Fergusson College (Autonomous)Pune
Learning Outcomes-Based Curriculum
for

Industrial Mathematics with Computer Applications (IMCA)
With effect from June 2023-2024
Deccan Education Society's
Fergusson College (Autonomous), Pune
Program Outcomes (POs)

PO1	**Disciplinary Knowledge:** Demonstrate comprehensive knowledge of the discipline that forms a part of a postgraduate programme. Execute strong theoretical and practical understanding generated from the specific programme in the area of work.
PO2	**Critical Thinking and Problem solving:** Exhibit the skill of critical thinking and understand scientific texts and place scientific statements and themes in contexts and also evaluate them in terms of generic conventions. Identify the problem by observing the situation closely, take actions and apply lateral thinking and analytical skills to design the solutions.
PO3	**Social competence:** Exhibit thoughts and ideas effectively in writing and orally; communicate with others using appropriate media, build effective interactive and presenting skills to meet global competencies. Elicit views of others, present complex information in a clear and concise way and help reach conclusions in group settings.
PO4	**Research-related skills and Scientific temper:** Infer scientific literature, build a sense of enquiry and able to formulate, test, analyse, interpret, and establish hypothesis and research questions; and to identify and consult relevant sources to find answers. Plan and write a research paper/project while emphasizing on academics and research ethics, scientific conduct and creating awareness about intellectual property rights and issues of plagiarism.
PO5	**Trans-disciplinary knowledge**: Create new conceptual, theoretical and methodological understanding that integrates and transcends beyond discipline-specific approaches to address a common problem.
PO6	**Personal and professional competence**: Performindependently and also collaboratively as a part of a team to meet defined objectives and carry out work across interdisciplinary fields. Execute interpersonal relationships, self-motivation and adaptability skills and commit to professional ethics.

PO7	**Effective Citizenship and Ethics**: Demonstrate empathetic social concern and equity centred national development, and ability to act with an informed awareness of moral and ethical issues and commit to professional ethics and responsibility.
PO8	**Environment and Sustainability**: Understand the impact of the scientific solutions in societal and environmental contexts and demonstrate the knowledge of and need for sustainable development.
PO9	**Self-directed and Life-long learning:** Acquire the ability to engage in independent and life-long learning in the broadest context of socio-technological changes.

Deccan Education Society's

Fergusson College (Autonomous), Pune

Program Specific Outcomes (PSOs) and Course Outcomes (COs)

Department of Mathematics

Programme: M.Sc. Industrial Mathematics with Computer Applications

PSO No.	Program Specific Outcomes (PSOs) Upon completion of this Programme the student will be able to
PSO1	**Academic competence** (i) Understand basic facts about Mathematics -annotations, terminology, geometrical figures, graphical displays, and its major subfields (Analysis, Algebra,Applied Mathematics and Statistics). (ii) Design and develop computer programs/computer-based systems in the areas related to algorithms, networking, web design, cloud computing, IoT and data analytics. (iii) Demonstrate unifying structures of Mathematics and the basic constructs of several programming languages and their application areas.

PSO2	**Personal and Professional Competence** (i) Apply mathematical solutions in a variety of contexts related to science, technology, business and industry, and carry out hands-on activities on several programming technologies as well as academic projects. (ii) Analyze the data by selecting and using appropriate mathematical formulae or techniques/programming technology stack in order to draw the relevant conclusion. (iii) Execute the problem-solving skills, equip with Mathematical modelling abilities and develop competent professionals who will be able to address challenges in the field of IT at global level.
PSO3	**Research Competence** (i) Apply advanced knowledge on topics in pure Mathematics and impart analytical skills to develop initiatives and come up with innovative ideas for R&D in various fields. (ii) Integrate the knowledge of Computer Science and Mathematics to solve and authenticate real-time data from various fields.
PSO4	**Entrepreneurial and Social competence** (i) Develop analytical skills required to get distinguishing employment opportunities in several fields including IT, Research and Development, teaching field and gain understanding about the ethical issues related to protection of intellectual property - copyrights, trademarks, and patents. (ii) Execute social competence including communication and effective interaction with others, listening, speaking, observational skills and presenting skills.

Programme Structure

PG I:

Semester	Paper Code	Paper Title	Credits
I	MTS -501	Mathematical Analysis	4
	MTS -502	Applied Linear Algebra	4
	MTS -503 OR	Theoretical Computer Science	4
	MTS -504	Mathematical foundations of Computer Science	
	MTS -510	Research Methodology	4
	MTS -520	Practical Lab -I Programming Language I	2
	MTS -521	Practical Lab -II Understanding of Data and Databases	2
	MNC - 01	Mandatory Non-credit Course (Human Rights)	2

	Total Semester Credits		**20**
II	MTS -551	Abstract Algebra	4
	MTS -552	Probability & Statistics	4
	MTS -553 OR	Graph Theory and its Applications	4
	MTS -554	Numerical Analysis	
	MTS -561	Digital Image Processing	4
	MTS -571	Practical Lab III: Programming and Problem solving with Python	2
	MTS -572	Practical Lab IV: Data Structures using C++	2
	MNC - 02	Mandatory Non-credit Course (Cyber Security -1)	2
	MNC - 03	Mandatory Non-credit Course (Skill Development -1)	2
	Total Semester Credits		**20**
Total PG-I Credits			**40**

PG II :

Semester	**Paper Code**	**Paper Title**	**Credits**
III	MTS -601	Design and Analysis of Algorithms	4
	MTS -604	Dynamical Systems	4
	MTS -605	Data Mining	
	MTS -606	Computational Intelligence	
	MTS -607	Cryptography	4

	MTS -610	Research Project	4
	MTS -621	Practical Lab V: Object Oriented Programming Language- Java	2
	MTS -622	Practical Lab VI: Introduction to Web Technologies	2
	MNC - 02	Mandatory Non-credit Course (Cyber Security -2)	2
	MNC - 03	Mandatory Non-credit Course (Skill Development -2)	2
	Students can choose any one course from MTS604 to MTS606		
		Total Semester Credits	**20**
IV	MTS -652	Applied Geometry for Computer Graphics using CAD	4
	MTS -653	Financial Mathematics	
	MTS -654	Optimization Techniques	
	MTS -655	Statistical Machine Learning	
	MTS -660	Research Project	6
	MTS -671	Emerging Technologies: Introduction to Blockchain Technology	2
	MTS -672	Emerging Technologies: Cloud Computing	
	MTS -673	Emerging Technologies: Edge Computing	
	MTS -674	OJT / Industrial Training	8
		Total Semester Credits	**20**
Students can choose any one course from MTS652 to MTS655			
Total PG-II Credits			**40**

SEMESTER I

Title of the Course and Course Code	MTS-501 Mathematical Analysis	Number of Credits : 04

Course Outcomes (COs) On completion of the course, the students will be able to:	
CO1	Retrieve basic concepts in Metric Topology
CO2	Interpret properties of Continuous and Differentiable functions
CO3	Implement Mean Value theorems to real applications and discuss its use
CO4	Identify series expansions of general continuously differentiable functions for computational needs
CO5	Evaluate Riemann Integrals and identify its applications
CO6	Formulate the theory of sequences and series of functions to use it in several applications

Unit No	Title of the Unit and Contents
1	**Basic Topology** Finite, Countable & Uncountable sets, Metric Spaces, Compact Sets, Perfect Sets Connected Sets
2	**Numerical Sequences and Series** Convergent sequences, sub sequences, Cauchy sequences, Special sequences, Series, Series of non-negative terms, The number e, Root and Ratio tests, Power series, Absolute Convergence
3	**Continuity** Limits of functions, Continuous functions, Continuity and Connectedness, Continuity and Compactness, Monotonic functions, Types of discontinuities
4	**Differentiation** Derivatives and Mean Value Theorems, Taylors theorem, convex functions, Cauchy form of Remainder, Differentiation of Vector Valued functions
5	**Riemann Integral** Concept of Partitions, Refinements, Upper and lower sums, Existence of Integral, Properties of Riemann Integral (without proof), Integral and Differentiation, Fundamental Theorem of Integral Calculus
6	**Uniform Convergence** Concept of uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, uniform convergence and differentiation, Example of a continuous nowhere differentiable function, Equicontinuous family, Stone Weierstrass Theorem (Statement only)

Learning Resources:

1) Walter Rudin, Principles of Mathematical Analysis, McGrawhill India (3rd Edition)
2) Ajit Kumar and S. Kumerasan, A First Course on Real Analysis, CRC Press.
3) J.E. Marsden and M.J. Hoffman, Elementary Classical Analysis, 2nd Edition, W.H.Freeman

Title of the Course and Course Code	**MTS-502 Applied Linear Algebra**	**Number of Credits: 04**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Describe the key concepts associated with vector spaces	
CO2	Illustrate mathematical properties of inner products and solve examples to justify the properties	
CO3	Apply Gram-Schmidt process to find an orthogonal basis to use it in applications	
CO4	Identify the role of Eigenvalue and Eigenvectors in Matrix Decompositions	
CO5	Determine the concept of Linear Transforms to solve real life problems	
CO6	Formulate the concept of Matrix Decompositions to discuss the problems in Engineering and Data Science	

Unit No	Title of the Unit and Contents
1	**Vector Spaces** Real Vector Spaces, Subspaces, Span , Linear Independence, Basis and dimension, Fundamental Matrix Subspaces, Kernel, Image, Cokernel, Coimage, Fundamental Theorem of Linear Algebra relating to these subspaces
2	**Inner products, Norms and Orthogonality** Inner products, Inner products on function spaces, Triangle and Cauchy Schwarz Inequality, Norms, Matrix norms, Positive Definite Matrices, Gram Matrices, Cholesky Factorization, Orthonormal Basis, Gram Schmidt Process, QR Factorization, Orthogonal Projections, Orthogonality of Fundamental Matrix subspaces, Orthogonal Polynomials
3	**Linearity** Linear Operators, Space of Linear Functions, Dual Spaces, Composition and Inverses of Linear Transforms, Change of Basis, Affine Transforms, Isometry, Adjoints, Self-Adjoint Operators, Positive definite Linear functions and Minimization
4	**Eigenvalues & Eigenvectors** Introduction, Gerschgorin Circle theorem, Eigenbases, Diagonalization, Invariant Subspaces, Eigenvalues of Symmetric Matrices, Spectral Theorem (Statement only), Jordan Canonical form, Singular Value Decomposition, Matrix Psuedo Inverse, Principal Component Analysis
5	**Applications**

	Applications of Eigenvalues and Eigenvectors to discrete dynamical systems, Markov Chains, Minimization of Quadratic functions, Closest points, Least Squares, Discrete Fourier Transform and Fast Fourier Transform Algorithm, Matrix Exponential and its applications to Geometry.

Learning Resources:

1) Peter Olver, Chehrzad Shakiban, Applied Linear Algebra, Springer (2nd Edition)
2) Gilbert Strang, Linear Algebra and its applications (4th Edition)
3) David Lay, Linear Algebra with Applications, Pearson Edition
4) Kenneth Hoffman and Ray Kunze, Linear Algebra, PHI India Private Limited
5) M.L. Artin, Algebra, PHI India Private Limited
6) A.G. Hamilton, Linear Algebra, Cambridge University Press
7) Linear Algebra and Learning from Data, Cambridge Press
   Walter Rudin, Principles of Mathematical Analysis, McGrawhill India (3rd Edition)
8) Ajit Kumar and S. Kumerasan, A First Course on Real Analysis, CRC Press.
9) J.E. Marsden and M.J. Hoffman, Elementary Classical Analysis, 2nd Edition, W.H.Freeman

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Title of the Course and Course Code	**MTS-503 Theoretical Computer Science**	**Number of Credits :4**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Define basic concepts of automata theory and describe various forms of grammar to know functioning, capabilities and limitations of computers.	
CO2	Explain and construct finite state systems and Context Free Grammar for the given language. Construct regular expressions to recognize patterns and PDA	
CO3	Apply various techniques and algorithms to transform computing mod and grammar.	
CO4	Analyze and simplify CFG, classify various grammars according to the Chomsky hierarchy.	
CO5	Evaluate various classes of problems, grammar, languages, and language recognizer machines.	
CO6	Integrate the concepts of finite automata, regular expression and context free grammar in order to generate regular expressionfor regular languages to recognize patterns.	

Unit. No.	Title of Unit and Contents
I	**Overview of theory of mathematics**: Sets, Functions, Logical statements, Proofs, relations, languages, Mathematical induction, strong principle, Recursive definitions
II	**Introduction to Theory of Computations:** Fundamental concepts, history, Applications, Phases of Compiler, basic terminologies used in theory of computation: automata, symbol, alphabet, String
II	**Introduction to Regular Languages and Finite Automata:** Regular expressions, regular languages, applications, Automata with output-Moore machine, Mealy machine, Finite automata, memory requirement in a recognizer, definition, union, intersection and complement of regular language, Non Determinism Finite Automata, Conversion from NFA to FA, Non Determinism Finite Automata Conversion of NFA to NFA and equivalence of three Kleene's Theorem, Minimization of Finite automata Regular and Non-Regular Languages – pumping lemma.

III	**Grammar**: Introduction to Grammar, Definition, elements of grammar, Application areas and comparison of different grammars, Comparison
IV	**Context Free Grammar:** Importance of Context free grammar**,** Unions Concatenations and Kleen's of Context free language Regular grammar, Derivations and Languages, Relationship between derivation and derivation trees, Ambiguity Unambiguous CFG and Algebraic Expressions Bacos Naur Form (BNF), Normal Form – CNF
V	**Pushdown Automata, CFL And NCFL:** Pushdown Automata, CFL And NCFL: Definition, deterministic PDA, Equivalence of CFG and PDA, Pumping lemma for CFL, Intersections and Complements of CFL, Non-CFL
VI	**Turing Machine (TM):** TM Definition, Model of Computation And Church Turning Thesis, computing functions with TM, Combining TM, Variations Of TM, Non-Deterministic TM, Universal TM, Recursively and Enumerable Languages, Context sensitive languages and Chomsky hierarchy
VII	**Computable Functions**: Partial, total, constant functions, Primitive Recursive Functions, Bounded Mineralization, Regular function, Recursive Functions

Learning References:

1. John Hopcroft, Rajeev Motwani and Jeffrey Ullman, "Introduction to Automata theory,Languages and computation", 3rd edition Pearson Education, 2009
2. Shirish S. Sane, "Theory of Computer Science", 2nd edition, 2007, Technical publication
3. Daniel I. A. Cohen, John Wiley & Sons, "Introduction to Computer Theory", 2nd edition,2009
4. John E. Hopcroft and Jeffrey Ullman,"Introduction to Automata theory, Languages andcomputation",Narosa Publishing House,1979.

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Title of the Course and Course Code	**MTS-504 Mathematical Foundations of Computer Science**	**Number of Credits : 04**

Course Outcomes (COs) **On completion of the course, the students will be able to:**	
CO1	State basic concepts in Counting and solve examples
CO2	Discuss the concepts of Generating functions
CO3	Apply the concepts of Recurrence relations to model problems in Computer Science
CO4	Analyze the concept of Inclusion Exclusion to count favorable union of events
CO5	Determine the Pigeons and Holes to apply the pigeon hole principle
CO6	Create a set of Boolean identities to model applications in Computer Science

Unit No	Title of the Unit and Contents
1	**General Counting for Arrangements and Selections** Two basic counting principles, Simple Arrangements and Selections, Arrangements and selections with repetitions, Distributions, Binomial Identities
2	**Generating functions** Generating function mod, Calculating coefficients with generating functions, Partitions, Exponential Generating functions.
3	**Recurrence Relations** Recurrence Relation Mod, Divide and Conquer relations, Solution to Linear Recurrences, Solution to Inhomogeneous Recurrence relations, Solutions with Generating Functions.
4	**Inclusion Exclusion Principle** Counting with Venn Diagrams, Inclusion Exclusion Formula, Restricted Positions and Rook Polynomials
5	**Pigeonhole Principle** Pigeonhole principle and its related problems
6	**Lattice Theory/ Boolean Algebra** Poset, Hasse Diagram, Lattices, Complemented Lattices, Bounded and Distributive Lattices, Introduction to Boolean variable, Boolean functions of degree n, Boolean identities, Definition of Boolean Algebra, Representation of Boolean Functions, Minterm Maxterm Disjucntive Normal form, Conjuctive Normal Form, Applications to Computer Science and some practical applications

Learning Resources

1) Alan Tucker, Applied Combinatorics, John Wiley & Sons
2) Course Notes for MATH 239, Introduction to Combinatorics , University of Waterloo
3) Chaun Chong Chen, Khee –Meng, Koh, Principles and Techniques in Combinatorics,
4) Vijay K Garg, Introduction to Lattice Theory with Computer Science Applications , Wiley Publications

Title of the Course and Course Code	MTS-510 Research Methodology	Number of Credits :4
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Define basic concepts of Research	
CO2	Explain significance of statistical analysis, Exploratory and confirmatory research along with various case studies.	
CO3	Applying various statistical methods and software to solve the case studies in various subjects.	
CO4	Analyzing data by collecting it using various methods such as questionnaires.	
CO5	Evaluate various classes of problems, grammar, languages, and language recognizer machines.	
CO6	Writing research paper/ thesis / presentation /research proposal.	

Unit No	Title of the Unit and Contents
1	**Introduction to Research Methodology**: History of research. Indian, Egyptian, Greek ideas methodologies and research in agriculture, chemistry, metallurgy, medical. Ancient Indian research methodology applications.
2	**Overview of Research Types and Statistical Techniques**: Statistical analysis and its significance, Exploratory and confirmatory research, Planned and ad-hoc methods of data collection, Non-response and methods of recovering the missing response, Various softwares for statistical analysis. The module will consist of case studies of the research performed in various subjects using statistical methods, Error and noise analysis, curve fitting
3	**Data Collection and Research Topic**: Creating questionnaire. Data analysis from answers, Selection of research topic (case study based). Selection of research topic (case study based)
4	**Identification of Research Problem**: Literature search, selection of research topic (case study based), maintaining laboratory records (case study based). Safety in Laboratories, Ethical considerations, effective verbal and nonverbal communication, field data collection, safety in field.
5	**Interpretation and Report Writing:** Writing research paper and/or thesis, making a presentation, writing a research proposal, and patents in Science, technology.

6	**Thesis Writing, Presentation and Visualization Tools:** Latex, Beamer, Introduction to Minitab.

Learning References:

1) 'History of the Scientific Methods' by Martin Shuttleworth, https://explorable.com/history-of-the- scientific-method.
2) 'The Statistical Analysis of Experimental Data' by, John Mandel, ISBN: 0486646661, ISBN13: 9780486646664

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Title of the Course and Course Code	MTS-520 Practical Lab– I Programming Language I	Number of Credits: 04
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Recall the basic concepts of the C programming language.	
CO2	Discuss basic concepts of computers, algorithms and algorithmic thinking.	
CO3	Apply stack for implementation of function calls and parameter passing mechanisms.	
CO4	Analyze and compare usage of arrays, strings, structures and files.	
CO5	Determine the solution for a given problem by distinguishing various memory allocation methods.	
CO6	Write C programs to validate the specifications.	

Unit No.	Title of Unit and Contents
1	**Introduction to Programming** Program and Programming, Programming Languages, Types of Software, Operating Systems, Basic Linux Commands and vi Editor, Compiler, Interpreter, Loader and Linker Introduction to algorithms, flow charts, Background of internal working of compilers.
2	**Basics of C** History and Features of C, Importance of C, Backslash Characters, Character set, Constants, Format Specifiers, Identifiers, Keywords, Variables, Data Types, Comments, const Qualifier, The Structure of a C Program, Building an Executable Version of a C Program, Debugging a C Program, Programming Examples
3	**Applications of C Programming** Demonstration of an application developed using C Note: This unit will not be considered for an assessment of students
4	**Control Statements** Decision Making Statements: if, if-else, switchLoop Control Structures: while, do. while, for Keywords- break and continue, exit () Function, return Statement,Programming Examples
5	**Operators and Expressions** Arithmetic Operators, Increment and Decrement Operators, Relational Operators, Logical Operators, Bitwise Operators, Assignment Operators, Conditional Operator, size of Operator, Comma Operator, Type Casting Operator, Other Operators, Precedence and Order of Evaluation, Programming Examples

6	**Input and Output** Unformatted I/O, Character I/O, String I/O, Formatted I/O, ProgrammingExamples
7	**Functions** Concept, Usage of a Function, Advantages, Function Prototype, Function example, Types of Function, Call by Value and Call by Address, Recursion,Library Functions, Local variable, Global Variable, Storage classes (automatic, static, register, external), Programming Examples
8	**Array** Array Declaration, Initialization, Types of Arrays (1-D, 2-D and Multidimensional), Passing Arrays to Functions, Programming Examples
9	**Pointers** Pointer Declaration and Initialization, Dereferencing Pointers, void Pointer, Pointer Arithmetic, Pointer to Pointer, Arrays and Pointers, Functions and Pointers, Passing Pointers to Function, Function Returning Pointer, Pointer toFunction, Dynamic Memory Allocation, Programming Examples
10	**String Handling** Declaration and Initialization, Reading and Writing Strings, Standard StringLibrary Functions, Array of Pointers to String, Command Line Arguments, Programming Examples
11	**Structures and Unions** Overview of Structures, Defining and Using a Structure, typedef Keyword, Nested Structures, Passing Structure to Function, Structure and Pointer, Union, Difference between Structure and Union, Programming Examples
12	**Pre-Processor Directives** Pre-Processor Directives, #define Macro, Conditional Compilation, Pre-defined Macros, #include and Header Files, Programming Examples
13	**File Handling** What is a Stream? Opening and Closing of Files, File Opening Modes,Writing and Reading in Text Format, Writing and Reading in Binary Format, Programming Examples

Learning Resources:

Include Reference Books/ e-resources / journals/any other learning material

1. Kernighan Brian W., Ritchie Dennis M., The C Programming Language, PHILearning Pvt. Ltd., 2nd Edition, 2010
2. Schildt Herbert, C: The Complete Reference, Tata McGraw Hill, 4th Edition, 2006
3. KanetkarYashavant, Pointers in C, BPB Publications, 4th Edition, 2013
4. KanetkarYashavant, Test your C Skills, BPB Publications, Rev. Edition, 2008

Practical Lab II: Understanding of Data and Databases

Title of the Course and Course Code	**Practical Lab -II** **MTS-521 Understanding of Data and Databases**	**Number of Credits: 02**
Course Outcome (COs) **On completion of the course, the students will be able to:**		
CO1	Describe and discuss the fundamentals of data, major components of Databases	
CO2	Interpret a problem and recognize the computing requirements appropriate to its solution	
CO3	Implement appropriate database for computer-based systems according to the user requirements, appropriate syntax to write SQLcommands to perform various RDBMS operations and NoSQL operations	
CO4	Analyze a problem to find out the computing requirements appropriate to its solution.	
CO5	Discuss the purpose of query processing for optimized solution.	
CO6	Design data requirements of an application with the help of conceptual modelling tools.	

Unit No.	Title of Unit and Contents
I	Introduction to data and databases - Data – Introduction / Concept, introduction to data structures, Introduction to databases, Significance of Database, System Applications, Data Independence, Entities and their Attributes, Relationship and Relationship Types, E-R Diagram, Data types, Creating tables (without keys)
2	**Overview of RDBMS (PostgreSQL)** Relational Database Management System, RDBMS Properties, Maintaining Integrity and Defining Data Integrity, Integrity Rules and Integrity Constraints, Relational Integrity Rules, Creating tables (with keys)
3	**SQL** Types of SQL, DDL, DML, Basic queries in SQL Single table, Deletion- Insertion- and Update in SQL, Simple queries (with insert, delete, and update), Multi table Retrievals, Nested queries (with foreign key and using multi tables), Aggregate-Functions, Joins, GROUPBY – HAVING clause, Nested Sub queries
4	**Views and Stored Functions** View definition, how to write view and its execution, Function definition, how to write function and its execution, Solving some problems with function
5	**Cursors** Cursor definition, how to write cursor and its execution, Solving some problems with cursor Introduction to triggers and some demo examples

6	**NoSQL** Introduction, Why NoSQL? RDBMS Vs NoSQL, Features of NoSQL, Types: Key-value Pair Based, Column-oriented, Graphs based, Document-oriented, ACID and BASE for reliable database transactions, CAP theorem
7	**Introduction to MongoDB** Basics, Installation and Set Up, CRUD operations
8	Working with online database (Demonstration)

Learning Resources:

1. Henry F. Korth, Abraham Silberschatz, S. Sudarshan Database System Concepts,ISBN:9780071289597, Tata McGraw-Hill Education
2. KorryDouglas, PostgreSQL, , ISBN:9780672327568
3. John Worsley, Joshua Drake Practical PostgreSQL (B/CD), ISBN: 9788173663925Shroff / O'reilly
4. Joshua D. Drake, John C Worsley Practical Postgresql, O'Reilly
5. Richard Stones, Neil Matthew Beginning Databases with PostgreSQL, From Noviceto Professional, 2nd Edition

E-Resources -

1. https://www.postgresql.org/docs/current/
2. https://www.mongodb.com/docs/atlas/

Semester II

Title of the Course and Course Code	MTS-551 Abstract Algebra	Number of Credits : 04
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Define basic concepts of Group theory with focus on axiomatic theory and key concepts associated with groups.	
CO2	Articulate the fundamental concepts of abstract algebra such as groups and rings and their role in modern Mathematics and applied contexts.	
CO3	Demonstrate capacity for mathematical reasoning through analyzing, proving, and explaining concepts from abstract algebra. Describe the structure of certain finite groups using Sylow's theorems.	
CO4	Compare different types of groups and rings. Explain the notion of rings, ideals.	
CO5	Justify theorems based on group theory, ring theory and articulate problem solving techniques based on them.	
CO6	Construct the structure of finite fields.	

Unit No.	Title of Unit and Contents
I	**Groups, Subgroups and Cyclic Groups:** Definition and Examples of Groups; Properties of Groups; Order of a group; Order of an element in group; Subgroups; Subgroup Tests. Cyclic Groups; Properties of Cyclic Groups; Classification of Subgroups of Cyclic Groups. **Permutation Groups- Isomorphism:** Definition and notation; Cycles; Properties of Permutations; Even and odd permutations; Alternating Group of degree n., Isomorphism of Group; Properties of Isomorphisms; Cayley's Theorem; Automorphisms. **Cosets, Lagrange's Theorem and Normal subgroups, Homomorphisms:** Definition and properties of Cosets; Lagrange's Theorem and consequence; Normal Subgroups; Factor Groups; Application of Factor Groups; Group Homomorphisms; Definition and examples; Properties of Homomorphisms; First Isomorphism Theorem. **Sylow Theorems (Without Proofs):** Fundamental Theorem of Finite Abelian Groups; Isomorphism Classes of Abelian Groups; Proof of the Fundamental Theorem. 5.2 Conjugacy Classes; Class Equation; The Sylow Theorems; Applications of Sylow's Theorems.

II	**Rings:** Definitions and examples, simple properties of rings, Commutative rings, ring with unity, integral domain, field, skew field, definitions examples and interrelationship between them. **Subring:** Definition, Examples, Properties. Characteristic of an integral domain. **Ideals and Factor Rings:** Definitions & Examples, Properties of ideals, Prime Ideals, Maximal Ideals, Quotient rings **Homomorphism and Isomorphism of rings:** Definition and examples, properties of ring homomorphisms, fundamental theorem of ring homomorphisms and its applications. **Euclidean rings:** Polynomial rings F[X] over a field F, F[X] is Euclidean ring, irreducible polynomial over a field, polynomials over a field of rationals, Gauss lemma and Eisenstein's criterion for irreducibility, Construction of finite fields.

Learning Resources:

1) Joseph Gallian, Contemporary Algebra, 9th Edition, Narosa Publishing House.
2) David S. Dummit, Richard M. Foote, Abstract Algebra, 2 nd Edition, John Wiley and Sons (Indian Edition)
3) J.B. Fraleigh, Abstract Algebra, 7th edition
4) I.S. Luthar and I.B.S. Passi, Algebra (Volume 1) Groups (Narosa Publishing House)
5) I.N. Herstein, Topics in Algebra (Wiley-Eastern Ltd)
6) M. Artin, Algebra (Prentice Hall)
7) N.S. Gopala Krishnan, University Algebra (Wiley-Eastern Ltd)
8) C. Musili, Rings and Modules, 2nd Revised Edition, Narosa Publishing House.

Title of the Course and Course Code	MTS-552 Probability & Statistics	Number of Credits : 04

Course Outcomes (COs) On completion of the course, the students will be able to:	
CO1	State basic concepts in probability theory and solve examples
CO2	Discuss concepts of distributions and their parameters
CO3	Apply the concepts of distributions to model a given data and check the goodness of fit
CO4	Analyze the concept of correlation and Regression for a given data
CO5	Determine the statistical significance of Null Hypothesis with inference based tests
CO6	Create methodologies to understand Random processes.

Unit No	Title of the Unit and Contents	No of Lectures
1	**Introduction to Probability** Classical definition of probability, Mutually Exclusive and Independent Events, Inclusion Exclusion Principle, Conditional Probability, Bayes theorem and related problems	4
2	**Distribution Theory** Concept of Random variables (discrete & continuous) distribution function, Joint distributions, Marginal distributions, Conditional distributions, Expected value and Variance of a random variables. Also discussion on specific distributions which include Binomial, Poisson, Uniform, Exponential, Normal distributions with specific examples	20
3	**Special Results** Discussion on Simple Random Walks, Union Bound Inequality, Markov and Chebyshev Inequalities, Chernoff Bounds, Cauchy Schwarz Inequality, Jensen Inequality, Law of Large Numbers, Central Limit theorem and problems related to all of these concepts	8
4	**Statistical Inference: Classical Methods** Introduction to Random Sampling, Concept of Point Estimation, Point Estimators of Mean and Variance, Maximum Likelihood Estimation, Asymptotic properties of MLE's, Concept of Interval Estimation, Finding Interval Estimators, Confidence intervals for normal Samples, General Concepts in Hypothesis testing, P values and related problems	14
5	**Correlation and Simple Linear Regression** Concept of Pearsonian Correlation, Simple Linear Regression Model, Method of Least Squares, Various Assumptions of the Simple Linear Regression Model	8

6	**Introduction to Random processes** Basic Concepts, pdfs and cdfs, Mean and Correlation functions, Multiple Random Processes, Stationary Processess, Gaussian Random Processes	8

Learning Resources

1) Sheldon Ross, Introduction to Probability & Statistics for Scientists and Engineers, Academic Press
2) Elliot Tannis and Robert Hogg, Probability & Statistical Inference, Pearson Edition
3) George Casella and Roger Berger, Statistical Inference, Cenage Learning

Title of the Course and Course Code	MTS-553 Graph Theory and Its Applications	Number of Credits : 04
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Define basic concepts of Graph theory with focus on key concepts associated with graphs.	
CO2	Illustrate various mathematical properties of graphs and solve examples to justify the properties.	
CO3	Apply basic graph theory, minimal weighted spanning tree algorithms, graph coloring algorithms.	
CO4	Compare different types of graphs and operations on graphs.	
CO5	Determine algorithms of fusion, matching algorithms, shortest path algorithms Formulate	
CO6	Formulate Matrix representation of graphs, shortest paths for various graphs	

Unit No.	Title of Unit and Contents
I	**Graph Theory:** **Graph:** Definition, vertex, edge, Terminal vertices, self-loop, parallel edges, incidence, adjacent, degree of vertex, isolated vertex, pendent vertex, null graph, hand shaking lemma, regular graph, bipartite graph, complete graph, complete bipartite graph. **Matrix Representation:** Incidence matrix, adjacency matrix, properties. Subgraph, Isomorphism and examples of isomorphic graphs. **Operations on graphs:** Union, intersection, deletion of vertex, deletion of edge, ring sum, fusion. **Connected graphs:** Walk, paths, circuit, Theorems on connected graphs. **Euler graph:** Definition, examples, Chinese postman problem, Fleury's algorithm, Theorems on Eulerian graphs. **Trees:** Definition, pendent vertex in a tree, distance and centres in a tree, rooted and binary trees, spanning trees and rank nullity, fundamental circuits, fundamental cutset, vertex connectivity, edge connectivity, spanning trees, weighted graphs, Kruskal's algorithms, Prim's algorithm, Breadth first search algorithm, depth first search algorithm, Dijkstra's algorithm, Warshall Floyd algorithm, Theorems on trees. **Directed graphs:** Incident out of a vertex, incident into a vertex, indegree, out degree, isolated vertex, pendent vertex, types of digraphs, arborescence

	definition. **Networks** Flows and cuts, Max ow and min cut theorem, The Ford and Fulkerson Algorithm **Graph Coloring:** **Vertex Coloring:** K-coloring, K-colorable, Chromatic Number, K-Chromatic. Vertex coloring Algorithm: Simple Sequential Coloring, Largest–First Sequential Algorithm (Wh and Powell) Smallest–Last Sequential Algorithm. **Edge Coloring:** Definition and Concept Only. **Planar Graphs:** Introduction Kuratowski's two graphs (K5, K3) Euler's theorem, Examples based on Euler's theorem. **Matching and Factors:** Matching in bipartite graphs, maximum matchings, Hall`s matching conditions, Min-Matching in bipartite graphs, sets, applications and algorithms, maximum bipartite matching, weighted bipartitematching, Tutte`s 1 factor theorem, factors of graphs.

Learning Resources:

1) John Clark, D. A. Holton: A First Look at Graph Theory, World Scientific, 1991.
2) N. Deo, Graph theory with Applications to Computer Science and Engineering, PHI
3) Douglas B. West, Introduction to Graph Theory, Pearson Education, Second Edition

Purna Chandra Biswal, Discrete Mathematics and Graph Theory, Fourth Edition (PHI.).

4)

Title of the Course and Course Code	**MTS-554 Numerical Analysis**	**Number of Credits : 04**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	State and apply different methods of Numerical Differentiation and Integration	
CO2	Explain the basic principles and theory of interpolation	
CO3	Implement all the standard curve fitting techniques	
CO4	Explain basic methods of solving Linear and Non-Linear Equations	
CO5	Test different methods of solving differential equations, compute and evaluate differential equations numerically	
CO6	Develop the knowledge to compute the errors in all of the techniques mentioned in the course	

Unit No	Title of the Unit and Contents
1	**Solution to Non-Linear Equations** Introduction to Big O notation, Types of Errors, Fixed point iterative method, Bracketing method for roots, initial approximation and convergence criteria, Newton Raphson and Secant method, Error Analysis, rate of convergence, Accelerated Newton Raphson Method, Mullers Method
2	**Solutions to Linear and Non-Linear Systems** Upper triangular linear systems, Gaussian Elimination and Pivoting, Triangular Factorization, Iterative methods to solve Linear Systems and their convergence, Newton's method to solve nonlinear systems, Computing Eigenvalues numerically using Power Method, computing Eigenvalues of Symmetric matrix using House holders' method.
3	**Interpolation and Polynomial Approximation** Introduction to the concept of Interpolation, Lagrangian Interpolation, Newton's Interpolation and its various forms (divided difference, forward and backward), Error Analysis with these approximations, Pade Approximations
4	**Curve Fitting** Least Square Line, Curve Fitting, Interpolation by Spline Functions, Fourier Series and Trignometric Polynomials
5	**Numerical differentiation and Integration** Approximating the derivatives, various Numerical differentiation formulas, Introduction to Quadrature, Composite Trapezoidal and Simpson Rule, Error Computations in Numerical Integration
6	**Solutions to Differential Equations** Introduction to Ordinary differential equations, Euler's method, Heun method, Taylor series method, Runge Kutta methods of various orders, Predicator- Corrector Methods with precision and Error analysis

Learning Resources

1) John Mathews & Kurtis Fink, Numerical Analysis using Matlab, Prentice Hall.
2) Kendall Atkinson, Numerical Analysis, Wiley Publications.
3) S.S.Sastry, Numerical Analysis, Prentice Hall India Publication.

Title of the Course and Course Code	**MTS-561 Digital Image Processing**	**Number of Credits: 04**

Course Outcomes (COs) **On completion of the course, the students will be able to:**	
CO1	State basic concepts related to mathematics behind digital image processing, different causes for image degradation.
CO2	Discuss different feature extraction and segmentation techniques.
CO3	Apply different techniques employed for the enhancement of images, various techniques of image enhancement and compression. Demonstrate and execute morphological image processing on various image formats.
CO4	Explain the need for image compression and apply.
CO5	Compare spatial transforms and intensity transforms, different techniques used in feature extraction in images.
CO6	Reconstruct the images using various reconstruction models.

Unit No	Title of the Unit and Contents
I	**Introduction** What is Digital Image Processing, Examples of Fields that use Digital Image Processing**,** Imaging in various electromagnetic bands**,** Fundamental steps in Digital Image Processing, Components of an Image Processing System
II	**Digital Image Processing Fundamentals** Elements of Visual Perception, Light and the Electromagnetic Spectrum, Image sensing and Acquisition, Image Sampling and Quantization, Some Basic Relationships between Pixels, An Introduction to the Mathematical Tools Used in Digital Image Processing
III	**Intensity and Spatial Filtering** Some Basic Intensity Transformation Functions ,Histogram Processing ,Histogram Equalization and Normalization, Histogram Matching (Specification), Local Histogram Processing Fundamentals of Spatial Filtering, Sharpening Spatial Filters Combining Spatial Enhancement Methods.
IV	**Filtering in Frequency Domain** Background and Preliminary Concepts, Sampling and the Fourier Transform of Sampled Functions, The Discrete Fourier Transform (DFT) of One variable, The Basics of Filtering in the Frequency Domain, Image Smoothing using Frequency Domain Filters, Image Sharpening Using Frequency Domain Filters
V	**Image Restoration and Reconstruction** A Model of the Image Degradation / Restoration Process, Noise Model, Restoration in the Presence of Noise Only-Spatial Filtering, Periodic Noise Reduction by Frequency Domain Filtering, Band reject Filters: Band pass Filters, Notch Filters, Estimating the Degradation Function, Geometric Mean Filter
VI	**Morphological Image Processing**

	Preliminaries, Erosion and Dilation, Opening and Closing, The Hit-or-Miss Transformation, Basic Morphological Algorithms, Boundary Extraction, Hole Filling Extraction of Connected Components, Convex Hull, Thinning and Thickening, Skeletons, Pruning, Morphological Reconstruction
VII	**Image Segmentation** Fundamentals, Point, Line, and Edge Detection, Edge Models, Basic Edge Detection Edge Linking and Boundary Detection, Thresholding: Foundation, Basic Global Thresholding, Optimum Global Thresholding, Thresholding using Otsu's Method Region-Based Segmentation
VIII	**Representation and Description** Representation: Boundary (Border) Following algorithms ,Polygonal Approximations Using Minimum-Perimeter Polygons, Other Polygonal Approximation Approaches, Some Simple Descriptors, Shape Numbers, Fourier Descriptors, Regional Descriptors, Some Simple Descriptors, Topological Descriptors, Textural descriptors
	Note: Lectures are assigned to implementation Laboratory Course on MATLAB / Open CV

Learning Resources

1. Gonzalez, R. C. and Woods, R. E. [2002 / 2008], Digital Image Processing, 3rd ed., Prentice Hall
2. Sonka, M., Hlavac, V., Boyle, R. [1999]. Image Processing, Analysis and Machine Vision (2nd edition), PWS Publishing, or (3rd edition) Thompson Engineering, 2007
3. Gonzalez, R. C., Woods, R. E., and Eddins, S. L. [2009]. Digital Image Processing Using MATLAB, 2nd edition, Gatesmark Publishing, Knoxville, TN.
4. Anil K. Jain [2001], Fundamentals of digital image processing (2nd edition), Prentice-Hall, NJ.
5. Willian K. Pratt [2001], Digital Image Processing (3rd Edition), John Wiley & Sons, NY.
6. Burger, Willhelm and Burge, Mark J. [2008]. Digital Image Processing
7. Kropatsch, Digital Image Analysis (With CD-ROM), Springer, ISBN: 978038795066

Title of the Course and Course Code	Practical Lab -II MTS-571 Programming and Problem solving with Python	Number of Credits: 02
Course Outcome (COs) On completion of the course, the students will be able to:		
CO1	Recall the basic concepts programming languages	
CO2	Discuss fundamentals of data structures	
CO3	Demonstrate Bootstrap5 features	
CO4	Apply fundamental concepts of functions using Python	
CO5	Determine the solution for a given problem by implanting various libraries.	
CO6	Integrating all the python features to solve the case studies.	

Unit No.	Title of the Unit
1	**Introduction** – What is Python? Features, History, Version, Applications, Install Python, Python Path, Python Example, Execute Python, Variables, Keywords, Identifiers, Literals, Operators, Comments, Control Statements
2	**Strings and Data Structures:** Accessing Strings, Basic Operators, Membership Operators, Relational Operators, Slice Notation, String functions and Methods Data Structures: List - Accessing Lists, List Operations, Functions and Methods of Lists, Tuple - Accessing Tuple, Tuple Operations, Functions and methods of Tuples, why use Tuple? Python Dictionary- Accessing Values, Functions & Methods
3	**Functions** Built-in Functions, User defined Functions, invoking a Function, return, Statement, Argument and Parameter, Positional Argument (Required Argument), Default Argument, Keyword Argument, Anonymous Function, Difference between Normal Functions and Anonymous, Function, Scope of a Variable
4	**Files I/O and Modules** Input from Keyboard, File Handling, Attributes of File, Modes of File, File Handling Methods-What is a Module? Importing a Module, Built in Modules in Python, Package
5	**Python-database Connectivity:** Establishing a Connection, CRUD (Create, Read, Update, Delete) Operations
6	**Introduction to data processing and visualization:** Concept, Overview of the data processing, Various applications and branches, what is dataset? importing dataset, various sources of datasets, visualization – concept and use
7	**Python Libraries:** Overview of few important Python Libraries for data processing and visualization - NumPy, Pandas: importing dataset, dataframe, series different functions – Scikit-Learn etc, matplotlib
8	Case Studies implementing python libraries

Learning Resources:

1) Beginning-Python, Second Edition by Magnus LieHetland

2) The Complete Reference Python by Martin C.Brown
3) Head First Python b y PatrickBarry
4) Learning Python, O'Reilly by MarkLutz
5) Python in a Nutshell, O'Reilly by AlexMartelli

Important URL:

- https://www.python.org

Title of the Course and Course Code	**Practical Lab -IV** **MTS-572 Data Structures using C++**	**Number of Credits: 02**

Course Outcomes (COs) **On completion of the course, the students will be able to:**	
CO1	Identify fundamental data structures.
CO2	Illustrate fundamental data structures, their uses, strengths, and weaknesses.
CO3	Compute the time complexity of various data structures algorithms.
CO4	Explain the memory representations of several data structures.
CO5	Determine appropriate data structures as per the specified problem definitions.
CO6	Identify fundamental data structures.

Unit No	Title of the Unit and Contents
I	**Introduction to C++** Overview, Basic Syntax – input/output, variables , constant ***(Comparative discussion),*** literal ,operators, loops, Storage Classes, functions, Arrays, Strings , Pointers, References
II	**Object Oriented Concepts** Object, Class, Encapsulation, Abstraction, Inheritance, Polymorphism, Types of Languages (Object Oriented, Procedure Oriented, Scripting)
III	**Introduction to Data Structures and Algorithms** Data, Data Types. Abstract Data Types, Data Structure and its types, Asymptotic Analysis of Algorithms
IV	**Array** Concept, Arrays as ADT, 1-D and Multidimensional Arrays, Advantages and Disadvantages **Application** (Sorting, Searching, Polynomial handling)
V	**Stack** Concept, Stack as ADT, Operations (Push and Pop), Stack Representation (Sequential), Advantages and Disadvantages **Applications** (Infix to Postfix conversion of Expression, Postfix Expression Evaluation & Recursion)
VI	Queue Concept, Queue as ADT, Operations (Insert, Delete and Traversal), Queue Representation (Sequential), Types of Queue (Priority Queue, Circular Queue, Dequeue), Advantages and Disadvantages **Applications** (CPU scheduling Algorithm: FCFS, SJF (Preemptive), Priority)
VII	**Linked List** Concept, Linked List as ADT, Types (Singly, Doubly and Circular), Operations (Insert, Delete and Traversal), Linked List Representation (Sequential, Linked), Advantages and Disadvantages **Applications** (Contiguous File Allocation as well as Linked File Allocation using Sequential Linked List, Linked Representation (Stack, Queue), Disk Scheduling

	Algorithm using Doubly Linked List- SCAN)
VIII	**Tree** Concept, Terminologies, Types of Trees (Binary and Binary Search Tree), Binary Search Tree Representation (Sequential and Linked), Operations on BST (Insert, Delete and Traversal (In-order, Pre-order and Post-order)) Application (Heap Sort, AVL tree)
IX	**Graphs** Concept, Terminologies, Graph Representation (Sequential and Linked), Traversals (DFS and BFS) Applications (Shortest path algorithm: Dijkstra's algorithm)

Learning Resources:

1. Sahni Horowitz, Fundamentals of Computer Algorithms
2. Langsam / Augenstein / Tenenbaum, Data Structures Using C and C++
3. Jean-Paul Tremblay &Paul G. Sorenson, An Introduction to Data Structures with Applications, Tata McGraw Hill.
4. Alfred V. Aho, John E. Hopcroft and Jeffry D. Ullman, "Data Structures & Algorithms"
5. Yashavant Kanetkar, Data Structure Through C++

Semester III

Title of the Course and Course Code	**MTS-601 Design and Analysis of Algorithms**	**Number of Credits : 04**

Course Outcomes (COs) On completion of the course, the students will be able to:	
CO1	Describe basic concepts in algorithms
CO2	Illustrate the concepts of recurrences, hash tables to run complex functions
CO3	Solve problems based on Polynomial and Non polynomial time approaches
CO4	Analyze concepts of dynamic programming, greedy and graph theoretic algorithms
CO5	Evaluate and compare performance of various algorithms
CO6	Develop algorithm based on design techniques to compute asymptotic complexities

Unit No	Title of the Unit and Contents
I	**Growth Functions** Asymptotic Notations
II	**Recurrences** The Substitution Method, Recursion Tree Method, Master theorem
III	**Sorting of Ordered Statistics** Heap Sort, Quick Sort, Sorting in Linear Time, Median and Ordered Statistics
IV	**Dynamic Programming** Matrix Chain Multiplication, Longest Common subsequence, Optimal Binary Trees
V	**Greedy Algorithm** Activity Selection problem, Elements of Greedy Strategy, Huffman Codes
VI	**String Matching** The Naïve String Matching Algorithm, The Rabin Karp Algorithm, String Matching with finite automata, The Knuth-Morris-Pratt algorithm
VII	**Hash Tables** Direct Address Tables, Hash Tables, Hash Functions, Open Addressing, Perfect Hashing
VIII	**NP completeness** Informal concepts of Deterministic and Non deterministic, P , NP and NP Completeness, Statement of Cooks Theorem, Discussion on Vertex cover problem, Discussion on Travelling Salesman Problem

Learning Resources :

1) Introduction to Algorithms, H Coremen, Rivest, Stein and Leiserson

2) Fundamentals of Algorithms, Horowiitz, Sahani and Rajasekeran

3) Mathematics for Analysis of Algorithms, Donald Knuth and H.Green

4) Algorithm Design, Eva Tardos , Jon Klienberg

5) An Introduction to Analysis of Algorithms, Micheal Soltys

6) The Algorithm Design Manual, Steven Skiena

Title of the Course and Course Code	**MTS-604 Dynamical Systems**	**Number of Credits : 04**

Course Outcomes (COs) **On completion of the course, the students will be able to:**	
CO1	Retrieve basic concepts in Differential Equations and Systems
CO2	Interpret properties of solutions to planar systems
CO3	Apply the concept of limit cycles and bifurcations to have a detailed study of planar autonomous systems
CO4	Analyze the interacting Species model within the survival ecosystem
CO5	Formulate the theory of Hamiltonian systems, Lyapanov Functions and determine its stability
CO6	Review the theory of three-dimensional autonomous systems and Chaos

Unit No	Title of the Unit and Contents
I	**Differential Equations** Simple Differential Equations, Applications to Chemical Kinematics, Applications to Electrical Circuits, Existence and Uniqueness Theorem
II	**Planar Systems** Canonical Forms, Eigen values defining Stable and Unstable Manifolds, Phase Plane Portraits, Linearization and Hartman's Theorem, Constructing Phase Plane Diagram
III	**Interacting Species** Competing Species, Predator Prey Models, Other Characteristics Affecting Interacting Species
IV	**Limit Cycles** Existence and Uniqueness of Limit Cycles in a Plane, Non-Existence of Limit Cycles,
V	**Hamiltonian Cycles, Lyapunov Functions and Stability** Hamiltonian Systems in the plane, Lyapanov Systems and Stability
VI	**Bifurcation Theory** Bifurcations of Non-Linear Systems, Normal Forms, Multistability and Bistability
VII	**Three Dimensional Autonomous Systems and Chaos** Linear System and Canonical Forms, Non-Linear Systems and Stability, The Rossler System and Choas, The Lorentz Equations

Learning Resources

1. Stephen Lynch, Dynamical Systems with Applications using Python, Birkhauser Publications
2. Morris Hirsch, Stephen Smale, Differential Equations, Dynamical Systems and introduction to Choas, Academic Press
3. James .D. Miess, Differential Dynamical Systems, Society for Industrial and Applied Mathematics (SIAM)
4. Lawrence Perko, Differential Equations and Dynamical Systems, Springer Texts in Applied Mathematics
5. Kathleen Alligood, Tim Sauer, James Yorke, CHAOS An introduction to Dynamical Systems, Springer

Title of the Course and Course Code	MTS- 605 Data Mining	Number of Credits : 04

Course Outcomes (COs) On completion of the course, the students will be able to:	
CO1	Define Data Mining and its functionalities, Data Warehouses and terminologies used for Attribute Oriented Analysis
CO2	Compare Memory Based Reasoning and Collaborative Filtering in Nearest Neighbors approach
CO3	Use techniques of Association rules to do Market Basket Analysis in Transactional data
CO4	Analyze various techniques for automatic cluster detection
CO5	Reframe concepts in Survival Analysis to apply for customer retention.
CO6	Develop concepts in Data Warehouse, OLAP for efficient data storage

Unit No	Title of the Unit and Contents
I	**Introduction to Data Mining:** What is data Mining, Tasks performed in data mining, Why data Mining, How data mining is used today with various Examples
II	**Decision trees** What is a decision tree, How a tree is grown, Tests for choosing the best split, Pruning, Further refinements of a decision tree model, Alternative representations of decision trees, Case study with decision trees
III	**Nearest Neighbour Approaches:** Memory Based Reasoning and Collaborative Filtering Memory based reasoning, Challenges with MBR, Measuring distance, The Combination Function: Asking the Neighbours for answers, Collaborative Filtering: A Nearest Neighbour approach to making recommendations Case Study with Nearest Neighbours
IV	**Market Basket Analysis and Association Rules** Defining Market Basket Analysis, Association Rules, Building Association Rules, Apriori Algorithm, FP Growth Algorithm, Case study with Market Basket Analysis
V	**Link Analysis** Basic Graph Theory, Directed Graphs, Revision of Travelling Salesman problem, Detecting Cycles in a Graph, A familiar application to Link Analysis, The Kleinberg Algorithm, Case study with Link Analysis
VI	**Automatic Cluster detection** Concept of K Means Clustering, Concept of Similarity and distance, Data Preparation for Clustering, Other approaches of Clustering, Agglomerative clustering Algorithm, Divisive Clustering Algorithm, Evaluating Clusters, Case Study with Clustering
VII	**Hazard Function and Survival Analysis** Problem of Customer Retention, Hazards, Hazard Functions, Censoring, From Hazard to Survival, Proportional Hazards, Cox Proportional Hazards, Limitations of Proportional Hazard Models, Case Study with Survival Analysis

Learning Resources:

1. Data Mining Techniques, Micheal Berry and Gordon Linoff, Wiley Publications
2. Data Mining Concepts and Techniques, Jiawei Han and Micheline Kamber, Elsevier Publications
3. Data Warehousing, Data Mining & OLAP, Alex Berson and Stephen Smith, Tata McGraw-Hill Edition
4. Data Mining Models and Methods, Daniel Lacrose, Wiley Interscience
5. Data Mining Techniques, Arun Pujari, Universities Press
6. Insight in to Data Mining Theory and Practice, Easter Economy Edition, Prentice Hall India

Title of the Course and Course Code	MTS-606 Computational Intelligence	Number ofCredits :4
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Describe key concepts associated with computational intelligence and hard computing.	
CO2	Illustrate various concepts associated with Genetic algorithms and compare Generic Algorithm vs. Traditional Algorithms	
CO3	Apply the concept of Artificial neural network to find linear separability and solve various problems.	
CO4	Explain and Compute Mathematical properties of Fuzzy Logic, Classical Sets and Fuzzy Sets and solve examples to justify the properties.	
CO5	Review the concept of Swarm Computing and Ant colony optimization, formulate the concept of Associative Memory Network and Neuro FuzzyModeling to discuss real life problems.	
CO6	Design and analyze the concept of Supervised learning and unsupervised learning to solve real life problems.	

Unit No.	Title of Unit and Contents
I	**Introduction to computational intelligence and Soft computing** What is soft computing? Differences between soft computing and hardcomputing, Soft Computing constituents, Methods in soft computing, Applications of Soft Computing
II	**Introduction to Fuzzy Logic, Classical Sets and Fuzzy Sets** Operations on classical and fuzzy sets Properties of Classical and fuzzy Sets Classical Relations and Fuzzy RelationsTolerance and Equivalence Relations Membership Functions Features of the Membership FunctionsFuzzification Methods of Membership Value Assignments Defuzzification Lambda-Curs for Fuzzy Sets (Alpha-Cuts)Lambda- Cuts for Fuzzy Relations Defuzzification Methods Fuzzy Arithmetic and Fuzzy MeasuresExtension Principle Fuzzy MeasuresFuzzy Integrals Introduction to Fuzzy Rule Base and Approximate Reasoning Introduction to Fuzzy Decision Making Introduction to Fuzzy Logic Control Systems

III	**Genetic Algorithms (GA)** What are Genetic Algorithms? Why Generic Algorithms?Biological Background Traditional Optimization and Search TechniquesGenetic Algorithm and Search Space Generic Algorithm vs. Traditional Algorithms Simple GA, General Genetic Algorithm, Operators in Generic Algorithm
IV	**Artificial Neural Network:** Fundamental Concept Evolution of Neural Networks Basic Models of Artificial Neural NetworkImportant Terminologies of ANN McCulloch-Pits Neuron Linear SeparabilityHebb Network
V	**Supervised Learning Network** Introduction Perceptron Nonworks Adaptive Linear Neuron (Adaline) Multiple Adaptive Linear Neurons Back-Propagation Network
VI	**Unsupervised Learning Networks** Introduction Fixed Weight Competitive Nets Kohonen Self-Organizing Feature MapsLearning Vector Quantization Counter propagation Networks Adaptive Resonance Theory Network
VII	**Introduction to Neuro Fuzzy Modeling, Swarm Computing and Ant colony optimization**

Learning Resources:

1. Timothy J. Ross, Fuzzy Logic: With Engineering Applications Wiley India, ThirdEdition ISBN: 978-81-265-3126-4
2. Kumar Satish, Neural Networks: A Classroom Approach,1/e TMH, ISBN:9780070482920
3. David E. Goldberg, Genetic Algorithms in search, Optimization & MachineLearning by, Pearson Education, ISBN: 81-7808-130-X
4. James A. Freeman and David M. Skapura, Neural Networks Algorithms, Applications, and Programming Techniques, Edition: Pearson Edn., 2003.V. Kecman,Learning and Soft Computing, MIT Press, 2001.
5. J. S. R. Jang, C. T. Sun, and E. Mizutani, "Neuro-Fuzzy and Soft Computing",PHI, 2004, Pearson Education.
6. S. N. Sivanandam, S. N. Deepa, Principles of Soft Computing (With CD)Wiley India, ISBN: 9788126527410
7. S. Rajasekaran and G. A. Vijayalaksmi Pai, Neural Network, Fuzzy Logic andGenetic Algorithms - Synthesis and Applications", (2005), Prentice Hall
8. Konar A., “Computational Intelligence: Principles, Techniques and Applications”, Springer Verlag, 2005

9. Engelbrecht, A.P, "Fundamentals of Computational Swarm Intelligence", John Wiley & Sons, 2006.

Title of the Course and Course Code	**MTS-607 Cryptography**	**Number of Credits : 04**

Course Outcomes (COs) **On completion of the course, the students will be able to:**	
CO1	Describe key notions and principles related to basic Cryptography.
CO2	Discuss the notion of classical cryptography, basic principles, theory of public key.
CO3	Implement basic symmetric key algorithms and public key algorithms using programming language.
CO4	Explain different cryptographic algorithms.
CO5	Justify different cryptographic algorithms to obtain security and to encrypt, decrypt data, different types of attacks on data.
CO6	Integrate basic algorithms on elliptic curves and its use in cryptography.

Unit No	Title of the Unit and Contents
I	**Basic number theoretic concepts** Congruence, Chinese Remainder Theorem, Primitive Roots**,** Quadratic reciprocity Finite fields**,** Arithmetic functions ,Primality Testing and factorization algorithms**,** Pseudo-primes, Fermat's pseudo-primes, Prime Numbers**,** Testing for Primality, Continued fractions, Hash Functions
II	**Classical Cryptosystems** Cryptography in Modern world, Substitution cipher, Ceaser cipher as a special case of substitution cipher, Mono alphabetic ciphers Transposition Cipher, Polyalphabetic substitution ciphers, Vigenère Cipher, Introduction to poly-graphic substitution ciphers cryptanalysis of substitution cipher
III	**Symmetric Key Cryptography** Introduction and overview, Stream Cipher, Block ciphers, one-time Pad, Modes of operation electronic codebook, Digital signature, Data Encryption Standard, Advanced Encryption Standard, IDEA (International Data Encryption Algorithm), Various attacks on data encryption algorithms
IV	**Public Key Cryptography** Introduction and Overview, The RSA algorithm, Generation of keys, Diffie Hellman Key Agreement protocol, EI Gamal Encryption Algorithms, Discrete Logarithm, Attacks against RSA, Discrete Logarithm Problem
V	**Elliptic Curve Cryptography** Introduction and Overview, Elliptic Curves over Real Numbers, Elliptic curves over finite fields, Elliptic curve cryptography, Diffie Hellman key exchange over Elliptic curves.
VI	**Hashing** Motivation and applications, Cryptographically secure hashing, Message authentication

	codes (MAC), Hash Algorithm - MD5, Hash Algorithms – SHA, Examples of Hashing using programming language.
VII	**Introduction to Quantum Cryptography** Over view of quantum cryptography and its applications.

Learning Resources:

1) D. R. Stinson: CRYPTOGRAPHY, Theory and practice, CRC Press, 1995
2) Neil Koblitz: A course in Number theory and Cryptography, 2nd Edition, Springer
3) Robert Edward Lewand: Cryptological Mathematics (Mathematical Association of America).
4) Jeffrey Hoffstein, Jill Pipher, Joseph H. Silverman: An introduction to Mathematical Cryptography, Springer
5) Adam J. Elbirt: (CRC press): Understanding and Applying cryptography and Data security.
6) Bruice Schneier: Applied Cryptography (Wiley India Edition)
7) Atul Kahate: Cryptography and Network security (Tata McGraw Hill)
8) Arvind Narayanan, Joseph Bonneau, Edward Felten, Andrew Miller, and Steven Goldfeder. Bitcoin and cryptocurrency technologies: a comprehensive introduction. Princeton University Press, 2016. (Free download available)
9) Joseph Bonneau et al, SoK: Research perspectives and challenges for Bitcoin and cryptocurrency, IEEE Symposium on security and Privacy, 2015 (article available for free download) { curtain raiser kind of generic article, written by seasoned experts and pioneers}.

Title of the Course and Course Code	**MTS-610 Research Project**	**Number of Credits :4**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	**Critical Thinking:** Encourage critical thinking skills by requiring students to evaluate and synthesize existing literature, identify research gaps, and propose innovative solutions or perspectives principles of research, including its purpose, significance, and different methodologies.	
CO2	**Hypothesis Formulation:** Help students formulate clear and testable hypotheses or research questions, guiding them through the process of defining the scope and objectives of their research	
CO3	**Research Design:** Familiarize students with various research designs and methodologies, enabling them to choose the most appropriate approach for their specific research question	
CO4	**Data Collection and Analysis:** Train students in the methods of collecting and analysing data, whether through qualitative or quantitative approaches, and help them develop skills in using relevant tools and techniques	
CO5	**Ethical Considerations:** Instil a strong understanding of research ethics, ensuring that students conduct their research in a responsible and ethical manner, respecting the rights and well-being of participants.	
CO6	**Communication, Time management and problem-solving Skills:** Improve students' ability to communicate their research effectively, both in written and oral forms. This includes preparing research proposals, reports, and presenting findings to diverse audiences Develop effective time management skills, helping students create realistic timelines, set milestones, and manage their project efficiently. Problem-solving: Cultivate problem-solving skills by challenging students to overcome obstacles and adapt their research methods when faced with unexpected issues. .	

Title of the Course and Course Code	Practical Lab V: MTS-621 Object Oriented Programming Language - Java	Number of Credits: 02

Course Outcomes (COs) On completion of the course, the students will be able to:	
CO1	Identify Java language components and their working in applications.
CO2	Discuss the concepts of OOPs and Java 8 features.
CO3	Implement object-oriented design with Java, file handling operations in Java.
CO4	Analyze Java APIs for program development.
CO5	Test and validate Java applications using exception handling mechanism.
CO6	Write applications using JDBC and Threads.

Unit No	Title of the Unit and Contents
I	**Introduction to the Java Technology** The Java Platform, API, JVM, Java Compiler, Byte Code, Java Editions, Difference between JDK, JRE & JVM
III	**Basics of Java** Introduction to Java, Writing & Compiling Java Programs- The main Method, Command Line Arguments, Primitive Data Types, Variables, and Assignment, Javadoc Comments, Naming Convention, Expressions, Data Conversion, Boolean Data Type and Expressions { if, switch } Statements,{for,while,do}Statements, for-each loop, Methods, Parameter Passing, Returning Values, Overloading Methods, Scope of Variables, Varargs
IV	**Arrays** Defining and Initializing Arrays, new Operator, Using Arrays, Passing Arrays to Methods, Returning Arrays from Methods, Command-Line Arguments, Dimensional Arrays
V	**Objects and Classes** Defining Class, Creating Object, Packages (Concept of package, package and import keywords, Use of predefined packages), Access Modifiers(public, private, protected, default), Object, Members and Class Members (static), Arrays of Objects, this Keyword, Wrapper Classes, Types of Classes (Inner Class, Anonymous Class), Static block , Scanner Class
VI	**String Handling** What is a String? Immutable Strings, Substring, Methods of String Class, toString() Method, String Buffer Class, String Builder Class, String Buffer vs String Builder
VII	**Inheritance and Polymorphism** Inheritance (IS-A), Aggregation/Composition (HAS-A), Superclass and Subclass – extends Keyword, super Keyword, Overriding Members, Protected Data Members-Object Class and its toString() Method, Final Classes, Methods and Variables, instance of Operator, Dynamic Binding, Casting Objects
VIII	**Abstract Classes & Interfaces** Concept of Interfaces, Implementing Interfaces, when to use which? Programming to Interface Concept
IX	**Exception handling**

	Exception Handling: What and why? try and catch Block, Multiple catch Block, Nested try, finally Block, throw Keyword, Exception Propagation, throws Keyword, Checked & Unchecked Exceptions, Custom Exceptions
X	**File Handling** File Output Stream & File Input Stream, Buffered Output Stream & Buffered Input Stream, File Writer & File Reader, Using Scanner Class to Read from File, Print Writer, Stream Tokenizer, Object Input Stream & Object Output Stream, Serialization & Deserialization, transient Keyword
XI	**Multithreading** Multithreading: What and why? Life Cycle of a Thread, Creating Thread (Extending Thread Class/ Implementing Runnable Interface), Thread Priority, what is a Daemon Thread? Thread synchronization, Inter-Thread Communication Methods (wait () &notify ())
XII	**Introduction to Collection Framework** Collection Framework, ArrayList Class, LinkedList Class, HashSet Class, TreeSet Class, Hash table Class, HashMap Class, TreeMap Class, Comparable and Comparator Interfaces
XIII	**JDBC** JDBC Driver (Type4), Connectivity with MySQL, Driver Manager, Connection interface, Statement interface, Result Set interface, Prepared Statement, Result Set Meta Data, Database Meta Data
XIV	**JAVA 8 Features** Lambda expression, Functional Interfaces, Method References, Default Method in interface, Streams API (filter,map,collect), DateTime API
XV	**JAVA 11 Features** New Utility methods in String class - isBlank(), repeat(), lines(), strip(),stripLeading(),stripTrailing() Reading/Writing strings to files – readString() & writeString()
XVI	**JAVA 17 Features** Pattern matching for switch, Sealed classes

Learning Resources:

1. Java: How to Program, Deitel & Deitel, PrenticeHall
2. Core Java 2: Volume I – Fundamentals, Cay S. Horstmann and Gary Cornell; Prentice-Hall 2002. ISBN 0130471771
3. Core Java 2: Volume II – Advanced Features, Cay S. Horstmann and Gary Cornell; Prentice Hall 2001. ISBN0130927384
4. Java: The Complete Reference, Herbert Schildt. Fifth Edition Important URLs: http://java.sun.com/reference/docs/

Title of the Course and Course Code	MTS-622 Practical Lab VI: Introduction to Web Technologies	Number of Credits: 02
Course Outcome (COs) **On completion of the course, the students will be able to:**		
CO1	State design process for single-page applications using ReactJS.	
CO2	Illustrate the use of JavaScript in webpages.	
CO3	Demonstrate React JS and Node JS features	
CO4	Analyze the importance of user experience in designing of the websites through various web-based technologies.	
CO5	Test and validate web applications using JavaScript.	
CO6	Write web pages using various web technologies.	

Unit No	Title of Unit and Contents
1	**Overview of HTML5 and CSS3** What is HTML? Tags, Heading, paragraph, anchor, image, table, Lists (ordered, unordered, description), form, label, input, button, br, hr, script (simple JavaScript code) Audio, Video, Progress, Data list Tag, Header Tag, Footer Tag, Article Tag, Aside Tag, Canvas, SVG, Google Maps, Geolocation, Web Storage What is CSS? Syntax, Selector, Types, Comments Background, colors, Border, Margin, Padding, Height/Width, Box Model, Outline, Text, Fonts, Icons, Links, Lists, Tables, Display, Max-width, Position, Overflow, Inline-block etc. (Cover basic properties)
2	**JavaScript** Introduction, JavaScript BOM, Comments, Variables, Operators, Data Types, Functions, Objects, Scope, Events (onclick, onchange, onmouseover, onmouseout, onkeydown, onload), Strings, String Methods (indexOf(), lastIndexOf(), search(), slice(), substring(),substr()),Numbers, Number Methods (toString(), toExponential(), toFixed(), toPrecision(), valueOf()), Math (min (), max (), pow (), random (), sqrt(), ceil(), floor() methods), Array, Array methods (toString(), join(), pop(), push(), shift(), unshift(), splice(),concat()), Date & its methods, Booleans, Comparisons, Conditions, Switch, for loop, while loop, break, Type Conversion, Debugging, Class, Objects, Object Properties, Object Methods Asynchronous Programming Callbacks, Promises. Async-Await
2	**Introduction to ReactJS** What is ReactJS? Benefits, Who is using it?, SPA(Single Page Application), What is JSX, What are state and props? , Stateful and Stateless components , CSS and

	ReactJS : CSS Modules , render() method , Lifecycle methods, Adding Styles to React Elements, Import and Export of Modules, Creating Class-based Components , setState() Method, How to pass Props to Class-based Components, How to pass Function as Props, Case study
3	**Node Js :** What is Node.js? Installing Node.js and Visual Studio Code, what is Node.js? What it's use? Your first Node.js script, Node.js Module System, how to import Node.js core modules? How to import your own files?, Importing npm modules Global npm modules and nodemon, Getting input from user, Storing data with JSON, ES6 Arrow functions, Debugging Node.js, Introduction to Asynchronous Node.js, Asynchronous basics, Http requests, Handling errors, Callback function, Node.js as a Web Server, Serving up HTML and JSON, Case Study

Learning Resources:

1) Beginning HTML5 and CSS3 by Christopher Murphy, Divya Manian, Oliver Stud Holme andRichard W. Clark (APress)
2) Beginning JavaScript by Jeremy McPeak and Paul Wilton (Wrox)
3) Beginning JQuery by Jack Franklin (APress)
4) Bootstrap by Jake Spurlock (O'Reilly)
5) Head First HTML5 Programming, Building Web Apps with JavaScript By Eric Freeman,Elisabeth Robson (O'Reilly)
6) Head First JavaScript Programming By Eric T. Freeman, Elisabeth Robson (O'Reilly)
7) Head First Ajax By Rebecca M. Riordan (O'Reilly)
8) Head First jQuery, A Brain-Friendly Guide By Ryan Benedetti, Ronan Cranley (O'Reilly)
9) Roger S. Pressman. *Software Engineering: A Practitioner's Approach* (Sixth Edition,International Edition). McGraw-Hill, 2005.
10) Ian Sommerville. *Software Engineering* (Seventh Edition). Addison-Wesley, 2004.

Important URLs: https://www.w3schools.com/, https://getbootstrap.com/

Title of the Course and Course Code	**MTS-652 Applied Geometry for Computer Graphics using CAD**	**Number of Credits : 04**

Course Outcomes (COs) **On completion of the course, the students will be able to:**	
CO1	Outline the basic principles and theory of homogeneous coordinates and transformations in plane and space, different types of projections on an object.
CO2	Explain the knowledge of basic concepts and principles related to transformations in plane.
CO3	Implement knowledge of basic concepts and principles related to transformations in plane, viewing pipeline, different types of projections on an object, standard 2D and 3D transformation algorithms.
CO4	Explain points on standard curves, Bezier curve.
CO5	Evaluate points on standard curves, Bezier curve and on B-Spline using computations.
CO6	Create different projections and transformations based on basic 2D and 3D transformations.

Unit No	Title of the Unit and Contents
I	**Transformations in a Plane** Translations, Scaling about the Origin, Reflections, Rotation about the Origin, Shears, Concatenation of Transformations, Applications, Instancing, Applications in Robotics
II	**Homogeneous Coordinates and Transformations of the Plane** Homogeneous Coordinates, Points at Infinity Visualization of the Projective Plane, Line Model of the Projective Plane, Spherical Model of the Projective Plane, Transformations in Homogeneous Coordinates, Translations, Scaling about the Origin Rotation about the Origin, Concatenation of Transformations, Inverse Transformations, Rotation about an Arbitrary Point, Reflection in an Arbitrary Line, Applications in Instancing, Device Coordinate Transformation
III	**Homogeneous Coordinates and Transformations of Space** Homogeneous Coordinates, Transformations of Space, Translations, Scaling and Reflections, Rotations about the Coordinate Axes, Rotation about an Arbitrary Line, Reflection in an Arbitrary Plane, Applications in Computer-aided Design, Orientation of a Rigid Body
IV	**Projections and the Viewing Pipeline:** Introduction, Projections of the Plane, Projections of Three-dimensional Space, The View plane Coordinate Mapping, The Viewing Pipeline, Classification of Projections, Classification of Parallel Projections, Classification of Perspective Projections.
V	**Curves** Introduction, Curve Rendering, Parametric Curves (Circle, Ellipse, Parabola, Hyperbola, Arc length and Reparameterization, The general conic equations, Application: Numerical Controlled Machining and Offsets
VI	**Bezier Curves** Introduction, Linear Bezier Curves, Quadratic Bezier Curves, Cubic Bezier Curves
VII	**B-splines** Integral B-spline Curves, Properties of the B-spline Curve, B-spline Types, Applications in Font

	Design, Applications in Morphing or Soft Object Animation Note

Learning Resources

1) Duncan Marsh, Applied Geometry for Computer Graphics and CAD, 2nd Edition, Springer.
2) D.F. Rogers, J. Alan Adams, Computer Graphics, 2nd Edition, McGraw-Hill Publishing Company.
3) David Lay, Linear Algebra Mathematical Elements of Computer Graphics

Title of the Course and Course Code	MTS-653 Financial Mathematics	Number of Credits: 04

Course Outcomes (COs) On completion of the course, the students will be able to:	
CO1	Retrieve basic concepts in Mathematical Finance
CO2	Interpret properties of Brownian and Geometric Brownian motion
CO3	Implement Arbitrage theorem to value investments
CO4	Analyze investments using Expected utility
CO5	Formulate the theory of Black Scholes to value options in continuous time
CO6	Choose the appropriate hedging strategy to value against options

Unit No	Title of the Unit and Contents
I	**Brownian Motion and Geometric Brownian Motion** Brownian Motion, Brownian Motion as Limit of Simpler Models, Geometric Brownian Motion, The Maximum Variable, The Cameron Martin Theorem
II	**Interest Rates and Present Value Analysis** Interest Rates, Present Value Analysis, Rate of Return, continuously varying Interest Rates
III	**Pricing Contracts vs Arbitrage** An example of Options Pricing, Other Examples of Pricing via Arbitrage, The Arbitrage Theorem, The Multi-period Binomial Model, Proof of Arbitrage theorem
IV	**Black Scholes Formula** Black Scholes Formula, Properties of Black Scholes Option Cost, The Delta Hedging Arbitrage Strategy, Some Derivations, European Put Options
V	**Additional Results and Options** Call Options on Dividend Paying Securities, Pricing American Put Options, Adding Jumps to Geometric Brownian Motion, Estimating Volatility Parameter
VI	**Valuing by Expected Utility** Limitations of Arbitrage Pricing, Valuing Investments by Expected Utility, The Portfolio Selection problem, Value at Risk and Conditional Value at risk, The Capital Assets Pricing Model, Rates of Return: Single Period and Geometric Brownian Motion

Learning Resources

1) Sheldon M Ross, An Elementary Introduction to Mathematical Finance, Third Edition, Cambridge University Press.
2) D.G. Luenberger, Investment Science, Oxford University Press
3) Marek Capinski, An introduction to Financial Engineering, Springer Publications.
4) Amber Habib, Calculus of Finance, Universities Press
5) John Hull, Sanskaran Basu, Options, Futures & Derivatives, Pearson Editio

Title of the Course and Course Code	MTS-654 Optimization Techniques	Number of Credits :4
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Identify and state basic concepts in Linear, Non-linear programming and Game theory.	
CO2	Interpret the Game as a Linear Programming problem and discuss methods to solve them.	
CO3	Apply methods to solve Integer programming problems and examine the solutions	
CO4	Analyze the primal-dual relationship of a Linear programming problem and compute the dual.	
CO5	Determine local solutions to develop techniques and solve non-linear programming problems.	
CO6	Formulate and solve a Linear Programming problem using Simplex method.	

Unit No	Title of the Unit and Contents
I	**Introduction to Linear Programming** Prototype Example, The Linear Programming Model, Assumptions ofLinear Programming, Additional Examples, Case Studies
II	**Solving Linear Programming Problem: Simplex Method** The Essence of Simplex Method, Setting up the Simplex Method, Algebra of Simplex method, Simplex Method in Tabular Form, Tie Breaking in Simplex Method, Adapting to Other forms, Post Optimality Analysis, Conclusions, Case Studies
III	**Duality and Sensitivity Analysis** The Essence of Duality Theory, Economic Interpretation of Duality, Primal Dual Relationships, Adapting to Other Primal Forms, The Roleof Duality in Sensitivity Analysis, The Essence of Sensitivity Analysis, Applying Sensitivity Analysis, Conclusions, Case Studies
IV	**Integer Programming** Prototype Example, Some BIP Applications, Innovative use of Binary Variables in Model Formulation, Some Formulation Examples, Some Perspectives of solving Integer Programming Problems, The Branch and Bound Technique and its applications to Integer Programming, A Branch and Bound Technique for Mixed Integer Programming, Other Developments in solving BIP Problems, Conclusions, Case Studies
V	**Non-Linear Programming** Sample Applications, Graphical Illustration of Non Linear Programming Problems, Types of Non Linear Programming Problems, One Variable unconstrained Optimization, Multivariable unconstrained Optimization, The Karush Kuhn Tucker conditions for constrained Optimization, Quadratic Programming, Separable Programming, Convex Programming, Non Convex Programming, Conclusions, Case StudiesProcess,
VI	**Game Theory** The Formulation of Two Person Zero Sum Games, Solving Simple Games-Prototype Example, Games with Mixed Strategies, Graphical Solution Procedure, Solving by Linear Programming, Extensions , Conclusion

References:

1. Frederick Hiller & Gerald Lieberman, Introduction to Operational Research, McGrawHill
2. Mykel J Kochenderfer and Tim Wheeler, Algorithms for Optimization, MIT Press
3. S.D. Sharma, Operations Research, Kedarnath Ram Nath
4. Prem Kumar Gupta, D.S. Hira, Operations Research

Title of the Course and Course Code	MTS-655 Statistical Machine Learning	Number of Credits : 04

Course Outcomes (COs) On completion of the course, the students will be able to:	
CO1	Retrieve basic concepts in Statistical Machine Learning
CO2	Discuss various Resampling Methods
CO3	Apply the concept of Linear Regression to build sustainable predictive models
CO4	Analyze the various classification problems using different methods
CO5	Formulate the theory for various tree based methods
CO6	Review the theory of Unsupervised Learning

Unit No	Title of the Unit and Contents
I	**Statistical Learning** What is Statistical Learning, Accessing Model Accuracy
II	**Linear Regression** Simple Linear Regression, Multiple Linear Regression, Other Considerations in Regression Model, The Marketing Plan, Comparison of Linear Regression with K Nearest Neighbours, Lab Regression
III	**Classification** An Overview of Classification, Logistic Regression, Linear Discriminant Analysis, A Comparison of Classification methods, Lab: Logistic Regression, LDA, QDA and KNN
IV	**Resampling Methods** Cross Validation, The Bootstrap, Lab: Cross Validation and the Bootstrap
V	**Tree Based Methods** The Basics of Decision trees, Bagging, Boosting, Random Forests, Lab: Decision Trees
VI	**Unsupervised Learning** The Challenge of Unsupervised Learning, Principal Component Analysis, Clustering Methods, Lab 1: Principal Component Analysis, Lab 2: Clustering

Learning Resources

1) Gareth James, Daneila Witten, Trevor Hastie, Robert Tibshirani: An Introduction to Statistical Learning, Springer Publications

2) Christopher Bishop, Pattern Recognition and Machine Learning, Springer Publications

3) Trevor Hastie, Robert Tibshirani, Jerome Friedman, The Elements of Statistical Learning, Springer

4) Alan Agresti, Christine Franklin, Statistics The Art and Science of Learning from Data, Pearson Edition

Title of the Course and Course Code	**MTS-660 Research Project**	**Number of Credits :4**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	**Critical Thinking:** Encourage critical thinking skills by requiring students to evaluate and synthesize existing literature, identify research gaps, and propose innovative solutions or perspectives principles of research, including its purpose, significance, and different methodologies.	
CO2	**Hypothesis Formulation:** Help students formulate clear and testable hypotheses or research questions, guiding them through the process of defining the scope and objectives of their research	
CO3	**Research Design:** Familiarize students with various research designs and methodologies, enabling them to choose the most appropriate approach for their specific research question	
CO4	**Data Collection and Analysis:** Train students in the methods of collecting and analysing data, whether through qualitative or quantitative approaches, and help them develop skills in using relevant tools and techniques	
CO5	**Ethical Considerations:** Instil a strong understanding of research ethics, ensuring that students conduct their research in a responsible and ethical manner, respecting the rights and well-being of participants.	
CO6	**Communication, Time management and problem-solving Skills:** Improve students' ability to communicate their research effectively, both in written and oral forms. This includes preparing research proposals, reports, and presenting findings to diverse audiences Develop effective time management skills, helping students create realistic timelines, set milestones, and manage their project efficiently. Problem-solving: Cultivate problem-solving skills by challenging students to overcome obstacles and adapt their research methods when faced with unexpected issues. .	

Title of the Course and Course Code	Emerging Technologies: MTS-671 Introduction to Block chain Technology	Number of Credits : 02

Course Outcomes (COs) On completion of the course, the students will be able to:	
CO1	Understand of basic concepts of Blockchain.
CO2	Learn the technology used for blockchain.
CO3	Familiarize the primitives of the distributed computing and cryptography related to blockchain.
CO4	Illustrate the concepts of Bitcoin and their usage.
CO5	To understand the Ethereum and smart contracts in block chain technology
CO6	Understand use of smart contract in real world applications.

Unit No	Title of the Unit and Contents
I	**Introduction**: Need for Distributed Record Keeping, Modeling faults and adversaries, Byzantine Generals problem, Consensus algorithms and their scalability problems, Nakamoto's concept with Blockchain based cryptocurrency, Technologies Borrowed in Blockchain – hash pointers, consensus, byzantine fault-tolerant distributed computing, digital cash etc.
II	**Basic Distributed Computing & Crypto primitives**: Atomic Broadcast, Consensus, Byzantine Models of fault tolerance, Hash functions, Puzzle friendly Hash, Collison resistant hash, digital signatures, public key crypto, verifiable random functions, Zero-knowledge systems
III	**Bitcoin basics:** Bitcoin blockchain, Challenges and solutions, proof of work, Proof of stake, alternatives to Bitcoin consensus, Bitcoin scripting language and their use
IV	**Ethereum basics**: Ethereum and Smart Contracts, The Turing Completeness of Smart Contract Languages and verification challenges, using smart contracts to enforce legal contracts, comparing Bitcoin scripting vs. Ethereum Smart Contracts, writing smart contracts using Solidity & JavaScript
V	**Privacy, Security issues in Blockchain**: Pseudo-anonymity vs. anonymity, Zcash and Zk-SNARKS for anonymity preservation, attacks on Blockchains: Sybil attacks, selfish mining, 51% attacks advent of algorand; Sharding based consensus algorithms to prevent these attacks
VI	**Case Studies:** Block chain in Financial Service, Supply Chain Management and Government Services

List of References:

1. Narayanan, Bonneau, Felten, Miller and Goldfeder, "Bitcoin and Cryptocurrency Technologies – A Comprehensive Introduction", Princeton University Press.
2. Josh Thompson, 'Blockchain: The Blockchain for Beginnings, Guild to Blockchain Technology and Blockchain Programming', Create Space Independent Publishing Platform, 2017.
3. Imran Bashir, "Mastering Blockchain: Distributed ledger technology, decentralization, and smart contracts explained", Packt Publishing.
4. Merunas Grincalaitis, "Mastering Ethereum: Implement Advanced Blockchain Applications Using Ethereum-supported Tools, Services, and Protocols", Packt Publishing.

5. Prof. Sandip Chakraborty, Dr. Praveen Jayachandran, “Blockchain Architecture Design and Use Cases” [MOOC], NPTEL: https://nptel.ac.in/courses/106/105/106105184/
6. BLOCKCHAIN BASICS, Daniel Drescher, Apress Publication, 2017.
7. Blockchain, Melanie Swan, O'reilly Publication, 2015.

Title of the Course and Course Code	**Emerging Technologies: MTS-672 Cloud Computing**	**Number of Credits: 02**

Course Outcomes (COs) On completion of the course, the students will be able to:	
CO1	Understanding the Overview of Cloud Computing
CO2	Learn the technology used for Cloud Computing Models
CO3	Familiarize the primitives of service models
CO4	Illustrate the concepts of Virtualization and Cloud Service Providers
CO5	To understand concept of Data centre in cloud computing
CO6	Understand use of services from the aspect of cloud service models and data centres.

Unit No	***Title of the Unit and Contents***
I	Introduction to Cloud Computing: Overview, Characteristics, Architecture, how it works? Advantages/Disadvantages, Risks of Cloud Computing, Applications
II	Cloud Computing Deployment Models: Cloud Computing Deployment Models Types of Cloud (Public Cloud, Private Cloud, Hybrid Cloud, Community Cloud, Multi-Cloud)
III	Cloud Computing Service Models: Software as a service (SaaS), Platform as a service (PaaS), Infrastructure as a service (IaaS), Difference between IaaS, PaaS, and SaaS
IV	Virtualization: What is Virtualization, what is Virtual Machine, what is Container, Data Virtualization, Hardware Virtualization, Software Virtualization, Server Virtualization, Storage Virtualization, OS Virtualization, Windows Virtualization, Demo (any one)
V	Cloud Service Providers: Cloud Service Provider Companies, Amazon Web Services (AWS), Microsoft Azure, Google Cloud (In brief)
VI	Data Centre in Cloud Computing: What is a Data Centre? How do Data Centres work? Why are data centres important? Main components of data centre, Data Centre vs. Cloud

Learning Resources:

1. Cloud Computing: Principles and Paradigms, Editors: Rajkumar Buyya, James Broberg, Andrzej M. Goscinski, Wiley,2011
2. Enterprise Cloud Computing - Technology, Architecture, Applications, Gautam Shroff, Cambridge University Press, 2010
3. Cloud Computing Bible, Barrie Sosinsky, Wiley-India, 2010
4. Cloud Security: A Comprehensive Guide to Secure Cloud Computing, Ronald L. Krutz, Russell Dean Vines, Wiley- India,2010

Title of the Course and Course Code	Emerging Technologies: MTS-673 Edge Computing	Number of Credits: 02

Course Outcomes (COs) On completion of the course, the students will be able to:	
CO1	Understanding the basics of cloud computing and Edge Computing
CO2	Learn the Architecture in Edge Computing
CO3	Familiarize the primitives of User applications in Edge Computing
CO4	Illustrate the concepts of Distributed Systems in Edge Computing
CO5	To understand edge data centres, services, and edge Containers.
CO6	Understand use of Data Integration Platform and Use cases

Unit No	Title of the Unit and Contents
I	Background of Edge Computing - Introduction to Cloud and its limitations to support low latency and RTT. From Cloud to Edge computing: Waves of innovation
II	Overview of Edge Computing, Architectures in Edge Computing
III	Supporting User Applications - Edge Computing to support User Applications (5G-Slicing, self-driving cars and more)
IV	Distributed Systems in Edge Computing: Concepts of distributed systems in edge computing such as time ordering and clock synchronization, distributed snapshot, etc.
V	Edge Data Centers and Services: Introduction to Edge Data Center, Lightweight Edge Clouds and its services provided by different service providers.
VI	Edge Containers: Introduction to docker container and Kubernetes in edge computing. Design of edge storage systems like key-value stores
VII	Data Integration Platforms: Introduction to MQTT and Kafka for end-to-end edge pipeline. Edge analytics topologies for M2M and WSN network (MQTT)
VIII	Use cases based on Machine Learning for edge sensor data in predictive maintenance, image classifier and self-driving cars.

Learning Resources:

1. “Fog and Edge Computing: Principles and Paradigms”, Rajkumar Buyya (Editor), Satish Narayana Srirama (Editor), Wiley, 2019

2. Cloud Computing: Principles and Paradigms”, Editors: Rajkumar Buyya, James Broberg,Andrzej M. Goscinski, Wiley, 2011

3. “Cloud and Distributed Computing: Algorithms and Systems”, Rajiv Misra, Yashwant Patel, Wiley 2020.

Title of the Course and Course Code	**MTS-674 Industrial Training**	**Number of Credits :8**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Describe and develop the various skills, attitude, and knowledge to understand the professionalism in the IT industry.	
CO2	Discuss and explain the working culture of the Industry in view to maintain quality standards.	
CO3	Implement the confidence, presentation skills and logical thinking, communication skills in developing the system.	
CO4	Differentiate between the academics and professional work culture in timely delivery of projects.	
CO5	Compare and contrast the professional development of the programs and project.	
CO6	Combine the techniques to enhance oneself as a thorough software professional.	

The structure for the Industrial Training Project (ITP) will be as follows

A student can complete Industrial Training Project (ITP) in any I.T. industry / academic institute / with a research project of a teacher / an expert funded by any funding agency for a minimum period of three months.
There will be a teacher coordinator mentoring a group of 10 students throughout the Semester. The teacher coordinator is expected to perform the following tasks

- Maintain a weekly status/progress report of the student. The student will report to the assigned student coordinator once a week either offline/ online mode regarding the progress of his/her work at the Industry/Academic Institute.
- Maintain contact with the Industry/Academic regarding the internship offered to the student.
- Help the student in solving difficulties
- Organize presentations and discussions as required
- Guide the student in preparing the Final Project Documentation
- Maintain a track record for each student through the semester
- Conduct an Internal Assessment for each student consisting of 50 Marks

The work load for the teacher coordinator is proposed as four hours per week.

The workload for a teacher coordinator who is guiding 3 students doing their ITP in Fergusson College (Autonomous) Pune (no mentor from industry) is proposed as four hours per week.

Guidelines for submitting the Final Project report

The student must include the project completion certificate issued by the respective industry/research institute/educational institute in the report. A student will submit two hard bound copies and one softcopy (pdf format): Student Copy, Department copy, Controller of Examinations copy of the work carried out during ITP (pdf format to be emailed by the respective emails).

2. Scheme of Assessment

- **Continuous Internal Assessment**

Evaluation for internal 50 Marks to be done by the Internal Teacher Coordinator

Description	Marks
Weekly reporting (Minimum 12) (Online or Offline Mode as needed	25 Marks
Final Project report documentation	15 Marks
Presentation Demo	10 Marks

End Semester Assessment:

Evaluation for external 50 Marks will be done by a panel of three consisting of One Industrial Expert, One Academic Expert (External from other college) and One Internal Examiner. Each examiner is expected to assess each student for 50 marks independently and average of the three scores is to be considered as the final ESE score (out of 50).

Description	**Marks**
Knowledge and Execution of the System	15
Final Project Report	15
Presentation	10
Viva Voce	10

The Internal Examiner will submit the total of 100 marks to the Examination Section

The final grade (to be printed on the mark list) is to be calculated based on UGC 10- point scale.

Marks	Grade	Grade Point
90-100	O : Outstanding	10
80-89	A+ : Excellent	9
70-79	A : Very Good	8
65-69	B+ : Good	7
60-64	B: Above Average	6
55-59	C+ : Average	5
50-54	C: Below Average	4
45-49	D: Satisfactory	3
40-44	E: Pass	2
0-39	Fail	0
	Absent	0

Note: - A student who has obtained Grade F will have to carry out this project once again for a complete semester (minimum three months).