Four Year Under Graduate Programme (FYUP) U.G. Fourth Year (U.G. with Honours)

B.Sc. (Mathematics) Fourth Year - Seventh Semester

Entry requirement	After completing the requirements of a 3-year bachelor's degree (120 credits and 2 additional credits under SSD, will be allowed to continue studies in the fourth year of the undergraduate program leading to the four year bachelor's degree (with Honours)		
Course Type	**Semester - VII**		
	Subject/Title	**Number of Papers**	**Credit**
Major Subject (One)	**Core Major -I :** Abstract Algebra-I	1	5
	Core Major –II: Complex Analysis	1	5
	Core Major –III: Operations Research-I	1	5
	Core Major –IV: Number Theory	1	5
	Core Major Elective-I: (Any one) 1. Mathematical Methods 2. Advanced Linear Algebra 3. Data Structures 4. Advanced Numerical Methods	1	4
Minor (One)	**Minor–I: (any one)** 1. Elementary Differential Calculus 2. Computational Number Theory 3. Ancient Indian Mathematics 4.Quantitative Aptitude	1	4
Total		6	28

B.Sc. (Mathematics) Fourth Year - Eighth Semester

Course Type	**Semester - VIII**		
	Subject/Title	**Number of Papers**	**Credit**
Major Subject (One)	**Core Major -I :** Abstract Algebra-II	1	5
	Core Major –II: Calculus of Several Variables	1	5
	Core Major –III: Operations Research-II	1	5
	Core Major –IV: Advanced Differential Equations	1	5
	Core Major Elective-I: (Any one) 1. Mathematical Methods 2. Advanced Linear Algebra 3. Data Structures 4. Advanced Numerical Methods	1	4
Minor (One)	**Minor–I: (any one)** 1. Elementary Differential Calculus 2. Computational Number Theory 3. Ancient Indian Mathematics 4.Quantitative Aptitude	1	4
Total		6	28
NHEQF Level- 6	**Students on exit after successfully completing four years (i.e., securing a minimum required 176 credits along with securing an additional 2 credits under SSD coursework) will be awarded "Four years Bachelor's Degree (Honours)", in the related field/discipline**		

Four Year Under Graduate Programme (FYUP) U.G. Fourth Year (U.G. with Honours with Research)

B.Sc. (Mathematics) Fourth Year - Seventh Semester

Entry requirement	After completing requirements of a 3-year bachelor's degree (120 credits) and 2 additional credits under SSD, candidates who meet a minimum CGPA of 7.5 will be allowed to continue studies in the fourth year of the undergraduate programme leading to the four years bachelor's degree (Honours with Research

Course Type	Semester - VII		
	Subject/Title	**Number of Papers**	**Credit**
Major Subject (One)	**Core Major -I :** Abstract Algebra-I	1	5
	Core Major –II: Complex Analysis	1	5
	Core Major –III: Operations Research-I	1	5
	Core Major –IV: Research Methodology	1	5
	Core Major Elective-II: (Any one) 1. Mathematical Methods 2. Number Theory 3. Data Structures	1	4
Minor (One)	**Minor–II: (any one)** 1. Elementary Differential Calculus 2. Computational Number Theory 3. Ancient Indian Mathematics 4.Quantitative Aptitude	1	4
Total		6	28

B.Sc. (Mathematics) Fourth Year - Eighth Semester

Course Type	Semester - VIII		
	Subject/Title	**Number of Papers**	**Credit**
Major Subject (One)	**Core Major -I :** Abstract Algebra-II	1	5
	Core Major –II: Research Writing & Ethics	1	3
	Core Major Elective-II: (Any one) 1. Calculus of Several Variables 2. Operations Research-II 3. Advanced Differential Equations	1	4
	Dissertation	1	12
Minor (One)	**Minor–II: (any one)** 1. Elementary Differential Calculus 2. Computational Number Theory 3. Ancient Indian Mathematics 4.Quantitative Aptitude	1	4
Total		6	28
NHEQF Level- 6	**Students on exit after successfully completing four years (i.e., securing a minimum required 176 credits along with securing an additional 2 credits under SSD coursework) will be awarded "Four years Bachelor's Degree (Honours)", in the related field/discipline**		

Core Major-I   **ABSTRACT ALGEBRA- I**

I.   Simple groups, Conjugacy, Normalization, Centre of a group, Class equation of a group and its consequences, Theorems for finite groups, Cauchy's theorem, Sylow's theorem.

II.   Homomorphism, Endomorphism, Automorphism, Inner automorphism, Kernel of a homomorphism, Fundamental theorem on homomorphism of group, Group of automorphisms, Results on group homomorphism.

III.   Maximal subgroups, Composition series, Jordan-Holder theorem, Solvable groups, Commutator subgroups, Direct products

IV.   Ideals, Algebra of ideals, Principal ideal ring, Units and associates, Polynomials ring, Division and Euclidean algorithm for polynomials, Unique factorization theorem

Books Recommended:
1.   Contemporary Abstract Algebra: Josheph A. Gallian, Narosa Pub. House P. Ltd.
2.   A First Course in Abstract Algebra: John. B. Fraleigh, Pearson Edu. Inc., 2003.
3.   Abstract Algebra: V.K. Khanna and S.K. Bhambri, Vikash Pub. House P. Ltd.
4.   Topics in Algebra: I. N. Herstein, John Wiley & Sons, New York.

Core Major-II   **COMPLEX ANALYSIS**

I.   Power series of analytic functions, Convergence of power series, Radius of convergence, Taylor's and Laurent's series, Residue and poles, Singularities, Classification of singularities.

II.   Residues, Residue at infinity, Cauchy residue theorem, Applications of residue theorem in evaluation of improper real integrals.

III.   Conformal mapping: properties, Mobius transformation, Elementary examples.

IV.   Maximum modulus theorem, Mittag-Leffler theorem, Rouche's theorem, Concept of entire functions with simple example, Analytic continuation.

Books Recommended:
1.   Complex Analysis: J.W. Brown and R.V. Churchill, McGraw-Hill Ed. Private Ltd.2015.
2.   Complex Analysis: Dennis G. Zill, Jones &Bartlet Learning,2016.
3.   Complex Analysis: H. S. Kasana, PHI Learning.
4.   Foundation of Complex Analysis: S. Ponnusamy, Alpha Int. Sci.

Core Major-III   **OPERATIONS RESEARCH –I**

I.   Lines and Hyperplanes, convex sets and their properties, extreme points, Convex Functions, Quadratic Forms, Linear programming models: Basic feasible solution, Infeasible and unbounded solution, alternate optima; graphical method, simplex method, two-phase methods.

II.   Revised simplex method, Duality theory, weak duality and strong duality, Dual Simplex methods, Sensitivity Analysis.

III. Transportation problems: Balanced and unbalanced transportation problems, Initial basic feasible solution of balanced transportation problems (least cost method, north-west corner rule, Vogel's approximation method, modified distribution method, assignment problems, The travelling salesman problem.

IV. Introduction to Game Theory, Two person Zero-sum game, Dominance rule, Mixed strategy, Graphical and Algebraic methods and formulation to Linear Programming Problem (LPP). Graphical solutions, Integer programming, Branch and bound Techniques. Gomory's cutting plane algorithm.

Books Recommended:
1. Operations Research: Kanti Swarup, P.K. Gupta & Man Mohan, S. Chand, 1978.
2. Operations Research: Theory and Applications: J.K. Sharma, Trinity Press, 2016.
3. Operations Research: H.A. Taha, Prentice Hall of India, 2011.
4. Operations Research: R. Bronson, Schaum's Outline Series. McGraw Hill, 1982.

Core Major-IV   **NUMBER THEORY**

I. The division algorithm, The g.c.d, The Euclidean algorithm, Diophantine equation $ax + by = c$, The fundamental theorem of arithmetic, The sieve of Eratosthenes, Goldbach conjucture.

II. The theory of congruence's, Binary and decimal representation of integers, Linear congruence and Chinese remainder theorem, Fermat's theorem, Wilson's theorem.

III. Number theoretic function, Tau and sigma function, the Mobius inversion formula, The greatest integer function, Euler's phi function, Properties of phi function, Euler theorem.

IV. The order of an integer modulo n, Primitive roots for primes, Composite numbers having primitive roots, the theory of indices, Continued fraction, Approximation of irrationals by rational.

Books Recommended
1. Elementary Number Theory: David M. Burton, McGraw-Hill.
2. Theory of Numbers: George Andrews, Courier Corporation, 1994.
3. Elementary Number Theory with Applications: Thomas Koshy, Harcourt Acad. Press.
4. Fundamental of Number Theory: William J. Lereque, Dover Pub. Inc. New York.

<p align="center"><strong style="color:red">SEMESTER-VII/VIII-Honours</p>

<p style="color:red">Core Major Elective-I/II (Any one out of 4 electives)</p>

Elective (paper-I)   **MATHEMATICAL METHODS**

I. Definitions of integral equations and their classification, Relation between integral and differential equations, Fredholm integral equations of second kind with separable kernels, Reduction to a system of algebraic equations.

II. Eigen values and eigen functions, iterated kernels, iterative scheme for solving Fredholm integral equation of second kind (Neumann series), Resolvent kernel, Application of iterative scheme to Volterra's integral equation of second kind. Hilbert Schmidt theory, symmetric kernels, Orthonormal systems of functions. Fundamental properties of eigenvalues and eigen functions for symmetric kernels. Solution of integral equations by using Hilbert Schmidt theory.

III. Basic elements of the calculus of variations. Necessary condition for an extremum. Euler's equation with the cases of one variable and several variables. Variational problems for functional involving several dependent variables, Invariance of Euler's equations. Variational problems in parametric form. Functionals depending on higher order derivatives. Functional dependent on the functions of several independent variables, Variational problems with subsidiary conditions.

IV. Variational problems with moving boundaries, Variational problem with a moving boundary for a functional dependent on two functions, Jacobi condition, Weierstrass function, Legendre condition, Weak minimum and weak maximum

Books Recommended:
1. Kanwal,R. P., Linear Integral Equation, Theory and Technique, 2nd edition, 1996, Academic Press New York 1971.
2. Gupta,A.S., Calculus of Variations with Applications, Ist edition, PHI, India.
3. Hildebrand, F. B., Method of Applied Mathematics, 2nd edition, PHI, India

SEMESTER-VII/VIII-Honours

Elective (paper-II)   ADVANCED LINEAR ALGEBRA

I. Linear functionals and the Dual spaces, Second dual space, Annihilators, Hyperspaces, Dual of linear transformations.

II. Inner product spaces, Orhtogonality and orthonormality, Operators on inner product spaces.

III. Triangularizable operators, Diagonalizable operators, Cayley-Hamilton theorem and minimal polynomial, Normal operators on inner product spaces.

IV. Bilinear forms and their matrices The effect of change of basis, Orthogonality and reflexive forms, Non-degenerate bilinear forms, Quadratic forms associated with bilinear forms, Diagonalization of quadratic forms.

Books Recommended:
1. Advanced Linear Algebra with Applications by M. Ashraf, V. De Filippis, M.A. Siddeeque, Springer Verlog Singapore Pte Ltd.
2. Advanced Linear Algebra by Nicholas A Loehr, CRC Press
3. Linear Algebra with Applications by Otto Bretscher, Pearson.
4. Linear Algebra, Kenneth Hoffman, Ray Alden Kunze,Pearson India Education Services, 2015

SEMESTER-VII/VIII-Honours

Elective (paper-III)   DATA STRUCTURES

I. Introduction to data structure and Array: Introduction: Basic Terminology: Elementary Data Organization, Data Structure Operations, Algorithms Complexity, Time-Space Trade off. Array Definition and Analysis, Representation of Linear Arrays in Memory, Traversing of Linear Arrays, Insertion and Deletion, Single Dimensional Arrays, Two Dimensional Arrays, Bubble Sorting, Selection Sorting, Linear Search, Binary Search, Multidimensional Arrays, Function Associated with Arrays, Character String in C, Character String Operations, Arrays as parameters, Implementing One Dimensional Array.

II. Stacks, Queues and Sorting: Introduction to Operations Associated with Stacks Push & Pop, Array representation of stacks, Operation associated with stacks: Create, Add, Delete, Application of stacks recursion polish expression and their compilation

conversion of infix expression to prefix and postfix expression, Tower of Hanoi problem, Representation of Queues, Operations of queues: Create, Add, Delete, Front, Empty, Priority of Queues, Sorting: Insertion Sort, Quick sort, two-way Merge sort, Heap sort.

III. Linked Lists and Trees: Singly linked lists: Representation of linked lists in memory, Traversing, Searching, and Insertion into, Deletion from linked list, Polynomial Addition, More on linked list, Header nodes, Doubly linked list, Generalized list.Trees: Basic Terminology, Binary Trees and their representation, expression evaluation, Complete Binary trees, Extended binary trees, traversing binary trees, Searching, Insertion and Deletion in binary search trees, Complexity of searching algorithm, Path length, Huffman's algorithm, General trees, AVL trees, Threaded trees, B trees.

IV. File Structure: The standard C Library: Input/Output: fopen, fread, etc. String handling functions, Math functions: log, sin etc. Other Standard C functions. Physical storage media, File organization, Organization records into blocks, Sequential blocks, Indexing & Hashing, Primary Indices. Secondary Indices, B+ tree index files, Static, Hash functions, Indexing & hashing comparisons.

Books Recommended:
1. Horowitz and Sahani, "Fundamentals of Data structures", Galgotia publications
2. Kruse, R.L., Leary, B.P., Tondo, CL., "Data structure and program design in C", PHI
3. Tannenbaum, "Data Structures", PHI
4. Tremblay, Jean Paul & Sorenson, Pal G. An introduction to data structures and application by (McGraw Hill)

SEMESTER-VII/VIII-Honours

Elective (paper-IV)   **ADVANCED NUMERICAL METHODS**

I.   The History and the Product, Creating Variables and Using Basic Arithmetic, Standard Functions, Vectors and Matrices, M-Files, The colon Notation and the for Loop, The if Construct, The while Loop, Plotting, Formatted Screen Output, File Input and Output,

II. Roots Finding Methods- Graphical Methods, Bisection, False Position Method, Simple Fixed-Point iteration, Newton-Raphson method. Solution of System of Equations, Eigenvalues and Eigenvectors: The Characteristic Polynomial, Power Method: Theory, Eigenvalues of Special Matrices, Eigenvalues, Diagonal Matrix, Eigenvalues, Upper Triangular Matrix

III. Ordinary Differential Equations: Introduction, First-Order Equations, Euler's Method, Runge–Kutta Methods, Fourth-Order Runge–Kutta, Systems of First-Order Equations, Higher Order Equations,

IV. Numerical Solution of ODE E: Shooting Method, Finite Difference Methods, Finite Difference Method for PDE – Elliptic Type PDE, Parabolic Type PDE, Hyperbolic Type PDE.

Books Recommended:
1. C. Woodford and C. Phillips, Numerical Methods with Worked Examples: Matlab Edition, Springer

2. Steven .C. Chapra, Applied Numerical Methods with MATLAB for Engineers and Scientist, Mc Graw Hill Education.
3. M.K. Jain, Numerical Solution of differential Equations, New Delhi : Wiley Eastern ; New York.

<p style="text-align:center; color:red">SEMESTER-VII/VIII-Honours</p>

<p style="color:red">Minor I/II (Interdisciplinary) (Any one out of these)</p>

Minor (Paper-I)   ELEMENTARY DIFFERENTIAL CALCULUS

I.   Limits, Continuity , Types of discontinuity, Differentiation and examples.
II.   Successive differentiation, Leibnitz theorem.
III.   Expansion of functions using Maclaurin's Taylor's theorems.
IV.   Indeterminate forms, L'Hopital's rule.

Books Recommended:
1. Differential Calculus by Gorakh Prasad, Pothishala Private Limited, Allahabad.
2. Differential Calculus by Shanti Narayan, S Chand & Company Private Ltd. New Delhi.

<p style="text-align:center">SEMESTER-VII/VIII-Honours</p>

Minor (Paper-II)   COMPUTATIONAL NUMBER THEORY

I. Greatest Common Divisor (GCD) algorithms, Chinese Remainder Theorem, Fast polynomial multiplication techniques.
II. Fast integer multiplication and division, Fast GCD computation, Fast matrix multiplication methods, Tensor rank and its applications.
III. Factorization over finite fields , Berlekamp and Cantor-Zassenhaus factoring algorithms, Reed-Solomon error-correcting codes, List decoding techniques   , Bivariate and multivariate polynomial factorization.
IV. Lattice-based cryptography, Lenstra-Lenstra-Lovász (LLL) algorithm and shortest vector problem, Primality testing methods, RSA cryptosystem and Diffie-Hellman key exchange, Discrete logarithm problem   , Integer factorization techniques, including Pollard's rho method and quadratic sieve.

Books Recommended:
1. Victor Shoup - A Computational Introduction to Number Theory and Algebra.
2. Henri Cohen - A Course in Computational Algebraic Number Theory.
3. Richard Crandall & Carl Pomerance - Prime Numbers: A Computational Perspective
4. J. von zur Gathen & J. Gerhard - Modern Computer Algebra.

<p style="text-align:center">SEMESTER - VII/VIII-Honours</p>
<p style="text-align:center">SEMESTER-VII/VIII-Honours</p>

Minor (Paper-III)   ANCIENT INDIAN MATHEMATICS

I. Mathematics in Vedic period, Significance of Sulba Sutras and their geometric contributions.
II. Contributions of Aryabhata and Brahmagupta on arithmetic, algebra and astronomy.
III. Contributions of Varahamihir and Sridharacharya.

IV. Works of Bhaskaracharya-I, II.

Books Recommended:
1. Studies in Indian Mathematics & Astronomy by A. Kolachana, K. Mahesh K. Ramasubbramanian. Springer, Singapore.
2. The History of Maths and Mathematicians of India by V D Haroor, Vidya Bharati, Banglore, 2006.

SEMESTER-VII/VIII-Honours.

Minor (Paper-IV)   **QUANTITATIVE APTITUDE**

I.   Simplifications, Percentage, Profit & Loss, Simple Interest, Compound Interest, H.C.F.& L.C.M., Mixed Problems
II.   Introduction of Equations, Simple Equation, Problems on S.E., Linear Equations, Problems on L.E., Quadratic Equations, Problems on Q.E.
III.   Problems On Number, Problems on Ages, Number System, Applications of Number System.
IV.   Height &Distance, Progressions, Arithmetic Progression, Geometric Progression, Harmonic Progression, Applications of Progressions

Books Recommended:
1. Aggarwal, R.S., Quantitative Aptitude for Competitive Exam, (S. Chand)
2. Guha, Abhijit., Quantitative Aptitude for Competitive Exam, (Mc, Graw. Hill Education)

Fourth Year- (U.G. with Honours)
VIII Semester
Core Major-I   ABSTRACT ALGEBRA-II

I.   Embedding of rings, Ring of residue classes, Fundamental theorem on homomorphism of ring , Prime ideals, Maximal ideal.
II.   Euclidean ring, Properties of Euclidean ring, Module, sub-module, Module homomorphism, Linear sum and direct sum of sub-module
III.   Extension fields, Simple field extension, Algebraic field extension, Minimal polynomial, Roots of polynomials, Multiple roots, Splitting field.
IV.   Automorphism of field, Fixed field, Normal extension, Galois group: Examples and characterizations, Construction with straight edge and compass.

Books Recommended:
1.   Contemporary Abstract Algebra :Josheph A. Gallian, Narosa Pub. House P. Ltd.
2.   A First course in Abstract Algebra :   John. B. Fraleigh, Pearson Edu. Inc. , 2003.
3.   Abstract Algebra :   V.K. Khanna and S.K. Bhambri, Vikash Pub. House P. Ltd.
4.   Topics in Algebra :   I. N. Herstein, John Wiley & Sons, New York.

Core Major-II   CALCULUS OF SEVERAL VARIABLES

I.   Functions of two or more variables, limit and continuity, partial derivatives, differentiability, chain rule, implicit function theorem, inverse function theorem.
II.   Directional derivatives and gradient vectors, Tangent planes and normal

lines, Extrema of functions of two variables, Lagrange multipliers.

III. Double integrals, Applications of double integrals, Surface area, Surface area, Triple integrals.

IV. Vector fields, Divergence and curl, Line integrals, Green's theorem.

Books Recommended:

1. Mathematical Analysis by S C Malik & Savita Arora, New Age International Publishers, New Delhi, 2020.

2. Calculus of Several Variables by E K McLachlan, Prentice Hall, Cambridge University Press.

3. Calculus of Several Variables, Third Edition by Serge Lang, Springer.

Core Major-III   OPERATIONS RESEARCH-II

I. Inventory control, Functional role of inventory control, Classification of EOQ models with shortages and without shortages, problems of EOQ with price breaks, multi-item deterministic problems.

II. Queuing theory, Characteristics of Queuing system, Probability distribution in queuing system, Single served queuing model, M|M|1 queuing models, Multiple server queuing models.

III. Markov chain, State and transition probabilities, Steady state conditions, Application of Markov analysis, Sequencing problems, Processing n jobs through two and three machines.

IV. Dynamic programming, Dynamic programming under certainty, Non-linear programming methods, Quadratic programming, Kuhn- Tucker conditions.

Books Recommended:
1. Operations Research: Kanti Swarup, P.K. Gupta & Man Mohan, S. Chand, 1978.
2. Operations Research: Theory and Applications: J.K. Sharma, Trinity Press, 2016.
3. Operations Research: H.A. Taha, Prentice Hall, 2011.
4. Operations Research: R. Bronson, McGraw Hill, 1982.

Core Major-IV   ADVANCED DIFFERENTIAL EQUATIONS

I. Well posed problems, Existence, uniqueness and continuity of solution of ODEs of first order, Picard's method, Existence and uniqueness of solution of simultaneous differential equations of first order and ODEs of higher order, Sturm separation and comparison theorems, Homogeneous linear systems, Non-homogeneous linear systems, Linear systems with constant coefficients.

II. Two point boundary value problems, Green's function, Construction of Green's Lioville systems, Eigen values and eigen functions, Stability of autonomous−function, Sturm system of differential equations, Critical point of an autonomous system and their classification as stable, Asymptotically stable, Strictly stable and unstable, Stability of linear systems with constant coefficients, Linear plane autonomous systems, Perturbed systems

III. Fourier transform and its application to solution of PDEs, Boundary value problems, Maximum and minimum principles, Uniqueness and continuous dependence on boundary data, Solution of the Dirichlet and Neumann problem for a half plane by

Fourier transform method, Solution of Dirichlet problem for a circle in form of Poisson integral formula, Theory of Green's function for Laplace equation in two dimension and application in solution of Dirichlet and Neumann problem for half plane and circle, Theory of Green's function for Laplace equation in three dimension and application in solution of Dirichlet and Neumann problem for semi-infinite spaces and spheres.

IV. Wave equation, Helmholtz's first and second theorems, Green's function for wave equation, Duhamel's principles for wave equation, Diffusion equation, Solution of initial boundary value problems for diffusion equation, Green's function for diffusion equation, Duhamel's principles for heat equation.

Books Recommended:
1. E.A. Coddington, An Introduction to Ordinary Differential Equations, Dover Publications, 2012.
2. T. Myint-U, Ordinary Differential Equations, Elsevier, North-Holland, 1978.
3. S.L. Ross, Differential Equations, Second Edition, John Wiley & Sons, India, 2007.
4. I.N. Sneddon, Elements of Partial Differential Equations, Dover Publications, 2006.

Fourth Year- (U.G. Honours with Research)

Core Major-I   ABSTRACT ALGEBRA- I
I. Simple groups, Conjugacy, Normalization, Centre of a group, Class equation of a group and its consequences, Theorems for finite groups, Cauchy's theorem, Sylow's theorem.
II. Homomorphism, Endomorphism, Automorphism, Inner automorphism, Kernel of a homomorphism, Fundamental theorem on homomorphism of group, Group of automorphisms, Results on group homomorphism.
III. Maximal subgroups, Composition series, Jordan-Holder theorem, Solvable groups, Commutator subgroups, Direct products
IV. Ideals, Algebra of ideals, Principal ideal ring, Units and associates, Polynomials ring, Division and Euclidean algorithm for polynomials, Unique factorization theorem

Books Recommended:
1. Contemporary Abstract Algebra: Josheph A. Gallian, Narosa Pub. House P. Ltd.
2. A First Course in Abstract Algebra: John. B. Fraleigh, Pearson Edu. Inc., 2003. 3. Abstract Algebra: V.K. Khanna and S.K. Bhambri, Vikash Pub. House P. Ltd.
3. Topics in Algebra: I. N. Herstein, John Wiley & Sons, New York.

Core Major-II   COMPLEX ANALYSIS
I. Power series of analytic functions, Convergence of power series, Radius of convergence, Taylor's and Laurent's series, Residue and poles, Singularities, Classification of singularities.

II. Residues, Residue at infinity, Cauchy residue theorem, Applications of residue theorem in evaluation of improper real integrals.
III. Conformal mapping: properties, Mobius transformation, Elementary examples.
IV. Maximum modulus theorem, Mittag-Leffler theorem, Rouche's theorem, Concept of entire functions with simple example, Analytic continuation.

Books Recommended:
1. Topics in Algebra: I. N. Herstein, John Wiley & Sons, New York.
2. Complex Analysis: J.W. Brown and R.V. Churchill, McGraw-Hill Ed. Private Ltd.2015.
3. Complex Analysis: Dennis G. Zill, Jones &Bartlet Learning,2016.
4. Complex Analysis: H. S. Kasana, PHI Learning.
5. Foundation of Complex Analysis: S. Ponnusamy, Alpha Int. Sci.

Core Major -III   OPERATIONS RESEARCH –I
I. Lines and Hyperplanes, convex sets and their properties, extreme points, Convex Functions, Quadratic Forms, Linear programming models: Basic feasible solution, Infeasible and unbounded solution, alternate optima; graphical method, simplex method, two-phase methods.
II. Revised simplex method, Duality theory, weak duality and strong duality, Dual Simplex methods, Sensitivity Analysis.
III. Transportation problems: Balanced and unbalanced transportation problems, Initial basic feasible solution of balanced transportation problems (least cost method, north-west corner rule, Vogel's approximation method, modified distribution method, assignment problems, The travelling salesman problem.
IV. Introduction to Game Theory, Two person Zero-sum game, Dominance rule, Mixed strategy, Graphical and Algebraic methods and formulation to Linear Programming Problem (LPP). Graphical solutions, Integer programming, Branch and bound Techniques. Gomory's cutting plane algorithm.

Books Recommended:
1. Operations Research: Kanti Swarup, P.K. Gupta & Man Mohan, S. Chand, 1978.
2. Operations Research: Theory and Applications: J.K. Sharma, Trinity Press, 2016.
3. Operations Research: H.A. Taha, Prentice Hall of India, 2011.
4. Operations Research: R. Bronson, Schaum's Outline Series. McGraw Hill, 1982.

Core Major-IV   RESEARCH METHODOLOGY
I. Perception of research, meaning of research, objective of research, different approaches to research, empirical and theoretical research, qualities of a research work, inductive and deductive logics.
II. The scientific method, examples of scientific methods, different phases in scientific method, the use of computers in obtaining proofs of mathematical results, valid and invalid generalization.
III. Problem posing, the soul of research methodology, chains of open ended problems, the art of solving problems, Polya's scheme for solving problems, model building in mathematics.
IV. Basic idea of probability distribution, Elementary sampling theory (a brief introduction), test of significance T, F, Z and Chi-square distribution (a brief introduction).

V. Perception & Definition of Research, Objectives & Motivations of Research, Importance of Research, Types of Research, Research Methods versus Methodology, Process of Research, Review of Literature, Formulation of the Research Problem, Sources and Identification of a Research Problem, Status of the Research Problem, Formulation of Hypothesis, Research Design, Ethics in Research.

VI. Synopsis, Funding Agencies in India for Research in Physical Sciences, Project Proposal, Project Report Writing, Research Paper Writing, Thesis Writing, Referencing, Formats of Writing References, Bibliography, Plagiarism, IPR, Technology Development and Transfer.

Books Recommended:

1. Research Methodology for Scientists and Engineers: J.N. Kapur, Mathematical Sciences Trust Society.
2. Fundamentals of Research Methodology and Statistics : Y.K. Singh, New Age International.
3. Thesis and Assignment Writing : Anderson and Jonathon. Wiley Eastern Bombay.
4. How to write Assignments, Research papers, Dissertation and Thesis : V.H. Bedkar, Karak Publication, New Delhi.
5. Creswell. W.: Research Design, Qualitative, Quantitative and Mixed Methods Approaches (3rd Edition), SAGE, Inc., 2018.
6. Gupta. S: Research Methodology: Methods and Statistical Techniques, Deep & Deep Publications, 2010.
7. Gupta. S.P.: Statistical Methods, Sultan Chand &Sons, 2014.
8. Kumar. R: Research Methodology: A Step-by-Step Guide for Beginners (3rd Edition), SAGE, Inc., 2011.
9. Melville. S. and Goddard. W.: Research Methodology: An Introduction (2nd edition),Juta Academic, 2004.

   Shortis, T.: The Language of ICT: Information and Communication Technology, Taylor & Francis, 2016

<div align="center">

SEMESTER-VII Honours with research
Core Major Elective-I (Any one out of 3 electives)

</div>

Core Major Elective-I (Paper I)   MATHEMATICAL METHODS

I.   Definitions of integral equations and their classification, Relation between integral and differential equations, Fredholm integral equations of second kind with separable kernels, Reduction to a system of algebraic equations.

II.   Eigen values and eigen functions, iterated kernels, iterative scheme for solving Fredholm integral equation of second kind (Neumann series), Resolvent kernel, Application of iterative scheme to Volterra's integral equation of second kind.Hilbert Schmidt theory, symmetric kernels, Orthonormal systems of functions. Fundamental properties of eigenvalues and eigen functions for symmetric kernels. Solution of integral equations by using Hilbert Schmidt theory.

III.   Basic elements of the calculus of variations. Necessary condition for an extremum. Euler's equation with the cases of one variable and several variables. Variational problems for functional involving several dependent variables, Invariance of Euler's equations. Variational problems in parametric form. Functionals depending on higher order derivatives. Functional dependent on the functions of several independent variables, Variational problems with subsidiary conditions.

IV.   Variational problems with moving boundaries, Variational problem with a moving boundary for a functional dependent on two functions, Jacobi condition, Weierstrass function, Legendre condition, Weak minimum and weak maximum

Books Recommended:
1. Kanwal,R. P., Linear Integral Equation, Theory and Technique, 2nd edition, 1996, Academic Press New York 1971.
2. Gupta,A.S., Calculus of Variations with Applications, Ist edition, PHI, India.
3. Hildebrand, F. B., Method of Applied Mathematics, 2nd edition, PHI, India

Core Major Elective-I (Paper-II)   NUMBER THEORY
I.   The division algorithm, The g.c.d, The Euclidean algorithm, Diophantine equation ax + by=c, The fundamental theorem of arithmetic, The sieve of Eratosthenes, Goldbach conjucture.
II.   The theory of congruence's, Binary and decimal representation of integers, Linear congruence and Chinese remainder theorem, Fermat's theorem, Wilson's theorem.
III.   Number theoretic function, Tau and sigma function, the Mobius inversion formula, The greatest integer function, Euler's phi function, Properties of phi function, Euler theorem.
IV.   The order of an integer modulo n, Primitive roots for primes, Composite numbers having primitive roots, The theory of indices, Continued fraction, Approximation of irrationals by rational.

Books Recommended:
1. Elementary Number Theory: David M. Burton, McGraw-Hill.
2. Theory of Numbers: George Andrews, Courier Corporation, 1994.
3. Elementary Number Theory with Applications: Thomas Koshy, Harcourt Acad. Press.
4. Fundamental of Number Theory: William J. Lereque, Dover Pub. Inc. New York.

Core Major Elective-I (Paper-III)   DATA STRUCTURES
I.   Introduction to data structure and Array: Introduction: Basic Terminology: Elementary Data Organization, Data Structure Operations, Algorithms Complexity, Time-Space Trade off. Array Definition and Analysis, Representation of Linear Arrays in Memory, Traversing of Linear Arrays, Insertion and Deletion, Single Dimensional Arrays, Two Dimensional Arrays, Bubble Sorting, Selection Sorting, Linear Search, Binary Search, Multidimensional Arrays, Function Associated with Arrays, Character String in C, Character String Operations, Arrays as parameters, Implementing One Dimensional Array.
II.   Stacks, Queues and Sorting: Introduction to Operations Associated with Stacks Push & Pop, Array representation of stacks, Operation associated with stacks: Create, Add, Delete, Application of stacks recursion polish expression and their compilation conversion of infix expression to prefix and postfix expression, Tower of Hanoi problem, Representation of Queues, Operations of queues: Create, Add, Delete, Front, Empty, Priority of Queues, Sorting: Insertion Sort, Quick sort, two-way Merge sort, Heap sort.
III.   Linked Lists and Trees: Singly linked lists: Representation of linked lists in memory, Traversing, Searching, and Insertion into, Deletion from linked list, Polynomial Addition, More on linked list, Header nodes, Doubly linked list, Generalized

list.Trees: Basic Terminology, Binary Trees and their representation, expression evaluation, Complete Binary trees, Extended binary trees, traversing binary trees, Searching, Insertion and Deletion in binary search trees, Complexity of searching algorithm, Path length, Huffman's algorithm, General trees, AVL trees, Threaded trees, B trees.

IV. File Structure: The standard C Library: Input/Output: fopen, fread, etc. String handling functions, Math functions: log, sin etc. Other Standard C functions. Physical storage media, File organization, Organization records into blocks, Sequential blocks, Indexing & Hashing, Primary Indices. Secondary Indices, B+ tree index files, Static, Hash functions, Indexing & hashing comparisons.

Books Recommended:
1. Horowitz and Sahani, "Fundamentals of Data structures", Galgotia publications
2. Kruse, R.L., Leary, B.P., Tondo, CL., "Data structure and program design in C", PHI
3. Tannenbaum, "Data Structures", PHI
4. Tremblay, Jean Paul & Sorenson, Pal G. An introduction to data structures and application by (McGraw Hill)

SEMESTER-VII/VIII-Honours with research
Minor I/II (Interdisciplinary) (Any one out of these)

Manor (Paper-I)   ELEMENTARY DIFFERENTIAL CALCULUS
I. Limits, Continuity , Types of discontinuity, Differentiation and examples.
II. Successive differentiation, Leibnitz theorem.
III. Expansion of functions using Maclaurin's Taylor's theorems.
IV. Indeterminate forms, L'Hospital's rule.

Books Recommended:
1. Differential Calculus by Gorakh Prasad, Pothishala Private Limited, Allahabad.
2. Differential Calculus by Shanti Narayan, S Chand & Company Private Ltd. New Delhi.

Manor (Paper-II)   COMPUTATIONAL NUMBER THEORY
I. Greatest Common Divisor (GCD) algorithms, Chinese Remainder Theorem, Fast polynomial multiplication techniques.
II. Fast integer multiplication and division, Fast GCD computation, Fast matrix multiplication methods, Tensor rank and its applications.
III. Factorization over finite fields , Berlekamp and Cantor-Zassenhaus factoring algorithms, Reed-Solomon error-correcting codes, List decoding techniques , Bivariate and multivariate polynomial factorization.
IV. Lattice-based cryptography, Lenstra-Lenstra-Lovász (LLL) algorithm and shortest vector problem, Primality testing methods, RSA cryptosystem and Diffie-Hellman key exchange, Discrete logarithm problem , Integer factorization techniques, including Pollard's rho method and quadratic sieve.

Books Recommended:
1. Victor Shoup - A Computational Introduction to Number Theory and Algebra.

2. Henri Cohen - A Course in Computational Algebraic Number Theory.
3. Richard Crandall & Carl Pomerance - Prime Numbers: A Computational Perspective
4. J. von zur Gathen & J. Gerhard - Modern Computer Algebra.

Manor (Paper-III) ANCIENT INDIAN MATHEMATICS

I.   Mathematics in Vedic period, Significance of Sulba Sutras and their geometric contributions.
II.   Contributions of Aryabhata and Brahmagupta on arithmetic, algebra and astronomy.
III.   Contributions of Varahamihir and Sridharacharya.
IV.   Works of Bhaskaracharya-I, II.

Books Recommended:
1. Studies in Indian Mathematics & Astronomy by A. Kolachana, K. Mahesh K. Ramasubbramanian. Springer, Singapore.
2. The History of Maths and Mathematicians of India by V D Haroor, Vidya Bharati, Banglore, 2006.

Manor (Paper-IV) QUANTITATIVE APTITUDE

I.   Simplifications, Percentage, Profit & Loss, Simple Interest, Compound Interest, H.C.F.& L.C.M., Mixed Problems
II.   Introduction of Equations, Simple Equation, Problems on S.E., Linear Equations, Problems on L.E., Quadratic Equations, Problems on Q.E.
III.   Problems On Number, Problems on Ages, Number System, Applications of Number System.
IV.   Height &Distance, Progressions, Arithmetic Progression, Geometric Progression, Harmonic Progression, Applications of Progressions

Recommended:
1. Aggarwal, R.S., Quantitative Aptitude for Competitive Exam, (S. Chand)
2. Guha, Abhijit., Quantitative Aptitude for Competitive Exam, (Mc, Graw. Hill Education)

Fourth Year- (U.G. with Honours)
VIII Semester
Core Major-I ABSTRACT ALGEBRA-II

I.   Embedding of rings, Ring of residue classes, Fundamental theorem on homomorphism of ring , Prime ideals, Maximal ideal.
II.   Euclidean ring, Properties of Euclidean ring, Module, sub-module, Module homomorphism, Linear sum and direct sum of sub-module
III.   Extension fields, Simple field extension, Algebraic field extension, Minimal polynomial, Roots of polynomials, Multiple roots, Splitting field.
IV.   Automorphism of field, Fixed field, Normal extension, Galois group: Examples and characterizations, Construction with straight edge and compass.

Books Recommended:
1. Contemporary Abstract Algebra :Josheph A. Gallian, Narosa Pub. House P. Ltd.

2. A First course in Abstract Algebra :   John. B. Fraleigh, Pearson Edu. Inc. , 2003.
3. Abstract Algebra :   V.K. Khanna and S.K. Bhambri, Vikash Pub. House P. Ltd.
4. Topics in Algebra :   I. N. Herstein, John Wiley & Sons, New York.

Core Major-II   RESEARCH WRITINGS AND ETHICS

I.   LaTeX Typesetting, MS Word: Handling graphics tables and charts, Formatting in MS-Word, MS Power point: Creating Slide Show, Research and Publication Ethics: Theory: - Philosophy and ethics, Scientific conduct, Publication ethics.

II.   Research and Publication Ethics: Practice: - Open access publishing, Publication misconduct, Databases and research metrics, Subject Classification Index, Citation, Citation Index, Impact Factor, h-index, i-10index, INFLIBNET, Introduction to Peer Reviewed and Open Access Journals, e-Journals, e-Library, Research Databases in Physical Sciences: Web of Science, Scopus, Science-Direct etc.

Books recommended

1. Martin J. Erickson and Donald Bindner, A Student's Guide to the Study, Practice, and Tools of Modern Mathematics, CRC Press, Boca Raton, FL, 2011.
2. L. Lamport, LATEX: A Document Preparation System, User's Guide and Reference Manual. Addison-Wesley, New York, second edition, 1994.
3. Ethics in Research Practice and Innovation, Antonio Sandu, Ana Frunza and Elena Unguru, IGI Global.
4. An Introduction to Programming and Numerical Methods in MATLAB: S.R. Otto and J.P. Denier, Springer. 3.Numerical Methods with MATLAB for Engineers and Scientists : S. Chapra, Mc-Graw-Hill.

<p style="text-align:center; color:red">SEMESTER-VIII Honours with research
Core Major Elective-II (Any one out of 3 electives)</p>

Core Major Elective-II (Paper-I)   CALCULUS OF SEVERAL VARIABLES

I.   Functions of two or more variables, limit and continuity, partial derivatives, differentiability, chain rule, implicit function theorem, inverse function theorem.

II.   Directional derivatives and gradient vectors, Tangent planes and normal lines, Extrema of functions of two variables, Lagrange multipliers.

III.   Double integrals, Applications of double integrals, Surface area, Surface area, Triple integrals.

IV.   Vector fields, Divergence and curl, Line integrals, Green's theorem.

Books Recommended:

1. Mathematical Analysis by S C Malik & Savita Arora, New Age International Publishers, New Delhi, 2020.
2. Calculus of Several Variables by E K McLachlan, Prentice Hall, Cambridge University Press.
3. Calculus of Several Variables, Third Edition by Serge Lang, Springer.

Core Major Elective-II (Paper-II)   OPERATIONS   RESEARCH-II

I.   Inventory control, Functional role of inventory control, Classification of EOQ models with shortages and without shortages, problems of EOQ with price breaks, multi-item deterministic problems.

II.   Queuing theory, Characteristics of Queuing system, Probability distribution in queuing system, Single served queuing model, M|M|1 queuing models, Multiple server queuing models.

III. Markov chain, State and transition probabilities, Steady state conditions, Application of Markov analysis, Sequencing problems, Processing n jobs through two and three machines.

IV.   Dynamic programming, Dynamic programming under certainty, Non-linear programming methods, Quadratic programming, Kuhn- Tucker conditions.

Books Recommended:
1. Operations Research: Kanti Swarup, P.K. Gupta & Man Mohan, S. Chand, 1978.
2. Operations Research: Theory and Applications: J.K. Sharma, Trinity Press, 2016.
3. Operations Research: H.A. Taha, Prentice Hall of India, 2011.
4. Operations Research: R. Bronson, Schaum's Outline Series. McGraw Hill, 1982.

Core Major Elective-II (Paper-III)   ADVANCED DIFFERENTIAL EQUATIONS

I.   Well posed problems, Existence, uniqueness and continuity of solution of ODEs of first order, Picard's method, Existence and uniqueness of solution of simultaneous differential equations of first order and ODEs of higher order, Sturm separation and comparison theorems, Homogeneous linear systems, Non-homogeneous linear systems, Linear systems with constant coefficients.

II.   Two point boundary value problems, Green's function, Construction of Green's Lioville systems, Eigen values and eigen functions, Stability of autonomous−function, Sturm system of differential equations, Critical point of an autonomous system and their classification as stable, Asymptotically stable, Strictly stable and unstable, Stability of linear systems with constant coefficients, Linear plane autonomous systems, Perturbed systems

III. Fourier transform and its application to solution of PDEs, Boundary value problems, Maximum and minimum principles, Uniqueness and continuous dependence on boundary data, Solution of the Dirichlet and Neumann problem for a half plane by Fourier transform method, Solution of Dirichlet problem for a circle in form of Poisson integral formula, Theory of Green's function for Laplace equation in two dimension and application in solution of Dirichlet and Neumann problem for half plane and circle, Theory of Green's function for Laplace equation in three dimension and application in solution of Dirichlet and Neumann problem for semi-infinite spaces and spheres.

IV.   Wave equation, Helmholtz's first and second theorems, Green's function for wave equation, Duhamel's principles for wave equation, Diffusion equation, Solution of initial boundary value problems for diffusion equation, Green's function for diffusion equation, Duhamel's principles for heat equation.

Suggested Readings:

1. E.A. Coddington, An Introduction to Ordinary Differential Equations, Dover Publications, 2012.
2. T. Myint-U, Ordinary Differential Equations, Elsevier, North-Holland, 1978.
3. S.L. Ross, Differential Equations, Second Edition, John Wiley & Sons, India, 2007.
4. I.N. Sneddon, Elements of Partial Differential Equations, Dover Publications, 2006.
   , 2004.

SEMESTER-VIII Honours with research

Dissertation (12 Credits)