, Quadratic residues, Legendre Symbol and its properties, quadratic reciprocity law, Jacobi Symbol, Quadratic Congruences with prime and composite moduli.

Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Books

1. Elementary Number Theory, Burton, D. M, 7th Edition, McGraw Hill Education, 2016
2. Elementary Number Theory, Gareth A. Jones, Josephine M. Jones, Springer, 2013

Reference Books			
1. Introduction to Analytic Number Theory, Tom M. Apostol, Springer, Narosa, 2013. 2. An Introduction to the Theory of Numbers, Hardy, G.H. and Wright, E. M., 6th Edition, Oxford University Press, 2008. 3. An Introduction to the Theory of Numbers, Niven, I., Zuckerman, H. S. and Montegomery, H. L. 5th edition, Wiley, 2008.			
Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes			
Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT307L	Fuzzy Set Theory and its Applications	L	T	P	C
		3	0	0	3
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To understand the concepts of fuzzy sets and its operations.
2. To introduce advanced concepts in Fuzzy Mathematics leading to research.
3. To know fuzzy numbers and fuzzy relations.
4. To understand the application of fuzzy in various Engineering fields.
5. To impart knowledge and skills in fuzzy decision making problems.

Course Outcomes

1. Examine the Set theory problems.
2. Interpret the systems which include fuzziness within the scope of fuzzy set theory.
3. Acquire the concept of function with Integration and Differentiation of fuzzy Set.
4. Improve the knowledge in relation and graph of fuzzy set theory.
5. Solve problems that include uncertainty with using fuzzy set theory.

Module:1	**Fuzzy Set and Operations**	**5 hours**

Concepts of Fuzzy Set, Standard Operations of Fuzzy Set, Fuzzy Complement, Fuzzy Union, Fuzzy Intersection, Other Operations in Fuzzy Set, T- norms and T- conorms. Interval, Fuzzy Number, Operation of Interval, Operation of - cut Interval, Examples of Fuzzy Number Operation.

Module:2	**Fuzzy Numbers**	**6 hours**

Definition of Triangular Fuzzy Number, Operation of Triangular Fuzzy Number, Operation of General Fuzzy Numbers. Approximation of Triangular Fuzzy Number, Operations of Trapezoidal Fuzzy Number, Bell Shape Fuzzy Number.

Module:3	**Fuzzy Functions**	**6 hours**

Function with Fuzzy Constraint, Propagation of Fuzziness by Crisp Function, Fuzzifying Function of Crisp Variable, Maximizing and Minimizing Set, Maximum Value of Crisp Function.Integration and Differentiation of Fuzzy Function, Product Set,

Module:4	**Fuzzy Relations**	**6 hours**

Definition and Examples of Fuzzy Relation, Fuzzy Matrix, Operations on Fuzzy Relation.Composition of Fuzzy Relation, α- cut of Fuzzy Relation, Projection and Cylindrical Extension, Extension by Relation, Extension Principle, Extension by Fuzzy Relation, Fuzzy distance between Fuzzy Sets.

Module:5	**Fuzzy Graphs**	**5 hours**

Graph and Fuzzy Graph, Fuzzy Graph and Fuzzy Relation, α- cut of Fuzzy Graph.

Module:6	**Applications-I**	**8 hours**

Linguistic variables, Fuzzy logic, Fuzzy Languages, Approximate Reasoning, Expert systems, Uncertainty modeling in expert system, Fuzzy control, Pattern recognition, Fuzzy clustering.

Module:7	**Applications-II**	**7 hours**

Modelling the diagnostic process, Applications in Management, Fuzzy decisions, Fuzzy linear programming, Fuzzy Dynamic Programming.

Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Books

1. Klir and Yuan : Fuzzy sets and Fuzzy logic – Theory and Applications, 2nd Edition, Pearson, 2015.
2. H.J. Zimmerman, Fuzzy Set Theory and its Applications, 2nd Edition, Springer 2014.

Reference Books

1. Chander Mohan, An Introduction to Fuzzy Set Theory and Fuzzy Logic, Viva Books, 2018
2. George J Klir and Tina A Folger, Fuzzy sets, Uncertainty and Information, Prentice Hall of India, 2000.
3. Kwang H. Lee, First Course on Fuzzy Theory and Applications, Springer International Edition, 2005.

Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes			
Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT308L	Mathematical Statistics	L	T	P	C
		3	1	0	4
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

1. Study the concepts of law of large numbers in probability theory.
2. Study properties and methods of Bivariate distribution and Stochastic processes.
3. Inculcate the Sampling techniques and order statistics procedures.
4. Draw inference about unknown population parameters based on random samples.
5. Impart knowledge on Linear models.

Course Outcomes

1. Understand the concepts and importance of Law of large numbers.
2. Develop the properties of Bivariate distribution.
3. Develop the methods and properties of order statistics and Stochastic Processes.
4. Obtain the optimal estimator for a given parametric function.
5. Identify the applications of Sampling Techniques with real life problem.
6. Derive the estimation methods of linear model.

Module:1	Law of Large Numbers	7 hours

Law of Large Numbers: Weak and Strong Law of Large Numbers – Bernoulli's Weak Law of Large Numbers - Kolmogorov's Strong law of large numbers – Central Limit Theorems – Problem.

Module:2	Bivariate and Truncated distribution	6 hours

Bivariate binomial, Bivariate Poisson and Bivariate normal distributions - Concept of truncated distribution – compound distribution and their properties.

Module:3	Order Statistics	6 hours

Order Statistics: Distribution of order statistics - Joint distribution of order statistics – Asymptotic distribution of r^{th} order statistics - Joint distribution of range and mid-range.

Module:4	Stochastic Processes	6 hours

Elements of Stochastic Processes – Definition and Examples – Classification of general Stochastic Processes – Markov Chains – Definition and Examples – Recurrent and Transient States, Periodicity – Examples.

Module:5	Estimation Theory	6 hours

Introduction to Point estimation – Properties – Minimum Variance Unbiased estimator – Uniformly Minimum Variance Unbiased estimator – Interval Estimation: Confidence level and confidence coefficient.

Module:6	Sampling Techniques	6 hours

Probability Sampling – Simple random sampling with replacement and without replacement – Systematic – Stratified random sampling - Unbiased Estimate of the Mean and Variance – Problems.

Module:7	Linear Models	6 hours

Linear models, Estimation – Least square estimation of parameters and properties (BLUE), Gauss Markov theorem – Estimation by MLE, Testing – general linear hypothesis and sub-hypothesis, Interval estimation – classification of linear models (Fixed, random and mixed).

Module:8	Contemporary Issues	2 hours

Total Lecture hours	**45 hours**
Total Tutorial hours	**15 hours**

Text Books

1. Gupta S.C and Kapoor V.K, Fundamentals of Mathematical Statistics, 12th Edition, Sultan Chand & Sons, New Delhi, 2020.
2. Medhi, J. Stochastic Processes, 5th Edition, New Age International Private Ltd., 2020. (Module 4 only).

Reference Books			
1.	Gupta S.C and Kapoor V.K, Fundamentals of Applied Statistics, 4th revised Edition, Sultan Chand & Sons, 2018. (Module 3 only).		
2.	Parimal Mukhopadhyay, Mathematical Statistics. Books and Allied, 2016.		
3.	Rohatgi V.K and Saleh E, An Introduction to Probability and Statistics, 3rd Edition, John Wiley & Sons Inc., New Jersey, 2015.		
4.	Rao, C.R. Linear Statistical Inference and Its Applications, 2nd Edition, Wiley, 2009.		
5.	Ross, S.M., Introduction to Probability and Statistics for Engineers and Scientists, 6th Edition, Elsevier, 2021.		
Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes			
Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT309L	Engineering Optimization	L	T	P	C
		3	1	0	4
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To introduce the concept of linear and nonlinear optimization methods.
2. To develop the model formulation and applications are used in solving decision problems.
3. To choose appropriate optimization method and solve real world problems.

Course Outcomes

On completion of the course students will be able to

1. Comprehend the need and applications of the optimization methods
2. Formulate the design problem in mathematical form which can be solved by suitable optimization algorithm.
3. Understand the concept of one-dimensional nonlinear optimization methods.
4. Understand and solve the constrained and unconstrained nonlinear optimization methods.
5. Analyze the concept of quadratic programming and its applications.

Module:1	**One-Dimensional Nonlinear Optimization**	**6 hours**

Fibonacci Method-Quadratic Interpolation Method- Cubic Interpolation Method -Direct Root Methods: Newton Method- Quasi-Newton Method -Secant Method.

Module:2	**Constrained and Unconstrained Optimization**	**7 hours**

Characteristics of a constrained optimization problems – direct methods – penalty function methods – steepest descent method – Characteristics of a unconstrained optimization problems-Direct search methods: Random, Univariate, Pattern search methods – Descent methods: Steepest descent, Conjugate gradient and Variable metric.

Module:3	**Nonlinear Optimization**	**6 hours**

Optimality conditions for constrained problems, Optimality conditions for Linear Equality Constraints, The Lagrange Multipliers and the Lagrangian Functions, Optimality conditions for Linear Inequality Constraints, Optimality conditions for Nonlinear Constraints.

Module:4	**GameTheory**	**6 hours**

Game theory-Two-Person, Zero-Sum Games, Games with Mixed Strategies, Graphical Solution, Solution by Simplex Method.

Module:5	**Queueing Theory**	**6 hours**

Single Server infinite Queue Length Model, Single Server finite Queue Length Model, Multiple Server infinite Queue Length Model, Multiple Server finite Queue Length Model.

Module:6	**Dynamic Programming**	**6 hours**

Dynamic programming problem (DPP) - Bellman's principle of optimality - General formulation - computation methods and application of DPP - Solving LPP through DPP approach.

Module:7	**Quadratic Programming Problem**	**6 hours**

Introduction-applications-necessary conditions- Wolfe's and Beale's algorithms for solving QPP – Convex programming.

Module:8	**Contemporary Issues**	**2 hours**

Total Lecture hours:	**45 hours**
Total Tutorials hours:	**15 hours**

Text Book

1. Rao Singiresu S. (2019), Engineering Optimization - Theory and Practice, John Wiley & Sons, Inc., 5th Edition.

Reference Books

1. Ravindran A., Ragsdell K. M., Reklaitis G. V. (2006), Engineering Optimization: Methods and Applications, John Wiley & Sons, 2nd edition.

2. Gupta C. B. (2007), Optimization Techniques in Operation Research, I. K. International House Pvt. Ltd.			
Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes			
Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT310L	Tensors and Differential Geometry	L	T	P	C
		3	0	0	3
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To provide the students with sufficient exposure to tensors and tensor algebra that is relevant to some specific field of research.
2. Improving the understanding of higher dimensional geometry and higher dimensional calculus.

Course Outcomes

1. In mathematics Tensor concept is needed to understand higher dimensional calculus. Definitions and basics of tensor and tensorial notations.
2. Getting ideas of algebra of tensors.
3. Calculation of different types of tensors and knowing their properties.
4. This course will provide an explanation about the differential geometry for students of mathematics, physics and engineering with a basic knowledge of linear algebra.
5. The focus lies mainly on acquiring an understanding of the principles and ideas underlying the concept of differential geometry.

Module:1	**Introduction to Tensors**	**8 hours**

Summation convention and indicial notation, Transformation of coordinates, Contravariant and covariant vectors, Scalar invariants, Scalar product of two vectors.
Tensor, Tensors of different types, Contravariant, Covariant and Mixed tensor of second order, Tensor of type (r, s), Symmetric and skew -symmetric tensors.

Module:2	**Algebra of Tensors**	**7 hours**

Addition and Multiplication of tensors, Contraction, Composition and Quotient law, Reciprocal symmetric tensors of second order, Tensor product of vector spaces, Algebraic operations, Symmetric and skew symmetric tensors, Fundamental tensors.

Module:3	**Covariant Differentiation**	**7 hours**

Metric tensor and 3-index Christoffel symbols, Law of transformation of Christoffel symbols, Covariant derivative, Covariant differentiation of tensors, Curvature tensor and its properties, Ricci tensor, Curvature tensor identities.

Module:4	**Curves and Surfaces**	**5 hours**

Regular curves, Tangent, Principal normal and Binormal, Curvature and torsion, Serret-Frenet's formulae, Contact between curves and surfaces, Osculating plane, Normal plane, Rectifying plane, Osculating sphere, Helices, Involutes and Evolutes.

Module:5	**Theory of Surfaces-I**	**5 hours**

Parametric patches on surfaces, Curves on a surface, First fundamental form and arc length, Orthogonal trajectories, Second fundamental form, Gauss's formulae, Weingarten's formulae.

Module:6	**Curvature**	**5 hours**

Curvature of a curve on a surface, Normal curvature, Meunier's theorem, Principal curvature, Gaussian curvature, Mean curvature, Lines of curvature, Euler's theorem.

Module:7	**Theory of Surfaces-II**	**6 hours**

Conjugate directions, Asymptotic lines, Null lines, Beltrami and Enneper's theorem, Gauss characteristic equations, Mainardi Codazzi equation, Geodesic Geodesic coordinates, Geodesic curvature.

Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Books

1. B. Spain, Tensor Calculus: A concise Course, Dover Publications, 2003.
2. T. J. Willmore, An Introduction to Differential Geometry, Dover Publications, 2012.

Reference Books			
1. D.J. Struik, Lectures on Classical Differential Geometry, Dover Publications, 1988. 2. B. O'Neill, Elementary Differential Geometry, Academic press, 2nd Ed., 2006. 3. Eisenhart, LP, Riemannian Geometry, Princeton University Press, Princeton, 1966. 4. S. Lang, Fundamentals of Differential Geometry, Springer, 1999.			
Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes.			
Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT311L	Classical Mechanics	L	T	P	C
		3	1	**0**	4
Pre-requisite	**NIL**	**Syllabus Version**			
		1.0			

Course Objectives

1. To provide the students with sufficient exposure to advanced mathematical methods and tools that is relevant to classical mechanics.
2. Demonstrate knowledge of the physical meanings, principles, and mathematics of motion and energy equations in classical mechanics.
3. To provide advanced treatment of the fundamental, unifying concepts of the mechanics of classical in order to facilitate further study in real time applications

Course Outcomes

1. Demonstrate conceptual understanding of the basic principles of classical mechanics.
2. Understanding of discipline-specific knowledge in classical mechanics, covering the basic concepts of classical mechanics and Newton's laws and their applications,
3. The classical mechanics also provide the knowledge of oscillations, Lagrange's and Hamiltonian equations
4. The concepts of classical mechanics and demonstrate a proficiency in the fundamental concepts in this area of science..
5. Students will be able to solve problems using their knowledge and skills in classical mechanics. They will use critical thinking skills to formulate and solve quantitative problems in applied mathematical physics.

Module:1	**Lagrangian Formulation**	**7 hours**

Mechanics of a system of particles, constraints and generalized Coordinates, D'Alembert's principle, Calculus of Variation and Lagrange's equations. Lagrangian formulation of continuous system, Simple applications of the Lagrangian formulation, Principle of least action.

Module:2	**Central force**	**6 hours**

Equations of motion, orbits: closure and stability of circular orbits, Virial theorem, Kepler problem,Collision and scattering in a central force field.

Module:3	**Hamiltonian formulation**	**6 hours**

Legendre transformations, Hamilton equations, cyclic coordinates and conservation theorems, Canonical transformations, Poisson theorem, Poisson brackets, Angular momentum, Hamilton-Jacobi theory, Generating functions, Properties.

Module:4	**Rigid body kinematics and Dynamics**	**6 hours**

Orthogonal transformations, Euler angles, Coriolis effect, angular momentum and kinetic energy, tensors and dyadic, inertia tensor, Euler equations, applications, heavy symmetrical top.

Module:5	**Small oscillations**	**6 hours**

Eigenvalue equation and principal axis transformation, frequencies of free vibrations and normal modes, forced vibrations, two coupled oscillations, normal modes and co-ordinates, dissipation.

Module:6	**Canonical Transformations**	**6 hours**

The equations of canonical transformation, Examples of Canonical Transformations, Characterizing Canonical Transformations by Symplectic Jacobians, Poisson Brackets, Infinitesimal Canonical Transformations and conservation theorems in Poisson bracket formulation, Liouville's Theorem.

Module:7	**Special relativity in classical mechanics**	**6 hours**

Lorentz transformations, Relativistic Mechanics of Mass Points, Covariant four-dimensional formulations, The force and energy equations in relativistic mechanics, Lagrangian formulation of relativistic mechanics, Covariant Lagrangian formulations.

Module:8	**Contemporary Issues**	**2 hours**

Total Lecture hours:	**45 hours**
Total Tutorial hours:	**15 hours**

Text Books

1. H. Goldstein, Classical Mechanics, Narosa, 1998.
2. N. C. Rana, P. S. Joag, Classical Mechanics, Tata McGraw Hill, 2001.

Reference Books

1. V. I. Arnold, Mathematical Methods of Classical Mechanics, Springer, Berlin,1978.
2. S. N. Biswas, Classical Mechanics, Books and Allied (P) Ltd., Kolkata, 2004
3. DiBenedetto, E., Classical mechanics: theory and mathematical modelling, Birkhäuser, 2011.
4. Greiner; Classical Mechanics: Systems of Particles and Hamiltonian Dynamics; Springer Verlag, 2004.
5. D. Rindler, Special Theory of Relativity, Oxford University Press 1982.

Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes			
Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT312L	Mathematical Ecology	L	T	P	C
		3	0	0	3
Pre-requisite	**NIL**	**Syllabus Version**			
		1.0			

Course Objectives

1. To provide the students with sufficient exposure to mathematical ecology and different tools and that are relevant to research ecology.
2. Improving the computational skills of students by giving sufficient knowledge of analytical and numerical techniques useful for solving problems arising in eco systems.
3. Imparting the knowledge of real time applications of Autonomous systems, Non-linear systems of ordinary differential equations and partial differential equations.

Course Outcomes

1. Distinguish and analyse a variety of tools for solving linear systems and finding eigenvalues of these systems.
2. Derive and use the analytical numerical techniques needed for the solution of a given environmental problems.
3. Understand and correlate the analytical and numerical methods.
4. Demonstrate their ability to write coherent mathematical proofs and scientific arguments needed to communicate the results obtained from differential equation models.
5. Demonstrate the understanding of how ecological phenomena are modeled by ordinary and partial differential equations.

Module:1	**Unstructured population models-1**	**6 hours**

Single-species models: Exponential, logistic, and Gompertz growth, Harvest models: bifurcations and breakpoints, stochastic birth and death processes.

Module:2	**Unstructured population model-2**	**6 hours**

Discrete-time models: Density independent growth,density dependent growth, delay models, branching processes.

Module:3	**Interacting populations**	**7 hours**

A classical predator-prey model, To cycle or not to cycle, Global bifurcations in predator-prey models, Chemostat models, Discrete-time predator-prey models, Competition models, Mutualism models.

Module:4	**Dynamics of exploited populations**	**6 hours**

Harvest models and optimal-control theory.

Module:5	**Structured population models**	**6 hours**

Spatially structured models: Formulating spatially structured models, spatial steady states: linear problems, spatial steady states: nonlinear problems, models of spread.

Module:6	**Age-structured models**	**6 hours**

Overview of Age-structured model, Lotka Integral equation, Leslie matrix, MacKendrick-von Forster PDE, Some simple nonlinear models.

Module:7	**Sex-structured models**	**6 hours**

Two-sex models: Age independent models, Female dominance, Male dominance, Intermediate dominance, Age dependent models.

Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Books

1. *Elements of Mathematical Ecology, Mark* Kot, Cambridge University Press, 2001.
2. Mathematical Ecology of Populations and Ecosystems, John Pastor, Wiley, 2008.

Reference Books

<table>
<tr><td colspan="4">1. Differential Equations and Dynamical Systems, Lawrence Perko, 3rd Ed., Springer-Verlag, 2001.
2. An introduction to Ordinary Differential Equations, James C. Robinson, Cambridge University Press, New York, 2008 (4th print).
3. Modeling Life: The Mathematics of Biological Systems by Alan Garfinkel, Jane Shevtsov ,Yina Guo, Springer, 2017.
4. Complex Population Dynamics: A Theoretical/Empirical Synthesis, Turchin, P. , Princeton University Press, 2003.</td></tr>
<tr><td colspan="4">Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes.</td></tr>
<tr><td>Recommended by Board of Studies</td><td colspan="3">15-02-2022</td></tr>
<tr><td>Approved by Academic Council</td><td>No. 65</td><td>Date</td><td>17-03-2022</td></tr>
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TMAT313L	Mathematical Finance	L	T	P	C
		3	0	0	3
Pre-requisite	**NIL**	**Syllabus Version**			
		1.0			

Course Objectives

1. Understanding basic concepts of financial markets and its instruments, and to understand time value of money.
2. To learn two basic frameworks-Portfolio theory and Option pricing theory.
3. To apply the concepts of mathematical finance in areas of financial engineering, computational finance, financial risk management, etc.

Course Outcomes

1. To learn the basics of financial markets and financial instruments, time value of money.
2. To understand Portfolio theory and asset management.
3. To understand derivative pricing and risk neutral pricing.
4. To learn introductory stochastic calculus.
5. To apply mathematical finance in areas of financial engineering, computational finance, financial risk management, etc.

Module:1	**Introduction to Financial Markets**	**6 hours**
Introduction to financial markets, financial instruments, bonds, stocks, Future & Forwards and Swaps, Options.		
Module:2	**Time value of money**	**6 hours**
Simple and compound interest rate, net present value, internal rate of return and annuities, amortization and bond yield, price yield curve and term structure of interest rates.		
Module:3	**Portfolio theory**	**7 hours**
Markowitz portfolio theory, risk and return, two and multi asset portfolio theory, efficient frontier, Capital Asset Pricing Model and portfolio performance analysis.		
Module:4	**Fundamentals of derivatives**	**6 hours**
No arbitrage principle, pricing of forwards and futures, properties of options, Derivative pricing by replication in binomial mode.		
Module:5	**Risk- Neutral pricing in Discrete time**	**6 hours**
Discrete probability spaces, filtration, conditional expectation, Discrete time martingales, Markov chain, risk-neutral pricing in binomial model for European and American derivatives.		
Module:6	**Stochastic Calculus**	**6 hours**
General probability spaces, conditional expectation, Brownian motion, Ito integral, Ito formula, Girsanov's theorem, martingale representation theorem, stochastic differential equation.		
Module:7	**Risk- Neutral pricing in Continuous time**	**6 hours**
Black-Scholes-Merton (BSM) model, pricing of European derivatives in BSM framework, Valuation of European options in BSM model, BSM formula, BSM partial differential equation, hedging, model completeness, fundamental theorems of asset pricing.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book

1. Financial Mathematics: An Introduction, S. Chandra, S. Dharmaraja, Aparna Mehra, R. Khemchandani, First Edition, Narosa Publishing House , 2012.

Reference Books

<table>
<tr><td colspan="4">Investment Science, David G. Luenberger, Second Edition, Oxford University Press, 2013.
Elementary Stochastic Calculus with Finance in view, Thomas Mikosch, World Scientific, 2006.
Mathematics for Finance: An Introduction to Financial Engineering, M. Capińsky and T. Zastawniak:, Springer, 2004.</td></tr>
<tr><td colspan="4">Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes</td></tr>
<tr><td>Recommended by Board of Studies</td><td colspan="3">15-02-2022</td></tr>
<tr><td>Approved by Academic Council</td><td>No. 65</td><td>Date</td><td>17-03-2022</td></tr>
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TMAT314L	Fluid Dynamics	L	T	P	C
		3	1	0	4
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

The course aims to give the student

1. A foundation in the fundamentals of fluid dynamics.
2. Practice in the analytical formulation of fluid mechanics problems using Newton's Laws of motion and thermodynamics.
3. Analyse equations of motion of a fluid, three dimensional flows, two dimensional flows and viscous flows and boundary layer theory.

Course Outcomes

On successful completion of the course, the student will be able to,

1. Learn the physical properties of fluids and mathematical fundamentals of fluid dynamics.
2. Understand the kinematics of fluid particles, including the concepts of coordinate system, derivatives, local and convective accelerations, flow visualization using timelines, path lines, streak lines, streamlines and strain tensor.
3. Apply the conservation principles of mass, momentum, and energy to fluid motions.
4. Describe the basic concepts of vorticity, circulation and use the stream function and the velocity potential in two-dimensional, axisymmetric, and two-dimensional flows past simple objects.
5. Developexact and approximate solutions to the viscous equations of fluid motion in confined and unconfined geometries and understand the concepts of viscous boundary layers, mathematical simplifications and momentum integral equation.

Module:1	**Physical Properties of fluids and Mathematical Fundamentals**	**7 hours**

Concept of fluids, Continuum Hypothesis, density, specific weight, specific volume, surface tension, dimensional analysis Cartesian tensor, First and Second Law of thermodynamics, Kroneckar Delta.

Module:2	**Kinematics of Fluids**	**6 hours**

Eulerian and Lagrangian methods of description of fluids, Equivalence of Eulerian and Lagrangian method, General motion of fluid element, integrability and compatibility conditions, stream line, path line, streak lines, stream function¸ Strain and Rotation Rates, Kinematics of Simple Plane Flows, Reynolds Transport Theorem.

Module:3	**Conservation Laws**	**6 hours**

Equation of conservation of mass, equation of conservation of momentum, Navier Stokes equation, equation of moments of momentum, Equation of energy, Basic equations in different co-ordinate systems, boundary conditions.

Module:4	**Vorticity**	**6 hours**

vortex lines, circulation, Kelvin's Circulation Theorem, Helmholtz's Vortex Theorems, Vorticity Equation in a Nonrotating Frame, Velocity Induced by a Vortex Filament: Law of Biot and Savart.

Module:5	**Ideal Flow**	**6 hours**

Relevance of Irrotational Constant-Density Flow Theory, Two-Dimensional Stream Function and Velocity Potential, Construction of Elementary Flows in Two Dimensions, Complex Potential, Forces on a Two-Dimensional Body, Blasius Theorem, Kutta-Zhukhovsky Lift Theorem, Conformal Mapping.

Module:6	**Viscous Flow**	**6 hours**

Exact Solutions for Steady Incompressible Viscous Flow, Steady Flow between Parallel Plates, Steady Flow in a Round Tube, Steady Flow between Concentric Rotating Cylinders, Elementary Lubrication Theory, Similarity Solutions for Unsteady, Incompressible Viscous Flow, Flow Due to an Oscillating Plate, Low Reynolds Number Viscous Flow Past a Sphere.

Module:7	**Boundary Layer Theory**	**6 hours**
Prandtl model for boundary layer, boundary layer equation, solution for a flow past a plate.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**
	Total Tutorial hours:	**15 hours**

Text Book

1.Fluid Mechanics, Pijush K. Kundu, Ira M. Cohen, David R. Dowling., 5th edition Elsevier, 2011.

Reference Books

1. Incompressible Flow by Ronald L. Panton, 4th edition, Wiley, 2013.
2. G. K. Batchelor, An Introduction to Fluid Dynamics, 2nd ed., Cambridge Univ. Press, 2000.
3. Fluid Mechanics, Landau and Lifshitz, 2nd Edition, Elsevier, 1987.
4. Boundary layer theory, H. Schlichting, Springer, 2017.

Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes.

Recommended by Board of Studies	15-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT315L	Difference Equations and its Applications	L	T	P	C
		3	0	0	3
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. Making mathematics relevant to other disciplines such as biology, economics, physics, and engineering.
2. Understand the basic facts of the theory of difference equations.
3. Apply theoretical and practical methods for solving difference equations.
4. Compare the differences in the theories of differential and difference equations and, in particular, understand the differences which arise in these theories.

Course Outcomes

1. Study the first order Linear difference Equations
2. Learn the solution methods to solve Linear Difference Equations of any order.
3. Apply Putzer Algorithm and Jordan form to study system of Difference equations.
4. Investigate stability of scalar equations and systems via linearization and Liapunov method.
5. Investigate the Oscillatory and Asymptotic behavior of Difference Equations.
6. Understand basics of control theory including controllability observability and stabilizability by feedback.

Module:1	**Dynamics of Linear First-order Difference Equations**	**6 hours**

Linear First-Order Difference Equations, Equilibrium Points, Asymptotic Stability of Equilibrium Points, Periodic Points and Cycles, Logistic Equation and Bifurcation, Basin of Attraction and Global Stability.

Module:2	**Linear Difference Equations**	**8 hours**

General Theory of Linear Difference Equations, Homogeneous Equations with Constant Coefficients, Nonhomogeneous Equations: Method of Undetermined Coefficients, Limiting behavior of Solutions, Nonlinear Equations Transformable to Linear Equations, Autonomous Systems.

Module:3	**Stability Theory**	**6 hours**

Norm of a Matrix, Notions of Stability, Stability of Linear Systems, Phase Space Analysis, Liapunov Second Method, Stability by Linear Approximation.

Module:4	**Higher-Order Scalar Difference Equations**	**6hours**

Linear Scalar Equations, Sufficient Conditions for Stability, Stability via Linearization, Global Stability of Nonlinear Equations.

Module:5	**Z-Transform**	**6 hours**

Z-Transform, Inverse Z-Transform and Solutions of Difference Equations, Z-Transform versus the Laplace Transform, Volterra Difference Equations and it's stability.

Module:6	**Oscillation theory and Asymptotic Behavior of Difference Equations**	**6 hours**

Three-Term Difference Equations, Self-Adjoint Second-Order Equations, Nonlinear Difference Equations, Tools of Approximation, Poincarés Theorem, Asymptotically Diagonal Systems, High-Order Difference Equations, Second-Order Difference Equations, Birkhoff's Theorem, Nonlinear Difference Equations, Extensions of the Poincaré and Perron Theorems.

Module:7	**Control Theory**	**5 hours**

Controllability, Observability, Stabilization by State Feedback, Observers.

Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book

1. An Introduction to Difference Equations, Saber Elaydi, 3rd ed., Springer, 2005.

Reference Books			
1. Discrete Hamiltonian Systems Difference Equations, Continued Fractions, and Riccati Equations, Calvin D. Ahlbrandt, Allan C. Peterson, Kluwer Academic Publishers, Dordrecht, 1996. 2. Introduction to Difference Equations With Illustrative Examples from Economics, Psychology, and Sociology, Samuel Goldberg, Dover, New York, 1986. 3. Difference Equations An Introduction with Applications, Walter G. Kelley and Allan C. Peterson, Elsevier, USA, 2012.			
Mode of Evaluation: CAT, FAT, Digital Assignments and Quizzes.			
Recommended by Board of Studies	15-02-.2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT390J	Study Project	L	T	P	C
		0	0	0	3
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives:

1. The student will be able to analyse and interpret published literature for information pertaining to niche areas.
2. Scrutinize technical literature and arrive at conclusions.
3. Use insight and creativity for a better understanding of the domain of interest.

Course Outcome:

1. Retrieve, analyse, and interpret published literature/books providing information related to niche areas/focused domains.
2. Examine technical literature, resolve ambiguity, and develop conclusions.
3. Synthesize knowledge and use insight and creativity to better understand the domain of interest.

Module Content

This is oriented towards reading published literature or books related to niche areas or focussed domains under the guidance of a faculty.

Mode of Evaluation: Evaluation involves periodic reviews by the faculty with whom the student has registered. Assessment on the project – Mark weightage of 20:30:50 – Report to be submitted, presentation and project reviews.

Recommended by Board of Studies	18-02-2022		
Approved by Academic Council	No.65	Date	17-03-2022

TMAT392J	Design Project	L	T	P	C
		0	0	0	3
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives:

1. Students will be able to upgrade a prototype to a design prototype.
2. Describe and demonstrate the techniques and skills necessary for the project.
3. Acquire knowledge and better understanding of design systems.

Course Outcome:

1. Develop new skills and demonstrate the ability to upgrade a prototype to a design prototype or working model.
2. Utilize the techniques, skills, and modern tools necessary for the project.
3. Synthesize knowledge and use insight and creativity to better understand and improve design systems.

Module Content

Students are expected to develop new skills and demonstrate the ability to develop prototypes to design prototype or working models related to an engineering product or a process.

Mode of Evaluation: Evaluation involves periodic reviews by the faculty with whom the student has registered. Assessment on the project – Mark weightage of 20:30:50 – Report to be submitted, presentation and project reviews.

Recommended by Board of Studies	18-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT393J	Laboratory Project	L	T	P	C
		0	0	0	3
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives:

1. The student will be able to conduct experiments on the concepts already learnt.
2. Analyse experimental data.
3. Present the results with appropriate interpretation.

Course Outcome:

1. Design and conduct experiments in order to gain hands-on experience on the concepts already studied.
2. Analyse and interpret experimental data.
3. Write clear and concise technical reports and research articles

Module Content

Students are expected to perform experiments and gain hands-on experience on the theory courses they have already studied or registered in the ongoing semester. The theory course registered is not expected to have laboratory component and the student is expected to register with the same faculty who handled the theory course. This is mostly applicable to the elective courses. The nature of the laboratory experiments is depended on the course.

Mode of Evaluation: Evaluation involves periodic reviews by the faculty with whom the student has registered. Assessment on the project – Mark weightage of 20:30:50 – Report to be submitted, presentation and project reviews.

Recommended by Board of Studies	18-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT397J	Special Project	L	T	P	C
		0	0	0	3
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives:

1. Students will be able to identify and solve problems in a time-bound manner.
2. Describe major approaches and findings in the area of interest.
3. Present the results in a clear and concise manner.

Course Outcome:

1. To identify, formulate, and solve problems using appropriate information and approaches in a time-bound manner.
2. To demonstrate an understanding of major approaches, concepts, and current research findings in the area of interest.
3. Write clear and concise research articles for publication in conference proceedings/peer-reviewed journals.

Module Content

This is an open-ended course in which the student is expected to work on a time bound research project under the supervision of a faculty. The result may be a tangible output in terms of publication of research articles in a conference proceeding or in a peer-reviewed Scopus indexed journal.

Mode of Evaluation: Evaluation involves periodic reviews by the faculty with whom the student has registered. Assessment on the project – Mark weightage of 20:30:50 – project report to be submitted, presentation and project reviews.

Recommended by Board of Studies	18-02-2022		
Approved by Academic Council	No. 65	Date	17-03-2022

TMAT408L	Advanced Abstract Algebra	L	T	P	C
		3	0	0	3

Pre-requisite	TMAT302L - Abstract Algebra	Syllabus version

Course Objectives

1. To introduce the basic concepts of Fields to exemplify its structures and different types.
2. To introduce the concepts of Galois Theory, Solvability and Linear Transformations.
3. To introduce the concept of Different Types of Canonical Forms.

Course Outcome

At the end of the course, students able to

1. Understand the difference between Inner product spaces and normed linear spaces
2. Understand the different types of fields
3. Understand the linear transformations and Various Canonical forms
4. Differentiate the Hermitian, Unitary and Normal Transformations.

Module:1	Inner Product Spaces	6 hours

Introduction – Vector space – Properties of Inner Product Space – Orthogonal – Gram – Schmidt Orthogonalization Process - Modules

Module:2	Fields	6 hours

Extension Fields – The Transcendence of e – Roots Polynomials – Construction with Straightedge and Compass

Module:3	Solvability and Galois Theory	6 hours

More about Roots – The Elements of Galois Theory – Solvability by Radicals – Galois Groups over the Rational.

Module:4	Linear Transformations	6 hours

The Algebra of Linear Transformations – Characteristic Roots – Matrices.

Module:5	Canonical Forms	6 hours

Triangular Form – Nilpotent Transformations – Rational Canonical Form – Jordan Form.

Module:6	Theoretical View of Trace, Transpose and Determinants	7 hours

Trace – Invertible - Transpose –Symmetric Matrix – Skew Symmetric Matrix – Adjoint - Determinants and its Properties.

Module:7	Hermitian, Unitary and Normal Transformations	6 hours

Unitary Transformation – Hermitian – Skew Hermitian – Normal Transformations – Real Quadratic Forms.

Module:8	Contemporary Topics	2 hours

Guest Lecture from Industry and R & D Organizations.

	Total Lecture Hours:	45 hours

Text Book(s)

1. I. N. Herstein, “Topics in Algebra”, 2nd Edition, 2022,Wiley Publications.

Reference Books

1.	P.B.Battacharya, S.K.Jain, S.R.Nagpaul , “Basic Abstract Algebra”, 1995., 2nd Edition, Cambridge Press.
2.	Michael Artin , “Algebra”, 2nd Edition, 2015,Pearson Education,
3.	Vijay K. Khanna and S. K. Bhambri , “A Course in Abstract Algebra”, 2015 , 5th Edition, Vikas Publishing House, New Delhi

Mode of Evaluation: CAT / written assignment / Quiz / FAT			
Recommended by Board of Studies	DD-MM-YYYY		
Approved by Academic Council	No. xx	Date	DD-MM-YYYY

Course Code	Course Title	L	T	P	C
TMAT409L	**Advanced Complex Analysis**	**3**	**0**	**0**	**3**
Pre-Requisite	**TMAT205L-Complex Analysis**	**Syllabus Version**			

Course Objectives

1. To study zeros of analytic (or holomorphic) functions and related theorems
2. To motivate the learners for understanding the fundamental concepts and basic Theorems in Analytic continuation and Monodromy, Hyperbolic geometry and the Riemann Mapping theorem

Course Outcomes

1. Explore the basic concepts of $C(G,\Omega)$-Space.
2. Familiarize with the concept of compact and convergence of analytic functions,
3. Getting knowledge of zeros of analytic functions and related theorems
4. Cognizant the basic principles of Singularities for solving various practical problems.
5. Understand the importance of Harmonic functions

Module: 1	**Compactness and Convergence in the space of Analytic functions**	**6 hours**

The space of continuous functions $C(G,\Omega)$-Space of analytic functions spaces of meromorphic functions.

Module:2	**Rouche's and Hurwitz theorems**	**6 hours**

Fundamental Theorems with Zeros of Analytic functions - Rouche's Theorem - Morera's theorem-Hurwitz's theorem - Normal Limits of Analytic functions and Univalent Functions

Module:3	**Analytic continuation and Riemann surface**	**hours**

Riemann open mapping theorem-Local Constancy of Multiplicities of Assumed Values Schwarz reflection principle-analytic continuation along a path - Monodromy theorem - Topological spaces and neighbourhood systems - the sheaf of germs of analytic functions on an open set-Analytic manifolds - Covering space

Module:4	**Monodromy**	**7 hours**

Analytic continuation along paths-Dependence of the initial function and on path-First version of the Monodromy theorem - Maximal domains of direct and indirect analytic continuation-Second version of the monodromy theorem-Existence and Uniqueness of analytic continuation on nearby paths - Algebraic Nature of Analytic Branches of the Functional Inverse of an Analytic Function at a Critical Point

Module:5	**Weierstrass Theory**	**6 hours**

The Weierstrass $\wp$-function-The functions$\boldsymbol{\zeta}$(s) and $\boldsymbol{\sigma}$(s)-The differential equation-The modular equation ($\boldsymbol{\tau}$)-The conformal mapping by ($\boldsymbol{\tau}$).

Module:6	**Harmonic functions**	**6 hours**

The Mean-Value Property, Harmonic Functions and the Maximum Principle -Uniqueness of Riemann Mappings - Reducing Existence of Riemann Mappings to Hyperbolic Geometry of Subdomains of the Unit Disc -sub harmonic functions-super harmonic functions.

Module:7	**Arzela-Ascoli and Montel theorem**	**6 hours**
Arzela-Ascoli Theorem - Equivalence of uniform boundedness, Equicontinuity-uniform sequential compactness - Montel's theorem		
Module:8	**Contemporary issues: (Industry Expert Lecture)**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1. L. V. Ahlfors, Complex Analysis, 2017, 3rd Edition., McGraw Hill,

Reference Book(s)

1. H,A. Priestly, Introduction to Complex Analysis, 2003, Clarendron Press, Oxford,.
2. R.V. Churchill and J.W. Brown, "Complex variables and applications",2017, 8th edition, 2017 McGraw Hill Education, New Delhi.

Mode of Evaluation: CAT, written assignment, Quiz, FAT.

Recommended by Board of Studies			
Approved by Academic Council		Date	

Course Code	Course Title	L	T	P	C
TMAT410L	Numerical Solution of Partial Differential Equations	3	0	0	3
Pre-requisite	TMAT404L - Partial Differential Equations	Syllabus version			
		1.0			

Course Objectives

1. To introduce the methods of solving one-dimensional and two-dimensional parabolic equations.
2. To display the methods of solving hyperbolic equations.
3. To reveal the ideas of solving elliptic equations.
4. To introduce the methods of solving PDEs using FEM

Course Outcomes

The students will be able to

1. Express Taylor series expansion to form several finite difference approximations which lead to solving parabolic equations in one dimension
2. Analyse and solve parabolic equations in two and three dimensions using explicit and implicit methods
3. Employ finite difference methods to tackle hyperbolic equations of first and second order.
4. Evaluate the consistency, stability, and convergence of a numerical scheme.
5. Learn the basics of finite element methods and their application for solving each type of PDEs (hyperbolic, parabolic, and elliptic).

Module:1	Finite difference methods for parabolic equations in one dimension	7 hours

Finite Difference Approximations: Taylor series-notation and truncation error, Thomas algorithm, Parabolic PDEs: classical explicit scheme, Dufort-Frankel scheme, implicit methods: backward implicit method, Crank-Nicolson method, difference schemes in polar coordinates.

Module:2	Parabolic equations in two and three dimensions	6 hours

The explicit method in a rectilinear box, Alternating Direction Implicit(ADI) method in two dimensions, ADI and Locally One-Dimensional (LOD) methods in three dimensions, Curved boundaries.

Module:3	Hyperbolic equations in one space dimension	6 hours

Characteristics, CFL condition, Lax–Wendroff scheme, leap-frog scheme, Explicit and Implicit finite difference methods for Second-order Linear Hyperbolic PDEs.

Module:4	Consistency, convergence and stability	6 hours

The finite difference mesh and norms, Consistency, order of accuracy and convergence, Stability and the Lax Equivalence Theorem, Calculating stability conditions, Von Neumann stability analysis

Module:5	Linear second order elliptic equations in two dimensions	6 hours

Elliptic PDE: Boundary and Compatibility Conditions, The Central Finite Difference Method for Laplace and Poisson Equations, The Maximum Principle and Error Analysis.

Module:6	Finite Element Approach for parabolic equations	6 hours
Finite element method (FEM) for parabolic equation in one dimension - Galerkin approximation, Linear basis function approximation, Higher-degree polynomial basis function approximation, FEM for parabolic equation in two dimensions - Galerkin approximation in space and time.		
Module:7	**Finite Element Approach for elliptic and hyperbolic equations**	**6 hours**
FEM for Elliptic equation- Galerkin approximation, FEM for first-order and second-order hyperbolic PDEs-Galerkin approximation.		
Module:8	**Contemporary Issues**	**2 hours**
Guest Lecture from Industry and R & D Organizations		
	Total Lecture hours:	**45 hours**

Text Book

1.	Sandip Mazumder, Numerical Methods for Partial Differential Equations: Finite Difference and Finite Volume Methods, 2016, Academic Press.

Reference Books

1.	L. Lapidus and G.F. Pinder, Numerical Solution of Partial Differential Equations in Science and Engineering, 1982, Wiley-Inderscience Press, New York.
2.	G.D. Smith, Numerical Solution of Partial Differential Equations: Finite Difference Methods, 1977, Oxford University Press, United Kingdom.
3.	Z. Li, Z. Qiao and T. Tang, Numerical Solution of Differential Equations: Introduction to Finite Difference and Finite Element Methods, 2017, Cambridge University Press, United Kingdom.

Mode of Evaluation: CAT, Written Assignment, Quiz, FAT and Seminar		
Recommended by Board of Studies	DD-MM-YYYY	
Approved by Academic Council	No. xx	Date: DD-MM-YYYY

Course Code	Course Title	L	T	P	C
TMAT411L	Stochastic Processes	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives:

1. To introduce the basic concepts of stochastic process.
2. To introduce how to model the renewal processes and study its theorems and their behaviour.
3. To review about the combination of renewal processes and Markov process.
4. To introduce the concept of birth and death process and model the queuing theory in real life problems.

Course Outcomes:

The students will be able to

1. To understand the concept of stationarity and its implications in time series analysis.
2. To develop a deep understanding of the interplay between Markov and renewal processes.
3. To understand the characteristics of birth and death processes, and to include its rates.
4. To develop skills to optimize queuing systems in real world problem.

Module:1	Stationary Processes	7 hours

Introduction – specification of stochastic processes - stationary processes-classification of general stochastic processes into discrete and continuous time - discrete and continuous state spaces - types of stochastic processes - applications.

Module:2	Markov Process	6 hours

Introduction - Markov chains - transition probability matrix - order of a Markov chain - higher transition probabilities – Chapman-Kolmogorov equations - applications

Module:3	Poisson Process	6 hours

Poisson process – postulates – properties - related distributions - exponential, uniform, geometric and negative binomial distributions

Module 4	Renewal Processes	6 hours

Renewal processes in continuous time – renewal equation – stopping time Wald's equation – renewal theorems – delayed and equilibrium renewal processes – renewal reward process – alternating renewal process.

Module:5	Markov Renewal and Semi-Markov Processes	6 hours

Markov renewal equation – limiting behaviour – first passage time-branching processes - generating functions of branching processes - applications.

Module:6	Birth and Death Process	6 hours

Pure birth process: Yule-Fury process - birth-immigration process - time dependent Poisson processes - birth and death process – applications.

Module:7	Queuing Theory	6 hours

Basic elements in a queuing model - Classification of queues – four types of queuing model (concepts only) – detailed study of (M/M/I): (∞/FCFS) and (M/M/I): (N/FCFS) – applications.

Module:8	**Contemporary Issues**	**2 hours**
Industry Expert Lecture		
	Total Lecture hours	**45 hours**

Text Book:	
1.	J. Medhi, Stochastic Processes, 2017, Fourth Edition, New Age International Press, New Delhi.
Reference Books:	
1.	U.N. Bhat and G.K. Miller, Elements of Applied Stochastic Processes, 2002, Third Edition, Wiley - Interscience Press, Hoboken.
2.	S. Karlin, H.M. Taylor, A First Course in Stochastic Processes, 2014, Second Edition, Academic Press, New York.
3.	S.M. Ross, Stochastic Processes, 2013, Second Edition, John Wiley & Sons Inc., United States of America.

Mode of Evaluation: CAT, Written Assignment, Quiz, FAT and Seminar		
Recommended by Board of Studies	DD-MM-YYYY	
Approved by Academic Council	No. xx	Date: DD-MM-YYYY

Course Code	Course Title	L	T	P	C
TMAT412L	Magnetohydrodynamics	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

1. To provide the introduction of magnetohydrodynamics.
2. To present the basic theory and apply it to a variety of physical problems.
3. To cover the fundamental equations in magnetohydrodynamics, dynamics and heat transfer of magnetofluid in a magnetic field, equilibrium and stability of magnetized plasmas.

Course Outcomes

The students will be able to

1. Describe the MHD spectrum and characterize the MHD waves in a cylinder and the basic modifications in a toroidal geometry.
2. Describe the basic structure of magnetic field lines in a three-dimensional geometry and magnetic confinement.
3. Achieve the ability to understand the basic concepts and the equations of flow of viscous fluids.
4. Achieve the ability to understanding the electromagnetic induction mechanism which has its origin in the movement of fluids that are good electrical conductors.
5. Translate a magnetic hydrodynamic problem in an appropriate mathematical form and to find solutions.

Module:1	Basic Magnetohydrodynamics	7 hours

Postulating the basic equations, Scale independence, Flux tubes, Global magnetic flux conservation, Conservation form of the MHD equations, Global conservation laws, Local conservation laws – conservation of magnetic flux, Magnetic helicity.

Module:2	Dissipative Magnetohydrodynamics and MHD Waves	6 hours

Resistive MHD, (Non-) conservation form of the dissipative equations, Shocks and jump conditions, Symmetric representation in primitive variables, Entropy wave and magnetic field constraint, Reduction to velocity representation: three waves, Dispersion diagrams, Application to the MHD waves.

Module:3	Solar Magnetism and Planetary Magnetic Fields	6 hours

The solar cycle, Magnetic structures in the solar atmosphere, The geomagnetic dynamo, Magnetic fields of the other planets, The solar wind and the heliosphere, Solar wind and planetary magnetospheres.

Module:4	Initial Value Problem and Wave Damping	6 hours

Reduction to a one-dimensional representation, Restoring the three-dimensional picture, Green's function, Spectral cuts, Dispersion equation, Exponential damping, Different kinds of quasi-modes, Normal-mode analysis, Initial value problem approach.

Module:5	Elements of Plasma Physics	6 hours

Plasma definition, Single particle motion, Cyclotron motion, Excursion: basic equations of electrodynamics and mechanics, Drifts, adiabatic invariants, Boltzmann equation and moment reduction, Collective phenomena: plasma oscillations, Landau damping, Alfven waves.

Module:6	**Fundamentals of Plasma Physics**	**6 hours**
Maxwell Equations, Lorentz Force, Charged particle drifts under EM fields, collisions, mean free path, Plasma Fluid Theory – Governing Equations, Partially ionized gases, Plasma sheath/Plasma material boundary.		
Module:7	**MHD in Plasma Physics**	**6 hours**
Ideal MHD, Magnetic tension and pressure, Equilibrium, Flux freezing, Waves, Shocks, Plasma thrusters, Non-ideal MHD, Resistivity, Ohm's Law, Internal & External flows: Duct/Channel flows and Boundary layers, Plasma actuators for flow control, Space Plasmas, Stellar plasma.		
Module:8	**Contemporary Issues**	**2 hours**
Guest Lecture from Industry and R & D Organizations		
	Total Lecture hours:	**45 hours**

Text Book	
1.	J. P. Hans Goedbloed and Stefaan Poedts, Principles of magnetohydrodynamics with Applications to Laboratory and Astrophysical Plasmas, 2010, Cambridge University Press.
2.	R. J. Hosking, R.L. Dewar, Fundamental Fluid Mechanics and Magenetohydrodynamics, 2016, First Edition, Springer, Singapore.
Reference Books	
1.	A. Piel, Plasma Physics, 2010, Springer, New York.
2.	M.G. Kivelson and C.T. Russell, Introduction to Space Physics, 1997, Cambridge University Press, Cambridge.

Mode of Evaluation: CAT, Written Assignment, Quiz, FAT and Seminar		
Recommended by Board of Studies	DD-MM-YYYY	
Approved by Academic Council	No. xx	Date: DD-MM-YYYY

Course Code	Course Title	L	T	P	C
TMAT413L	Fractional Calculus	3	0	0	3
Pre-requisite	NIL	Syllabus version			

Course Objectives

1. To motivate the learners for understanding the fundamental concepts of special functions, integer order derivatives and fractional calculus.
2. To acquire the required knowledge in fractional derivatives and its types, properties of fractional derivatives, geometrical and physical interpretations of fractional differentiation and integration, and transforms of fractional derivatives.
3. To propose the solving methods of fractional differential equations and to implement the learned techniques in realistic projects for analyzing the various types of fractional dynamical systems.

Course Outcomes

The students will be able to

1. Know the basic concepts of special types of functions, integer order derivatives and the fractional derivatives, various types of fractional derivatives.
2. Recognize the important properties of fractional derivatives and geometrical & physical interpretations of differentiation & integration in fractional calculus.
3. Learn the Laplace and Fourier transforms for fractional order derivatives with suitable applications.
4. Understand the concepts of fractional ordinary and partial differential equations and its solving methods.
5. Analyze the advanced techniques of fractional calculus and also implement the learned techniques for realistic problems of fractional dynamical systems.

Module: 1	Special Functions	5 hours

Gamma Function and its Properties – Beta Function – Contour Integral Representation – Mittag-Leffler Function.

Module: 2	Fractional Calculus	6 hours

Basics of Integer Order Derivatives and Integrals – Geometric and Physical Interpretations – Fractional Derivatives – Grunwald-Letnikov – Riemann-Liouville – Caputo's Fractional Derivatives.

Module: 3	Fractional Derivatives and Integrals	6 hours

Sequential Fractional Derivatives – Left and Right Fractional Derivatives – Properties of Fractional Derivative – Linearity – Zero Rule – Product and Leibnitz Rule for Fractional Derivative – Composition with Fractional Derivatives – Geometric and Physical Interpretation of Fractional Integration and Fractional Differentiation.

Module: 4	Transforms of Fractional Derivatives	6 hours

Laplace Transforms of Fractional Derivatives – Fourier Transforms of Fractional Derivatives.

Module: 5	**Linear Fractional Differential Equations**	**7 hours**
Fractional Differential Equation of a General Form – Existence and Uniqueness Theorem as a Method of Solution – Dependence of a Solution on Initial Conditions – The Laplace Transform Method – Standard Fractional Differential Equations – Sequential Fractional Differential Equations.		
Module: 6	**Solutions of Fractional Differential Equations**	**7 hours**
Introduction – Linearly Independent Solutions – Solutions of the Homogeneous and Non-Homogeneous Fractional Differential Equations – Reduction of Fractional Partial Differential Equations to Ordinary Differential Equations.		
Module: 7	**Applications of Fractional Calculus**	**6 hours**
Applications in Electrical Circuits – Tree Fractance – Chain Fractance – Fractional-Order Chua-Hartley System.		
Module: 8	**Contemporary Issues**	**2 hours**
Expert Guest Lectures from Academic Institutes, Industries or R & D Organizations.		
	Total Lecture hours:	**45 hours**

Text Book

1.	H. Singh, H.M. Srivastava, J.J. Nieto, Handbook of Fractional Calculus for Engineering and Science, 2022, First Edition, CRC Press.

Reference Books

1.	K.B. Oldham and J. Spanier, The Fractional Calculus: Theory and Applications of Differentiation and Integration to Arbitrary Order, 2006, Dover Publications Inc., New York.
2.	K.S. Miller and B. Ross, An Introduction to the Fractional Calculus and Fractional Differential Equations, 1993, Willey Blackwell, New York.
3.	A. Kilbas, H. Srivastava and J.J. Trujillo, Theory and Applications of Fractional Differential Equations, 2006, Elsevier, Amsterdam.

Mode of Evaluation: Digital Assignments, Quizzes, Seminars, CATs and FAT.

Recommended by Board of Studies	DD-MM-YYYY	
Approved by Academic Council	No. XX	Date DD-MM-YYYY

Course Code	Course Title	L	T	P	C
TMAT414L	Finite Element Methods	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

1. To introduce the concepts of Mathematical Modeling of Engineering Problems.
2. To familiarize the fundamental concepts of FEM.
3. To appreciate the use of FEM to a range of Engineering Problems.

Course Outcome

The students will be able to

1. Summarize the basics of finite element formulation and solve the problems by variational methods.
2. Develop element characteristic equations and analysis of frame structures.
3. Apply finite element formulations to solve one and two dimensional Problems.
4. Apply finite element formulations to solve heat transfer and fluid flow problems.
5. Apply finite element formulations to solve Axi-symmetric problems.

Module:1	Introduction to Finite Element Methods	4 hours

Basic concepts of Finite Element Analysis - Steps in Finite Element Analysis - Engineering applications of Finite Element Method - Advantages of the Finite Element Method - Introduction to Elasticity - Boundary and initial conditions - Stress and Equilibrium; Strain – Displacement relations - Stress – strain relations.

Module:2	Variational Methods	6 hours

Virtual work and variational Principle - Calculus of variation - Potential energy method - Rayleigh-Ritz and Galerkin methods - Displacement method of finite element formulation - Convergence criteria - Discretization process.

Module:3	Element Properties	6 hours

Natural coordinates - Triangular elements - Rectangular elements - Lagrange and serendipity elements - Solid elements - Isoparametric formulation - Stiffness matrix of isoparametric elements - Numerical integration: one, two and three dimensional.

Module:4	Analysis of Frame Structures	7 hours

Stiffness of truss members - Analysis of truss - Stiffness of beam members - Finite Element Analysis of continuous beam - Plane frame analysis - Analysis of grid and space Frame.

Module:5	Finite element analysis of 1-D and 2-D problems	7 hours

Finite Element Analysis of 1-D problems: formulation by different approaches (direct, potential energy and Galerkin) - Derivation of elemental equations and their assembly - Solution and its postprocessing - Bending of beams - Finite element analysis of 2-D problems: finite element modelling of single variable problems - Triangular and rectangular elements.

Module:6	Applications in Heat transfer	7 hours
Basic equations of heat transfer - Energy balance equation - Rate equation – conduction – Convection – Radiation - 1D finite element formulation using vibration method - Problems with temperature gradient and heat fluxes - Heat transfer in composite sections - Straight fins.		
Module:7	**Axi-symmetric Solid Elements**	**6 hours**
Derivation of stiffness matrix of axisymmetric bodies with triangular elements - Numerical solution of axisymmetric triangular element(s) subjected to surface forces - Point loads - Angular velocity - Pressure vessels.		
Module:8	**Contemporary Issues**	**2 hours**
Guest Lecture from Industry and R & D Organizations		
	Total Lecture hours:	**45 hours**

Text Books

1.	D.L. Logan, First Course in the Finite Element Method, 2022, Fifth Edition, Cengage Learning Publisher, Boston.

Reference Books

1.	S.S. Rao, The Finite Element Method in Engineering, 2017, Fifth Edition, Butterworth-Heinemann Publisher, United States.
2.	T.R. Chandrupatla, A.D. Belegundu, Finite Elements in Engineering, 2013, Fourth Edition, Pearson Publisher, United Kingdom.
3.	N.S. Ottosen and H. Petersson, Introduction to the Finite Element Method, 1992, Prentice-Hall Publisher, United States.
4.	K.J. Bathe, Finite Element Procedures in Engineering Analysis, 2009, Second Edition, Prentice-Hall Publisher, United States.
5.	C.S. Krishnamurthy, Finite Element Analysis: Theory and Programming, 1990, Tata McGraw-Hill Publisher, India.
6.	K.H. Huebner, D.L. Dewhirst, D.E. Smith and T.G. Byrom, The Finite Element Method for Engineers, 2001, Fourth Edition, Wiley-Inderscience Publisher, New York.

Mode of Evaluation: CAT, Written Assignment, Quiz, FAT and Seminar		
Recommended by Board of Studies	DD-MM-YYYY	
Approved by Academic Council	No. xx	Date DD-MM-YYYY

Course Code	Sobolev Spaces	L	T	P	C
TMAT415L		3	0	0	3
Pre-requisite	TMAT403L - Functional Analysis	Syllabus version			

Course Objectives

1. To illustrate functional analytic methods to understand analysis on Sobolev Spaces.
2. To use tools from Sobolev Space in the understanding of Partial Differential Equations.
3. To apply the knowledge of nonlinear analysis in the context of real life, geometric problems.

Course Outcome

1. Ability to understand and learn to apply the concepts of nonlinear analysis on function spaces.
2. Ability to understand the properties of Sobolev spaces.
3. Apply the knowledge of nonlinear analysis to approximate functions on Sobolev spaces.
4. Derive and appropriately use different inequalities to approximate functions in Sobolev norms.
5. Analyse the compactness properties of Sobolev spaces to extract convergence properties, possibly in dual norm.

Module:1	Elements of Functional Analysis	8 hours

Function Spaces: Banach Spaces, Hilbert Spaces, Dual Spaces, Banach-Alaoglu Theorem; Weak and Weak-* convergence on function spaces; Theory of Distributions, Density of smooth functions in function spaces.

Module:2	Introduction to Sobolev Spaces	8 hours

Definition of Hölder Spaces, Hölder continuity of Brownian Motion; Definition of Weak Derivatives, Sobolev spaces, Properties of Weak Derivatives, Completeness of Sobolev Spaces, Hilbert Space Structure.

Module:3	Analysis on Sobolev Spaces	7 hours

Interior approximation by smooth functions, Local approximation by smooth functions in Sobolev Spaces, Global approximation by smooth functions in Sobolev Spaces, Chain rule, Truncation, Weak convergence on Sobolev spaces.

Module:4	Extension of Sobolev Functions	4 hours

Extension of Sobolev Functions, Trace operator and trace inequality, Gagliardo-Nirenberg-Sobolev inequality.

Module:5	Inequalities in Sobolev Spaces	4 hours

Morrey's inequality, Poincaré's inequality, General Sobolev inequality.

Module:6	Compactness in Sobolev Spaces	8 hours

Relich - Kondrachov compactness theorem, Difference quotients in Sobolev Spaces, Lipschitz functions and space, Differentiability almost everywhere of Lipschitz function and Rademacher's

theorem.		
Module:7	**Dual of Sobolev Spaces**	**4 hours**
Fourier transform methods; Dual of Sobolev Spaces, The space-time dependent Sobolev Spaces.		
Module:8	**Contemporary Issues**	**2 hours**
Guest Lecture from Academia and/or Industry and/or R & D Organizations		
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	S. Kesavan, "Topics in Functional Analysis and Applications", 2019, 3rd Edition, New Age International Publishers, India.
Reference Books	
1.	Lawrence C. Evans, "Partial Differential Equations", 2010, 2nd Edition, American Mathematical Society.
2.	Haim Brezis, "Functional Analysis, Sobolev Spaces and Partial Differential Equations", 2010 Springer Publishers.
3.	Robert A. Adams and John J. F. Fournier, "Sobolev Spaces", 2006, 2nd Edition, Elsevier Publishers.

Mode of Evaluation: CAT, Written Assignment, Quiz, FAT and Seminar		
Recommended by Board of Studies	DD-MM-YYYY	
Approved by Academic Council	No. xx	Date DD-MM-YYYY

Course Code	COMPUTATIONAL FLUID DYNAMICS	L	T	P	C
TMAT416L		3	0	0	3
Pre-requisite	TMAT404L – PARTIAL DIFFERENTIAL EQUATIONS	Syllabus version			

Course Objectives

1. To introduce Governing Equations of viscous fluid flows.
2. To introduce numerical modelling and its role in the field of fluid flow and heat transfer.
3. To enable the students to understand the various discretization methods, solution procedures and turbulence modelling.

Course Outcome

1. Explain the differential equations for flow phenomena and numerical methods for their solution.
2. Analyze different mathematical models and computational methods for fluid flow and heat transfer simulations.
3. Solve computational problems related to fluid flows and heat transfer.
4. Analyze the accuracy of a numerical solution by comparison to known solutions of simple test problems and by mesh refinement studies.
5. Determine forces in both internal and external flows.

Module:1	Governing Equations and Boundary Conditions	6 hours

Basics of computational fluid dynamics – Governing equations of fluid dynamics – Continuity, Momentum and Energy equations – Chemical species transport – Physical boundary conditions – Time-averaged equations for Turbulent Flow – Turbulent–Kinetic Energy Equations

Module:2	Mathematical behaviour of partial differential equations	6 hours

Classification of quasi-linear partial differential equations, Methods of determining the classification, General behaviour of Hyperbolic, Parabolic and Elliptic equations.

Module:3	Finite Difference Method	6 hours

Derivation of finite difference equations–General Methods for first and second order accuracy – solution methods for finite difference equations – Elliptic equations – Iterative solution Methods – Parabolic equations – Explicit and Implicit schemes – Example problems on elliptic and parabolic equations.

Module:4	Finite Volume Method (FVM) for Diffusion	6 hours

Finite volume formulation for steady state One, Two and Three -dimensional diffusion problems. One dimensional unsteady heat conduction through Explicit, Crank – Nicolson and fully implicit schemes.

Module:5	Finite Volume Method for Convection Diffusion	7 hours

Steady one-dimensional convection and diffusion – Central, upwind differencing schemes-properties of discretization schemes – Conservativeness, Boundedness, Transportiveness, Hybrid, Power-law, QUICK Schemes		
Module:6	**Calculation Flow Field by FVM**	**6 hours**
Representation of the pressure gradient term and continuity equation – Staggered grid – Momentum equations – Pressure and Velocity corrections – Pressure Correction equation, SIMPLE algorithm and its variants. Turbulence models, mixing length model– High and low Reynolds number models.		
Module:7	**Grid generation- Finite volume method for unstructured grids**	**6 hours**
Algebraic Grid Generation, Elliptic Grid Generation, Hyperbolic Grid Generation, Parabolic Grid Generation.		
Module:8	**Contemporary Issues**	**2 hours**
Guest Lecture from Industry and R & D Organizations		
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	T.J. Chung, "Computational Fluid Dynamics", 2002, 1st Edition, Cambridge University Press.
2.	Atul Sharma, "Introduction to Computational Fluid Dynamics", 2022, First Edition, Springer, Switzerland.

Reference Books

1.	S.V. Patankar, "Numerical Heat Transfer and Fluid Flow", 2004, Hemisphere Publishing Corporation.
2.	K. Muralidhar and T. Sundararajan, "Computational Fluid Flow and Heat Transfer", 1995, Narosa Publishing House, NewDelhi.
3.	P.S. Ghoshdastidar, "Heat Transfer", 2005, Oxford University Press.
4.	Anil W. Date, "Introduction to Computational Fluid Dynamics", 2005, Cambridge University Press,
5.	H. Versteeg, W. Malalasekera, "An Introduction to Computational Fluid Dynamics: The finite volume Method", 1998, Longman Scientific & Technical.

Mode of Evaluation: CAT, Written Assignment, Quiz, FAT and Seminar		
Recommended by Board of Studies	DD-MM-YYYY	
Approved by Academic Council	No. xx	Date DD-MM-YYYY

Course Code	MATHEMATICAL MODELLING AND SIMULATION	L	T	P	C
TMAT417L		3	0	0	3
Pre-requisite	TMAT204L – ORDINARY DIFFERENTIAL EQUATIONS	Syllabus version			

Course Objectives

1. Familiarize with mathematical modelling and its uses.
2. To Formulate models, dimensional analysis, analyze the qualitative behavior of the solutions.
3. To apply modelling to design the uncertainties that arise in nature and analyzing the effect of these uncertainties.
4. To introduce various simulation techniques to simulate the real-life patterns modelled using the mathematical techniques.

Course Outcome

1. Use of mathematical models to nature inspired problems.
2. Apply and analyze the tools required for differential equation models qualitatively.
3. Able to understand the techniques to study the behavior of the solutions geometrically.
4. Illustrate the concepts on biochemical kinetics and tools to model them.
5. Ability to model the stochasticity arising in nature and simulate these models.

Module:1	Introduction to Mathematical Modeling	4 hours

Introduction, Problem categories, Polyäs four steps in problem-solving; Formulation of a mathematical model; Solving the model equations; Drawing qualitative conclusions; Choosing parameters; Robustness; Analysis of results; Success and failures of modeling.

Module:2	Qualitative Behavior of Simple Differential Equation Models	6 hours

Nondimensionalization and Scaling; Qualitative analysis of models with bifurcations; Bistability and hysteresis; A host of bifurcations – fold, transcritical, pitchfork bifurcations; Bifurcation points and zero eigenvalues

Module:3	Phase Plane Analysis	6 hours

Phase plane trajectories; Nullclines; Steady States; Stability of steady states; Classification of steady-state behavior; Qualitative behavior and phase plane analysis; Limit cycles, attractors, and domains of attraction; Bifurcations continued.

Module:4	Biochemical Kinetics	7 hours

Transitions between states at the molecular level; Transitions between states at the population level; The law of mass action; Enzyme kinetics – Saturating and cooperative reactions; Simple models for polymer growth dynamics.

Module:5	Enzyme-mediated Biochemical Kinetics	7 hours

Transitions between three states; Enzyme-substrate complex and the quasi-steady state (QSS)

approximation; Conditions for validity of QSS; Overview and discussion of QSS; Applications.		
Module:6	**Stochastic Modelling**	**7 hours**
Stochastic Process; Probability Generating Function; Markov Chains; Random Walks.		
Module:7	**Computer Simulations**	**6 hours**
Deterministic Structure; Stochastic Structure; Monte-Carlo Methods.		
Module:8	**Contemporary Issues**	**2 hours**
Guest Lecture from Industry and R & D Organizations		
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Lee A. Segael, Leach Edelstein-Keshet, "A Primer on Mathematical Models in Biology", 2013,1st Edition, Society for Industrial and Applied Mathematics, Philadelphia.
2. Seyed M. Moghadas, Majid Jaderi-Douraki, "Mathematical Modelling – A Graduate Textbook", 2019, John Wiley & Sons, Inc., USA.

Reference Books

1. Natali Hritonenko, Yuri Yassenko, "Applied Mathematical Modelling of Engineering Problems", 2003, Springer, New York.
2. Dilwyn Edwards, Michael Hamson, "Mathematical Modeling Skills", 1996, Macmillan Press, London.
3. Simon Serovajsky, "Mathematical Modelling", 2022, CRC Press, Boca Rotan

Mode of Evaluation: CAT, Written Assignment, Quiz, FAT and Seminar

Recommended by Board of Studies	DD-MM-YYYY	
Approved by Academic Council	No. xx	Date DD-MM-YYYY

Course Code	Infinite Dimensional Optimization and Control Theory	L	T	P	C
TMAT418L		3	0	0	3
Pre-requisite	NIL	Syllabus version			

Course Objectives

1. To introduce and apply relevance of theory of semigroups of bounded linear operators and its applications to partial differential equations.
2. To analyse the theory on the abstract Cauchy problems.
3. To compare the finite and infinite dimensional control problems.

Course Outcome

At the end of the course, the students will be able to

1. Have the knowledge about basic concepts of semigroup theory and applications.
2. Understand Cauchy problem and find the solution for the problem.
3. Apply the semigroup for solving problems in finite and infinite dimensional control problems.
4. Describe the facts of evolution equations and apply the same solving wave equations.
5. Apply the control theory concepts for solving abstract minimization problems and time optimal control problems

Module:1	Semigroups of Bounded Linear Operators	7 hours

Uniformly Continuous Semigroups of Bounded Linear Operators - Strongly Continuous Semigroups of Bounded Linear Operators - The Hille-Yosida Theorem - The Lumer Phillips Theorem - The Characterization of the Infinitesimal Generators of Co Semigroups.

Module:2	The Abstract Cauchy Problem	6 hours

The Homogeneous Initial Value Problem - The Inhomogeneous Initial Value Problem - Regularity of Mild Solutions for Analytic Semigroups - Asymptotic Behaviour of Solutions.

Module:3	Finite Dimensional Control Problems	6 hours

Calculus of Variations: Surface of Revolution of Minimum Area - Interpretation of the Results - Mechanics and Calculus of Variations - Optimal Control: Fuel Optimal Landing of a Space Vehicle.

Module:4	Infinite Dimensional Control Problems	6 hours

Banach Spaces and Their Duals. Uniform Boundedness Principle - Hahn-Banach theorem - One-step Hahn-Banach Lemma - Zorn's lemma - Bohnenblust-Sobczyk theorem - Closed graph theorem - Abstract Cauchy Problems

Module:5	**Evolution Equations**	**6 hours**
Evolution Equations - Perturbation Theory - Wave Equations – Semi-linear Wave Equations: Local Existence – Semi-linear Equations in Banach Spaces: Global Existence		
Module:6	**Abstract Minimization Problems in Hilbert Spaces**	**6 hours**
Control Systems: Continuity of the Solution Map - Patch Perturbations and Directional Derivatives - Continuity of the Solution Operator of the Variational Equation.		
Module:7	**Time Optimal Problem**	**6 hours**
The Minimum Principle for the Time Optimal Problem - The Minimum Principle for General Control Problems - Optimal Problems for Some Linear and Semi-linear Equations.		
Module:8	**Contemporary Issues**	**2 hours**
Guest Lecture from Industry and R & D Organizations		
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	O.H. Lerma, L.R.L. Guarachi, S.M.P. David, G. Sanchez, "An Introduction to Optimal Control Theory", 2023, First Edition, Springer Cham, Switzerland.
2.	Hector O. Fattorini, "Infinite Dimensional Optimization and Control Theory, Encyclopaedia of Mathematics and its Applications", 2013, Cambridge University Press.
Reference Books	
1.	Kalyan Sinha and Sachi Srivastava "Theory of Semigroups and Applications, Texts and Readings in Mathematics", 2017, Springer Nature Singapore Pte Ltd.
2.	K. Yosida, "Lectures on Semi-group Theory and its Application to Cauchy's Problem in Partial Differential Equations", 1957, Tata Institute of Fundamental Research Bombay, India.
3.	Phillipe Clement, "Semigroup theory and applications: 116 (Lecture Notes in Pure and Applied Mathematics)", 1989, 1st edition, CRC Press Inc.

Mode of Evaluation: CAT, Written Assignment, Quiz, FAT and Seminar		
Recommended by Board of Studies	DD-MM-YYYY	
Approved by Academic Council	No. xx	Date DD-MM-YYYY

Projects and Internship

Course Code	Course Title	L	T	P	C
TMAT497J	Project	0	0	0	2
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives:

1. To provide sufficient hands-on learning experience related to the design, development and analysis of suitable product / process so as to enhance the technical skill sets in the chosen field.

Course Outcomes:

At the end of the course student will be able to

1. Demonstrate professional and ethical responsibility.
2. Evaluate evidence to determine and implement best practice.
3. Mentor and support peers to achieve excellence in practice of the discipline.
4. Work in multi-disciplinary teams and provide solutions to problems that arise in multidisciplinary work.

Module Content

1. Project may be a theoretical analysis, modeling & simulation, experimentation & analysis, prototype design, fabrication of new equipment, correlation and analysis of data, software development, applied research and any other related activities.
2. Can be individual work or a group project, with a maximum of 3 students. In case of group projects, the individual project report of each student should specify the individual's contribution to the group project.
3. The project should be carried out inside the university.
4. Publications in the peer reviewed journals/ International Conferences will be an added advantage.

Mode of Evaluation: Assessment on the project - project report to be submitted, presentation and project reviews

Recommended by Board of Studies	
Approved by Academic Council	Date

Course Code	Course Title	L	T	P	C
TMAT498J	Research Project I	0	0	0	4
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives:

1. To provide sufficient hands-on learning experience related to the design, development and analysis of suitable product / process so as to enhance the technical skill sets in the chosen field.

Course Outcomes:

At the end of the course student will be able to

1. Formulate specific problem statements for well-defined real-life problems with reasonable assumptions and constraints.
2. Conduct experiments / Design and Analysis / solution iterations and document the results.
3. Perform error analysis/ benchmarking/ costing.
4. Synthesize the results and arrive at scientific conclusions / products / solution.
5. Document the results in the form of technical report/ presentation.

Module Content

1. Project may be a theoretical analysis, modeling & simulation, experimentation & analysis, prototype design, fabrication of new equipment, correlation and analysis of data, software development, applied research and any other related activities.
2. Project can be for one or two semesters based on the completion of required number of credits as per the academic regulations.
3. Can be individual work or a group project, with a maximum of 3 students.
4. In case of group projects, the individual project report of each student should specify the individual's contribution to the group project.
5. The project should be carried out inside the university.
6. Publications in the peer reviewed journals/ International Conferences will be an added advantage.

Mode of Evaluation: Assessment on the project - project report to be submitted, presentation and project reviews

Recommended by Board of Studies	
Approved by Academic Council	Date

Course code	Research Project II / Internship	L	T	P	C
TMAT499J					8
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

1. To understand the application of social work research by recalling research methodology, tools, techniques in the actual undertaking of a research study with faculty guidance.
2. To author research report, going through each stage of research: Identifying research problem, the review of literature, data collection, consolidation, interpretation, using statistics as appropriate, adding key findings and presenting enlisting suggestions and recommendations.
3. To demonstrate professionalism in the agency of placement for intensive field training (Internship) to reinforce further learning through observation and practice of different methods of social work in dedicated internship mode.

Course Outcomes

On completion of this course the student will be able to:

1. Compare and contrast the different research designs and methods. Organize, analyze and interpret the data to provide meaningful findings and recommendations to draft a comprehensive report.
2. Execute independent research in a systematic manner by applying the research expertise to come up with baseline, midline and end-line studies in any project.
3. Design projects based on research-based evidence and conduct campaigns and advocate for policy change powered by strong research.
4. Apply the knowledge on different organizations, the experience of using Social Work methods abiding by the principles, values and ethics of social work to fulfil the expectations outlined by the organization.
5. Identify and apply personal strengths aligning with the organizational requirements to enhance professional enhancement during Internship.
6. Develop and demonstrate thorough professionalism in the documentation and timely submission of reports and presentations in sharing and receiving feedback by active participation in discussions.

General Guidelines — **One Semester**

1. With the guidance of the research supervisor, students identify the research problem and fix the title of the Study. They then draft the Need and significance of the study along with the Objectives of the study.
2. The Research methodology including the field of study, sampling design, Research design, Tool for data collection are fixed. After the pre-test, the tools are finalized and data collection carried out in online / personal mode. Students then carry out the Data Analysis and apply statistical tools as needed
3. The major findings of the Research emerge as the data is tabulated, presented and interpreted and then the summary & conclusion of the study are presented along with suggestions and recommendations
4. The Internship is an intensive field training in select agencies to hone professional social work skills and values wherein trainees get opportunity to learn by doing and observing as unpaid staff of the agency.
5. Students make real, meaningful contributions during Internship. Along with the opportunity to learn the day-to-day functioning of the setting by working there, students may contribute through specific tasks in research, communication,

capacity-building, resource mobilization, Campaign and advocacy areas of the organization or institution.

6. The students can opt either research work or internship.

Mode of Evaluation: Research Internal Assessment 60 marks and External Viva Voce 40 marks.

Internship: The daily report and consolidated report of the trainee reviewed by the field and faculty supervisors evaluated.

Internal Assessment 60 marks and External Assessment 40 marks.

Recommended by Board of Studies			
Approved by Academic Council		Date	

Open Elective

TMAT419L	Exploratory Data Analysis and Visualisation	L	T	P	J	C
		3	0	0	0	3
Pre-requisite	**Nil**	**Syllabus version**				
		1.0				

Course Objectives:

1. To introduce the methods for data preparation and data understanding.
2. To cover essential exploratory techniques for understanding multivariate data by summarizing it through statistical methods and graphical methods.
3. To familiarize with predictive analytics, data science and Data Visualization.

Course Outcome:

At the end of the course the student should be able to

1.Handle missing data in the real world data sets by choosing appropriate methods.
2.Visualize the data using basic graphs and plots.
3. Identify the outliers if any in the data set.
4. Choose appropriate feature selection and dimensionality reduction.
5.Techniques for handling multi-dimensional data.

Module:1	**Introduction To Exploratory Data Analysis**	**3 hours**

Data Analytics life cycle, Exploratory Data Analysis(EDA) – Definition, Motivation, Steps in data exploration, The basic data types Data Type Portability

Module:2	**Preprocessing- Traditional Methods and Maximum Likelihood Estimation**	**4 hours**

Introduction to Missing data, Traditional methods for dealing with missing data, Maximum Likelihood Estimation – Basics, Missing data handling, Improving the accuracy of analysis.

Module:3	**Preprocessing Bayesian Estimation**	**4 hours**

Introduction to Bayesian Estimation, Multiple Imputation -Imputation Phase, Analysis and Pooling Phase, Practical Issues in Multiple Imputation, Models for Missing Notation Random Data.

Module:4	**Data Summarization & Visualization**	**4hours**

Statistical data elaboration, 1-D Statistical data analysis, 2-D Statistical Data Analysis, N- D Statistical data analysis.

Module:5	**Outlier Analysis**	**3hours**

Introduction, Extreme Value Analysis, Clustering based, Distance Based and Density Based outlier analysis, Outlier Detection in Categorical Data.

Module:6	**Feature Selection Methods**	**4hours**

Feature selection algorithms: filter methods, wrapper methods and embedded methods, Forward selection backward elimination, Relief, greedy selection, genetic algorithms for feature selection.

Module:7	**Dimensionality Reduction**	**6hours**

Introduction, Principal Component Analysis(PCA), Kernel PCA, Canonical Correlation Analysis, Factor Analysis, Multidimensional scaling, Correspondence Analysis.

Module:8	**Contemporary issues:**		**2hours**
Recent Trends			
	Total Lecture hours:	**30hours**	

Text Book(s)

1. Martinez, W &, Martines, A: Exploratory Data Analysis with MATLAB, 2005,Chapman & Hall.
2. Peng, Roger D. Exploratory Data Analysis with R, 2015.

Reference Books

1. Charu C.Aggarwal, Data Mining: The Text Book, 2015, Springer International Publishing, Switzerland.
2. Craig K. Enders, "Applied Missing Data Analysis", 2010, The Guilford Press.
3. Inge Koch, "Analysis of Multivariate and High dimensional data", 2014, Cambridge University Press.
4. Michael Jambu, "Exploratory and multivariate data analysis", 1990, Academic Press Inc..
5. Charu C. Aggarwal, "Data Classification Algorithms and Applications", 2015, CRC press.

Mode of assessment: CAT, Assignment, Quiz and FAT			
Recommended by Board of Studies			
Approved by Academic Council		**Date**	

TMAT 420L	Artificial Intelligence	L	T	P	C
		3	0	0	3
Pre-requisite	**Nil**	**Syllabus version**			
		1.0			

Course Objectives:

1. To introduce the basic principles of Artificial Intelligence.
2. To impart the knowledge related to the basics of AI including problem solving, knowledge representation, reasoning, planning and perception.
3. To introduce AI techniques in real time problems.

Course Outcomes

At the end of the course the student will be able to

1. Understand the basic concepts of AI.
2. Apply format methods of knowledge representation and reasoning.
3. Understand the foundation principles, mathematical tools and program paradigms of AI.
4. Apply AI in planning and NLP.

Module:1	**Overview of Artificial Intelligence**	**5 hours**

Meaning and Definition of Artificial Intelligence – Characteristics of Intelligent Agents – AI Techniques, Planning Overview – Components of planning system - Criteria for success – Agents and environments – Good Behavior: The concept of Rationality – The Nature of Environments – The structure of Agents.

Module:2	**Problem Solving Techniques**	**6 hours**

Problem solving methods – Search Strategies – Problem Solving by informed search – Heuristic search; Greedy – A^* Search – Problem Reduction Search – Constraint Satisfaction problems

Module:3	**Reasoning with Logic**	**7 hours**

Logic – Propositional and predicate logic – Syntax – Informal and formal semantics – Equivalence – De Morgan's laws – Decidable problems – Many sorted logic – First order logic – Higher order logic – Reasoning methods – Formal program techniques – Pre and post conditions.

Module:4	**Logic and Networks**	**7 hours**

Network – based representation and reasoning – Semantic networks – Conceptual Graphs – Frames – Description Logic (DL) – Concept language – Reasoning using DL – Conceptual Dependence (CD) – Scripts - Reasoning using CD

Module:5	**Game Theory**	**6 hours**

Classification of Games - Game Playing Strategies – Prisoner's Dilemma – Game Playing Techniques – Minimax Procedure - Alpha – beta cut offs – Complexity of alpha – beta search

Module:6	**Probabilistic Reasoning**	**7 hours**

Probabilistic reasoning – Bayes Theorem – Construction of Bayesian networks – Belief propagation – Markov Processes and Hidden Markov Models.

Module:7	**Natural Language Processing**	**5 hours**

Introduction to natural language processing – NLP Basics: Syntax, - Semantics – Introduction to statistical NLP – NLP Applications: Types of chatbots.

Module:8	**Contemporary issues:**	**2 hours**

	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Stuart J. Russell. Peter Novig, Artificial Intelligence – A modern Approach, 2022, 4th edition, Prentice Hall, New Jersey.
Reference Books	
1	Dheepak Kehmani, A First Course in Artificial Intelligence, 2017, 1st edition, McGraw Hill Education, New Delhi.
2.	Steven Bird, Ewan Klein and Edward Loper, Natural Language Processing with Python, 2014, 2nd edition, O' Reilly, United States.
3.	Nil J Nilsson, Artificial Intelligence, A New Synthesis, 2003, 1st Edition, Morgan Kaufman Publishers, United States.
4.	George F Luger, Artificial Intelligence, 2015, 4th edition, Pearson, United Kingdom.
5.	Elaine Rich, Kevin Knight, Shivashankar B Nair, Artificial Intelligence, 2017, 3rd Edition, Tata Mc Graw Hill Education, United States.

Mode of Evaluation: CAT, Assignment, Quiz and FAT			
Recommended by Board of Studies			
Approved by Academic Council		**Date**	

TMAT 421L	Neural Networks	L	T	P	C
		3	0	0	3

Pre-requisite	Nil	Syllabus version
		1.0

Course Objectives:

1. To Introduce the Fundamental Principles of Neural Networks and apply it to real world Problems.
2. To Analyse the different models in ANN and their applications.
3. To introduce the complexity of Deep Learning algorithms and CNN techniques and its applications.
4. To analyse and select appropriate neural network architectures for a variety of tasks.

Course Outcomes

At the end of the course the student will be able to

1. Identify and describe Artificial Neural Networks techniques in building intelligent machines.
2. Model Neuron and Neural Network and to analyse an ANN learning and its applications.
3. Identify the deep learning algorithms which are more appropriate for various types of learning task in various domains.
4. Develop different single layer/ multiple layer perception learning algorithms.
5. Implement deep learning algorithms and solve real - world problems.

Module:1	Introduction to Artificial Neural Networks	5 hours

Fundamental of Neural Networks, Model Of Artificial Neuron, Neural Networks Architectures, Learning Methods , Taxonomy Of Neural Network Architectures, Applications.

Module:2	Feed Forward Neural Networks	7 hours

Perceptron Models: Discrete, Continuous and Multi - Category Training Algorithms. Discrete and Continuous Perceptron Networks, Limitations of the Perceptron , Model Credit Assignment Problem, Generalised Delta Rule, Derivation Of Back Propagation (BP) Training.

Module:3	Other ANN Architectures	7 hours

Associative Memory – Exponential BAM – Associative Memory for Real Coded Pattern Pairs – Applications Adaptive Resonance Theory - Introduction - ART 1 – ART 2- Applications – Neural Network based on Competition – Kohenen Self Organising Maps.

Module:4	Deep Learning	6 hours

Deep Feed Forward network, regularizations, training deep models, dropouts, Training Deep Neural Networks using Back Propagation – Setup and initialization issues, vanishing and exploding Gradient problems, Gradient – Descent Strategies.

Module:5	Convolution Neural Network	6 hours

Convolution Neural Network, Basic Structure of Convolution Neural Network, Case studies: Alexnet, VGGNet, GoogLeNet, Applications of CNN – Object Detection – Content based Image Retrieval.

Module:6	Deep Reinforcement Learning	7 hours

Introduction – Stateless Algorithms – Framework of Reinforcement Learning – Bootstrapping for value function Learning – Policy Gradient Methods – Monte Carlo Tree Search.

Module:7	Advanced Topics in Deep Learning	5 hours
Introduction – Attention Mechanisms – Neural Networks with External Memory – Generative Adversarial Networks (GANs) – Competitive Learning.		
-		
Module:8	**Contemporary issues:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Charu C. Aggarwal "Neural Networks and Deep Learning", 2018, First Edition, Springer International Publishing.
2. Eugene Charniak "Introduction to Deep Learning", 2019, First Edition, MIT Press.

Reference Books

1. Goodfellow, I., Bengio, Y., and Courville, A., Deep Learning, 2016, First Edition,MIT Press.
2. Joshua Chapmann, Neural Networks: Introduction to Artificial Neurons, Backpropogation Algorithms and Multilayer Feedforward Networks, 2017, First Edition, CreateSpace Independent Publishing Platform.
3. Bishop, Christopher M., Pattern Recognition and Machine learning, 2016, Reprint, Springer.

	Mode of Evaluation:	**CAT, Assignments, Quiz, FAT**
	Recommended by Board of Studies	
	Approved by Academic Council	

TMAT422L	Machine Learning	L	T	P	C
		3	0	0	3
Pre-requisite	**Nil**	**Syllabus version**			
		1.0			

Course Objectives:

1. To introduce theoretical knowledge on setting hypothesis for pattern recognition.
2. To introduce how to apply suitable machine learning techniques for data handling and knowledge extraction.
3. To introduce how to evaluate the performance of algorithms and to provide solutions for various real-world applications.

Course Outcomes

At the end of the course the student will be able to

1. Recognize the characteristics of machine learning strategies.
2. Analyse and apply the supervised learning methods for real world problems
3. Identify and integrate more than one technique to enhance the performance of learning.
4. Create a suitable unsupervised learning model for handling unknown patterns.
5. Design models to handle large datasets with online learning.

Module:1	**Introduction**	**5 hours**

PAC Learning – Consistent and inconsistent hypothesis, FIND-S, Candidate Elimination, deterministic and stochastic generalities, error, VC Dimensions, lower bounds – Convex Optimization review -Probability review.

Module:2	**Dimensionality Reduction**	**7 hours**

Feature representation in different domains: text, image, video and audio, Feature selection: Filter, wrapper and embedded models, Feature Reduction, PCA, t-SNE.

Module:3	**Model Selection and Validation**	**7 hours**

Estimation and approximation errors: ERM – SRM – Validation - Regularized based algorithms.

Module:4	**Classification Models**	**7 hours**

Supervised Learning, Perceptron – Single layer & Multi – layer – Linear SVM – Hard, Soft Margins, Kernal Methods, Lazy SVM for instance Based Learning, Handling imbalanced data: One Class SVM.

Module:5	**Ensemble Learning**	**6 hours**

Bagging – Committee Machines and Stacking – Boosting – Ranking based aggregation.

Module:6	**Clustering**	**6 hours**

Unsupervised Learning, Partitional Clustering – K-Means -Linkage – Based Clustering Algorithms – Birch Algorithm – CURE Algorithm – Density-based Clustering – Spectral Clustering.

Module:7	**Online Learning**	**5 hours**

Online Classification in the Realizable Case – Online Classification in the unrealizable Case – Online Convex Optimization – The Online Perceptron Algorithm – On – line to batch conversation - Federated Learning .

Module:8	**Contemporary issues:**	**2 hour**

	Total Lecture hours:	**45 hours**
Text Book(s)		
1.	M. Kubat, "An Introduction to Machine Learning", 2018, Second Edition, Springer Cham.	
Reference Books		
1	Mehryar Mohri, Afshin Rostamizadeh, Ameet Talwalkar "Foundation of Machine Learning", 2018, 2nd Edition, MIT Press.	
2.	Duda, Richard, Peter Hart, and David Stork, "Pattern Classification", 2000, 2nd Edition, John Wiley & Sons, Hoboken.	
3.	Tom Mitchell, "Machine Learning", McGraw Hill, 1997, 3rd Edition.	
Mode of Evaluation: CAT, Assignment, Quiz and FAT		
Recommended by Board of Studies		
Approved by Academic Council		**Date**

TMAT423L	Quantum Computing	L	T	P	C
		3	0	0	3

Pre-requisite	Nil	Syllabus version
		1.0

Course Objectives:

1. To introduce the quantum computing concepts and principles.
2. To provide comprehensive understanding and applications of quantum algorithms.
3. To analyse deeply about technique for design of Quantum.

Course Outcomes

At the end of the course the student will be able to

1. Understand various quantum computing principles and properties.
2. Apply matrix algebra techniques for quantum algorithms.
3. Design quantum gate and circuit operations.
4. Distinguish classical and quantum information theory analyse the techniques for quantum algorithms.
5. Apply and evaluate quantum algorithms

Module:1	Introduction	4 hours

Introduction To Quantum Computing - Motivation - Difference Between Classical and Quantum Computing Reversible Computing - Probabilistic Computing - Quantum Properties - Wave Particle - Duality - Superposition - Entanglement – Coherence – Measurement.

Module:2	Mathematics of Quantum Computing	6 hours

Matrix Algebra: Basis Vectors and Orthogonality - Inner Product and Hilbert Spaces - Matrices and Tensors - Tensor Product of Vector Spaces - Dirac Notation - Density Operators - Probabilities and Measurements - Measurements In Bases.

Module:3	Quantum Computing Building Blocks	8 hours

Qubits – Bra- Ket Notation - Multi-qubits States – Bloch Sphere Representation - Superposition of Qubits – Quantum Entanglement – Operations on Qubits Quantum Gates: NOT – Hadamard, T ,CNOT, Toffoli, Z -Quantum Measuring and Transforming using Gates – Design of Quantum Circuits.

Module:4	Quantum Information	6 hours

Quantum State Machines - Comparison between Classical and Quantum Information Theory - Bell States - Quantum Teleportation - No Cloning Theorem - Quantum Key Distribution - Quantum Error Correction Codes.

Module:5	Techniques for Quantum Algorithms	6 hours

Quantum Fourier Transform - Phase Kick -back Quantum Phase Estimation - Quantum Walks.

Module:6	Quantum Algorithms	7 hours

Deustsch – Jozsa Algorithm – Grover's Search Algorithm – Simmon's Periodicity Algorithm – Shor's Algorithm.

Module:7	Quantum Programming Models	6 hours

Quantum Programming Languages - Development Libraries for Quantum Programs - Applications and Quantum Supremacy.

Module:8	**Contemporary issues:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Benrnhard.C., Quantum Computing for Everyone, 2019, MIT Press.

Reference Books

1. Hidary. J.D, Quantum Computing: An Applied Approach Springer, 2019.
2. Nielsen. and Chuang. I., Quantum Computing and quantum information, 2010, Cambridge University Press.
3. Yanosfky.N.S and Mannucci.M.A., Quantum computing for Computer Scientists, 2008, Cambridge University Press.

	Mode of Evaluation:	**CAT, Assignments, Quiz, FAT**
	Recommended by Board of Studies	
	Approved by Academic Council	

TMAT424L	Deep Learning	L	T	P	C
		3	0	0	3

Pre-requisite	Nil	Syllabus version
		1.0

Course Objectives:

1. To introduce the fundamentals of neural networks and recurrent neural networks, long/short term memory cells and convolutional neural networks.
2. To introduce complex learning models and deep learning models.
3. To explore different learning models for various real time applications.

Course Outcomes

At the end of the course the student will be able to

1. Understand the fundamentals of deep learning and build deep learning models
2. Apply the most appropriate deep learning method in any given situation.
3. Develop neural network models in data-intensive real-time problems.
4. Develop efficient generative models
5. Learn and apply convolutional and recurrent neural network techniques.

Module:1	Introduction	5 hours

Introduction to neural network, Biological Neuron, Idea of computational units, McCulloch Pitts unit and Thresholding logic, Linear Perceptron, Perceptron Learning Algorithm, Convergence theorem for Perceptron Learning Algorithm, Linear separability, feed-forward networks, input, hidden and output layers, organization and architecture of neural networks, linear and nonlinear networks

Module:2	Training algorithms for Feedforward networks	7 hours

Learning the weights, Cost functions, Back-propagation algorithms, gradient descent algorithm, unit saturation, heuristics to avoid local optima, accelerated algorithms, Multilayer Perceptron, Empirical Risk Minimization, regularization, auto encoders

Module:3	Deep Neural Networks	7 hours

Architectures, Properties of CNN representations: invertibility, stability, invariance, convolution, pooling of layers, CNN and TensorFlow, Difficulty of training deep neural networks, Greedy layer-wise training.

Module:4	Better Training of Neural Networks	7 hours

Newer optimization methods for neural networks (Adagrad, adadelta, rmsprop, adam, NAG), second order methods for training, Saddle point problem in neural networks, Regularization methods (dropout, drop connect, batch normalization).

Module:5	Recurrent Neural Networks	6 hours

LSTM, GRU, Encoder-decoder architectures, Auto-encoders (standard, de-noising, contractive, etc), Variational Autoencoders, kohonen SOM, : Back propagation through time, Long Short

Term Memory, Gated Recurrent Units, Bidirectional LSTMs, Bidirectional RNNs		
Module:6	**Deep Generative Learning**	**6 hours**
Dynamic memory models. Reinforcement learning, Restrictive Boltzmann Machines (RBMs), Introduction to MCMC and Gibbs Sampling, gradient computations in RBMs, Deep Boltzmann Machine., deep belief networks, convolutional networks, LeNet, AlexNet		
Module:7	**Recent Trends**	**5 hours**
Variational Auto-encoders, Generative Adversarial Networks, Multi-task Deep Learning, Multiview Deep Learning		
Module:8	**Contemporary issues:**	**2 hours**
Research and Analytical problems related to data science.		
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Bengio, Yoshua, Ian Goodfellow, Aaron Courville, Deep learning, 2016, MIT press.

Reference Books

1.	Raúl Rojas, Neural Networks: A Systematic Introduction, 1996, 2nd edition, Springer Science & Business Media.
2.	Bishop C., Neural networks for pattern recognition, 1995, Oxford university press.

Mode of Evaluation: CAT, Assignment, Quiz, FAT,			
Recommended by Board of Studies			
Approved by Academic Council		**Date**	

TMAT425L	Data Analytics	L	T	P	C
		3	0	0	3
Pre-requisite	**Nil**	**Syllabus version**			
		1.0			

Course Objectives:

1. To explain how to design, construct quality checks the data set before using it to a building prediction model.
2. To explain the importance about feature selection in data models.
3. To familiarise on how probability concepts are used to build prediction models.

Course Outcomes

At the end of the course the student will be able to

1. Understand the basic concepts of data mining and data analytics.
2. Apply the different data preprocessing techniques.
3. Analyse the characteristics of the data and its important feature.
4. Apply deep prediction model for decision making for a given set of problems.
5. Understand the concept of distributed machine learning.

Module:1	Introduction to Data Mining	5 hours

Introduction to Data Mining, Challenges in Data Mining, Data mining tasks, Machine learning, Predictive Data Analytics life cycle Predictive Data Analytic Tools

Module:2	Exploring Data	7 hours

Different Types of Data. Normal Distribution, Identifying Data Quality Issues, Missing Values, Irregular Cardinality, Outliers, Advanced Data Exploration, Visualising Relationships Between Features, Measuring Covariance and Correlation, Data Preparation Normalization Binning, Sampling

Module:3	Feature Selection	7 hours

Feature Reduction, Feature Selection, Statistics for Feature Selection, Chi- Square Test For Feature Selection. ANOVA F test for Feature Selection, RFE feature selection, Dimensionality Reduction and PCA

Module:4	Decision Tree and Similarity-based Learning	7 hours

Decision Trees, Shannon's Entropy Model, Information Gain, Standard Approach: The ID 3 Algorithm Features Space, Measuring Similarity Using Distance Metrics, Standard Approach: The Nearest Neighbour Algorithm, Extensions and Variations, Handling Noisy Data, Deficiency Memory Search. Data Normalization, Predicting Continuous Targets

Module:5	Probability -based Learning	6 hours

Fundamentals, Bayes Theorem, Bayesian Prediction, Conditional Independence and Factorization, Standard Approach: The Naïve Based Model

Module:6	Error Based Learning	6 hours

Simple Linear Regression, Measuring Error, Error Surfaces, Standard Approach: Multivariable Linear Regression with Gradient Descent, Multivariable Linear Regression, Gradient Descent, Choosing Learning Rates and Initial Weights

Module:7	**Distributed Machine Learning**	**5 hours**

Data Parallelism, Splitting Input Data, Parameter Server and All- Reduce Building a Data Parallel Training and Serving Pipeline, Model Parallelism Splitting the Model, Pipeline Input and Layers Split, Implementing Model Parallel Training and Serving Workflows, Federated Learning and Edge Devices

Module:8	**Contemporary issues:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1. John D. Kelleher, Brain Mac Namee, Aoife D'Arcy, Fundamental of Machine Learning for Predictive Data Analytics: Algorithms, Worked Examples, 2020, 2nd Edition, MIT Press.
2. Jason Brownlee, Data Preparation for Machine Learning: Data Cleaning, Feature Selection, and Data Transforms in Python, 2020, First Edition, Machine Learning Mastery.

Reference Books

1. Pang-Ning Tan, Michael Steinbach, Anuj Karpatne, Vipin Kumar, Introduction to Data mining, 2019, 2nd Edition, Pearson.
2. Guanhua Wang, Distributed Machine Learning with Python, 2022, Packt Publishing Ltd.

Mode of Evaluation: CAT, Assignment, Quiz and FAT			
Recommended by Board of Studies			
Approved by Academic Council		**Date**	

Ability Enhancement

TCHY140L	Environmental Studies	L	T	P	C
		3	0	0	3
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives:

1. To make students understand and appreciate the unity of life in all its forms and the implications of life style on the environment.
2. To broaden the understanding of global climate changes and the importance of renewable sources of energy.
3. To give students a basic understanding of the major causes of environmental degradation on the planet, with specific reference to Indian situation
4. To inspire students to find ways in which they can contribute personally and professionally to prevent and rectify environmental problems.

Course Outcome:

Upon Completion of the course, the students will be able to

1. Students will recognize the environmental issues in a problem oriented interdisciplinary perspectives.
2. Students will understand the key environmental issues, the science behind those problems and potential solutions.
3. Students will demonstrate the significance of biodiversity and its preservation.
4. Students will identify various environmental hazards.
5. Students will design various methods for the conservation of resources.
6. Students will formulate action plans for sustainable alternatives that incorporate science, humanity, and social aspects.
7. Students will have foundational knowledge enabling them to make sound life decisions as well as enter a career in an environmental profession or higher education.

Module:1	**Environment and Natural Resources**	**7 hours**

Definition, scope, importance; need for public awareness on natural resources Forest resources – use, exploitation, causes and consequences of deforestation. Water resources – use of surface and subsurface water; dams - effect of drought, water conflicts. Land resources - Land degradation, soil erosion and desertification. Indian Case studies. Food resources – Definition,
world food problems, Traditional and modern agriculture and its impacts and remedies.

Module:2	**Energy Resources**	**7 hours**

Definition for renewable and non-renewable energy resources. Non-renewable energy resources - oil, Natural gas, Coal, Nuclear energy. Renewable energy - Solar energy, Hydroelectric power,
Ocean thermal energy, Wind and geothermal energy. Biomass energy and Bio Gas.

Module:3	**Ecosystem and Biodiversity**	**5 hours**

Concept of ecosystem, Structure and functions of an ecosystem, Food chains, food webs. Energy flow in an ecosystem, ecological pyramids and ecological succession. Case studies: Bio magnification of DDT. Biodiversity-Bio-geographical classification of India, hotspots, values of
biodiversity. Threats to biodiversity - Case study. Conservation of bio-diversity. GM Crops

Module:4	**Environmental changes and Remediation**	**6 hours**

Air, water, soil, Thermal Pollution: Causes, effects and control measures; Nuclear hazard. Solid waste Management- Causes, Effects and control measures. Floods, earthquakes, cyclones,

tsunami and landslides, Case studies.		
Module:5	**Global Climatic Change and Mitigation**	**5 hours**
Global climate change and greenhouse effect – Kyoto Protocol, Carbon sequestration, Acid rain, Ozone depletion problem – Montreal Protocol.		
Module:6	**Social Issues and the Environment**	**6 hours**
Urban problems related to energy and sustainable development, Water conservation, Rain water harvesting, Wasteland Reclamation. Environment Protection Act - Prevention and control of Pollution of Air and Water. Wildlife protection and Forest Conservation Acts.		
Module:7	**Human Population and the Environment**	**7 hours**
Population growth, variation among nations, population explosion, Family Welfare Programme, Environment, Women and Child Welfare, Human rights, HIV/AIDS, Role of information Technology on environment and human health. Discussion on current environmental issues / topics by an Industrial expert or faculty		
Module:8	**Contemporary issues**	**2 hours**
Lecture by Industry Experts		
	Total Lecture hours:	**45 hours**
Lecture by Industry Experts		
Text Book(s)		
1.	Anubha Kaushik and C.P. Kaushik, Environmental Science and Engineering, 2016, 5th Edition, ISBN: 978-81-224-4013-3, New Age International.	
2.	G. Tyler Miller Jrand Scott E. Spoolman, Living in the Environment, 2012. 17th Edition, ISBN-13: 978-0-538-73534-6, Brooks / Cole.	
Reference Books		
1.	Environmental Science and Engineering by Anjali Bagad, 2014, 1st Edition, ISBN-10: 9350997088, Technical Publications.	
2.	Introduction to Environmental Engineering by Masters, 2015, 3rd Edition,	
3.	Basic Environmental Sciences For Undergraduates by Dr.Tanu Allen, Dr.Richa K. Tyagi Dr.Sohini Singh, 2014, 1st Edition, ISBN-10: 938375827, Vayu Education of India.	
Mode of Evaluation: Internal Assessment (CAT, Quizzes, Digital Assignments) & FAT		

Recommended by Board of Studies	28.06.2021		
Approved by Academic Council	No. 63	Date	23.09.2021

TENG101L	Effective English Communication	L	T	P	C
		2	0	0	2
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To enhance the basic communication skills
2. To enable the learners develop proficiency in general and academic writing
3. To expose the learners to the nuances of receptive skills

Course Outcome

1. Use appropriate vocabulary and grammar in writing sentences and paragraphs
2. Write effective letters and E-mails in workplace situations
3. Read and comprehend different texts at the intermediate level
4. Demonstrate effective listening and speaking skills with clear pronunciation

Module:1	**Vocabulary**	**2 hours**
	Synonyms and Antonyms, Prefixes and Suffixes, Word Formation, One Word Substitution, frequently used Idioms and Phrases, Homophones and Homonyms	
Module:2	**Grammar**	**4 hours**
	Parts of Speech, Articles, Tenses, Sentence Structure, Types of Sentences, Subject-Verb Agreement, Connectives and Conjunctions	
Module:3	**Drafting Paragraphs**	**4 hours**
	Elements of Paragraph writing, Keywords Development, Topic Sentence, Writing Paragraphs using Connectives	
Module:4	**Email and Letter Writing**	**4 hours**
	Email writing and etiquettes; Letter writing- process, form and structure, types of formal letters - permission, apology and request	
Module:5	**Reading**	**5 hours**
	Mechanics of Reading, Types of Reading- Skimming and Scanning, Intensive & Extensive, Reading Strategies- Summarizing; Reading short stories and essays for comprehension	
Module:6	**Listening**	**4 hours**
	Process, Types, Barriers**,** Effective Listening strategies, Comprehension of speech, Listening to short speeches and Note taking	
Module:7	**Speaking**	**5 hours**
	Introduction to phonetics, need and use of it - Word stress and Sentence stress - Intonation- rate of speech, pitch, tone – Clarity of voice- Nuances of delivery; modes of delivery, guidelines for effective delivery	
Module:8	**Contemporary Topics**	**2 hours**
Guest Lectures from Industry and, Research and Development Organizations		
	Total Lecture hours:	**30 hours**

Text Book(s)

1. Rizwi, Ashraf. (2017).*Effective Technical Communication*. New Delhi:McGraw-Hill Education

Reference Books

1. Watkins, P. (2018). *Teaching and Developing Reading Skills: Cambridge Handbooks for Language teachers.* India: Cambridge University Press.
2. Koneru Aruna. (2020*). English Language Skills for Engineers.* India: McGraw Hill

	Education.
3.	Wren, P.C. & Martin, H. (2018). *High School English Grammar & Composition* N.D.V. Prasada Rao (Ed.). New Delhi: S. Chand & Company Ltd
4.	Delvin, J. (2017). *How to Speak and Write Correctly*. California, US: Create Space Independent Publishing Platform.
Mode of Evaluation: CAT / written assignment / Quiz / FAT / Seminar / group discussion	

Recommended by Board of Studies	28.06.2021		
Approved by Academic Council	No. 63	Date	23.09.2021

TENG102L	Technical English Communication	L	T	P	C
		2	0	0	2
Pre-requisite	NIL	**Syllabus version**			
		1.0			

Course Objectives:

1. To develop LSRW skills for effective communication in professional situations
2. To enhance knowledge of grammar and vocabulary for meaningful communication
3. To understand information from diverse texts for effective technical communication

Course Outcomes:

1. Use grammar and vocabulary appropriately while writing and speaking
2. Apply the concepts of communication skills in formal and informal situations
3. Demonstrate effective reading and listening skills to synthesize and draw intelligent inferences
4. Write clearly and significantly in academic and general contexts

Module:1	**Introduction to Communication**	**4 hours**
	Nature and Process - Types of communication: Intra-personal, Interpersonal, Group-verbal and non-verbal communication / Cross-cultural Communication - Communication Barriers and Essentials of good communication - Principles of Effective Communications	
Module:2	**Grammatical Aspects**	**4 hours**
	Sentence Pattern - Modal Verbs - Concord (SVA) - Conditionals - Error detection	
Module:3	**Written Correspondence**	**4 hours**
	Job Application Letters - Resume Writing - Statement of Purpose	
Module:4	**Business Correspondence**	**4 hours**
	Business Letters: Calling for Quotation, Complaint & Sales Letter – Memo - Minutes of Meeting - Describing products and processes	
Module:5	**Professional Writing**	**4 hours**
	Paraphrasing & Summarizing - Executive Summary - Structure and Types of Proposal – Recommendations	
Module:6	**Team Building & Leadership Skills**	**4 hours**
	Principles of Leadership - Team Leadership Model - Negotiation Skills - Conflict Management	
Module:7	**Research Writing**	**4 hours**
	Interpreting and Analysing a research article - Approaches to Review Paper Writing - Structure of a research article - Referencing	
Module:8	**Guest Lecture from Industry and R&D organizations**	**2 hours**
	Contemporary Issues	
	Total Lecture hours:	**30 hours**

Text Book(s)	
1.	Raman, Meenakshi & Sangeeta Sharma. (2015). *Technical Communication: Principles and Practice*, (3rd Edition). India: Oxford University Press.
Reference Books	
1.	Taylor, Shirley & Chandra .V. (2010). *Communication for Business A Practical Approach* 4th Edition. India: Pearson Longman.
2.	Kumar, Sanjay & Pushpalatha. (2018). *English Language and Communication Skills for Engineers.* India: Oxford University Press.
3.	Koneru Aruna. (2020*). English Language Skills for Engineers.* India: McGraw Hill Education.
4.	Rizvi, M. Ashraf. (2018). *Effective Technical Communication* 2nd Edition. Chennai: McGraw Hill Education.
5.	Mishra, Sunitha & Muralikrishna,C. (2014). *Communication Skills for Engineers*. India: Pearson Education.
6.	Watkins, P. (2018). *Teaching and Developing Reading Skills: Cambridge Handbooks for Language teachers*. India: Cambridge University Press.
Mode of Evaluation : CAT / Assignment / Quiz / FAT / Group Discussion	

Recommended by Board of Studies		28.06.2021	
Approved by Academic Council	No. 63	Date	23.09.2021

TENG102P	Technical English Communication Lab	L	T	P	C
		0	0	2	1
Pre-requisite	NIL	**Syllabus version**			
		1.0			

Course Objectives:

1. To use appropriate grammatical structures in professional communication
2. To improve English communication skills for better employability
3.To enhance meaningful communication skills in writing and public speaking

Course Outcomes:

1.Demonstrate professional rhetoric and articulate ideas effectively
2. Interpret material on technology and deliver eloquent presentations
3. Apply receptive and productive skills in real life situations and develop workplace communication

Indicative Experiments

1.	**Grammar & Vocabulary** Error Detection **Activity:** -Worksheets
2.	**Listening to Narratives** Interviews of eminent personalities & Ted Talks **Activity:** Listening Comprehension / Summarising
3.	**Video Resume** SWOT Analysis & digital resume techniques **Activity:** Preparing a digital résumé for mock interview
4.	**Product & Process Description** Describing and Sequencing **Activity:** Demonstration of product and process
5.	**Mock Meetings** Types of meetings and meeting etiquette **Activity: Conduct of meetings and drafting minutes of the meeting**
6.	**Reading research article** Scientific and Technical articles **Activity:** Writing Literature review
7.	**Analytical Reading** Case Studies on Communication, Team Building and Leadership **Activity:** Group Discussion
8.	**Presentations** Preparing Conference/Seminar paper **Activity:** Individual/ Group presentations
9.	**Intensive Listening** Scientific documentaries **Activity:** Note taking and Summarising
10.	**Interview Skills** Interview questions and techniques **Activity:** Mock Interviews

Total Laboratory Hours	**30 hours**

Mode of Assessment: Continuous Assessment / FAT / Written Assignments / Quiz/ Oral Presentation and Group Activity.

Recommended by Board of Studies	28.06.2021		
Approved by Academic Council	No. 63	Date	23.09.2021

TENG103P	Technical Report Writing	L	T	P	C
		0	0	2	1
Pre-requisite	Technical English Communication	**Syllabus version**			
		1.0			

Course Objectives:

1. To augment specific writing skills for preparing technical reports
2. To think critically, evaluate, analyse general and complex technical information
3. To acquire proficiency in writing and presenting reports

Course Outcomes:

1.Write error free sentences using appropriate grammar, vocabulary and style
2. Synthesize information and concepts in preparing reports
3. Demonstrate the ability to write and present reports on diverse topics

Indicative Experiments

1.	**Advanced Grammar, Vocabulary and Editing** Usage of Tenses - Adjectives and Adverbs - Jargon vs Technical Vocabulary – Abbreviations - Mechanics of Editing: Punctuation and Proof Reading **Activity:** Worksheets
2.	**Research and Analyses** Synchronise Technical Details from Newspapers - Magazines - Articles and e-content **Activity**: Writing introduction and literature review
3.	**Systematisation of Information** Techniques to Converge Objective-Oriented data in Diverse Technical Reports **Activity:** Preparing Questionnaire
4.	**Data Visualisation** Interpreting Data - Graphs - Tables – Charts - Imagery - Infographics **Activity:** Transcoding
5.	**Introduction to Reports** Meaning - Definition - Purpose - Characteristics and Types of Reports **Activity:** Worksheets on Types of reports
6.	**Structure of Reports** Title – Preface – Acknowledgement - Abstract/Summary – Introduction - Materials and Methods – Results – Discussion - Conclusion - Suggestions/Recommendations **Activity:** Identifying the structure of report
7.	**Report Writing** Data Collection - Draft an Outline and Organize Information **Activity:** Drafting reports
8.	**Supplementary Texts** Appendix – Index – Glossary – References – Bibliography - Notes **Activity:** Organizing supplementary texts
9.	**Review of Final Reports** Structure – Content – Style - Layout and Referencing **Activity:** Examining clarity and coherence in final reports
10.	**Presentation** Presenting Technical Reports **Activity:** Planning, creating and digital presentation of reports
	Total Laboratory Hours **30 hours**

Mode of assessment: Continuous Assessment / FAT / Assignments / Quiz / Presentations / Oral examination

Recommended by Board of Studies	28.06.2021		
Approved by Academic Council	No. 63	Date	23.09.2021

Skill Enhancement

TCSE201E	Programming in Java	L	T	P	C
		3	0	2	4
Pre-requisite	**Nil**	**Syllabus version**			
		1.0			

Course Objectives

1. To apply the core Java fundamentals to learn the advanced concepts in J2SE.
2. To design and develop web application development and database connectivity using Servlets, JSP and JDBC.
3. To apply the advanced Java frameworks for the problems in Scientific Domain.

Course Outcomes

1. Provide a basic understanding of core Java concepts.
2. Comprehend Java's support in parallel programming, GUI creation and network programming.
3. Design and develop server side programming using Servlets.
4. Design and implement Java Applications for real world problems involving Database Connectivity.
5. Design, Develop and Deploy dynamic web applications using Servlets and Java Server Pages.

Module:1	**Java Basics:**	**4 hours**

History of Java, Java buzzwords, JVM architecture, Data types, Variables, Scope and life time of variables, arrays, operators, control statements, type conversion and casting, simple Java program.

Module:2	**Object Oriented Programming:**	**5 hours**

Class Fundamentals, Object & Object reference, Constructor & initialization code block, Modifiers, Nested Methods, Argument Passing Mechanism, Method Overloading, Recursion, Dealing with Static Members, Inheritance, Finalize() Method, Native Method. Use of "this "reference, Use of Modifiers with Classes & Methods.

Module:3	**Exception Handling:**	**5 hours**

The idea behind Exception, Exceptions & Errors ,Types of Exception, Control flow in Exceptions, JVM reaction to Exceptions ,Use of try, catch, finally, throw, throws in Exception Handling ,In-built and User Defined Exceptions, Checked and un-Checked Exceptions.

Module:4	**Array & String:**	**6 hours**

Defining an Array, Initializing & Accessing Array, Multi –Dimensional Array, Operation on String, Mutable & Immutable String, Using Collection Bases Loop for String, Tokenizing a String, Creating Strings using String Buffer.

Module:5	**Thread:**	**6 hours**

Understanding Threads , Needs of Multi-Threaded Programming ,Thread Life-Cycle, Thread Priorities ,Synchronizing Threads, Inter Communication of Threads ,Critical Factor in Thread –Deadlock

Module:6	**Files, Streams, Object serialization and JDBC**	**8 hours**

Java I/O streams Working with files Serialization and deserialization of objects Lambda expressions, Collection framework List, Map, Set Generics Annotations, accessing databases using JDBC connectivity.

Module:7	**Java Server Technologies: Servlet**	**9 hours**

Web Application Basics, Architecture and challenges of Web Application, Introduction to servlet, Servlet life cycle, Developing and Deploying Servlets, Exploring Deployment , Descriptor (web.xml), Handling Request and Response, JSP Tags and Expressions - JSP Expression Language (EL) - Using Custom Tag.		
Module:8	**Contemporary issues:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Herbert Schildt, The Complete Reference-Java, Tata Mcgraw-Hill Edition, Eighth Edition, 2014.
2.	Richard M. Reese, Jennifer L. Reese, Alexey Grigorev, Java: Data Science Made Easy, Pocket Publishing, 2017.
Reference Books	
1.	Nicholas S. Williams, Professional Java for Web Applications, Wrox Press, 2014.
2.	Ed Burns, Chris Schalk, Java Server Faces 2.0, The Complete Reference, McGraw-Hill Publishers, 2010.
3.	Christian Bauer, Gavin King, Gary Gregory, Java Persistence with Hibernate, 2015.
4.	Rajat Mehta, Big Data Analytics with Java, Pocket Publishing, 2017.

List of Experiments (Indicative)	
Basic Java Programs	2 hours
Inheritance and Polymorphism	3 hours
Multidimensional arrays and looping constructs.	2 hours
Exception handling, File handling, String handling	4 hours
String handling and Inheritance	4 hours
Multithreaded Programming	4 hours
Problems on Application development	3 hours
Program to register students' data using JDBC with MySQL Database.	2 hours
Creating and configuring servlets, HTTP methods	3 hours
Servlets and JSP	3 hours
Total Laboratory Hours	**30 hours**

Recommended by Board of Studies	12-07-2021		
Approved by Academic Council	No. 64	Date	16-12-2011

Course code	Course Title	L	T	P	C
TCSE202P	Scientific Computing Lab	0	0	4	2
Pre-requisite	NIL	Syllabus version			

Course Objectives

1. To enable the students for having experimental knowledge of basic concepts of scientific computing using Matlab and Python programming.
2. To make students capable to do experimental research using scientific computing in various engineering problems.
3. To enable the students to create computer programs that solve directly, or contribute to solutions of, complex problems in mathematics, chemistry and physics.

Course Outcomes

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

1. Describe the needs and requirements of scientific computing and to familiarize programming language for scientific computing.
2. Analyze and present scientific data in a clear and professional manner.
3. To design, implement, and test code in Python.
4. To emphasis on design and performance considerations of various numerical and discrete algorithms encountered in scientific computing.

Indicative Experiments

1.	Familiarization of the Computing Tool	Total Laboratory hours: 60
2.	Familiarization of Scientific Computing	
3.	Introduction to MATLAB environment, plotting and modifying basic graphs, and evaluating basic mathematical expressions.	
4.	Exploring Interactive inputs and outputs, manipulation of character strings, advanced plotting features and iterations using Matlab	
5.	Introduction to Matrices and Vectors	
6.	Create an interactive function that calculates the RMS value, arithmetic mean, geometric mean and harmonic mean from the user-entered data	
7.	Exploring Interactive inputs and outputs, manipulation of character strings, advanced plotting features and iterations using Python	
8.	Programming problems based on Numpy, scipy and sympy	
9.	Programming problems based on matplotlib	
10.	Mathematical modeling of real-world problems	
11.	Solving Optimization Problems using Python	
12.	Applications of scientific computing in science, engineering and technology.	

Text Book

1. An Introduction to Scientific Computing with MATLAB® and Python Tutorials, Sheng Xu, CRC Press, 2022
2. Practical Numerical and Scientific Computing with MATLAB® and Python, Eihab B. M. Bashier, CRC Press, 2020

Reference Books

1. Scientific Computing with Python-A Hands-on- Approach, Abubeker K M and Shafeena Karim A , Notion Press, 2022
2. Scientific Computing with MATLAB, Alfio Quarteroni, Fausto Saleri, Springer Berlin, Heidelberg, 2002

Mode of assessment: Weekly Assessment, FAT and Oral examination			
Recommended by Board of Studies			
Approved by Academic Council		Date	

S.No.	Benchmarking Institute	% of Match	URL for syllabus
1	College of Engineering, Trivandrum	60%	http://ece.cet.ac.in/computer-lab/
2	University of Technology, Iraq	70%	https://uotechnology.edu.iq/dep/coe/lectures/dr-uosra/New%20folder/Matlab%20LAB2.pdf
3	WorldQuant University, USA	60%	https://www.wqu.edu/programs/applied-ds-lab/
4	University of California,USA	60%	https://extendedstudies.ucsd.edu/courses-and-programs/data-analytics-using-python
5			

Course code	Course Title	L	T	P	C
TCSE203P	Data Analysis Lab	0	0	4	2
Pre-requisite	NIL	Syllabus version			

Course Objectives

To enable the students for acquiring a basic knowledge of data analysis through Python programming.
To perform simple statistical analyses and create meaningful data visualizations, so as to predict future trends from data.

Course Outcomes

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

1. Interpret data in Python using multi-dimensional arrays and vectors in NumPy
2. Handling datasets using Pandas and create informative visualizations using Matplotlib and Seaborn
3. Conduct statistical tests and statistical data exploration using statsmodels

Indicative Experiments

1.	Array and Vector computations using NumPy	Total Laboratory hours: 60
2.	Perform Linear Algebra operations using NumPy	
3.	Working with tabular or heterogeneous data using Pandas	
4.	Series and Data Frame using Pandas - Sorting and Ranking the datasets	
5.	Working with various formats of input and output data using Pandas	
6.	Interacting with databases - loading the results of a SQL query into a Dataframe	
7.	Handling missing and duplicate data using Pandas	
8.	Hierarchical indexing with pandas	
9.	Data visualization with Matplotlib and Seaborn	
10.	Data aggregation and group operations	
11.	Creating Model Descriptions with Patsy	
12.	Applying classification and regression models using statsmodels	
13.	Analysis of variance (ANOVA) methods using statsmodels	
14.	Time series processes using statsmodels	
15.	Perform data analysis on datasets such as MovieLens 1M, USDA Food database, etc.	

Text Book

1. Python for Data Analysis: Data Wrangling with Pandas, NumPy and Jupyter, Wes Mckinney, 3rd Edition, O'Reilly Media, 2022.

Reference Books

1. Pandas for Everyone: Python Data Analysis, Daniel Y Chen, Pearson Education; First Edition, 2018.
2. Hands-on Data Analysis & Visualization with Pandas, Purna Chander Rao. Kathula, BPB Publications, India, 2020.

Mode of assessment: Weekly Assessment, FAT and Oral examination

Recommended by Board of Studies			
Approved by Academic Council		Date	

S. No.	Benchmarking Institute	% of Match	URL for syllabus
1	Stanford University, USA	80%	https://online.stanford.edu/courses/csp-xcs65w-data-analysis-python
2	Simon Fraser University, Canada	70%	https://www.sfu.ca/~mjbrydon/tutorials/BAinPy/01_intro.html
3	University of California, Davis, USA	70%	https://cpe.ucdavis.edu/section/python-data-analysis
4	Indian Institute of Technology Roorkee	70%	https://tih.iitr.ac.in/Ritvij_DAPP.html
5	Indian Institute of Technology Kanpur	60%	https://www.iitk.ac.in/cce/courses/2019/data-analytics-with-python/