Five years integrated M. Sc. (Mathematics)

Revised Curriculum

Applied Mathematics & Humanities Department
S. V. National Institute of Technology Surat
Gujarat-395007

Five years Integrated M. Sc. (Mathematics)
Teaching Scheme

Semester-III

Sr. No.	Course	Code	Teaching Scheme Hours per week			Credits	Examination Scheme				Total Marks
			L	T	P		Theory	Tutorial	Practical Cont. Eval.	Practical End Sem	
1	English & Professional Communication -II	HU 201	3	0	0	3	100	0	0	0	100
2	Elements of Analysis	MA 201	3	2	0	5	100	50	0	0	150
3	Analytical Geometry	MA 203	3	2	0	5	100	50	0	0	150
4	Discrete Mathematical Structure	MA 205	3	1	0	4	100	25	0	0	125
5	Interdisciplinary Subject (Physics/Chemistry) : Electromagnetics and Relativity	PH 207	3	1	0	4	100	25	0	0	125
6	Computer Lab: Mathematical Software Lab	MA 207	0	0	4	2	0	0	60	40	100
			15	6	4	23					

Total contact Hours per week = 25 **Total Credits = 23** **Total Marks = 750**

Semester-IV

Sr. No.	Course	Code	Teaching Scheme Hours per week			Credits	Examination Scheme				Total Marks
			L	T	P		Theory	Tutorial	Practical Cont. Eval.	Practical End Sem	
1	Communication Skills for Employability	HU 202	3	0	0	3	100	0	0	0	100
2	Numerical Analysis	MA 202	3	1	2	5	100	25	30	20	175
3	Linear Algebra	MA 204	3	2	0	5	100	50	0	0	150
4	Elementary Number Theory	MA 206	3	1	0	4	100	25	0	0	125
5	Computational Life Science	MA 208	3	0	0	3	100	0	0	0	100
6	Data Structures	CS 210	3	1	2	5	100	25	25	25	175
			18	5	4	25					

Total contact Hours per week = 27 **Total Credits = 25** **Total Marks = 825**

HU 201: English and Professional Communication-II

L	T	P	Credit
3	0	0	03

1. Course Outcomes (COs)

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

CO1: express themselves using appropriate vocabulary and grammar

CO2: draft scientific reports and formal proposals

CO3: comprehend scientific and general content more skilfully and meaningfully

CO4: predict human transactions and behavioural modes

CO5: communicate effectively through various means and at varied levels

2. Syllabus

- **FUNCTIONAL ENGLISH GRAMMAR** **(08 Hours)**

  Language functions, Modals, Tenses, Active and Passive Voice, Conditional sentences, Concord errors.

- **TECHNICAL WRITING** **(06 Hours)**

  Formal and informal report- Information and recommendation reports, Progress and Periodic report, Feasibility and trip report. Proposal writing- types, logistics of proposals, the deliverables of proposals persuasion and proposal, the structure of the proposal.

- **LISTENING AND READING COMPREHENSION** **(10 Hours)**

  Listening and note taking, Paraphrasing, Reading using SQ3R, Predicting, Understanding Gist reading and listening general and scientific texts and developing vocabulary

- **LANGUAGE THROUGH LITERATURE** **(08 Hours)**

  Short Stories:

  1. The Remarkable Rocket by Oscar Wild.
  2. An Astrologer's Day by R. K. Narayan.
  3. The Case of the Lower Case Letter by Jack Delany.

- **GROUP COMMUNICATION & ACADEMIC WRITING** **(10 Hours)**

  Transactional analysis; SOP; LOR; Research paper, Dissertation, Thesis; Types of group communication- Seminar, Conferences, Convention, Symposium, Panel discussion etc.

Total Lecture Hours: 42

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3. Books Recommended

1. M. Markel, Practical Strategies for Technical Communication, 2^{nd} Edition, Bedford/St. Martin's, 2016.
2. R. V. Lesikar and M. E. Flatley, Basic Business Communication Skills for Empowering the Internet Generation, Tata McGraw Hill Publishing Company Limited, New Delhi, 2005.

3. L. J. Gurak and J. M. Lannon, Strategies for Technical Communication in The Workplace, Pearson, 2013.
4. C. L. Bovee, J. V. Thill and M. Chaturvedi, Business Communication Today, 9^{th} Edition, Pearson, 2009.
5. W. S. Pfeiffer and T. V. S. Padmaja, Technical Communication: A Practical Approach, 6^{th} Edition, Pearson, 2013.

MA 201: Elements of Analysis

L	T	P	Credit
3	2	0	05

1. Course Outcomes (COs)

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

CO1: discuss the convergence and divergence of sequences and series

CO2: predict the existence of Riemann integral with their properties

CO3: demonstrate the convergence of improper integral

CO4: examine the uniform convergence using different tests

CO5: develop the Fourier series in different intervals

2. Syllabus

- **REAL SEQUENCES** **(06 Hours)**

  Sequences, Limit points of a sequence, Limits inferior and superior, Convergent sequences, Non Convergent sequences, Cauchy's general principle of convergence, Algebra of sequences, Some important theorems, Monotonic sequences.

- **INFINITE SERIES** **(06 Hours)**

  Introduction, Positive term series, Comparison test, Cauchy's root test, D'Alembert's test, Raabe's test, Logarithmic test, Integral test, Gauss's test, Series with arbitrary terms, Rearrangement of terms.

- **THE RIEMANN INTEGRAL** **(10 Hours)**

  Definitions and existence of the integral, Refinement of partitions, Darboux's theorem, Conditions of integrability, Integrability of the sum and difference of integrable functions, The integral as a limit of sums, Some integrable functions, Integration and differentiation, The fundamental theorem of calculus, Mean value theorem, Integration by parts, Change of variable in an integral, Second mean value theorem.

- **VECTOR OPERATORS** **(04 Hours)**

  Green's, Gauss' & Stokes' theorem with proof.

- **IMPROPER INTEGRAL** **(06 Hours)**

  Introduction, Integration of unbounded functions with finite limit of integration, Comparison tests for convergence of $\int_a^b f(x)\ dx$, Infinite range of integration, Integrand as a product of functions.

- **UNIFORM CONVERGENCE** **(06 Hours)**

  Pointwise convergence, Uniform convergence on an interval, Tests for uniform convergence, Properties of uniformly convergent sequences and series, The Weierstrass approximation theorem.

- **FOURIER SERIES** **(04 Hours)**

  Trigonometric series, Some preliminary theorems, The main theorem, Intervals other than $[-\pi, \pi]$.

Total Lecture Hours: 42

3. Books Recommended

1. W. Rudin, Principles of Mathematical Analysis, 3^{rd} Edition, McGraw Hill, New York, 1976.
2. R. R. Goldberg, Methods of Real Analysis, Oxford and IBH Publishing, 1970.
3. T. Apostol, Mathematical Analysis, 2^{nd} Edition, Narosa Publishers, 2002.
4. H. L. Royden, Real Analysis, 4^{th} Edition, Macmilan Publishing Co. Inc., New York, 1993.
5. S. Narayan and M. D. Raisinghania, Elements of Real Analysis, 7^{th} Edition, S. Chand Publication, New Delhi, 1980.

MA 203: Analytical Geometry

L	T	P	Credit
3	2	0	05

1. Course Outcomes (COs)

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

CO1: demonstrate the fundamentals of analytical geometry in Cartesian and polar coordinates

CO2: discuss the the equation of straight line in different forms and related properties

CO3: solve the problems related to plane and sphere

CO4: evaluate the equation of cone and cylinder and their tangent plane

CO5: elaborate the equations and other properties related to plan section and conicoids

2. Syllabus

- **ORIENTATION OF COORDINATE GEOMETRY (08 Hours)**

  Distance between two points, Coordinates of a point which divides the line joining the given points in a given ratio, Equation of surfaces, Cylindrical coordinates, Polar coordinates, Angle between two lines, Direction cosines of a line, Direction ratios of a line, Projections, Projection of a line segment.

- **STRAIGHT LINE (08 Hours)**

  General equation of straight line, Equations of a line in symmetrical form, Reduction of general equation of a line into symmetrical form, Angles between two lines, Angle between line and plane, Line intersecting two given lines, Locus of a line, Distance of a point from a line, Shortest distance between two lines, Equations of two skew lines in simplified form, Intersection of three planes.

- **PLANE AND SPHERE (08 Hours)**

  General equation of a plane, Normal form of the equation of a plane, Projection of a segment, Angles between two planes, Equation of a plane in various forms, Length of perpendicular from a point to a plane, General equation of a plane passing through the line of intersection of two planes, General equation of sphere, Equation of sphere passing through four points, Sphere on the join of two points as diameter, Intersection of two sphere, Intersection of sphere and plane, Intersection of sphere and line, Angle of intersection of two sphere, Orthogonal sphere, Radical sphere.

- **THE CYLINDER AND CONE (10 Hours)**

  Equation of a cylinder, Right circular cylinder and its equation, Interpretation of equations, Equation of tangent plane to a given cylinder, Cone and its equation, Cone with vertex at origin, Right circular cone, Condition for general equation of second degree to represent a cone, Tangent plane to a cone and condition of tangency, Reciprocal cone, Cone with three mutually perpendicular generators, Number of mutually perpendicular generators, Intersection of a plane through the vertex and a cone.

- **PLANE SECTION AND CONICOIDS (08 Hours)**

  Some standard equation of central conicoids, Diametral planes and principal planes, Tangent lines and tangent plane at a point, Condition of tangency of a plane, Section with a given centre, Locus of the mid-points of a system of parallel chords, Polar plane, Polar lines, Enveloping cone, Classification of central conicoids, Normal to an ellipsoid, Conjugate diametral plane and diameters of ellipsoid, Paraboloids: Equation, Classification and Properties, Conicoids: General equation and examples.

Total Lecture Hours: 42

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3. Books Recommended

1. R. Ballabh, A Textbook of Coordinate Geometry, 3^{rd} Edition, Prakashan Kendra, Lucknow, 1965.
2. S. Narayan and P. K. Mittal, Analytical Solid Geometry, 17^{th} Revised Edition, S.Chand & Company, New Delhi, 2007.
3. R. J. T. Bell, An Elementary Treatise on Coordinate Geometry of Three Dimensions, MacMillon & Co. Ltd., 1960.
4. C. Smith, An Elementary Treatise on Solid Geometry, MacMillon & Co. Ltd., 1931.
5. P. K. Jain and K. Ahmad, A Text Book of Analytical Geometry of Three Dimensions, New Age International Publishers, New Delhi, 2005.

MA 205: Discrete Mathematical Structure

L	T	P	Credit
3	1	0	04

1. Course Outcomes (COs)

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

CO1: apply knowledge of Mathematical Logic in programming

CO2: analyze the problems for developing the solution, its correctness and performance using graphs

CO3: analyze the real world problems using group theory, relations, lattices and Boolean algebra

CO4: develop an algorithm using Asymptotic analysis

CO5: design solutions for various types of problems in different disciplines like information security, optimization, mathematical analysis

2. Syllabus

- **MATHEMATICAL LOGIC AND PROGRAM VERIFICATION** **(10 Hours)**

  Propositions, logical operators and propositional algebra, Predicates and quantifiers, Interaction of quantifiers with logical operators, Logical interference & proof techniques, Formal verification of computer programs (elements of Hoare logic).

- **GRAPH THEORY** **(08 Hours)**

  Graphs, Definition and basic concepts of finite and infinite graph, Incidence and Degree, Isomorphism, Subgraph, Walk, Path & Circuits, Operations on graphs, Connected Graph, Disconnected graph and Components, Complete graph, Regular graph, Bipartite graph, Euler's graph, Hamiltonian paths and Circuits, Weighted graphs, Applications, Directed & Undirected graphs, Connectivity of graphs.

- **TREES** **(06 Hours)**

  Definition & properties of trees, Pendent vertices in a tree, Distance between two vertices, Centre, Radius and diameter of a tree, Rooted and binary trees, Representation of Algebraic structure by Binary trees, Binary search trees, Spanning trees and fundamental circuits.

- **LATTICES** **(05 Hours)**

  Definition and properties of lattice, Sublattice, Distributive and modular lattices, Complemented and bounded lattices, Complete lattices.

- **BOOLEAN ALGEBRA** **(06 Hours)**

  Introduction, Definition, Properties of Boolean algebra, Boolean variables, Boolean expression, Boolean function, Min term, Max term, Canonical forms, Switching network from Boolean expression, Karnaugh map method.

- **ASYMPTOTIC ANALYSIS** **(07 Hours)**

  Complexity analysis, Time and storage analysis, Big-oh, Big-Omega, Big–Theta notation, Illustration and application to real problems.

Total Lecture Hours: 42

3. Books Recommended

1. K. H. Rosen, Discrete Mathematics and its Applications, 6^{th} Edition, McGraw-Hill, 2006.
2. B. Kolman, R. C. Busby, and S. Ross, Discrete Mathematical Structure, 5^{th} Edition, Prentice Hall Inc., 2003.
3. J. P. Tremblay and R. Manohar, Discrete Mathematical Structure with Applications to Computer Science, McGraw Hill Book Co., 1999.
4. N. Deo, Graph Theory with Applications to Engineering & Computer Science, Prentice Hall of India Pvt. Ltd., 2000.
5. D. F. Stanat and D. F. McAllister, Discrete Mathematics in Computer Science, Prentice-Hall, Englewood Cliffs, New Jersey, 1977.

PH 207: Electromagnetics & Relativity

L	T	P	Credit
3	1	0	04

1. Course Outcomes (COs)

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

CO1: interpret the Coulomb's and Gauss's law and their applications in electrostatics

CO2: interpret the Lorenz force, Biot-Savert's an Ampere's law and their applications in magnetostatics

CO3: elaborate the Legendre polynomials and Bessel function and related applications

CO4: explain magnetization in materials and magnetic fields in matter

CO5: demonstrate the basic of theory of relativity

2. Syllabus

- **ELECTROSTATICS** **(06 Hours)**

  Coulomb's Law, Intensity of electric field, Gauss' law and its applications, Divergence and curl of electric field, Electric potential, Work and energy in electrostatics.

- **ELECTRIC FIELDS IN MATTER** **(06 Hours)**

  Conductors, Dielectrics, Polarization, The field of Polarized object, The electric displacement, Boundary Conditions, Conduction and convection currents, Ohm's law.

- **BOUNDARY VALUE PROBLEMS** **(08 Hours)**

  Laplace equation in one, two, and three-dimensions, 1^{st} and 2^{nd} uniqueness theorem, Classic image problem, Induced surface charge, Force and energy, Other image problems, Separation of variables, Multipole expansion.

- **MAGNETOSTATICS** **(08 Hours)**

  The Lorentz force law, Biot-Savert's law, The divergence and curl of magnetic field, Magnetic vector potential, Magnetic flux density, Ampere circuital law and its applications.

- **MAGNETIC FIELDS IN MATTER** **(08 Hours)**

  Magnetization in materials, The field of a magnetized object, The auxiliary field H, Linear and non-linear media, Magnetic boundary conditions.

- **THEORY OF RELATIVITY** **(06 Hours)**

  Principles of relativity, Length contraction, Time dilation, Lorentz transformations, Mass-Energy equivalence.

Total Lecture Hours: 42

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3. Books Recommended

1. D. J. Griffiths, Introduction to Electrodynamics, 3^{rd} Edition, Prentice-Hall of India Private Limited, 1999.
2. M. N. O. Sadiku, Elements of Electromagnetics, 3^{rd} Edition, Oxford University Press, 2003.

3. J. V. Stewart, Intermediate Electromagnetic Theory, Allied Publishers (with World Scientific), 2005.

4. J. D. Jackson, Classical Electrodynamics, Wiley Eastern, 2012.

5. A. Beiser, S. Mahajan and S. R. Choudhary, Concepts of Modern Physics, 7^{th} Edition, McGraw Hill, 2015.

MA 207: Mathematical Software Lab

L	T	P	Credit
0	0	4	02

1. Course Outcomes (COs)

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

CO1: create a scientific and technical document using Latex

CO2: design user defined commands and environment in Latex

CO3: develop a computer code using MATLAB/Sci-Lab/Octave for mathematical algorithm

CO4: adapt Python library Numpy and SciPy for scientific computations

CO5: analyze the effectiveness and uses of different mathematical software

2. Syllabus

- **WORKING IN LATEX** **(12 Hours)**

  Document types in LaTex, Packages in LaTex: Useful elementary packages such as geometry, amsmath, amssymb, ragged2e, graphic, xcolor, amsthm, Math formatting in LaTex, Environments in LaTex: tables, figure, minipage, Article, Report and Book writing in LaTex, Creating graphics, Bibliography in Latex, User defined commands and environments, Introduction to the Beamer package.

- **MATLAB/SCI-LAB/OCTAVE** **(22 Hours)**

  Scope of MATLAB in matrix computations, Creating vectors and matrices, Vector and matrix operations, Operators: arithmetic, relational, logical, Element-wise operations, Built-in logical functions, Some matrix related command and functions, Creating and running M-Files, Loops and Controls, Creating user defined functions, plotting in 2D and 3D, Data import and export.

- **INTRODUCTION TO PYTHON** **(22 Hours)**

  Introduction to Python: Shell/Terminal programming and Interactive python (IPython), Saving Scripts, Basic Data Types, Core Data Structure in Python, Control Flow, List Comprehension, Dictionary Comprehension, Functions, Files, Modules, Plotting graph in Python, Numpy Arrays, Introduction to SciPy, Exception Handling, Closures, Decorators, Classes and Object-Oriented Programming: Abstract Data Types and Classes, Inheritance.

Total Contact Time(Practical): 56

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3. Books Recommended

1. S. Apostolos, T. Antonis and S. Nick, Digital Typography Using LaTeX, Springer-Verlag, New York, 2003
2. R. Pratap, Getting Started with MATLAB: A Quick Introduction for Scientists & Engineers, Oxford Publication, 2010.
3. S. J. Chapman, MATLAB Programming for Engineers, 6^{th} Edition, Cengage Learning, 2019.
4. M. Dawson, Python Programming for the Absolute Beginner, 3^{rd} Edition, Cengage Learning, 2011.
5. B. Lubanovic, Introducing Python: Modern Computing in Simple Packages, 2^{nd} Edition, O'Reilly Media, 2019.

HU 202: Communication Skills for Employability

L	T	P	Credit
3	0	0	03

1. Course Outcomes (COs)

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

CO1: exhibit professional communication skills and cognitive skills

CO2: demonstrate ability to communicate efficiently for employability

CO3: show enhanced reception towards the use of English language

CO4: develop awareness and acumen in netiquette

CO5: adapt to the use of digital media in professional setting

2. Syllabus

- **WORKPLACE COMMUNICATION** **(06 Hours)**

  Introduction to workplace communication, Understanding ethical and legal obligations, Planning and drafting documents, Analysing your audience and purpose, Researching your subject, Writing collaboratively, Introduction to Intellectual property rights (IPR).

- **WRITTEN CORRESPONDENCE** **(08 Hours)**

  Understanding the process of written correspondence: Presenting yourself effectively in correspondence, Writing letters, Emails, Writing correspondence to multicultural readers.

- **STRATEGIES IN THE JOB SEARCH PROCESS** **(10 Hours)**

  Building a network of contacts, Introduction to employability skills, Identifying appropriate jobs, Finding your employer, Writing job application materials- Establishing your professional brand, Understanding four major ways to look for a position, Writing resumes, Writing job application letters, Writing follow up letters or emails after an interview, Process of interviews, Answering techniques in interviews, Mock interviews, Other job search messages- continuing job search activity.

- **READING AND LISTENING AND WORKPLACE** **(08 Hours)**

  Reading documents using comprehension techniques, Reading to summarise, Understanding the audience and purpose of summaries, Writing summary step by step, Special types of summaries, Listening to comprehend and respond in workplace.

- **DIGITAL MEDIA AND PRESENTATIONS** **(07 Hours)**

  Email and text messages, Blogs, Wikis and social networks, Web pages and online videos, Designing online documents, Designing print documents.

Total Lecture Hours: 42

3. Books Recommended

1. M. Markel, Practical Strategies for Technical Communication, 2^{nd} Edition, Bedford/St. Martin's, 2016.

2. R. V. Lesikar and M. E. Flatley, Basic Business Communication Skills for Empowering the Internet Generation, Tata McGraw Hill Publishing Company Limited, New Delhi, 2005.
3. L. J. Gurak and J. M. Lannon, Strategies for Technical Communication in The Workplace, Pearson, 2013.
4. C. L. Bovee, J. V. Thill and M. Chaturvedi, Business Communication Today, 9^{th} Edition, Pearson, 2009.
5. W. S. Pfeiffer and T. V. S. Padmaja, Technical Communication: A Practical Approach, 6^{th} Edition, Pearson, 2013.

MA 202: Numerical Analysis

L	T	P	Credit
3	1	2	05

1. Course Outcomes (COs)

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

CO1: design an algorithm to solve a mathematical problem numerically

CO2: analyze an algorithm's accuracy, efficiency and convergence properties

CO3: develop a computer code for the designed algorithm

CO4: analyze classical techniques and recognize common pitfalls in numerical analysis

CO5: solve initial value problems using computational methods

2. Syllabus

- **PRELIMINARIES OF COMPUTING** **(3 Hours)**

  Errors, Types of errors, Propagation of Error, Floating point arithmetic, Approximation using Taylor's series.

- **SOLUTION OF NONLINEAR EQUATIONS** **(7 Hours)**

  Bisection Method, Methods of false position, Newton's method, Modified Newton's method, Fixed point iterative method, Newton's and fixed point iterative method for system of nonlinear equations. Roots of polynomials, Error and convergence analysis of these methods.

- **SOLUTION OF SYSTEM OF LINEAR EQUATIONS** **(8 Hours)**

  Direct Methods: Gauss elimination with pivoting, LU decomposition method, Cholesky decomposition method, Error analysis for direct methods, Iterative methods: Jacobi, Gauss Seidel method, SOR method, Vector and matrix norm, Convergence of iterative methods, Eigenvalue problems: Jacobi's and Power method.

- **INTERPOLATION** **(12 Hours)**

  Finite difference operators, Divided difference operators, Relation between difference operators, Application of difference operators, Polynomial Interpolation, Existence and uniqueness of interpolating polynomials, Lagrange and Newton's interpolation, Newton's forward and backward difference formula, Error in interpolation.

- **DIFFERENTIATION AND INTEGRATION** **(6 Hours)**

  Numerical differentiation: Methods based on interpolation and finite differences, Error in approximation, Order of approximation, Numerical Integration: Quadrature formula, Newton Cotes Methods, Trapezoidal and Simpson's rules with error analysis. Gauss quadrature methods with error analysis.

- **INITIAL VALUE PROBLEMS (ODE)** **(6 Hours)**

  Picard's method, Taylor's series method, Euler and Runge-Kutta methods for initial value problems of order one and higher and system of first order ODEs with error analysis.

Total Lecture Hours: 42

3. Practicals

Students can use MATLAB, PYTHON, Octave, SciLab, to write computer program.

1. To solve nonlinear equations.
2. To solve a system of nonlinear equations.
3. To solve a system of linear equations using direct methods.
4. To solve a system of linear equations using indirect methods.
5. To find the eigenvalue of a matrix.
6. To make a difference table.
7. For interpolating arbitrary spaced and equally spaced data.
8. To approximate the derivative numerically.
9. To integrate a function numerically.
10. To solve the initial value problems of order one and more and system of first order ODEs.

4. Books Recommended

1. K. E. Atkinson, An Introduction to Numerical Analysis, 2^{nd} Edition, John Wiley & Sons, 2008.
2. R. L. Burden and J. D. Faires, Numerical Analysis, 9^{th} Edition, Cengage Learning, 2011.
3. S. D. Konte and C. de-Boor, Elementary Numerical Analysis: An Algorithmic Approach, 3^{rd} Edition, McGraw-Hill, 1981.
4. M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical Methods : For Scientific And Engineering Computation, 6^{th} Edition, New Age International Publishers, 2014.
5. J. H. Mathews and K. D. Fink, Numerical Methods using MATLAB, 4^{th} Edition, Pearson India Education Services Pvt. Ltd., 2015.

MA 204: Linear Algebra

L	T	P	Credit
3	2	0	05

1. **Course Outcomes (COs)**

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

   CO1: evaluate the solution of system of linear equation through elimination and decomposition procedure

   CO2: determine the basis and dimension of vector spaces and subspaces

   CO3: discuss the matrix representation of a linear transformation given bases of the relevant vector spaces

   CO4: adapt the knowledge of eigenvalues and eigenvectors for matrix diagonalization

   CO5: interpret the the applications of linear algebra and special matrices

2. **Syllabus**

   - **MATRICES** **(04 Hours)**

     Properties of matrices, Non-singular Matrices, Reduced Row-Echelon form, Consistency and Solution of system of linear equations.

   - **VECTOR SPACES** **(08 Hours)**

     Fields, Vector spaces over a field, Subspaces, Linear Independence and Dependence, Coordinates, Bases and Dimension.

   - **LINEAR TRANSFORMATIONS** **(08 Hours)**

     Rank Nullity Theorem, Duality and transpose, Isomorphism, Matrix representation of linear transformation, Change of basis, Similar matrices, Linear functional and Dual Space.

   - **INNER PRODUCT SPACES** **(08 Hours)**

     Cauchy-Schwarz's inequality, Gram-Schmidt orthonormalization, Orthonormal basis, Orthogonal projection, Projection theorem, Fundamental subspaces and their relations.

   - **DIAGONALIZATION** **(08 Hours)**

     Eigenvalues and eigenvectors, Characteristic polynomials, Minimal polynomials, Cayley-Hamilton theorem, Diagonalizability, Invariant subspaces, Adjoint of an operator, Normal, Unitary and Self-Adjoint operators, Schur's lemma, Diagonalization of normal matrices, Triangularization, Rational canonical form, Jordon canonical form.

   - **SOME APPLICATIONS** **(06 Hours)**

     Lagrange interpolation, QR and SVD decompositions, Least square solutions, Least square fittings, Pseudo-inverses, Rayleigh quotients, Special matrices and their properties.

   Total Lecture Hours: 42

3. **Books Recommended**

   1. K. Hoffman and R. Kunze, Linear Algebra, PHI Publication, 2015.

2. G. Strang, Linear Algebra and its Applications, 4^{th} edition, Cengage Learning, 2007.
3. S. Lang, Linear Algebra: Undergraduate Texts in Mathematics, Springer-Verlag, New York, 1989.
4. G. William, Linear Algebra with Applications, 6^{th} Revised Edition, Jones and Bartlett Publishers Inc., 2007.
5. H. E. Rose, Linear Algebra: A Pure Mathematical Approach, Birkhauser, 2002.

MA 206: Elementary Number Theory

L	T	P	Credit
3	1	0	04

1. Course Outcomes (COs)

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

CO1: explain congruence relations and number theoretic functions

CO2: demonstrate Fermat's theorem and its applications

CO3: solve Diophantine equations

CO4: elaborate primitive roots and quadratic reciprocity

CO5: adapt the knowledge of various techniques in cryptography

2. Syllabus

- **INTRODUCTION** **(06 Hours)**

  Divisibility, Greatest Common Divisor (gcd), Euclidean Algorithm, Primes and their elementary properties, Fundamental theorem of Arithmetic.

- **CONGRUENCE RELATION** **(08 Hours)**

  Congruence and their Basic properties, Chinese Remainder Theoerm, Euler's phi-function, Fermat's Little Theorem, Wilson's Theorem, Euler's theorem.

- **NUMBER THEORETIC FUNCTIONS** **(12 Hours)**

  Greatest integer function, Arithmetic functions, Mobiüs inversion formula, Fibonacci numbers, Representation of an integer as sum of two and four squares, Diophantine Equations: $ax + by = c$, $x^2 + y^2 = z^2$ and $x^4 + y^4 = z^4$.

- **PRIMITIVE ROOTS, INDICES AND RESIDUES** **(12 Hours)**

  Order of an integer modulo n, Primitive roots for primes, Theory of indices, Residue classes and Residued residue classes, Quadratic residues, Legendre symbol, Gauss's Lemma about Legendre symbol, Law of quadratic reciprocity, Jacobi symbol.

- **INTRODUCTION TO CRYPTOGRAPHY** **(04 Hours)**

  Basic definitions of plaintext, ciphertext, cipher, enciphering (encrypting), deciphering (decrypting), The Caesar cipher, Monoalphabetic and Polyalbhabetic ciphers, Nonalphabetic ciphers, Exponential cryptosystem, Applications of Euler's theorem in cryptography, Introduction to public-key cryptography and RSA cryptosystems.

Total Lecture Hours: 42

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3. Books Recommended

1. T. Apostol, Introduction to Analytic Number theory, Springer-Verlag, 1976.
2. A. Baker, A Concise Introduction to the Theory of Numbers, Cambridge University Press, 1990.
3. D. M. Burton, Elementary Number Theory, 6^{th} Edition, McGraw Hill, 2007.
4. G. H. Hardy, and E. M. Wright, An Introduction to the Theory of Numbers, 6^{th} Edition, Oxford University Press, 2008.
5. I. Niven, H. S. Zuckerman and L. Montgomery, An Introduction to the Theory of Numbers, 6^{th} Edition, Wiley, New York, 2003.

MA 208: Computational Life Sciences

L	T	P	Credit
3	0	0	03

1. **Course Outcomes (COs)**

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

   CO1: exhibit enhanced knowledge of evolution theory

   CO2: assess biological inferences that depend on population genetics

   CO3: demonstrate knowledge of biological systems and microbiology

   CO4: utilize the concepts of network models in biology

   CO5: apply biological mechanisms in technology

2. **Syllabus**

   - **THEORY OF EVOLUTION** **(07 Hours)**

     Evolution of life: Origin of Life, Structure and types of cell, Cell organelles, Biomolecules of cell, Evolutionary Invasion Analysis: Introduction to Game Theory, Concept of evolutionary stability, General technique for invasion analysis.

   - **POPULATION GENETICS** **(07 Hours)**

     Stochastic models of genetics, Genetic structure and selection in subdivided populations, Kin selection and limited dispersal.

   - **BIOLOGICAL SYSTEMS** **(07 Hours)**

     Body systems required to sustain human physiology, Special sense organs including hearing, taste, smell and visual receptors, Diffusion in biology: Constructing diffusion models, Diffusion as approximation of stochastic systems, Biological waves, Pattern formation and Turing bifurcations, Chemo-taxis.

   - **MICROBIOLOGY** **(07 Hours)**

     Microbiology, Microbial taxonomy: principle and its types, Classical approach: numerical, chemical, serological and genetic, Diversity analysis Methods, Nutrition, Microbiological media and Microbial growth curve.

   - **NETWORK MODELS IN BIOLOGY** **(07 Hours)**

     Networks in biology: Spread of disease in contact networks, Random graphs, moment closure techniques in complex graphs.

   - **MOLECULAR BIOLOGY** **(07 Hours)**

     Molecular Sequences: Nucleotide and protein, Sequence comparisons: Dynamic programming, heuristic methods, Pattern and profile, Small molecules and Protein structures and geometry optimization.

   Total Lecture Hours: 42

3. **Books Recommended**

   1. A. R. Leach, Molecular Modelling: Principles and Applications, Addison-Wesley Pub. Co., 1997.
   2. J. L. Tymoczko, J. M. Berg and L. Stryer, Biochemistry, 8^{th} Edition, W. H. Freeman & Co., 2015.

3. N. Hopkins, J. W. Roberts, J. A. Steitz, J. Watson and A. M. Weiner, Molecular Biology of the Gene, 7^{th} Edition, Benjamin Cummings, 1987.
4. C. R. Cantor and P. R. Schimmel, Biophysical Chemistry (Parts I, II and III), W.H. Freeman & Co., 1980.
5. C. C. Chatterjee, Human Physiology, 13^{th} revised Edition, Vol 1 & 2, CBS Publisher, 2020.

Further Reading

1. B. K. Hall, Evolution, Principles and Processes, Jones & Bartlett, 2011.
2. O. A. Hougen, K. M. Watson and R. A. Ragatz, Chemical Process Principles Part-I: Material and Energy Balances, CBS Publishers New Delhi, 2^{nd} Edition, 2004.
3. D. Baxevanis, and B. F. F. Ouellette, Bioinformatics – A Practical Guide to the Analysis of Genes and Proteins, 2^{nd} Edition, John Wiley and Sons Inc., 2001.
4. B. Bernd, K. Juergen, S. Lewi, Complex Population Dynamics: Nonlinear Modeling in Ecology, Epidemiology And Genetics, World Scientific Publishing Co. Pvt. Ltd., 2007.

CS 210: Data Structures

L	T	P	Credit
3	1	2	05

1. Course Outcomes (COs)

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

CO1: recognize the need of different data structures and understand its characteristics

CO2: apply different data structures for given problems

CO3: design and analyse different data structures, sorting and searching techniques

CO4: evaluate data structure operations theoretically and experimentally

CO5: solve the complex engineering problems

2. Syllabus

- **INTRODUCTION TO DATA STRUCTURES** **(02 Hours)**

  Review of Concepts: Information and meaning, Abstract data types, Internal representation of primitive data structures, Arrays, Strings, Structures, Pointers.

- **LINEAR LISTS** **(06 Hours)**

  Sequential and linked representations of linear lists, Comparison of insertion, Deletion and search operations for sequential and linked lists, Doubly linked lists, Circular lists, Lists in Standard Template Library (STL), Applications of lists.

- **STACKS** **(06 Hours)**

  Sequential and linked implementations, Representative applications such as Recursion, Expression evaluation viz., Infix, Prefix and Postfix, Parenthesis matching, Towers of Hanoi, Wire routing in a circuit, Finding path in a maze.

- **QUEUES** **(06 Hours)**

  Operations of queues, Circular Queue, Priority Queue, Dequeue, Applications of queues, Simulation of time sharing operating systems, Continuous network monitoring system, etc.

- **SORTING AND SEARCHING** **(04 Hours)**

  Sorting methods, Bubble sort, Selection sort, Quick sort, Radix sort, Bucket sort, Dictionaries, Hashing, Analysis of collision resolution techniques, Searching methods, Linear search, Binary search, Character strings and different string operations.

- **TREES** **(08 Hours)**

  Binary trees and their properties, Terminology, Sequential and linked implementations, Tree traversal methods and algorithms, Complete Binary trees, General trees, AVL trees, Threaded trees, Arithmetic expression evaluation, Infix-prefix-postfix notation conversion, Heaps as priority queues, Heap implementation, Insertion and deletion operations, Heapsort, Heaps in Huffman coding, Tournament trees, Bin packing.

- **MULTIWAY TRESS** **(04 Hours)**

  Issues in large dictionaries, M-way search trees, B-trees, Search, insert and delete operations, Height of B-tree, 2-3 trees, Sets and multisets in STL.

- **GRAPHS** **(06 Hours)**

  Definition, Terminology, Directed and undirected graphs, Properties, Connectivity in graphs, Applications, Adjacency matrix and linked adjacency chains, Graph traversal, Breadth first and depth first traversal, Spanning trees, Shortest path and transitive Closure, Activity networks, Topological Sort and critical paths.

Total Lecture Hours: 42

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3. Tutorials

1. Problems on Array
2. Problems on Stack and Queue
3. Problems on Linked List
4. Problems on Trees
5. Problems on Graph

4. Practicals

1. Implementation of Array and its applications
2. Implementation of Stack and its applications
3. Implementation of Queue and its applications
4. Implementation of Link List and its applications
5. Implementation of Trees and its applications
6. Implementation of Graph and its applications
7. Implementation of Hashing functions and collision resolution techniques
8. Mini Project (Implementation using above Data Structure)

5. Books Recommended

1. J. P. Trembley and P. G. Sorenson, An Introduction to Data Structures with Applications, 2^{nd} Edition, Tata McGraw Hill Education, 1991.
2. Y. Langsam, M. J. Augenstein and A. M. Tanenbaum, Data Structures using C and C++, 2^{nd} Edition, Pearson Education India, 2007.
3. E. Horowitz and S. Sahani, Fundamentals of Data Structures in C, 2^{nd} Edition, Silicon Press, 2007.
4. T. H. Cormen, C. E. Leiserson and R. L. Rivest, Introduction to Algorithms, 3^{rd} Edition, MIT Press, 2009.
5. R. L. Kruse, C. L. Tondo and B. Leung, Data Structures and Program Design in C, 2^{nd} Edition, Pearson Education, 2001.

Five years Integrated M. Sc. (Mathematics)
Teaching Scheme

Semester-V

Sr. No.	Course	Code	Teaching Scheme Hours per Week			Credits	Examination Scheme				Total Marks
			L	T	P		Theory	Tutorial	Practical Cont. Eval.	Practical End Sem.	
1	Probability & Statistics- I	MA 301	3	2	0	5	100	50	0	0	150
2	Mechanics	MA 303	3	1	0	4	100	25	0	0	125
3	Ordinary Differential Equations	MA 305	3	2	0	5	100	50	0	0	150
4	Computer Networks	CS 303	3	1	2	5	100	25	25	25	175
5	***Institute Elective – 1***		3	0	0	3	100	0	0	0	100
	Advanced Mathematical Methods	MA 361									
	Stochastic Differential Equations	MA 363									
			15	6	2	22					

Total contact Hours per week = 23 **Total Credits = 22** **Total Marks = 700**

Semester-VI

Sr. No.	Course	Code	Teaching Scheme Hours per Week			Credits	Examination Scheme				Total Marks
			L	T	P		Theory	Tutorial	Practical Cont. Eval.	Practical End Sem.	
1	Complex Analysis	MA 302	3	2	0	5	100	50	0	0	150
2	Continuum Mechanics	MA 304	3	1	0	4	100	25	0	0	125
3	Metric Spaces	MA 306	3	1	0	4	100	25	0	0	125
4	Artificial Intelligence	CS 308	3	0	2	4	100	0	25	25	150
5	***Institute Elective-2***		3	0	0	3	100	0	0	0	100
	Integral and Wavelet Transform	MA 362									
	Mathematical Finance	MA 364									
	Fuzzy Set Theory	MA 366									
6	Mini Project	MA 308	0	0	4	2	0	0	40	60	100
			15	4	6	22					

Total contact Hours per week = 25 **Total Credits = 22** **Total Marks = 750**

MA 301: Probability and Statistics-I

L	T	P	Credit
3	2	0	05

1. Course Outcomes (COs)

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

CO1: explain the basic ideas of measures of central tendency, dispersion and their applications

CO2: adapt the knowledge of various Probability distributions and their applications

CO3: evaluate correlation, regression and confidence intervals to formulate hypotheses

CO4: apply statistical techniques for sampling of big data

CO5: select the appropriate statistical techniques for estimation of data

2. Syllabus

- **REVIEW ON PROBABILITY AND DESCRIPTIVE MEASURES (07 Hours)**

  Historical development, Basic Concepts, Measures of Central Tendency, Measures of Dispersion, Tchebycheff's theorem and Empirical rule, Measures of relative standing, some principles of statistical model. Random variables, Probability, conditional probability and Bayes' theorem. Expected value, Moment generation function and variance of a random variable, covariance.

- **PROBABILITY DISTRIBUTIONS (08 Hours)**

  Probability Distributions: binomial and multinomial distribution, geometric distribution, hypergeometric distribution, normal distribution, gamma distribution, exponential distribution, negative binomial distribution, Two dimensional distribution, Joint and Marginal distribution.

- **CENTRAL LIMIT THEOREM (04 Hours)**

  Central limit theorem for Bernoulli trails, Normal approximation to binomial, The general central limit theorem.

- **SAMPLING METHODS (07 Hours)**

  Random Sampling and Methods of Sampling, Sampling Distribution and Standard Error, Sampling Distribution of the Sample Mean, Central Limit Theorem, Sampling Distribution of the Sample Proportion, Sampling Distribution of the difference between two sample means and Sampling Distribution of the difference between two sample proportions.

- **ESTIMATION METHODS (08 Hours)**

  Point Estimation, Interval Estimation, Confidence Interval, Large Sample Confidence Interval for a Population Mean μ, Large Sample Confidence Interval for a Population Proportion, estimating the difference between two Population means, estimating the Difference between two Binomial proportions, Maximum Likelihood Estimation.

- **CORRELATION AND REGRESSION (08 Hours)**

  Correlation, Multiple correlation, Linear Regression, Properties of the Least Square Estimators, Inferences concerning the Regression coefficients, Analysis of variance for Linear Regression, Testing the usefulness of the Linear Regression Model. Multiple regression, Testing the significance of the regression coefficients, Testing of linear hypothesis, Bias in the regression estimators due to choice of wrong model.

Total Lecture Hours: 42

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3. Books Recommended

1. W. Mendenhall, R. J. Beaver and B. M. Beaver, Introduction to Probability & Statistics, 15^{th} Edition, Cengage Learning, 2020.
2. C. M. Grinstead and J. L. Snell, Introduction to Probability, American Mathematical Society, 2^{nd} Revised Edition, 1997
3. D. C. Montgomery, Applied Statistics and Probability for Engineers, 6^{th} Edition, Wiley India Pvt Ltd., 2016
4. R. E Walpole, R. H. Myers, S. L. Myers and K. E. Ye, Probability & Statistics for Engineers & Scientists, 8^{th} Edition, Pearson, 2006
5. K. Black, Business Statistics: For Contemporary Decision Making, 9^{th} Edition, Wiley, 2016.

MA 303: Mechanics

L	T	P	Credit
3	1	0	04

1. Course Outcomes (COs)

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

CO1: explain the concepts of plane statics

CO2: apply fundamental laws of Newtonian mechanics and conservation principles to practical applications.

CO3: explain the motion of a particle in resisting medium and General motion under a central force

CO4: illustrate the motion of a rigid body rotating about a fixed axis and its practical applications

CO5: demonstrate motion of a rotating frame and motion of a particle relative to a rotating frame

2. Syllabus

- **PLANE STATICS** **(09 Hours)**

  Introduction, Equilibrium of a particle, The triangle of forces, The polygon of forces, Lamy's theorem, equilibrium of system of particles, External and Internal forces, Necessary conditions for equilibrium (forces), Moment of a vector about a line, The theorem of Varignon, Necessary conditions for equilibrium (moments), Equipollent systems of forces, Couples, Moment of a couple, reduction of a general plane force system, Work and potential energy, The principle of virtual work.

- **APPLICATIONS IN PLANE STATICS** **(05 Hours)**

  Mass center, Theorems of Pappus, Gravitation, Friction, Laws of static and kinetic friction, Flexible cables, General formula for all flexible cables hanging freely, The suspension bridge, The common catenary.

- **PLANE KINEMATICS** **(05 Hours)**

  Kinematics of a particle, Tangential and Normal components of velocity and acceleration, Radial and transverse components, The hodograph.

- **PLANE DYNAMICS** **(08 Hours)**

  Equations of motion of a particle, Principle of angular momentum for a particle and system, Principle of energy for a particle and system, Principle of linear momentum for a system, d'Alembert's principle, Hamilton's principle, Some techniques of calculus of variation, Derivation of Lagrange's equation from Hamilton's principle.

- **APPLICATIONS IN PLANE DYNAMICS** **(09 Hours)**

  Motion in resisting medium, motion of particles of varying mass, Central orbits, Kepler's law of motion, Moment of inertia: theorem of parallel axes, Theorem of perpendicular axes, Kinetic energy and angular momentum, Konig's theorem, Rigid body rotating about a fixed axis, The compound pendulum, Cylinder rolling down an inclined plane.

- **INTRODUCTION TO DYNAMICS IN SPACE** **(06 Hours)**

  Euler's dynamical equations for the motion a rigid body, Motion of rigid body about fixed axis, Motion of rigid body about rotating axis, Coriolis acceleration.

Total Lecture Hours: 42

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3. Books Recommended

1. J. L. Synge and B. A Griffith, Principle of Mechanic, 2^{nd} Edition, Tata McGraw Hill, New Delhi, 1949.
2. H. Goldstein, C. P. Poole and J. L. Safko, Classical Mechanics, 3^{rd} Edition, Addison Wesley Publishing company, Inc., 1980.
3. N. C. Rana and P. C. Joag, Classical Mechanics, Tata McGraw-Hill, 1991.
4. R. G. Takwale and P. S. Puranik, Introduction to Classical Mechanics, Tata McGraw-Hill, 2000.
5. P. V. Pant, Classical Mechanics, Alpha Science International, 2004.

MA 305: Ordinary Differential Equations

L	T	P	Credit
3	2	0	05

1. Course Outcomes (COs)

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

CO1: analyze the existence, uniqueness of first and higher order linear ODEs on a given interval.

CO2: develops skills for different types of methods for finding the solution of ODEs.

CO3: elaborate the properties of dynamical system

CO4: assess the asymptotic behavior of dynamical system

CO5: determine the solution of higher order BVP through eigen-functions and Green functions.

2. Syllabus

- **REVIEW OF SOLUTION METHODS FOR DIFFERENTIAL EQUATIONS (06 Hours)**

  Second order linear differential equations with variable coefficients and its solution properties, Series solution (Bessel functions and Legendre polynomials).

- **EXISTENCE AND UNIQUENESS OF INITIAL VALUE PROBLEMS (08 Hours)**

  Fixed Point theorem, Picard's and Peano's Theorems, Gronwall's inequality, Continuation of solutions and maximal interval of existence, Dependence on the initial conditions, Extensibility of solutions, Non-Local existence theorem.

- **HIGHER ORDER AND SYSTEM OF LINEAR DIFFERENTIAL EQUATION (06 Hours)**

  Fundamental solutions, Wronskian, Variation of constants, Matrix exponential solution, Behaviour of solutions.

- **DYNAMICAL SYSTEM AND PHASE SPACE ANALYSIS (08 Hours)**

  Dynamical system, The flow of an autonomous equation, Orbits and invariant sets, The Poincare map, Critical points, Proper and improper nodes, Spiral points and saddle points.

- **ASYMPTOTIC BEHAVIOUR (06 Hours)**

  Stability of fixed points, Stability via Liapunov's method.

- **BOUNDARY VALUE PROBLEMS FOR SECOND ORDER EQUATIONS (08 Hours)**

  Sturm comparison theorems, Oscillation theory, Regular and periodic Sturm-Liouville problems, Green's function.

Total Lecture Hours: 42

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3. Books Recommended

1. M. Brown, Differential Equations and Their Applications, Springer, 1992.

2. S. L. Ross, Introduction to Ordinary Differential Equations, Wiley, 1980.
3. M. W. Hirsch, S. Smale and R. L. Deveney, Differential Equations, Dynamical Systems and Introduction to Chaos, Academic Press, 2004.
4. S. G. Deo, V. Raghavendra, R. Kar and V. Lakshmikantham, Textbook of Ordinary Differential Equations, McGraw-Hill Education, 2015.
5. G. F. Simmons and S. G. Krantz, Differential Equations: Theory, Technique and Practice, McGraw Hill Education, 2006.

CS 303: Computer Networks

L	T	P	Credit
3	1	2	05

1. Course Outcomes (COs)

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

CO1: understand computer network models and services offered at different layers of network protocol stack.

CO2: apply knowledge of data communication, data transmission techniques using various transmission media to deliver error free data and communicate with multiple nodes.

CO3: analyse various routing methods to identify effective routing protocols.

CO4: evaluate network performance by means of transport and flow control protocols, Congestion Control protocols and Quality of services.

CO5: create a computer network application using modern network tools and simulation softwares.

2. Syllabus

- **INTRODUCTION** **(06 Hours)**

  Overview of computer networks and data communication, Computer networking protocols and standards, Types of computer networks, Network topology, Protocol hierarchies and design issues, Interfaces and services, Networking devices, OSI and TCP/IP reference models.

- **PHYSICAL LAYER** **(06 Hours)**

  Physical layer design issues, Data transmission techniques, Multiplexing, Transmission media, Asynchronous communication, Wireless transmission, ISDN, ATM, Cellular radio, Switching techniques and issues.

- **LOGICAL LINK CONTROL LAYER** **(06 Hours)**

  LLC design issues, Framing, Error and flow control, Framing techniques, Error control methods, Flow control methods, PPP and HDLC.

- **MEDIUM ACCESS CONTROL LAYER** **(06 Hours)**

  MAC layer design issues, Channel allocation methods, Multiple access protocols - ALOHA, CSMA, CSMA/CD protocols, Collision free protocols, Limited contention Protocols, LAN Architectures, IEEE -802 standards, Ethernet(CSMA/CD), Token bus, Token ring, DQDB, FDDI, Bridges and recent developments.

- **NETWORK LAYER** **(06 Hours)**

  Network layer design issues, Routing algorithms and protocols, Congestion control algorithms and QoS, Internetworking, Addressing, N/W layer protocols and recent developments.

- **TRANSPORT LAYER** **(06 Hours)**

  Transport layer design issues, Transport services, Sockets, Addressing, Connection establishment, Connection release, Flow control and buffering, Multiplexing, Transport layer protocols, Real Time Transport Protocol (RTP), Stream Control Transmission Protocol (SCTP), Congestion control, QoS and Recent developments, Virtualization, Network Functions Virtualization(NFV), Software defined networks.

- **APPLICATION LAYER** **(06 Hours)**

  Client server model, Domain Name System (DNS), Hyper Text Transfer Protocol (HTTP), Email: SMTP, MIME, POP3, Webmail, FTP, TELNET, Dynamic Host Control Protocol (DHCP), Simple Network Management Protocol (SNMP) and recent developments.

Total Lecture Hours: 42

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3. Practicals

1. Study network configuration commands and computer network setup.
2. Implementation of different Data Link and MAC Layer protocols.
3. Implementation of different Network Layer protocols.
4. Implementation of different Transport and Application Layer protocols.
5. Design and configure a network systems using modern network simulator softwares.
6. Implementation of Secured Socket Layer protocol.
7. Implementation of ICMP based message transmission over network.
8. Implementation of SMTP protocol for mail transfer.

4. Tutorials

1. Problem solving on basics of data communication and networking.
2. Problem solving on framing, error control and flow control of Data link layer.
3. Problem solving on various LAN standards.
4. Problem solving on logical address, sub net masking and routing protocols of Network Layer.
5. Problem solving on congestion control, flow control and error control of transport layer.
6. Problem solving on various services provided by application layer.

5. Books Recommended

1. W. Stalling, Data and Computer Communication, 10^{th} Edition, Pearson India, 2017.
2. B. Forouzan, Data Communication and Networking, 5^{th} Edition, McGraw Hill, 2017.
3. D. E. Comer, Internet working with TCP/IP Volume – I, 6^{th} Edition, Pearson India, 2015.
4. A. S. Tanenbaum, Computer Network, 5^{th} Edition, Pearson India, 2013.
5. W. R. Stevens, TCP/IP Illustrated Volume - I, 2^{nd} Edition, Addison Wesley, 2011.

MA 361: Advanced Mathematical Methods

L	T	P	Credit
3	0	0	03

1. Course Outcomes (COs)

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

CO1: demonstrate a common framework that distinguishes various multivariate analytic techniques

CO2: develop the solution of ODEs using asymptotic methods

CO3: apply perturbation theory to solve various problems related to engineering and sciences

CO4: solve non-linear ODEs related to engineering and sciences using homotopy analysis method

CO5: design and implement a techniques based on varied factors for ODEs

2. Syllabus

- **INTRODUCTION** **(06 Hours)**

  Review on Power Series Method, Taylor Series Method.

- **ASYMPTOTIC METHOD** **(09 Hours)**

  Introduction, Asymptotic Solutions at Irregular Singular Points at Infinity, Method of Finding Solutions at Irregular Points, Asymptotic Method for Constructing Solutions along with the validity for large values, Asymptotic Solutions of Perturbed Problems, Solutions to ODEs Containing a Large Parameter, Applications.

- **PERTURBATION TECHNIQUES** **(11 Hours)**

  Basic Idea behind the Perturbation Method, Regular Perturbation Theory, Singular Perturbation Theory, Boundary-Layer Method, Applications.

- **METHOD OF MULTIPLE SCALES** **(07 Hours)**

  Introduction, Method of Multiple Scales, Applications.

- **HOMOTOPY ANALYSIS METHOD** **(09 Hours)**

  Introduction, Background, A brief history of the HAM, Characteristic of homotopy analysis method, Some advances of the HAM, Generalized zeroth-order deformation equation, Basic ideas of the homotopy analysis method, Convergence of homotopy-series solution.

Total Lecture Hours: 42

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3. Books Recommended

1. C. M. Bender and S. A. Orszag, Advanced Mathematical Methods for Scientists and Engineers: Asymptotic Methods and Perturbation Theory, Springer Science & Business Media, 1999.
2. S. I. Hayek, Advanced Mathematical Methods in Science and Engineering, 2^{nd} Edition, Chapman and Hall/CRC, 2010.
3. J. B. Doshi, Analytical Methods in Engineering, Narosa Publishing House, 1998.

4. A. D. Polyanin and V. F. Zaitsev, Handbook of Ordinary Differential Equations: Exact Solutions, Methods, and Problems, 3^{rd} Edition, Chapman and Hall/CRC, 2017.

5. S. Liao, Homotopy Analysis Method in Nonlinear Differential Equations, Springer-Verlag Berlin Heidelberg, 2012.

MA 363: Stochastic Differential Equations

L	T	P	Credit
3	0	0	03

1. Course Outcomes (COs)

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

CO1: explain the basics of stochastic differential equations

CO2: elaborate Ito integrals, and its application to stochastic differential equations

CO3: analyze existence and uniqueness of stochastic differential equations.

CO4: solve stochastic differential equations.

CO5: explain its application to different boundary value problems

2. Syllabus

- **INTRODUCTION** **(06 Hours)**

  Stochastic analogues of classical differential equations.

- **MATHEMATICAL PRELIMINARIES** **(06 Hours)**

  Probability space, Random variable, Stochastic process, Brownian motion.

- **ITO INTEGRAL** **(06 Hours)**

  Definition, Properties, Extensions.

- **ITO FORMULA AND MARTINGALE REPRESENTATION THEOREM** **(08 Hours)**

  One-dimensional Ito formula, Multi-dimensional Ito formula, Martingle representation theorem.

- **STOCHASTIC DIFFERENTIAL EQUATIONS** **(08 Hours)**

  Examples and some solution methods, Existence and Uniqueness result, Weak and strong solutions.

- **APPLICATIONS** **(08 Hours)**

  Boundary value problems, Filtering, Optimal stopping, Stochastic control, The Black-Scholes formula and its application to mathematical finance.

Total Lecture Hours: 42

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3. Books Recommended

1. B. K. Oksendal, Stochastic Differential Equations: An Introduction with Applications, 6^{th} Edition, Springer, 2010.
2. I. Karatzas and S. E. Shreve, Brownian Motion and Stochastic Calculus, Springer, 1991.
3. P. Protter, Stochastic Integration and Differential Equations, Springer, 2^{nd} Edition, 2010.
4. I. Karatzas and S. E. Shreve, Methods of Mathematical Finance, Springer, 2010.
5. S. Watanabe and N. Ikeda, Stochastic Differential Equations and Diffusion Processes, North-Holland, 1981.

MA 302: Complex Analysis

L	T	P	Credit
3	2	0	05

1. Course Outcomes (COs)

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

CO1: explain the fundamentals of function of complex variables

CO2: evaluate contour integrals

CO3: deduct the poles and singularities with applications

CO4: evaluate proper and improper integrals

CO5: explain the basic concept of conformal mappings in complex plane with applications

2. Syllabus

- **FUNCTIONS OF COMPLEX VARIABLE** **(12 Hours)**

  Limit, Continuity, Differentiability, Analytic function, Cauchy-Riemann equation, Construction of analytic function, Harmonic function.

- **CONTOUR INTEGRATION** **(10 Hours)**

  Cauchy's theorem, Cauchy's inequality, Morera's theorem, Liouville's theorem. Power Series, Taylor's series, Maximum/Minimum modulus principle, Schwarz lemma.

- **SINGULARITIES AND RESIDUES** **(12 Hours)**

  Classification of Singularities: Isolated, removable, pole and essential singularities, Properties of zeroes and poles, Residue at pole, Residue at infinity, Cauchy's residue theorem, Number of poles and zeroes of an analytic function, Cauchy's integral formula, Laurent's series, Open mapping theorem, Rouche's theorem, Evaluation of integrals of the type $\int_0^{2\pi} f(\sin\theta, \cos\theta)\, d\theta$ and $\int_{-\infty}^{\infty} f(x)\, dx$, Improper real integrals of the form $\int_{-\infty}^{\infty} \cos ax\, f(x)\, dx$ and $\int_{-\infty}^{\infty} \sin ax\, f(x)\, dx$, Improper integrals with singular points on the real axis.

- **CONFORMAL MAPPINGS** **(08 Hours)**

  Introduction, Conformality Theorem, Mobiüs transformation, translation, rotation, inversion, cross-ratio, critical value of a transformation.

Total Lecture Hours: 42

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3. Books Recommended

1. J. W. Brown and R. V. Churchill, Complex Variables and Applications, 8^{th} Edition, McGraw-Hill Higher Education, 2009.
2. J. B. Conway, Functions of one Complex variable, Springer, International Student Edition, Narosa, 1980.
3. H. S. Kasana, Complex Variables: Theory and Applications, 2^{nd} Edition, PHI Learning Private Limited, Delhi, 2013.

4. S. Ponnusamy, Foundations of Complex Analysis, Narosa, 1997.
5. A. R. Shastri, An Introduction to Complex Analysis, Macmillan India, New Delhi, 1999.

MA 304: Continuum Mechanics

L	T	P	Credit
3	1	0	04

1. Course Outcomes (COs)

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

CO1: demonstrate the usefulness of tensors in Continuum Mechanics

CO2: analyze the Cauchy's stress principle to develop the stress vector–stress tensor relationship

CO3: solve problems in continuum theory

CO4: illustrate the Material derivative concept in obtaining the basic equations of Continuum Mechanics

CO5: apply the concept of mechanics in modern engineering and technology

2. Syllabus

- **REVIEW OF TENSORS** **(05 Hours)**

  Cartesian tensors, Tensor rank, Indicial notations; Range and summation conventions, Transformation laws for Cartesian tensors, Kronecker delta, Orthogonality conditions, Addition of Cartesian tensors, Multiplication by a scalar, Tensor multiplication, Matrix representation of Cartesian tensors, Principal values Principal directions of symmetric second order tensors.

- **ANALYSIS OF STRESS** **(08 Hours)**

  The continuum concept, Homogeneity, Isotropy, Mass density, Body forces, surfaces forces, Cauchy stress principle; The stress vector, State of stress at a point, The stress tensor - stress vector relationship, Principal stresses, Stress invariants, Stress ellipsoid.

- **DEFORMATION AND STRAIN** **(06 Hours)**

  Lagrangian and Eulerian description, Finite strain tensor, Small deformation theory, Rotation tensor, Strain invariant, Principal strains, Cubical dilatation.

- **MOTION AND FLOW** **(08 Hours)**

  Material derivatives, Pathline and stream lines, Rate of deformation, Vorticity vector, Material derivative of Line, Surface and Volume integrals.

- **FUNDAMENTAL LAWS OF CONTINUUM MECHANICS** **(07 Hours)**

  Equation of continuity, Equations of motion, Principle of angular momentum, Conservation of energy, Clausius-Dirhem inequality, Dissipation Function

- **LINEAR ELASTICITY** **(03 Hours)**

  Generalized Hooke's law, Strain energy function, Isotropy, Anisotropy, Elastic symmetry, Isotropic media, Elastic constants, Elastostatic problems, Elastodynamic problems.

- **CLASSICAL FLUIDS** **(05 Hours)**

  Viscous Stress Tensor, Stokesian, and Newtonian Fluids, Relation between stresses and rate of strain for compressible Newtonian viscous fluids.

Total Lecture Hours: 42

3. Books Recommended

1. G. T. Mase and G. E. Mase, Continuum Mechanics for Engineers, CRC press, 1999.
2. G. E. Mase, Theory and Problems of Continuum Mechanics, Schaum's Outline Series, McGraw Hill Book company, 1970.
3. J. W. Rudnicki, Fundamentals of Continuum Mechanics, John Wiley & Sons Ltd., 2015.
4. J. N. Reddy, An Introduction to Continuum Mechanics with Applications, Cambridge University Press, 2008.
5. X. Oliver and C. A. de-Saracibar, Continuum Mechanics for Engineers: Theory & Problems, 2^{nd} Edition, 2017.

MA 306: Metric Spaces

L	T	P	Credit
3	1	0	04

1. Course Outcomes (COs)

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

CO1: explain the basic definition of metric spaces and corresponding topological concepts

CO2: discuss sequences in metric spaces and its convergences

CO3: elaborate the compactness and its characterization

CO4: illustrate the concept of connectedness and can apply different aspects related to metric continuity

CO5: discuss the continuity and its geometric properties along with fixed point concepts

2. Syllabus

- **BASIC DEFINITIONS AND NOTIONS** **(10 Hours)**

  Need for "metric", abstract definition and examples of metric spaces, Consequences: Open balls and open sets and their properties and characterizations, Closed Sets and their properties and characterizations. Meaning of "Topology", Subspace topology and product topology with characterizations, Interior, Exterior, Boundary Points, Interior, Exterior and Boundary of a set and their properties and characterizations in terms of open and closed sets, Limit Points and Cluster points, Closure of a set, Dense sets and their properties and characterizations, Bounded sets and their properties and characterizations, Distance between sets, Equivalent metrics.

- **SEQUENCES IN METRIC SPACE** **(06 Hours)**

  Sequences and their convergence in a metric space, Characterizations of closed sets, limit points, cluster points, dense sets in terms of sequences and their convergence, Cauchy sequences in a metric space, Complete metric space: Difference between Cauchyness and convergence in abstract metric spaces, Completion of a metric space, Baire category theorem with a few applications at the beginner level.

- **COMPACTNESS** **(06 Hours)**

  Compact Spaces: Motivation, definition and their properties, Characterization of compact spaces in terms of sequentially compact, Closed and totally bounded and open cover definition, Equivalence of these definitions.

- **CONNECTEDNESS** **(05 Hours)**

  Connected sets, Connected Components, Totally disconnected sets.

- **CONTINUITY** **(10 Hours)**

  Motivation behind continuity of functions in metric spaces, The three equivalent definitions of continuity: sequence definition, epsilon–delta definition and open sets definition, Other characterizations of continuity in terms of open sets, closed sets, closure and interior of images and pre-images of sets, Uniform continuity and Lipschitz continuity, its properties and characterizations, Continuous functions on compact spaces and the Arzela-Ascolli's theorem, Continuous functions on connected spaces and path connectedness, Open and closed maps and their properties, Homeomorphisms and their importance.

- **BANACH CONTRACTION PRINCIPLE AND ITS APPLICATIONS** **(05 Hours)**

Contraction mappings, Contractive mappings, Non-expansive mappings, Fixed points, Banach contraction principle, Applications of Banach contraction principle to root finding problems, System of linear equations, Implicit function theorem.

Total Lecture Hours: 42

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3. Books Recommended

1. P. K. Jain and K. Ahmed, Metric Spaces, 2^{nd} Edition, Narosa Publications, 2004.
2. S. Kumaresan, Topology of Metric Spaces, 2^{nd} Edition, Narosa Publications, 2011.
3. S. Shirali and H. L. Vasudeva, Metric Spaces, Springer, 2006.
4. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Education, 1963.
5. D. Gopal, P. Kumam and M. Abbas, Background and Recent Developments in Metric Fixed Point Theory, CRC Press, 2017.

CS 308: Artificial Intelligence

L	T	P	Credit
3	0	2	04

1. Course Outcomes (COs)

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

CO1: understand the role of agents and how it is related to environment and the way of evaluating it and how agents can act by establishing goals

CO2: apply various knowledge representation technique, searching techniques, constraint satisfaction problem and example problems- game playing techniques.

CO3: analyse the current scope, potential, limitations, and implications of intelligent systems.

CO4: evaluate the AI techniques suitable for recent areas of applications like expert systems, neural networks, fuzzy logic, robotics, natural language processing, and computer vision.

CO5: design a real world problem for implementation and understand the dynamic behaviour of a system.

2. Syllabus

- **INTRODUCTION TO AI** **(03 Hours)**

  Intelligent agents, AI techniques, AI-problem formulation, AI applications, Production systems, Control strategies.

- **KNOWLEDGE REPRESENTATION** **(06 Hours)**

  Knowledge representation using predicate logic, Introduction to predicate calculus, Resolution, Use of predicate calculus, Knowledge representation using other logic-structured representation of knowledge.

- **PRODUCTION SYSTEM** **(06 Hours)**

  Defining the problems as a state space search, Production systems, Production characteristics, Production system Characteristics, Forward and backward, State-space search, Problem solving methods – Problem Graphs, Matching, Indexing.

- **PROBLEM-SOLVING THROUGH SEARCH** **(06 Hours)**

  Generate and test, BFS, DFS, Blind, Heuristic, Problem-reduction, A, A*, AO*, Minimax, Constraint propagation, Neural, Stochastic, and Evolutionary search algorithms, Sample applications, Measure of performance and analysis of search algorithms, Problem reduction, Constraint satisfaction, Means-ends analysis, Issues in the design of search programs.

- **KNOWLEDGE INFERENCE** **(06 Hours)**

  Knowledge representation -Production based system, Frame based system. Inference – backward chaining, Forward chaining, Rule value approach, Fuzzy reasoning – certainty factors, Bayesian theory-Bayesian network-Dempster – Shafer theory, Symbolic logic under uncertainty : Non-monotonic reasoning, logics for non-monotonic reasoning, Statistical reasoning : Probability and Bayes theorem, Certainty factors, Probabilistic graphical models, Bayesian networks, Markov networks, Fuzzy logic.

- **GAME PLAYING AND PLANNING** **(06 Hours)**

  Overview and example domain: Overview, Minimax, Alpha-Beta cut-off, Refinements, Iterative deepening, The blocks world, Components of a planning system, Goal stack planning, Nonlinear planning using constraint posting, Hierarchical planning, Reactive systems, Other planning techniques.

- **NATURAL LANGUAGE PROCESSING** **(04 Hours)**

  Introduction, Syntactic processing, Semantic analysis, Semantic analysis, Discourse and pragmatic processing, Spell checking.

- **EXPERT SYSTEMS** **(05 Hours)**

  Expert systems – Architecture of expert systems, Roles of expert systems – Knowledge acquisition – Meta Knowledge, Heuristics, Typical expert systems – MYCIN, DART, XOON, Expert systems shells.

Total Lecture Hours: 42

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3. Practicals

1. Practical assignment to understanding basic concepts of prolog.
2. Practical assignment to implement various search strategies.
3. Practical assignment to implement various algorithm based on game theory.
4. Implementation of heuristic based search techniques.
5. Implementation of neural network based application.
6. Implementation of fuzzy logic based application.
7. Implementation of fuzzy inference engine for an application.
8. Implementation of neuro-fuzzy based system.

4. Books Recommended

1. E. Rich and K. Knight, Artificial Intelligence, 2^{nd} Edition, Tata McGraw-Hill, 2003.
2. S. Russell, P. Norvig, Artificial Intelligence: A Modern Approach, 3^{rd} Edition, Prentice Hall, 2009.
3. N. Nilsson, Artificial Intelligence: A New Synthesis, Morgan Kaufmann, 1998,
4. W. Patterson, Introduction to Artificial Intelligence and Expert Systems, Prentice Hall of India, 2010.
5. I. Bratko, Prolog Programming for Artificial Intelligence, 3^{rd} Edition, Addison-Wesley, 2001,

MA 362: Integral and Wavelet Transform

L	T	P	Credit
3	0	0	03

1. Course Outcomes (COs)

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

CO1: discuss Fourier integral theorem and condition of its validity

CO2: determine the Fourier, Fourier Sine and Cosine transform of a function

CO3: utilize integral transform techniques to solve 2nd order ODE and PDE arising in Mathematical Physics

CO4: evaluate the solution of difference equation using Z-transform

CO5: demonstrate basic idea of Wavelets and Wavelet transform.

2. Syllabus

- **INTRODUCTION TO FOURIER TRANSFORM** **(10 Hours)**

  Fourier Integral Theorem, Definition and basic properties of Fourier transform. Inversion theorem, Convolution theorem, Parseval's relation, Fourier Cosine and Sine transform, Fast Fourier Transform, Applications to Ordinary and Partial Differential Equations.

- **HANKEL TRANSFORM** **(07 Hours)**

  Hankel transform, Inversion formula of Hankel transform, Parseval relation, Finite Hankel transform, Application to Partial differential equations.

- **MELLIN'S TRANSFORM** **(07 Hours)**

  Properties of Mellin's transform. Inversion theorem, Convolution theorem, Application of Mellin' s transform.

- **Z-TRANSFORM** **(08 Hours)**

  Introduction, Linear Systems, Impulse response, Definition of Z-transform and examples, basic operational properties, Inverse Z-transform and examples, Applications of Z-transform to solve finite difference equations, Summation of infinite series.

- **WAVELETS AND WAVELET TRANSFORM** **(10 Hours)**

  Introduction to Wavelet, brief history, Continuous Wavelet Transform, Discrete Wavelet Transform, Basic Properties of Wavelet Transform, Applications of Wavelet Transforms. Triple integrals, evaluation techniques, Application of triple integrals for evaluation of volume.

Total Lecture Hours: 42

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3. Books Recommended

1. L. Debnath and D. Bhatta, Integral Transforms and Their Applications, 3^{rd} Edition, Chapman & Hall, New York, 2014.
2. I. N. Sneddon, The Use of Integral Transform, McGraw-Hill, New York, 1972.
3. L. C. Andrews and B. K. Shivamoggi, Integral Transforms for Engineers, SPIE Press, Bellingham, 1999.

4. L. Debnath and F. Shah, Wavelet Transforms and Their Applications, Springer, New York, 2015.
5. R. V. Churchill, Operational Mathematics, McGraw-Hill, New York, 1972.

MA 364: Mathematical Finance

L	T	P	Credit
3	0	0	03

1. Course Outcomes (COs)

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

CO1: demonstrate the basic concepts in Probability theory

CO2: demonstrate the concepts relating to functions and annuities

CO3: demonstrate the Arbitrage theorem and Black-Scholes formula.

CO4: employ methods related to these concepts in a variety of financial applications

CO5: apply logical thinking to problem related to call and put options and valuing of investment.

2. Syllabus

- **INTRODUCTION** **(06 Hours)**

  Probability Theory, Stochastic Processes, Poisson Process, Brownian Motion, Martingales Present Value Analysis.

- **INTERESTS RATES AND PRESENT VALUE ANALYSIS** **(06 Hours)**

  Interest rates, Present value analysis, Rate of return, Continuously varying Interest rates.

- **THE ARBITRAGE THEOREM** **(06 Hours)**

  Market Model Specification problems. Arbitrage Theorem, Multi-period binomial Model, Proof of the Arbitrage Theorem.

- **THE BLACK-SCHOLES FORMULA** **(08 Hours)**

  The Black-Scholes formula, Properties of the Black–Scholes Option Cost, The Delta Hedging Arbitrage Strategy.

- **ADDITIONAL RESULTS ON OPTION** **(06 Hours)**

  Call Options on Dividend-Paying Securities, Pricing American Put Options, Estimating the Volatility Parameter.

- **VALUING BY EXPECTED UTILITY** **(10 Hours)**

  Valuing investments by expected utility, Portfolio selection problem, Capital Assets Pricing model, Rates of return, Single period and geometric Brownian motion, Mean-variance analysis of risk - neutral priced call options, Autoregressive models and mean regression, Other pricing options and applications.

Total Lecture Hours: 42

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3. Books Recommended

1. S. M. Ross, An Introduction to Mathematical Finance, Cambridge University Press, 1999.
2. A. J. Prakash, R. M. Bear, K. Dandapani, G. L. Ghai, T. E. Pactwa and A. M. Parhizgari, The Return Generating Models in Global Finance, Pergamon Press, 1998.

3. M. S. Joshi, The Concepts and Practice of Mathematical Finance, 2^{nd} Edition, Cambridge University Press, 2008.
4. M. Capiński and T. Zastawniak, Mathematics for Finance: An Introduction to Financial Engineering, 2^{nd} Edition Springer, 2011.
5. P. Wilmott, Derivatives: The Theory and Practice of Financial Enginering (Frontiers in Finance Series), John Wiley & Sons, 1998.

MA 366: Fuzzy Set Theory

L	T	P	Credit
3	0	0	03

1. Course Outcomes (COs)

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

CO1: demonstrate the concepts of crisp sets and fuzzy sets

CO2: apply various operations on fuzzy sets

CO3: demonstrate the fuzzy arithmetic

CO4: solve the fuzzy equations

CO5: solve the Engineering problems using the theory of fuzzy sets and fuzzy mathematics

2. Syllabus

- **INTRODUCTION** **(05 Hours)**

  Definition of Fuzzy sets. Fuzzy sets verse crisp sets, Alpha-cuts. Theorems on Cuts, Normality Extension Principle.

- **OPERATIONS ON FUZZY SETS** **(05 Hours)**

  Types of operations, Completion, Union and intersection, Difference, t-norm, t-conorms.

- **FUZZY ARITHMETIC** **(06 Hours)**

  Fuzzy numbers. Addition, Subtraction, Multiplication and Division, Triangular and trapezoid fuzzy numbers.

- **FUZZY RELATIONS AND FUZZY EQUATIONS** **(13 Hours)**

  Crisp verses fuzzy relations, Binary fuzzy relations, Fuzzy equivalence relations, Fuzzy ordering relations. Fuzzy relation equations, Sup-i composition, Inf-w composition, Solution methods.

- **FUZZY LOGIC** **(07 Hours)**

  Fuzzy proposition, Fuzzy Quantifiers, Multivalued Logic, Inference Systems.

- **ENGINEERING APPLICATIONS** **(06 Hours)**

  Fuzzy controlar, Applications in Civil engineering, Mechanical engineering and Computer engineering.

Total Lecture Hours: 42

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3. Books Recommended

1. H. J. Zimmerman, Fuzzy Set Theory and its Applications, 3^{rd} Edition, Kluwer Academic Publishers, Boston, MA, 1996
2. D. Dubois and H. Prade, Fuzzy Sets and Systems: Theory and Applications, Academic Press, Cambridge, MA, 1980
3. T. J. Ross, Fuzzy Logic with Engineering Applications, 3^{rd} Edition, Wiley Publication, 2011

4. G. J. Klir, U. St. Clair and B. Yuan, Fuzzy Set Theory Foundations and Applications, PHI Inc. USA, 1997
5. C. Mohan, An Introduction to Fuzzy Set Theory and Fuzzy Logic, Viva Books Private Limited, 2017

MA 308: Mini Project

L	T	P	Credit
0	0	4	02

1. **Course Outcomes (COs)**

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

   CO1: discover various research fields

   CO2: improve their mathematical knowledge in the field of interest

   CO3: develop collaborative skills

   CO4: take part in group activity

   CO5: formulate the problem of engineering and sciences into mathematical form

2. **Syllabus**

   Students will work on a research topic in a group under the guidance of faculty member(s).

Five years Integrated M. Sc. (Mathematics)
Teaching Scheme

SEMESTER – VII

Sr. No.	Subject	Code	Teaching Scheme Hours Per Week			Credits	Examination Scheme			Total Marks
			L	T	P		Theory	Tutorial	Practical	
1	Topology	MA 401	3	1	0	04	100	25	0	125
2	Abstract Algebra	MA 403	3	1	0	04	100	25	0	125
3	Fluid Dynamics	MA 405	3	2	0	05	100	50	0	150
4	Optimization Techniques	MA 407	3	2	0	05	100	50	0	150
5	***Core Electives***		3	0	0	03	100	0	0	100
	Sobolev Space	MA 421								
	Data Science	CS 491								
	Block Chain Technology	CS 423								
			15	6	0	21				
Total Contact Hours per Week = 21				**Total Credits = 21**				**Total Marks = 650**		

SEMESTER – VIII

Sr. No.	Subject	Code	Teaching Scheme Hours Per Week			Credits	Examination Scheme			Total Marks
			L	T	P		Theory	Tutorial	Practical	
1	Functional Analysis	MA 402	3	1	0	04	100	25	0	125
2	Higher Transcendental Functions	MA 404	3	1	0	04	100	25	0	125
3	Partial Differential Equations	MA 406	3	2	0	05	100	50	0	150
4	Calculus of Variations & Integral Equations	MA 408	3	2	0	05	100	50	0	150
5	***Core Electives***		3	0	0	03	100	00	0	100
	Multiobjective optimization	MA 422								
	Natural Language Processing	CS 492								
			15	6	0	21				
Total Contact Hours per Week = 21				**Total Credits = 21**				**Total Marks = 650**		

MA 401: Topology

L	T	P	Credit
3	1	0	04

1. Course Outcomes (COs)

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

CO1: explain the concept of topology and intrinsic properties of topological spaces

CO2: demonstrate homeomorphism and topological manifold.

CO3: discuss compactness, connectedness and related theorems

CO4: explain the concept of Countability Axioms, Seperability

CO5: discuss the Metrization Theorem and its applications in topology

2. Syllabus

- **INTRODUCTION** **(14 Hours)**

  Topological Spaces, Examples of topological spaces, Subspace topology, Product topology, Metric topology, Order topology, Quotient topology, Bases, Sub bases, Continuous function, Homeomorphism, Topological manifold.

- **COMPACTNESS** **(10 Hours)**

  Compact spaces, Heine-Borel theorem, Local compactness, One-point compactification, Tychnoff theorem. The Stone-Cech compactification.

- **CONNECTEDNESS** **(06 Hours)**

  Connected spaces, Components and local connectedness.

- **COUNTABILITY & SEPARATION AXIOMS** **(12 Hours)**

  Countability Axioms, Seperability i.e. T0, T1, T2 spaces, Regularity, Completed regularity, Normality, Urysohn lemma, Tychnoff embedding and Urysohn metrization theorem, Tietze extension theorem.

Total Lecture Hours: 42

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3. Books Recommended

1. M. A. Armstrong, Basic Topology, Springer(India), 2004.
2. K. D. Joshi, Introduction to General Topology, New Age International, New Delhi, 2000.
3. J. L. Kelley, General Topology, Van Nostrand, Princeton,1955.
4. J. R. Munkres, Topology, 2^{nd} Edition, Pearson Education (India), 2001.
5. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, New York, 1963.

MA 403: Abstract Algebra

L	T	P	Credit
3	1	0	04

1. **Course Outcomes (COs)**

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

CO1: demonstrate insight into abstract algebra with focus on axiomatic theories

CO2: develop capacity for mathematical reasoning through analyzing, proving and explaining concepts from advance group theory

CO3: explain the fundamental concepts of ring theory and their role in modern mathematics

CO4: prove fundamental results and solve algebraic problems using appropriate techniques

CO5: discuss about field extension and fundamental theorems of Galois theory

2. **Syllabus**

- **ADVANCED GROUP THEORY** **(14 Hours)**

  Solvable groups and theorem of them, Conjugacy, Conjugate classes, Theorems on finite groups, Class equations, Sylow's theorem, Normal and subnormal series, Composition series, Jordan-Holder theorem, Nilpotent groups.

- **RING THEORY** **(12 Hours)**

  Rings, Subrings and ideals, Sum of ideals, Product of ideals, Minimal ideal, Maximal ideal, Quotient rings, Homomorphisms. Polynomial rings, Division ring, Factorization in R[x], Divisibility, Integral domain, Euclidean domains, Prime and irreducible elements, Principal ideal domains and unique factorization domains.

- **FIELD THEORY** **(08 Hours)**

  Fields, Skew fields, Finite fields, Field of quotients and embedding theorems, Eisenstein's irreducibility criterion.

- **FIELD EXTENSIONS AND GALOIS THEORY** **(08 Hours)**

  Prime field, field extensions, Splitting fields and normal extensions, Separable and inseparable extensions. Automorphisms of field extensions, Galois extensions and Galois groups, Fundamental theorems of Galois theory.

Total Lecture Hours: 42

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3. **Books Recommended**

1. M. Artin, Algebra, 2^{nd} Edition, Pearson Education India, 2010.
2. J. A. Gallian, Contemporary Abstract Algebra, 9^{th} Edition, Cengage Learning India (P.) Ltd., 2019.
3. J. B. Fraleigh, First Course in Abstract Algebra, 3^{rd} Edition, Narosa Publishing House, New Delhi, 2003.
4. I. N. Herstein, Topics in Algebra, 2^{nd} Edition, Wiley India (P.) Ltd., New Delhi, 2009.
5. P. M. Chon, Algebra, Vols. I, II & III, John Wiley & Sons, 1989, 1991, 1992.

MA 405: Fluid Dynamics

L	T	P	Credit
3	2	0	05

1. Course Outcomes (COs)

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

CO1: explain the physical properties of fluid and their consequence on fluid flow

CO2: identify the fundamental kinematics of a fluid element

CO3: analyze practical applications of Bernoulli's equation

CO4: formulate conceptual and analytical models of flow system

CO5: solve problems in fluid dynamics using finite difference methods

2. Syllabus

- **GENERAL INTRODUCTION** **(04 Hours)**

  Introduction to fluid dynamics, Normal and shear stress, The concept of a fluid, Kinds of fluids, Characteristics of fluid, Density, Pressure, Viscosity, Surface tension and compressibility, Different types of flows, Visualization of flows.

- **EQUATIONS OF MOTION** **(06 Hours)**

  Pressure equation (Bernoulli's equation for steady and unsteady motion), Practical applications of Bernoulli's equation to Orifice meter, Pitot-tube, Venturimeter.

- **POTENTIAL FLOW** **(06 Hours)**

  Velocity potential and irrotational flow, Circulation and Kelvin's theorem, Theorem of Blasius, Stream function in two dimensions, Complex velocity potential.

- **GOVERNING EQUATION OF FLUID DYNAMICS** **(10 Hours)**

  Derivation of the Navier-stokes equation, Flow between parallel plates – Couette flow and plane Poiseuille flow. Hagen – Poiseuille flow through pipes, Steady flow through a cylindrical pipe, Steady flow between co-axial circular cylinders.

- **BOUNDARY LAYER FLOW** **(06 Hours)**

  Drag and lift, Prandtl's boundary layer theory, Boundary layer equation, Karman's integral (condition) equation, Flow parallel to a semi-infinite flat plate, Reynold's number, Prandtl number, Nusselt number, Froude number, Eckert number.

- **INTRODUCTION TO COMPUTATIONAL DYNAMICS** **(10 Hours)**

  General introduction and role of computational fluid dynamics in modern fluid dynamics, The method of finite differences, Derivation of elementary finite difference quotients, Basic aspects of finite-difference equations, Errors and an analysis of stability, Explicit finite difference methods; The Lax–Wendroff method, MacCormack's method, Stability criterion, Applications of the explicit time-dependent technique, Generalized Crank–Nicholson scheme.

Total Lecture Hours: 42

3. Books Recommended

1. G. K. Bachelor, An Introduction to Fluid Dynamics, Cambridge University Press, 2000.
2. P. K. Kundu, and Ira M. Cohen, Fluid Mechanics, 3^{rd} Edition, Burlington Elsevier, 2004.
3. M. E. O'Neill and F. Chorlton, Ideal and Incompressible Fluid Dynamics, John Wiley & Sons, 1986.
4. J. K. Goyal and K. P. Gupta, Fluid Dynamics and Advanced Hydrodynamics, Pragati Prakashan, 2016.
5. J. F. Wendt, Computational Fluid Dynamics: An Introduction, 3^{rd} Edition, Springer, 2009.

MA 407: Optimization Techniques

L	T	P	Credit
3	2	0	05

1. **Course Outcomes (COs)**

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

   CO1: demonstrate the importance of optimization in real life problems.

   CO2: formulate the real world problems into optimization problems

   CO3: analyze the sensitivity of different components of an LPP towards its solution.

   CO4: estimate the solution of different real life problems using the concept of LPP

   CO5: explain the basic concept of non-linear optimization

2. **Syllabus**

   - **LINEAR PROGRAMMING PROBLEMS** **(08 Hours)**

     Introduction, Structure of L.P.P., Formulation of an L.P.P., Graphical Method of solution of L.P.P., Standard form of L.P.P., Simplex Algorithm, Simplex Tableau, Two Phase Method, Big-M Method, Types of Linear Programming solutions, Duality.

   - **REVISED SIMPLEX METHOD** **(05 Hours)**

     Revised simplex method (with and without artificial variable), Bounded variable technique, Dual simplex method, Modified dual simplex method.

   - **SENSITIVITY ANALYSIS** **(06 Hours)**

     Change in the objective function, Change in the requirement vector, Addition of a variable, Addition of a constraint, Parametric analysis of cost and requirement vector.

   - **INTEGER PROGRAMMING PROBLEMS** **(04 Hours)**

     Gomory's cutting plane algorithm, Gomory's mixed integer problem algorithm, A branch and bound algorithm.

   - **TRANSPORTATION PROBLEMS** **(05 Hours)**

     Mathematical Model for Transportation Problem, North-West Corner Method, Least Cost Method, Vogel's Approximation Method, Test for optimality, Degeneracy in Transportation Problem, Variations in Transportation Problem.

   - **ASSIGNMENT PROBLEMS** **(05 Hours)**

     Mathematical Model for Assignment Problem, Solution Method for Assignment Problem, Variations in Assignment Problem, Traveling Salesman Problem.

   - **SEQUENCING PROBLEMS** **(04 Hours)**

     Processing of Jobs through machines: Problems with n jobs two machines, n jobs three machines and n jobs m machines.

   - **INTRODUCTION TO NONLINEAR OPTIMIZATION** **(05 Hours)**

     General NLPP, Formulation, unconstrained and constrained optimization, constrained optimization with equality constraints (Lagrange's theory), constrained optimization with inequality constraints (Kuhn-Tucker conditions).

Total Lecture Hours: 42

3. Books Recommended

1. E. M. L. Beale and L. Mackley, Introduction to Optimization, John Wiley, 1988.
2. K. Swarup, P. K. Gupta and M. Mohan, Operations Research, 19^{th} Edition, S. Chand & Sons, New Delhi, 2017.
3. S. S. Rao, Optimization Theory and Applications, 2^{nd} Edition, Willey Eastern Ltd., New Delhi, 1985.
4. H. A. Taha, Operations Research: An Introduction, 9^{th} Edition, Pearson, New Delhi, 2014.
5. J. K. Sharma, Operations Research: Theory and Applications, 6^{th} Edition, Trinity Press, New Delhi, 2017.

MA 421: Sobolev Space

L	T	P	Credit
3	0	0	03

1. Course Outcomes (COs)

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

CO1: explain the concept of distribution

CO2: demonstrate L^1, L^2 and L^p Fourier transform

CO3: discuss the $W^{1,p}_\infty(\Omega)$, $W^{1,p}(\Omega)$, $H^1(\Omega)$ spaces and their properties

CO4: explain the imbedding theorem and weighted space

CO5: discuss various inequalities in Sobolev space

2. Syllabus

- **DISTRIBUTION** **(04 Hours)**

  Test function spaces and distributions, Convergence distribution derivatives

- **FOURIER TRANSFORM** **(06 Hours)**

  L^1–Fourier transform, Fourier transform of a Gaussian, L^2–Fourier transform, Inversion formula, L^p–Fourier transform, Convolution

- **SOBOLEV SPACE** **(08 Hours)**

  The spaces $W^{1,p}_\infty(\Omega)$ and $W^{1,p}(\Omega)$, Their simple characteristic properties, Density result, Min and Max of $W^{1,p}$ functions, The space $H^1(\Omega)$

- **IMBEDDING THEOREM** **(06 Hours)**

  Continuous and compact imbedding of Sobolev spaces into Lebesgue spaces, Sobolev imbedding theorem, Rellich–Kondrasov theorem

- **WEIGHTED SPACE** **(08 Hours)**

  Definition, Motivation, Examples of practical importance, Special weights of power type, General weights, Weighted Lebesgue space $P(\Omega, \sigma)$, weighted Sobolev spaces $W^{k,p}(\Omega, \sigma)$, $W_o^{\Omega,\sigma}$ and their properties.

- **INEQUALITIES** **(10 Hours)**

  Methods of local co-ordinates, The classes C^o, $C^{0,k}$, Holder's condition, Partition of unity, The class $K(x_0)$ including cone property. Hardy inequality, Jensen's inequality, Young's inequality, Hardy–Littlewood–Sobolev inequality, Sobolev inequality and its various versions.

Total Lecture Hours: 42

3. Books Recommended

1. R. A. Adams, Sobolev Spaces, Academic Press Inc. New York, 1975.
2. K. Kesavan, Topics in Functional Analysis and Applications, John Wiley & Sons Ltd , 1989.
3. A. Kufner, Weighted Sobolev Spaces, John Wiley & Sons Ltd. New York,1985.
4. G. Leoni, A First Course in Sobolev Spaces, Americal Mathematical Society, 2009
5. R. S. Pathak, A course in Distributioin Theory and Applications, Narosa Publication House, 2001.

CS 321: Data Science

L	T	P	Credit
3	0	0	03

1. **Course Outcomes (COs)**

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

   CO1: understand types of data and various data science approaches

   CO2: apply various data pre-processing and manipulation techniques including various distributed analysis paradigm using hadoop and other tools and perform advance statistical analysis to solve complex and large dataset problems.

   CO3: analyse different large data like text data, stream data, graph data.

   CO4: interpret and evaluate various large datasets by applying Data Mining techniques like clustering, filtering, factorization.

   CO5: design the solution for the real life applications.

2. **Syllabus**

   - **INTRODUCTION** **(02 Hours)**

     Examples, Applications and results obtained using data science techniques, Overview of the data science process.

   - **MANAGING LARGE SCALE DATA** **(02 Hours)**

     Types of data and data representations, Acquire data (E.G., Crawling), Process and parse data, Data manipulation, Data wrangling and Data cleaning.

   - **PARADIGMS FOR DATA MANIPULATION, LARGE SCALE DATA SET** **(08 Hours)**

     MapReduce (Hadoop), Query large data sets in near real time with Pig and Hive, Moving from traditional warehouses to map reduce. Distributed databases, Distributed Hash Tables.

   - **TEXT ANALYSIS** **(10 Hours)**

     Data flattening, Filtering and chunking, Feature scaling, Dimensionality reduction, Nonlinear factorization, Shingling of Documents, Locality Sensitive Hashing for Documents, Distance Measures, LSH Families for Other Distance Measures, Collaborative filtering.

   - **MINING DATA STREAM** **(08 Hours)**

     Sampling data in a stream, Filtering streams, Counting distinct elements in a stream, Moments, Windows, Clustering for streams.

   - **ADVANCED DATA ANALYSIS** **(12 Hours)**

     Graph visualization, Data summaries, Hypothesis testing, ML model-checking and comparison, Link analysis, Mining of graph, Frequent item sets analysis, High dimensional clustering, Hierarchical clustering, Recommendation systems.

   Total Lecture Hours: 42

3. **Books Recommended**

1. Tom White, Hadoop: The Definitive Guide, 4^{th} Edition, O'Reilly Media, 2015, ISBN: 9781491901687.
2. Anand Rajaraman and Jeffrey David Ullman, Mining of Massive Datasets, 2^{nd} Edition, Cambridge University Press, 2014, ISBN: 9781107077232.
3. Andrew Bruce and Peter Bruce, Practical Statistics for Data Scientists, 1^{st} Edition, O'Reilly Publishing House, 2017.
4. J. Joel Grus, Data Science from Scratch, 1^{st} Editiion, O'Reilly Media, 2015. ISBN: 9781491901410.
5. Montgomery, C. Douglas, and George C. Runger, Applied Statistics and Probability for Engineers, John Wiley & Sons, 7^{th} Edition, 2018. ISBN: 9781119400363.

CS 423: Block Chain Technology

L	T	P	Credit
3	0	0	03

1. Course Outcomes (COs)

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

CO1: understand the need, functions and challenges of blockchain technology.

CO2: deploy smart contracts for given use cases.

CO3: analyse blockchain based system structure and security offered therein.

CO4: asses functions, benefits and limitations of various blockchain platforms.

CO5: design and develop solution using blockchain technology in various application domains.

2. Syllabus

- **INTRODUCTION (04 Hours)**

  Introduction to Blockchain Technology, Concept of Blocks, Transactions, Distributed Consensus, the Chain and the Longest Chain, Cryptocurrency, Blockchain 2.0, Permissioned Model of Blockchain, Permission less Blockchain.

- **DECENTRALIZATION USING BLOCKCHAIN (06 Hours)**

  Methods of Decentralization, Disintermediation, Contest-Driven Decentralization, Routes to Decentralization, the Decentralization Framework Example, Blockchain and Full Ecosystem Decentralization, Storage, Communication, Computing Power and Decentralization, Smart Contracts, Decentralized Autonomous Organizations, Decentralized Applications (DApps), Requirements and Operations of DApps, DApps Examples, Platforms for Decentralizations.

- **CRYPTO PRIMITIVES FOR BLOCKCHAIN (04 Hours)**

  Symmetric and Public Key Cryptography, Cryptographic Hard Problems, Key Generation, Secure Hash Algorithms, Hash Pointers, Digital Signatures, Merkle Trees, Patricia trees, Distributed Hash Tables.

- **BITCOINS AND CRYPTOCURRENCY (06 Hours)**

  Introduction, Digital Keys and Addresses, Private and Public Keys in Bitcoins, Base58Check Encoding, Vanity Addresses, Multi Signature Addresses, Transaction Lifecycle, Data Structure for Transaction, Types of Transactions, Transaction Verification, The Structure of Block in Blockchain, Mining, Proof of Work, Bitcoin Network and Payments, Bitcoin Clients and APIs, Wallets, Alternative Coins, Proof of Stake, Proof of Storage, Various Stake Types, Difficulty Adjustment and Retargeting Algorithms, Bitcoin Limitations.

- **SMART CONTRACTS (02 Hours)**

  Smart Contract Templates, Oracle, Smart Oracle, Deploying Smart Contract on Blockchain.

- **PERMISSIONED BLOCKCHAIN (05 Hours)**

  Models and Use-cases, Design Issues, Consensus, Paxos, RAFT Consensus, Byzantine General Problem, Practical Byzantine Fault Tolerance.

- **DEVELOPMENT TOOLS AND FRAMEWORKS (05 Hours)**

  Solidity Compilers, IDEs, Ganache, Metamask, Truffle, Contract Development and

Deployment, Solidity Language, Types, Value Types, Literals, Enums, Function Types, Reference Types, Global Variables, Control Structures, Layout of Solidity Source Code File.

- **HYPERLEDGER** **(05 Hours)**

  The Reference Architecture, Requirements and Design Goals of Hyperledger Fabric, The Modular Approach, Privacy and Confidentiality, Scalability, Deterministic Transactions, Identity, Auditability, Interoperability, Portability, Membership Services in Fabric, Blockchain Services, Consensus Services, Distributed Ledger, Sawtooth Lake, Corda.

- **BLCOKCHAIN USE-CASES AND CHALLENGES** **(05 Hours)**

  Finances, Government, Supply Chain, Security, Internet of Things, Scalability and Challenges, Network Plane, Consensus Plane, Storage Plane, View Plane, Block Size Increase, Block Interval Reduction, Invertible Bloom Lookup Tables, Private Chains, Sidechains, Privacy Issues, Indistinguishability Obfuscation, Homomorphic Encryption, Zero Knowledge Proofs, State Channels, Secure Multiparty Computation, Confidential Transactions.

Total Lecture Hours: 42

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3. Books Recommended

1. Imran Bashir, Mastering Blockchain, 2^{nd} Edition, Packt publishing, Mumbai, 2018.
2. Andreas Antonopoulos, Mastering Bitcoin: Unlocking Digital Cryptocurrencies, 2^{nd} Edition, O'Reilly, 2014.
3. Melanie Swan, "Blockchain Blueprint for a New Economy", 1^{st} Edition, O'Reilly Media, 2015.
4. Don and Alex Tapscott, "Blockchain Revolution", 1^{st} Edition, Penguin Books Ltd, 2018.
5. Alan T. Norman, "Blockchain Technology Explained", 1^{st} Edition, CreateSpace Independent Publishing Platform, 2017.

MA 402: Functional Analysis

L	T	P	Credit
3	1	0	04

1. Course Outcomes (COs)

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

CO1: demonstrate the concept of normed linear spaces

CO2: explain bounded linear map, their properties and applications

CO3: prove the theorems related to Hilbert space

CO4: discuss the concept of dual spaces and corresponding operator theory

CO5: prove spectral theorem for different operators

2. Syllabus

- **FUNDAMENTALS OF NORMED LINEAR SPACE** **(06 Hours)**

  Normed Linear Spaces, Finite dimensional spaces, Riesz lemma.

- **BOUNDED LINEAR MAPS ON NORMED LINEAR SPACES** **(10 Hours)**

  Definition and examples, linear maps on finite dimensional spaces, operator norm, Banach Spaces, HahnBanach theorems and its applications, Open mapping and Closed Graph theorems, Uniform Boundedness Principle.

- **HILBERT SPACES** **(07 Hours)**

  Inner product spaces, orthonormal sets, Gram-Schmidt orthogonalization, Bessel's inequality, orhtonormal basis, Separable Hilbert spaces, projection and Riesz representation theorem, Divergence of Fourier series.

- **DUAL SPACES AND ADJOINT OF AN OPERATOR** **(06 Hours)**

  Duals of classical spaces, weak and weak* convergence, BanachAlaoglu theorem, Adjoint of an operator.

- **BOUNDED OPERATORS ON HILBERT SPACE** **(07 Hours)**

  Adjoint operator, normal, unitary, self adjoint operator, compact operator, eigen value, eigen vectors, Banach algebras.

- **SPECTRAL THEOREM** **(06 Hours)**

  Spectral theorem for compact self adjoint operators, spectral theorem for bounded self adjoint operators, and unitary operators.

Total Lecture Hours: 42

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3. Books Recommended

1. J. B. Conway, A Course in Functional Analysis, 2^{nd} Edition, Springer-Verlag, New York, 1990.
2. E. Kreyszig, Introductory Functional Analysis with Applications, 1^{st} edition, John Wiley & Sons, New York, 1989.
3. B. V. Limaye, Functional Analysis, 3^{rd} Revised Edition, New Age International Private Limited, 2014.

4. G. F. Simmons,Introduction to Topology and Modern Analysis, 1^{st} Edition McGraw-Hill Education, New York, 2017.
5. W. Rudin, Functional Analysis, 2^{nd} Edition, McGraw-Hill, New York, 1991.

MA 404: Higher Transcendental Functions

L	T	P	Credit
3	1	0	04

1. Course Outcomes (COs)

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

CO1: explain the fundamentals of higher transcendental functions

CO2: demonstrate the infinite products and their convergence with applications

CO3: analyze with the solution of hypergeometric function and their properties

CO4: develop the generating relations of different functions and polynomials

CO5: explain the concept of q-series with applications

2. Syllabus

- **INFINITE PRODUCT** **(08 Hours)**

  Definition of infinite product, convergence conditions, The associated series of logarithm Absolute convergence, Uniform convergence, The Euler or Mascheroni constant, Gamma function, Psi function, Euler product of gamma function, , Euler integral for gamma function, Beta function, Legendre duplication formula, Gauss' multiplication theorem.

- **HYPERGEOMETRIC FUNCTION** **(10 Hours)**

  Introduction, Hypergeometric function and generalized hypergeometric function, Integral representation, Differential properties of hypergeometric function, Confluent hypergeometric function and its integral representation.

- **THEORY OF GENERATING FUNCTION** **(08 Hours)**

  Introduction to generating functions, Generating functions of the family of the form $G(2xt - t^2)$, $e^t\phi(t)$ etc., with suitable examples (Bessel function, Legendre Polynomial, Hermite polynomial and Laguerre Polynomial), Boas and Buck type, Pure recurrence relations, Appell, Sheffer and 0-type characterizations of polynomial sets.

- **ORTHOGONAL POLYNOMIALS** **(08 Hours)**

  Introduction, The moment functional, and orthogonality, Existence of OPS, The fundamental recurrence formula, Zeros, Gauss quadrature, Kernel polynomials, Symmetric moment functional, Certain related recurrence relations, Orthogonality of Lagguere, Legendre, Hermite and Bessel Functions.

- **BASIC HYPERGEOMETRIC SERIES AND THEIR APPLICATIONS** **(08 Hours)**

  Introduction to basic Hyper geometric series, q-analogue of orthogonal polynomials, q-Gamma and q-Beta functions.

Total Lecture Hours: 42

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3. Books Recommended

1. G. E. Andrews, R. Askey and R. Roy, Special Functions, Cambridge Univ. Press, 1990.

2. W. N. Bailey, Generalized Hypergeometric Series, Stechert-Hafner Service Agency, New York and London, 1964.
3. E. T. Copson, Introduction to the Theory of Functions of a Complex Variable, The English Language Book Society, London, 1978.
4. T. S. Chihara, Introduction to Orthogonal Polynomials, Gordon and Breach Science Publishers Inc., New York, 1978.
5. E. D. Rainville, Special Functions, The Macmillan Company, New York, 1960.

MA 406: Partial Differential Equations

L	T	P	Credit
3	2	0	05

1. Course Outcomes (COs)

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

CO1: formulate the physical problem into partial differential equations.

CO2: solve first order linear and nonlinear equations

CO3: analyze the existence and uniqueness of solutions

CO4: classify second order equations into three types of PDEs: parabolic, hyperbolic and elliptic

CO5: discuss the formulation and solution of Laplace, wave and heat equation

2. Syllabus

- **INTRODUCTION TO PDE** **(06 Hours)**

  Order and degree of PDE, Types of PDE, Solution of simple PDE, Formation of PDE, Initial and Boundary conditions, Types of solution.

- **FIRST ORDER PDE** **(12 Hours)**

  The method of characteristics, The existence and uniqueness theorem, Cauchy problem, Lagrange's method, Compatible system of first order PDEs , Charpit's method, Jacobi method, Geometrical interpretation and applications of first order PDE.

- **SECOND AND HIGHER ORDER PDE** **(12 Hours)**

  Homogeneous and non-homogeneous PDE of order two and higher with constant coefficient. PDEs reducible to equations with constant coefficients.
  PDEs of order two with variable coefficients. Classification of PDE, Reduction to canonical or Normal form, Riemann Method, Monges's method.

- **LAPLACE EQUATION** **(04 Hours)**

  Formulation and physical interpretation, Derivation of fundamental solution, Uniqueness of solution, Dirichlet's principle, Method of separation of variables.

- **HEAT EQUATION** **(04 Hours)**

  Formulation and physical interpretation, Derivation of fundamental solution, Uniqueness of solution, Method of separation of variables.

- **WAVE EQUATIONS** **(04 Hours)**

  Formulation and physical interpretation, D'Alembert's solution, Uniqueness of solution, Method of separation of variables.

Total Lecture Hours: 42

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3. Books Recommended

1. M. P. Coleman, An Introduction to Partial Differential Equations with MATLAB, 2^{nd} Edition, CRC Press, 2013.
2. P. Prasad and R. Ravindran, Partial Differential Equations, New Age International Publishers, 2009.

3. Ian N. Sneddon, Elements of Partial Differential Equations, McGraw-Hill, 1957.
4. L. C. Evans, Partial Differential Equations, 2^{nd} Edition, American Mathematical Society, 2010.
5. T. Amarnath, An Elementary Course in Partial Differential Equations, 2^{nd} Edition, Narosa Publications, 2003.

MA 408: Calculus of Variations & Integral Equations

L	T	P	Credit
3	2	0	05

1. Course Outcomes (COs)

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

CO1: formulate variational problems and analyse them to deduce key properties of system behaviour.

CO2: explain the extremals of the BVP's through variational approach.

CO3: interpret the difference between Volterra and Fredholm integral equations.

CO4: solve IVP's and BVP's through integral equation approach.

CO5: solve integral equations through different analytical and numerical approach.

2. Syllabus

- **INTRODUCTION TO CALCULUS OF VARIATIONS (08 Hours)**

  Maxima and minima, Natural boundary conditions and transition conditions, Variational notation, constraints and Lagrange multipliers, Hamilton's principle, Lagrange's equations, Constraints in dynamical systems.

- **VARIATIONAL PROBLEMS (08 Hours)**

  The Euler-Lagrange Equation, Minimum Surface of revolution, Geodesic, The Brachistochrone, Several dependent variables, Parametric representation, Undetermined end points,Brachistochrone from a given curve to a fixed point.

- **ISOPERIMETRIC PROBLEMS (08 Hours)**

  The simple isoperimetric problem, Direct Extension, Problem of the maximum enclosed area, Moving boundaries and transversality condition, Essential and Suppressible boundary conditions, Variational problems for deformable bodies, useful transformations, Rayleigh-Ritz method, Kantorovich method.

- **INTEGRAL EQUATIONS (10 Hours)**

  Linear Integral Equations, Eigen values and Eigen functions, The Green's function, Linear equations in cause and effect, The influence function, Fredholm equations with separable kernels,Hilbert Schmidt theory, Volterra Integral equation, Solution by Resolvent kernel, Method of successive approximations, The Neumann series, Fredholm theory, Singular Integral Equations.

- **APPROXIMATION OF INTEGRAL EQUATIONS (08 Hours)**

  Iterative approximations to characteristic functions, Approximations of Fredholm equations by sets of algebraic equations, Approximate method of undermined coefficients, the method of collocation, the method of weighting functions, the method of least squares, Approximation of the kernel.

Total Lecture Hours: 42

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3. Books Recommended

1. F. B. Hilderbrand, Methods of Applied Mathematics, 2^{nd} Edition, Prentice Hall Inc., 1992.

2. R. P. Kanwal, Generalized Functions: Theory and Technique, 2^{nd} Edition, Academic Press, New York, 1998.
3. A. M. Wazwaz, A First Course in Integral Equations, 2^{nd} Edition, World Scientific Publishing Company, 2015.
4. M. R. Seikh and P. K. Nayak, Integral Equations and Calculus of Variations, 1^{st} Edition, Narosa Publishing House, 2019.
5. Ian N. Sneddon, Mixed Boundary Value Problems in Potential Theory, 1^{st} Edition, North Holland, 1966.

MA 422: Multiobjective Optimization

L	T	P	Credit
3	0	0	03

1. Course Outcomes (COs)

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

CO1: classify simple (single) objective and multi-objective optimization problems

CO2: formulate real world problems in multiobjective optimization.

CO3: solve multiobjective optimization problems by classical approaches

CO4: solve multiobjective optimization problems by Evolutionary approaches

CO5: explain the importance of multiobjective optimization in real life

2. Syllabus

- **ELEMENTS OF MULTIOBJECTIVE DECISION MAKING PROBLEM (06 Hours)**

  Introduction, Multiobjective decisions making process, Judgment and the value system, Decision making unit and the decision makers, Objectives and attributes, Decision Situation, Symbolic representation of the multiobjective Decisions problem, Scale of measurement, Elementary decision analysis, types of decision problems, Choosing a decision rule, decision tree.

- **MULTIOBJECTIVE OPTIMIZATION (06 Hours)**

  Definition of Multiobjective optimization, Difference between Single and Multiobjective optimization, Formation of multiobjective optimization problem, Pareto-optimality, Efficiency and dominance, Compromise Solution.

- **METHODS TO SOLVE MULTIOBJECTIVE OPTIMIZATION PROBLEMS (14 Hours)**

  Graphical method, Multiobjective simplex method, Goal programming method, ε constraint method, weighted sum method, Fuzzy programming approach with linear, exponential and hyperbolic membership function.

- **EVOLUTIONARY APPROACHES (08 Hours)**

  Introduction to Evolutionary approaches, Difficulties with classical optimization algorithm, Genetic Algorithm for the solution of multiobjective optimization problem.

- **SELECTED MULTIOBJECTIVE OPTIMIZATION PROBLEMS (08 Hours)**

  Multiobjective transportation problems, Multiobjective solid transportation problems, Multiobjective assignment problems.

Total Lecture Hours: 42

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3. Books Recommended

1. C. Vira, Y. H. Yacov, Multiobjective Decision Making Theory and Methodology, North Holand, Elsevier Science Publishing Company Newyork, 2008.

2. K. Deb, Multiobjective Optimization using Evolutionary Algorithms, John Willey & Sons, 2003.
3. S. N. Sivanandam, S. N. Deepa, Introduction to Genetic Algorithms, Springer-Verlag Berlin Heidelberg, 2008.
4. D. T. Luc, Multiobjective Linear Programming an Introduction, Springer International Publishing Switzerland, 2016
5. J. Lu, G. Zhang, D. Ruan and F. Wu, Multiobjective Group Decision Making Methods, Software and Applications With Fuzzy Set Techniques, Imperial College Press London, 2007.

CS 324: Natural Language Processing

L	T	P	Credit
3	0	0	03

1. Course Outcomes (COs)

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

CO1: understand basics principles of natural language processing.

CO2: apply machine learning techniques for NLP based different tasks.

CO3: perform statically analysis and classification, recognition using NLP knowledge acquired.

CO4: evaluate the performance of machine translation solutions through statistical parameters.

CO5: design efficient solution for parser, translator and different applications based on NLP for day to day usage.

2. Syllabus

- **INTRODUCTION** **(04 Hours)**

  Human Languages, Language Models, Computational Linguistics , Ambiguity and Uncertainty in Language, Processing Paradigms; Phases in Natural Language Processing, Basic Terminology, Overview of Different Applications, Regular Expressions and Automata, Finite State Transducers and Morphology, Automata, Word Recognition, Lexicon, Morphology, Acquisition Models, Linguistics Resources, Introduction to Corpus, Elements in Balanced Corpus.

- **SYNTAX AND SYMANTICS** **(08 Hours)**

  Natural Language Grammars, Lexeme, Phonemes, Phrases and Idioms, Word Order, Tense, Probabilistic Models of Spelling, N-grams, Word Classes and Part of Speech Tagging using Maximum Entropy Models, Transformation Based Tagging (TBL), Context Free Grammars for English, Features and Unification, Lexicalized and Parsing, Treebanks, Language and Complexity, Representing Meaning, Semantic Analysis, Lexical Semantics, Word Sense Disambiguation.

- **PROBABILISTIC LANGUAGE MODELLING** **(08 Hours)**

  Statistical Inference, Hidden Markov Models, Probabilistic (weighted) Finite State Automata, Estimating the Probability of a Word, and Smoothing, Probabilistic Parsing, Generative Models of Language, Probabilistic Context Free Grammars, Probabilistic Parsing, Statistical Alignment and Machine Translation, Clustering, Text Categorization, Viterbi Algorithm for Finding Most Likely HMM Path.

- **PRAGMATICS** **(06 Hours)**

  Discourse, Dialogue and Conversational Agents, Natural Language Generation, Machine Translation, Dictionary Based Approaches, Reference Resolution, Algorithm for Pronoun Resolution, Text Coherence, Discourse Structure, Applications of NLP- Spell-Checking.

- **MACHINE TRANSLATION** **(08 Hours)**

  Probabilistic Models for Translating One to Another Language, Alignment, Translation, Language Generation, Expectation Maximization, Automatically Discovering Verb Subcategorization, Language Modelling Integrated into Social Network Analysis, Automatic Summarization, Question-Answering, Interactive Dialogue Systems.

- **ADVANCED TOPICS** **(08 Hours)**

  Summarization, Information Retrieval, Vector Space Model, Term Weighting, Homonymy, Polysemy, Synonymy, Improving User Queries, Document Classification, Sentence Segmentation, and Other Language Tasks, Automatically-Trained Email Spam Filter, Automatically Determining the Language, Speech Recognition.

Total Lecture Hours: 42

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3. Books Recommended

1. Daniel Jurafsky and James H. Martin, "Speech and Language Processing", 2^{nd} Edition, Pearson Education, 2009.
2. James Allen, "Natural Language Understanding", 2^{nd} Edition, Addison-Wesley, 1994.
3. Christopher D. Manning and Hinrich Schutze, "Foundations of Statistical Natural Language Processing", MIT Press, 1999.
4. Steven Bird, "Natural Language Processing with Python", 1^{st} Edition, O'Reilly Publication, 2009.
5. Jacob Perkins, "Python Text Processing with NLTK 2.0 Cookbook", Packt Publishing, 2010.

Further Reading

1. A. Bharati, R. Sangal and V. Chaitanya, "Natural Language Processing: A Paninian Perspective", PHI, 2000.
2. T. Siddiqui and U. S. Tiwary, "Natural Language Processing and Information Retrieval", Oxford University Press, 2008.

Five years Integrated M. Sc. (Mathematics)
Teaching Scheme

Semester – IX

Sr. No.	Subject	Code	Teaching Scheme Hours Per Week			Credits	Examination Scheme				Total Marks
			L	T	P		Theory	Tutorial	Practical		
									Cont. Eval.	End Sem	
1	Measure Theory & Integration	MA 501	3	1	0	04	100	25	0	0	125
2	Probability & Statistics II	MA 503	3	1	0	04	100	25	0	0	125
3	Mathematical Modelling & Simulation	MA 505	3	1	2	05	100	25	50	0	175
4	Academic Writing	HU 501	3	0	0	03	100	00	0	0	100
5	Dissertation Preliminaries	MA 507	0	0	8	04	0	0	80	120	200
6	***Core Elective***		3	1	0	04	100	25	0		125
	Advanced Operations Research	MA 521									
	Fluid Dynamics in Porous Media	MA 523									
	Advanced Numerical Analysis	MA 525									
	Linear Operators and Approximation Theory	MA 527									
			15	4	10	24					
Total Contact Hours per Week = 29				**Total Credits = 24**					**Total Marks = 850**		

Semester – X

Sr. No.	Subject	Code	Teaching Scheme Hours Per Week			Credits	Examination Scheme				Total Marks
			L	T	P		Theory	Tutorial	Practical		
									Cont. Eval.	End Sem.	
1	Dissertation	MA 502	0	0	24	12	0	0	160	240	400
Total Contact Hours per Week = 24				**Total Credits = 12**					**Total Marks = 600**		

MA 501: Measure Theory & Integration

L	T	P	Credit
3	1	0	04

1. Course Outcomes (COs)

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

CO1: explain the fundamentals of measure theory

CO2: explain the Lebesgue measure with their properties and characterisation

CO3: apply the concept of measure theory in integration

CO4: explain the theorems related to measure theory and integration

CO5: utilize the concept of integration in different spaces

2. Syllabus

- **INTRODUCTION** **(09 Hours)**

  Introduction, Extended real numbers, Algebra and sigma algebra of subsets of a set, Sigma algebra generated by a Class, Monotone Class, Set functions, The length function and its properties. Countably additive set functions on intervals, Uniqueness problem for measure. Extension of measure, Outer measure and its properties, A Measurable sets.

- **LEBESGUE MEASURE** **(11 Hours)**

  Lebesgue measure and its properties, Characterization of Lebesgue measurable sets, Measurable functions, Properties of measurable functions, Measurable functions on measure spaces, Integral of non-negative simple measurable functions, Properties of non-negative simple measurable functions, Monotone convergence theorem and Fatou's Lemma.

- **INTEGRATION OF FUNCTION (REAL VARIABLE)** **(09 Hours)**

  Properties of integrable functions and dominated convergence theorem, Dominated convergence, Theorem and applications, Lebesgue integral and its Properties.

- **MEASURE AND INTEGRATION** **(09 Hours)**

  An introduction to product measure, Construction of product measures, Computation of product measure, Integration on product spaces, Fubini's theorems, Lebesgue measure and integral in Euclidean space, Properties of Lebesgue measure in Euclidean space, Lebesgue integral in Euclidean space.

- **THE RIEMANN-STEILTJES INTEGRAL** **(04 Hours)**

  Definitions and existence of the integral, Conditions of integrability, The integral as a limit of sum, Some important theorems.

Total Lecture Hours: 42

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3. Books Recommended

1. I. K. Rana, An Introduction to Measure and Integration, Narosa Publishing House, New Delhi, 2007.
2. G. De Barra, Measure Theory and Integration, New Age International Publisher, New Delhi, 2017.

3. P. K. Jain, Measure Theory and Integration, New Age International Publisher, New Delhi, 2019.
4. J. L. Doob, Measure Theory, Springer, New York, 2010.
5. S. C. Malik and S. Arora, Mathematical Analysis, 2^{nd} Edition, New Age International (P) Limited, New Delhi, 1994.

MA 503: Probability & Statistics-II

L	T	P	Credit
3	1	0	04

1. Course Outcomes (COs)

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

CO1: analyze the differences among group variance in a sample using ANOVA

CO2: elaborate nonparametric statistics and analysis of categorical data

CO3: apply statistical techniques for quality control

CO4: discuss various stochastic processes and their applications

CO5: apply the knowledge of Markov Chain in industrial requirements

2. Syllabus

- **DESIGN OF EXPERIMENTS** **(09 Hours)**

  The Design of an Experiment, The Completely Randomized Design-A one –way classification, ANOVA for a completely Randomized design, random effects model, The Randomized Block Design- a Two-way classification, ANOVA for a Randomized Block Design. Factorial experiments, two factor factorial experiments, general factorial experiments, $2k$ factorial experiments.

- **NON-PARAMETRIC STATISTICS** **(05 Hours)**

  Wilcoxon Rank sum list: Independent random samples. The sign test for a paired experiment. A comparison of statistical tests, Wilcoxon signed- rank test for a paired experiment, The Kruskal-Wallis H-test for Completely Randomized Design.

- **ANALYSIS OF CATEGORICAL DATA** **(05 Hours)**

  Chi-square statistic, The goodness of fit test, The chi-square test of significance, Contingency tables: A two way classification, ways of comparing proportions, Measures of associations.

- **STATISTICAL QUALITY CONTROL** **(05 Hours)**

  Objectives of Quality Control, Causes of Variation in quality, Techniques of SQC, Control charts for Variables (X-charts & R-chart S-chart & σ -chart), 6σ concept, Control charts for Attributes (p-charts, np-chats, C-charts),Statistical process control, Terms used in sampling Inspection plans.

- **STOCHASTIC PROCESS** **(05 Hours)**

  Description & Specification of Stochastic Process, Stationary Processes, Martingales. Poisson Process, Inter-arrival & waiting time distributions, Non-homogeneous Poisson Process, Conditional Poisson process.

- **MARKOV CHAINS AND RANDOM WALKS** **(08 Hours)**

  Definitions, Chapman-Kolmogorov Equations & classification of states, Applications of Markov chains, Time reversible Markov chains . Continuous time Markov chains, Birth & Death Processes, Kolmogorov differential equations, Randomization.Duality in random walks, Use of Martingales to analyze random walks.

- **MARKOV PROCESSES AND RENEWAL THEORY** **(05 Hours)**

  Brownian motion, Wiener process, differential equations for a wiener process, Kolmogorov equations Renewal process, renewal processes in continuous time, Renewal equation, stopping time.

Total Lecture Hours: 42

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3. Books Recommended

1. W. Mendenhall, R. J. Beaver and B. M. Beaver, Introduction to Probability & Statistics, 15^{th} Edition, Cengage Learning, 2020.
2. D. C. Montgomery, Design and Analysis of Experiments, 8^{th} Edition, John Wiley & Sons, 2012.
3. S. Ross, A First Course in Probability, 9^{th} Edition, Pearson Education India, 2013.
4. D. C. Montgomery and G. C. Runger, Applied Statistics and Probability for Engineers , 6^{th} Edition, Wiley, 2013
5. J. Medhi, Stochastic Processes, New Age International Private Limited, 2019.

MA 505: Mathematical Modelling & Simulation

L	T	P	Credit
3	1	2	05

1. Course Outcomes (COs)

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

CO1: explain the concept of mathematical modelling & simulation

CO2: formulate the real world problem into Mathematical form

CO3: analyze the mathematical model

CO4: apply simulation in analysis of the real world problems

CO5: develop a computer code for the simulation of a system

2. Syllabus

- **INTRODUCTION TO MATHEMATICAL MODELLING (10 Hours)**

  Introduction to mathematical modelling, Real world problems, Identification of parameters, Significant parameters, Importance of parameters, Reduction of an open problem to a closed form, Conversion of a real problem into a mathematical problem, Quest for a mathematical technique for solution, Importance of numerical techniques, Physical interpretation of solution, Types of mathematical models, Characteristics of mathematical models, Framework of mathematical models, Validation of mathematical model, Advantage and disadvantage of mathematical model.

- **MATHEMATICAL MODELS (12 Hours)**

  Models based on system of algebraic equations, ODE based simple modelling, Population dynamics modelling, Multi-compartmental modelling, Detection of diabetic model, Technological innovation model, Heat and mass transport Models, Heat conduction and diffusion Problems.

- **INTRODUCTION TO SIMULATION (10 Hours)**

  Introduction to simulation, Types of simulation, Simulation methodology, Random number generation, Monte-Carlo simulation, Simulation of continuous system, Discrete event simulation, Design of experiments, Validation.

- **SOME CASE STUDIES (10 Hours)**

  Simulation of queuing system, Simulation of inventory control, Simulation of forecasting, Simulation of maintenance problem, Simulation of network problems, Simulation of regression analysis, Simulation of linear programming problems.

Total Lecture Hours: 42

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3. Practicals

1. Radioactive decay and Newton's law of Colling Model with their simulation
2. Population dynamics model and their simulation
3. Single Compartment modelling and their simulation
4. Multi compartment modelling and their simulation

5. Technological innovation model and their simulation
6. Detection of Diabetic model and their simulation
7. Analytical solution of PDE with MATLAB and their simulation (Heat Equation)
8. Analytical solution of PDE with MATLAB and their simulation (Wave Equation)
9. Simulation for Forecasting and PERT Network
10. Operation research based Simple simulation problems

4. Books Recommended

1. J. N. Kapoor, Mathematical Modeling, New Age International(p) Limited, 2018.
2. B. Barnes and G. R. Fulford, Mathematical Modelling with Case Studies, Using Maple and MATLAB, 3^{rd} Edition, CRC press, 2015.
3. J. Caldwell, K. S. Ng Douglas and J. Caldwell, Mathematical Modeling: Case Studies and Projects (Texts in the Mathematical Sciences), Springer Netherlands, 2004.
4. N. Deo, System Simulation with Digital Computer, PHI New Delhi, 2006.
5. F. L. Severvance, System Modeling and Simulation: An Introduction, John Wiley, 2001.

HU 501: Academic Writing

L	T	P	Credit
3	0	0	03

1. Course Outcomes (COs)

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

CO1: show expertise in writing skills in English

CO2: demonstrate the skill of editing and producing error free documents

CO3: effectively translate their ideas into written articles

CO4: learn the process of advance writing skills required for research

CO5: explain their work through presentations

2. Syllabus

- **REVISING GRAMMAR** **(04 Hours)**

  Sentences, Tenses, Modals, Determiners, Conditionals.

- **THE WRITING PROCESS** **(08 Hours)**

  Understanding the Word order, Breaking up Long Sentences, Structuring Paragraphs and Sentences, Paragraph Writing, Summarising and Paraphrasing, Using Linking Words.

- **EDITING YOUR WORK** **(07 Hours)**

  Common Errors, Right Vocabulary, Avoiding Ambiguity, Removing Redundancy, and Avoiding Plagiarism.

- **WRITING FOR RESEARCH** **(05 Hours)**

  Note Making, Drafting the abstract, Writing literature review, Parts of a scientific paper, Writing longer essays, Types of essays.

- **PRESENTING YOUR RESEARCH** **(04 Hours)**

  Types of Presentation, Steps of Making a Good Presentation, Use of Visual Aids in Presentation.

Total Lecture Hours: 28

3. Books Recommended

1. G. Yule, Oxford Practice Grammar, Oxford University Press, 2008.
2. C. K. Cook, Line by Line How to Edit Your Own Writing, The Modern Language Association of America, 1985.
3. A. Wallwork, English for Writing Research Papers, Springer, 2011.
4. R. Murray and S. Moore, The Handbook of Academic Writing: A Fresh Approach, Open University Press, 2006.
5. S. Bailey, Academic Writing: A Practical Guide for International Students, 4^{th} Edition, Routledge, 2014.

MA 521: Advanced Operations Research

L	T	P	Credit
3	1	0	04

1. Course Outcomes (COs)

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

CO1: explain the importance of operations research in real life problems.

CO2: apply basic concepts of Mathematics to formulate and solve OR problems.

CO3: incorporate chance factor and calculate project completion time in PERT & CPM.

CO4: interpret multi-stage decision process through dynamic programming

CO5: solve NLPP using different methods.

2. Syllabus

- **INTRODUCTION** **(04 Hours)**

  Nature and scope of Operations Research, Convex sets and convex functions and their properties.

- **INVENTORY MODELS** **(07 Hours)**

  Inventory control -Deterministic including price breaks and Multi-item with constraints, Probabilistic (with and without lead time).

- **QUEUING THEORY** **(07 Hours)**

  Basic Structures of queuing models, Poisson queues –M/M/1, M/M/C for finite and infinite queue length, Non-Poisson queue -M/G/1, Machine Maintenance (steady state).

- **PERT AND CPM** **(07 Hours)**

  Introduction, Basic difference between PERT and CPM, Steps of PERT/CPM Techniques, PERT/CPM Network components and precedence relationships, Critical path analysis, Probability in PERT analysis, Project Time-Cost, Trade-off, Updating of the project, Resource allocation-resource smoothing and resource leveling.

- **DYNAMIC PROGRAMMING** **(06 Hours)**

  Introduction, Nature of dynamic programming, Deterministic processes, Non-Sequential discrete optimization, Allocation problems, Assortment problems, Sequential discrete optimization, Long-term planning problem, Multi-stage decision process, Application of Dynamic Programming in production scheduling and routing problems.

- **NONLINEAR PROGRAMMING** **(06 Hours)**

  Quadratic Programming, Duality theory, Search techniques - one variable (Fibonacci, Golden Section method) and several variables (Conjugate Gradient, Newton's method).

- **GEOMETRIC PROGRAMMING** **(05 Hours)**

  Introduction, Posynomial, Arithmatic-Geometric inequality, Geometric programming (both unconstrained and constrained).

Total Lecture Hours: 42

3. **Books Recommended**

1. F. S. Hiller and G. J. Lieberman, Introduction to Operations Research, 8^{th} Edition, Tata McGraw-Hill, New Delhi, 2009.
2. K. Swarup, P. K. Gupta and M. Mohan, Operations Research, 19^{th} Edition, S. Chand & Sons, New Delhi, 2017.
3. H. A. Taha, Operations Research: An Introduction, 9^{th} Edition, Pearson, New Delhi, 2014.
4. J. K. Sharma, Operations Research: Theory and Applications, 6^{th} Edition, Trinity Press, New Delhi, 2017.
5. M. S. Bazarra, H. D. Sherali and C. M. Shetty, Nonlinear Programming: Theory and Algorithms, 3^{rd} Edition, John Wiley & Sons, New Jersy, 2016.

MA 523: Fluid Dynamics in Porous Media

L	T	P	Credit
3	1	0	04

1. Course Outcomes (COs)

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

CO1: explain the fundamental properties of porous media

CO2: elaborate filtration theory

CO3: elaborate the permeabilty and hydraulic conductivity

CO4: implement appropriate method in ground water problem.

CO5: use continuity equation for groudwater flow.

2. Syllabus

- **FUNDAMENTAL PROPERTIES OF POROUS MEDIA (11 Hours)**

  Porosity: general aspects and definition, Determination of porosity, Compressibility of porous media, Classification of porosity, Capillary properties, Saturation, Wettability, Classification of reservoir rocks based on wettability, Measurement of wettability, Contact angle measurement, Amott method, Capillary pressure, Definition, Measurement of capillary pressure in a porous medium, Method of centrifuge, Mercury injection (Purcell method), The Leverett function, Pore size distribution, Vertical equilibrium, Permeability, Darcy's law , Definition and units of permeability , Measurements of permeability, Klinkenberg effect , Analogies between the laws of Darcy, Ohm and Fourier, Filtration velocity , Quadratic equation of filtration, Relative permeabilities, Definition of relative permeability, Definitions of end-point saturations, Relative permeability measurements, The HASSLER method, PENN-STATE-method, Welge-method, Saturation distribution and relative permeability

- **INTRODUCTION TO GROUND WATER (06 Hours)**

  Introduction, Types of springs, Infiltration gallery, Karsez, distribution of water on earth, Groundwater resources of India, Geological formations, Properties of aquifers: void ratio, Specific retention, Specific yield, Methods of determining specific yield, Pumping method, The porosity, Specific yield and specific retention of different formations

- **PERMEABILITY AND HYDRAULIC CONDUCTIVITY IN SOIL FORMATION (09 Hours)**

  Permeability and hydraulic conductivity , Hydraulic conductivity or permeability coefficient, The effect of porosity, Pore space geometry, Submergence, Tortuosity of soil pores, Entrapped air, Measurement of hydraulic conductivity, Constant head method, Variable head method, Field methods, Below the water table field methods, Above the water field method, Intrinsic permeability, Apparent specific yield, Coefficient of storage, Specific storage, Hydraulic resistance, Leakage factor, Distribution of subsurface water, Zone of aeration, Soil water zone, Intermediate zone, Capillary fringe, Important features of the capillary fringe zone, Zone of saturation, Soil moisture, Groundwater flow potential, Measurement of groundwater, Conjunctive use of groundwater.

- **CONTINUITY EQUATIONS FOR GROUNDWATER FLOW (16 Hours)**

Introduction, Three dimensional continuity equation for groundwater flow, Continuity equation for homogeneous and isotropic formation(Medium), Confined and unconfined aquifer, General continuity equation in Cartesian coordinates, General continuity equation in polar coordinates, Continuity equation for confined aquifer with leakage from top and bottom, Dupuit-Forchheimer theory for unconfined aquifer with recharge, Flow through an unconfined aquifer.

Total Lecture Hours: 42

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3. Books Recommended

1. J. Bear, Dynamics of Fluids in Porous Media, Dover Pulication, New York, 1988.
2. V. C. Agarwal, Groundwater Hydrology, PHI Learning Private Limited, New Delhi, 2012.
3. F. Charlton, Textbook of Fluid Dynamics, CBS Publishers, 1985.
4. J. Bear, Hydraulics of Groundwater, Dover Publications, 2007.
5. G. K. Bachelor, An Introduction to Fluid dynamics, Cambridge University Press, 2000.

MA 525: Advanced Numerical Analysis

L	T	P	Credit
3	1	0	04

1. Course Outcomes (COs)

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

CO1: solve the initial value problems using multistep methods.

CO2: develop a finite difference scheme for ODEs and PDEs

CO3: analyze the stability and convergence of difference schemes

CO4: determine the solution for ODEs and PDEs using finite difference methods

CO5: assess suitability and effectiveness of finite difference schemes

2. Syllabus

- **REVIEW ON THE SYSTEM OF LINEAR EQUATIONS (04 Hours)**

  Condition number and ill conditioned systems. Matrix and vector norms. Error bounds, tridiagonal and pentagonal system of equations.

- **INITIAL VALUE PROBLEMS IN ODES (08 Hours)**

  Review single step methods, explicit multistep methods, implicit multistep methods, Predictor and corrector methods, Stability and convergence analysis.

- **FINITE DIFFERENCE METHODS FOR BVPS IN ODES (08 Hours)**

  Review on numerical approximation to derivatives, Approximation of boundary conditions of different kind, Solution of linear and non-linear boundary value problems, Convergence of difference schemes.

- **FINITE DIFFERENCE METHODS FOR HYPERBOLIC PDES (08 Hours)**

  Difference schemes in one space dimension with constant coefficient,Convergence and consistency, Stability, The Lax-Richtmyer theorem, The CFL condition, Analysis of difference schemes: Fourier and Von Neumann analysis, Stability condition, Order of accuracy of difference schemes.

- **FINITE DIFFERENCE METHODS FOR PARABOLIC PDES (07 Hours)**

  Explicit and implicit Difference schemes in one, two and three space dimensions. Two level and multilevel schemes, Solution of convection-diffusion equation. Consistency, stability and convergence of difference scheme.

- **FINITE DIFFERENCE METHODS FOR ELLIPTIC PDES (07 Hours)**

  Approximation to ∇^2 and ∇^4. Five point and nine point approximation for Laplace and Poisson equations, Dirichlet problem, ADI method, Neumann Problem, Mixed boundary value problems.

Total Lecture Hours: 42

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3. Books Recommended

1. G. D. Smith, Numerical Solutions of Partial Differential Equations, 3^{rd} Edition, Clarendon Press, Oxford, 1985.

2. M. K. Jain, Numerical Solution of Differential Equations, New Age Publication, New Delhi, 2008.
3. R. Mitchell and S. D. F. Griffiths, The Finite Difference Methods in Partial Differential Equations, Wiley and Sons, NY, 1980.
4. J. C. Strikwerda, Finite Difference Schemes for Partial Differential Equations, 2^{nd} Edition, SIAM, 2004.
5. R. J. LeVeque, Finite Difference Methods for Ordinary and Partial Differential Equations: Steady State and Time Dependent Problems, SIAM, 2007

MA 527: Linear Operators and Approximation Theory

L	T	P	Credit
3	1	0	04

1. Course Outcomes (COs)

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

CO1: demonstrate the basics of approximation theory and basic problems

CO2: evaluate the order of approximation of functions by means of polynomials and polynomial operators

CO3: apply notions and theorems concerning trigonometric and polynomial approximation

CO4: demonstrate the concepts of linear continuous operators.

CO5: construct the Fourier series approximation of periodic function.

2. Syllabus

- **LINEAR FUNCTIONALS AND OPERATORS (10 Hours)**

  Linear positive functional, Linear positive operators, Approximation of functions by algebraic polynomials, Approximation of functions by trigonometric polynomials, Conditions for convergence of a sequence of linear positive operators.

- **ORDER OF APPROXIMATION OF FUNCTIONS BY POLYNOMIALS (10 Hours)**

  Polynomials which deviate the least from functions, Modulus of continuity, General methods of summation of Fourier series, Order of approximation of functions by means of trigonometric polynomials, Order of approximation of functions by means of algebraic polynomials. Order of growth of derivatives of polynomials and trigonometric polynomials.

- **ORDER OF APPROXIMATION OF FUNCTIONS BY MEANS OF LINEAR POSITIVE POLYNOMIAL OPERATORS (10 Hours)**

  Order of approximation of functions by means of linear positive functional, Order of approximation of functions by means of Fejer operators, Order of approximation of functions by means of Bernstein polynomials, Order of approximation of functions by means of linear positive polynomial operators.

- **LINEAR CONTINUOUS POLYNOMIAL OPERATORS (05 Hours)**

  Linear continuous operators, Auxiliary relations, Non-uniformly convergent sequence of linear continuous polynomial operators, Valle e-Poussin operators.

- **FOURIER SERIES (07 Hours)**

  The Fourier series, Uniform convergence of Fourier series, Mean convergence of Fourier series, Local convergence, Estimate of the deviation of partial sums of a Fourier series, Example of a continuous function not expandable in a Fourier series, Convergence of sequence of linear positive polynomial operators, General methods of summation of Fourier series

Total Lecture Hours: 42

3. Books Recommended

1. E. W. Cheney, Introduction to Approximation Theory, 2^{nd} Revised Edition, AMS Chelsea Publishing Co., 1999.
2. P. P. Korovkin, Linear Operators and Approximation Theory, Hindustan Publishing Corporation (India), 2017.
3. H. M. Mhaskar, and D. V. Pai, Fundamentals of Approximation Theory, Narosa Publishing House, 2000.
4. I. P. Natanson, Constructive Function Theory Volume-I, Fredrick Ungar Publishing Co., 1964
5. A. F. Timan, Theory of Approximation of Functions of a Real Variable, Dover Publication Inc., 1994.