APPENDIX-I

Detailed Programme Structure
&
Syllabus

M.Sc. /M.A. (Mathematics) (PGMM/MAMM)

Semester	Course Code	Title of Papers	Credit	Max. Marks
1st SEM	PGMM-101N/MAMM-101N	Advanced Real Analysis and Integral Equations	4	100
	PGMM-102N/ MAMM-102N	Classical Optimization Techniques	4	100
	PGMM-103N/ MAMM-103N	Discrete Mathematics	4	100
	PGMM-104N/ MAMM-104N	Numerical Analysis	4	100
	PGBR-01	Basic in Research	4	100
Total Credit of 1st Semester			20	500
2nd SEM	PGMM-106N/ MAMM-106N	Advanced Algebra	4	100
	PGMM-107N/ MAMM-107N	Complex Analysis	4	100
	PGMM-108N/ MAMM-108N	Mathematical Statistics	4	100
	PGMM-109N/ MAMM-109N	Topology	4	100
	PGED-02	Entrepreneurship Development	4	100
Total Credit of 2nd Semester			20	500
3rd SEM	PGMM-111N/ MAMM-111N	Advanced Differential Equations	4	100
	PGMM-112N/ MAMM-112N	Functional Analysis	4	100
	PGMM-113N/ MAMM-113N	Measure Theory and Integration	4	100
	PGMM-114N/ MAMM-114N	Theory of Probability	4	100
	PGRT-03	Research Tools	4	100
Total Credit of 3rd Semester			20	500
4th SEM	PGMM-116N/ MAMM-116N	Operation Research	4	100
	PGMM-117N/ MAMM-117N	Fluid Dynamics	4	100
	PGMM-122N/ MAMM-122N	Dissertation with Viva-voce	4	100
	Select any one of the following			
	PGMM-118N/ MAMM-118N	Soft Computing	4	100
	PGMM-119N/ MAMM-119N	Number Theory and Cryptography	4	100
	Select any one of the following			
	PGMM-120N/MAMM-120N	Machine Learning Techniques	4	100
	PGMM-121N/MAMM-121N	Vedic Mathematics	4	100
Total Credit of 4th Semester			20	500
Total Credit			80	2000

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** I	**Semester:** I
Subject: Mathematics		
Course Code: PGMM-101N/MAMM-101N	**Course Title:** Advanced Real Analysis and Integral Equations	
Course Objectives: The course covers three important areas with the objectives to acquaint students with new techniques namely advanced real analysis, Fourier series and Integral equations. After reading this course, the students will be able to apply the real analysis, Fourier series and integral equations to many physical problems in science and engineering.		
Course Outcomes: **CO1:** To study the advanced real analysis and its applications. **CO2:** The student will be able to understand the basic concepts of function of several variables and its applications. **CO3:** Able to understand the Fourier series and its applications in boundary value problems. **CO4:** Able to understand and use of eigenvalues and Eigen functions in linear integral equations.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Real Analysis**
Unit I	**Riemann Integral** Partition, lower and upper Riemann-Stieltjes sums, lower and upper Riemann-Stieltjes integrals, Definition of Riemann-Stieltjes integral, necessary and sufficient condition for Riemann-Stieltjes integrability, algebra of Riemann-Stieltjes integrable functions.
Unit II	**Integration and Differentiation** Integral Function, primitive, fundamental theorem of integral calculus, integration by parts, Integration of vector-valued functions.
Unit III	**Uniform Convergence of Sequences** Uniformly bounded sequence, uniform convergence of sequences, Uniform convergence of a series of function, Cauchy's general principle of uniform convergence, test for uniform convergence, Uniform convergence and integration, Uniform convergence and differentiation.
Unit IV	**Power Series** Power series, Cauchy's theorem on limits, Radius of convergence, Uniform convergence of power series. Abel's and Tauber's theorems.
Block 2	**Function of Several Variables**
Unit V	**Limit and continuity of function of two variables** Introduction, simultaneous limit, Limit of a function of two variables, continuity of a function of two variables.
Unit VI	**Partial Differentiation** Introduction, Partial derivatives, partial derivative of higher order, example based on partial derivatives.
Unit VII	**Euler's Theorem** Introduction, Homogeneous function, Euler's theorem on Homogeneous function, some deductions from Euler's theorem.
Unit VIII	**Jacobians** Introduction, Jacobians and their properties.
Block 3	**Fourier Series**
Unit IX	**Introduction to Fourier series** Trigonometric Fourier series, Periodic function, even and odd function, Euler

	formula for the Fourier coefficients, Convergence of Fourier series and Dirichlet's conditions.
Unit X	**Half Range Fourier series** Half-range expansions, Fourier sine series, Fourier Cosine series, Change of Interval, Parseval's identity for Fourier series.
Block 4	**Integral Equations**
Unit XI	**Classifications of Integral Equations** Introduction, Integral equation, differentiation of a function under and integral sign, relation between differential and integral equation.
Unit XII	**Fredholm Integral Equations-I** Fredholm Integral equation, Fredholm first theorem, Fredholm second theorem, Fredholm third theorem, Fredholm Integral equation with separable kernel.
Unit XIII	**Fredholm Integral Equations-II** Fredholm Integral equation, Resolved kernel for Fredholm Integral equation, separable kernel.
Unit XIV	**Volterra Integral Equations** Volterra Integral equation, Solution of non-homogeneous Volterra integral equation of second kind by the method of successive substitution and successive approximation, iterated kernels.

Suggested Text Book Readings:

1. M. D. Raisinghania, Integral Equations and Boundary Value Problems, S. Chand Publishing, 2007.
2. Apostol, T. M. Mathematical Analysis. Fifth edition. Wesley Publishing Co. 1981.
3. Walter, R. Principles of Mathematical Analysis. 3rd edition, McGraw-Hill, 1976.
4. Malik, S. C. and Arora, S. Mathematical Analysis. 2nd edition reprint. New Age International Publishers 2005.
5. Royden, H. L. Real Analysis, Macmillan Pub. Co., Inc. 4th edition, New York, 1993.
6. Somasundram, D. and Chaudhary, B. A First Course in Mathematical Analysis. Narosa Publishing House, 1996.
7. Malik, A. K., Mathur, P, Purohit, S.D., A text Book of Engineering Mathematics-I, Manakin Press, 2020.

This course can be opted as an elective by the students of following subjects: NA

Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** I	**Semester:** I
Subject: Mathematics		
Course Code: PGMM-102N/MAMM-102N	**Course Title:** Classical Optimization Techniques	
Course Objectives: The main objective of the course is presents the theory and applications of classical optimization techniques. It extends the theory of optimization methods to more realistic problems.		
Course Outcomes: **CO1:** To distinguish between single objective and multiple objective functions. **CO2:** To have deep insight in solving optimization problems which are non-linear, **CO3:** The formulation and solving of problems arising from practical, real-life settings. **CO4:** Able to know the mathematical structure and properties of fundamental problem classes (e.g., linear, non-linear,integer programming, dynamic programming and game theory).		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Optimization Techniques**
Unit I	**Introduction to Optimization Techniques** Introduction, Optimization techniques, applications of optimization techniques, optimization problems, classification of optimization problems.
Unit II	**Unconstrained Optimization Problem** Introduction, unconstrained optimization problem, single and multi-variable optimization problems.
Unit III	**Constrained Optimization Problem** Introduction, constrained optimization problem, constrained multi-variable optimization problem with equality and inequality constraints.
Block 2	**Non-Linear Programming Problem**
Unit IV	**Non-Linear Programming-I** Introduction, unconstrained non-linear optimization problems, direct search method: Fibonacci method of search, Golden section method, univariate method and pattern search method, indirect search method: steepest descent method.
Unit V	**Non-Linear Programming-II** Introduction, constraints non-linear optimization problem, direct methods: complex method and zoutendijk method, indirect methods: transformation techniques and penalty function methods.
Unit VI	**Quadratic Programming** Introduction, Kuhn-Tucker conditions, Quadratic programming: Wolfe's modified simplex method, Beale's method.
Unit VII	**Separable Programming Problem** Introduction, Separable programming problem.
Block-3	**Dynamic Programming Problem**
Unit VIII	**Introduction to Dynamic Programming** Introduction, multi-decision process, Bellman's principle of optimality, dynamic programming algorithm.
Unit IX	**Applications of Dynamic Programming** Introduction, solution of linear programming problem using dynamic programming and applications of dynamic programming problem.
Block 4	**Advanced Optimization Techniques**
Unit X	**Networking** Introduction, shortest route problem, minimum spanning tree problem and

	maximum flow problem.
Unit XI	**Game Theory** Introduction, Game theory, lower and upper value of game, procedure to find saddle point, games without saddle point.
Unit XII	**Goal Programming** Introduction, formulation of Goal programming, single goal models, goal-programming algorithm and multi goal models.
Unit XIII	**Integer Programming Problem-I** Introduction, formulation of Integer programming problem, Gomory's cutting plane method.
Unit XIV	**Integer Programming Problem-II** Introduction, Branch and Bound Techniques.

Suggested Text Book Readings:

1. Yadav, S. R. and Malik, A. K., Operations Research, Oxford University Press, 2014.
2. Malik, A. K, Yadav, S. K. and Yadav, S. R. and., Optimization Techniques, Dreamtech Press, 2020.
3. Rao, S.S.: Optimization Theory and Applications (2^{nd} Edition), New Age Int., New Delhi, 1995.
4. Taha, H. A. Operation Research: An Introduction. 9 th edition, Pearson, 2010.
5. Gupta, P.K. and Hira, D.S. Introduction to Operations Research, S. Chand & Co. 2008.
6. Hardy, G.: Nonlinear and Dynamic Programming (4^{th} edition), Addison-Wesley, Reading Mass, 1974.
7. Sharma, J. K., Mathematical Model in Operation Research, Tata McGraw Hill, 1989.

This course can be opted as an elective by the students of following subjects:
MCA/MBA/M.Sc.(Data Science & Analytics/Statistics)

Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** I	**Semester:** I
Subject: Mathematics		
Course Code: PGMM-103N/MAMM-103N	**Course Title:** Discrete Mathematics	
Course Objectives: The main aim of the course is provide the basic knowledge of mathematical logic, lattice theory, Boolean algebra, and graph theory and apply for solving the real life problems.		
Course Outcomes: **CO1:** Able to use this theory in the development of many computer languages. **CO2:** To solve many engineering and science problems using mathematical logic and methods. **CO3:** To know about the Boolean algebra for solving the problems of coding theory, reliability and others. **CO4:** To solve many research problems and real-world problems by using graph theory.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Set Theory**
Unit I	**Sets** Introduction, Representation of sets, types of sets, subset, universal set, Venn diagram, operations on sets, and algebra of sets.
Unit II	**Relations** Introduction, inverse relation, representation of relations, types of relations, equivalence relation, and partial order relation.
Unit III	**Functions** Introduction, inverse function, types of functions, real valued function, identity function, constant function, composition of functions.
Unit IV	**Techniques of counting** Introduction, partition, principle of inclusion-exclusion, pigeonhole principle, permutations and combinations.
Block 2	**Logic**
Unit V	**Mathematical Logic** Introduction, proposition, basic logical operations, truth table, logical equivalence, algebra of propositions, Tautology, contradiction.
Unit VI	**Normal Form** Introduction, normal form, disjunctive normal form, conjunctive normal form, logic in proof, universal and existential quantifiers.
Unit VII	**Mathematical Induction** Introduction, methods of proof, principle of mathematical induction.
Unit VIII	**Recurrence Relations** Introduction, generating function, properties of generating functions, numeric function, recurrence relation, solution of recurrence relation.
Block 3	**Boolean Algebra**
Unit IX	**Boolean Algebra** Introduction, binary operations, algebraic structure, Boolean algebra, Boolean expression, Boolean functions and logic gates.
Unit X	**Lattices** Introduction, Lattice, properties of lattice, principle of duality, semi and complete lattice, sublattice, isomorphic and bounded lattice.
Block 4	**Graph Theory**

Unit XI	**Introduction to Graph** Definition of a graph, simple and multi-graph, degree of a vertex, types of graph: null graph, complete graph, regular graph.
Unit XII	**Advanced Graph Theory** Introduction, Path, cycle and circuit, Eulerian and Hamiltonian graph, matrix representation of graph, planner graph, graph coloring.
Unit XIII	**Tree** Introduction, tree, types of tree.
Unit XIV	**Tree** Introduction, rooted tree, spanning tree, minimal spanning tree, binary tree.

Suggested Text Book Readings:

1. Rosen, K. H. Discrete Mathematics and Its Applications. 7th edition, Tata McGraw Hill, 2011.
2. Trembley, J. P. and Manohar, R. A First Course in Discrete Structure with applications to Computer Science. Tata McGraw Hill, 1999.
3. Khanna, V. K. Lattices and Boolean Algebras. PHI Publication, 2004.
4. Liu, C. L. Elements of Discrete Mathematics. Tata McGraw Hill, 2000.
5. Ram, B. Discrete Mathematics, Pearson Education, 2012.
6. Lipschutz, S., Lipson, M. L. and Patil, V. H. Discrete Mathematics. Schaum's Outline Series, Tata McGraw-Hill Education, 2006.

This course can be opted as an elective by the students of following subjects:
MCA/M.Sc. (Data Science & Analytics/Statistics)

Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** I	**Semester:** I
Subject: Mathematics		
Course Code: PGMM-104N/MAMM-104N	**Course Title:** Numerical Analysis	
Course Objectives: The main aim of this course is provide the numerical techniques in solving the complex mathematical problems for approximate solution whenever exact and appropriate solution are not exist.		
Course Outcomes: **CO1:** Able to be understand the numerical methods and how they are used to determine the approximate solution. **CO2:** To know about the analysis and modification of numerical problems used in science and engineering. **CO3:** The formulation and solving of numerical problems arising from practical, real-life settings. **CO4:** Able to know the solution of linear and non-linear equations and solution of differential equations and integrations.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Calculus of Finite Differences**
Unit I	**Finite Differences** Introduction, finite differences, forward differences, backward differences, central differences, shift operator, relations between the relations.
Unit II	**Application of Finite Differences** Fundamental theorem of the difference calculus, factorial function, properties of factorial function.
Block 2	**Interpolation**
Unit III	**Newton's Interpolation formula with Equal Intervals** Introduction, to find one missing terms, to find two missing terms, Newton's forward and backward interpolation with equal intervals.
Unit IV	**Gauss' and Stirling Interpolation formula with Equal Intervals** Introduction, Gauss's forward and backward interpolation with equal intervals, Stirling's difference formula.
Unit V	**Lagrange's Interpolation Formula for Unequal Intervals** Introduction, Lagrange's interpolation with unequal intervals.
Block 3	**Solution of Linear Simultaneous Equations**
Unit VI	**Solution of Linear Simultaneous equations-I** Introduction, Linear equations, Gauss elimination method, Gauss-Seidel method.
Unit VII	**Solution of Linear Simultaneous equations-II** Introduction, LU Decomposition method or triangular method, Crout's method and Choleski's method.
Block 4	**Solving Algebraic and Transcendental Equations**
Unit VIII	**Numerical Method for solving Algebraic and Transcendental Equations-I** Introduction, Polynomial, algebraic and transcendental equations, Bisection method and Newton Method.
Unit IX	**Numerical Method for solving Algebraic and Transcendental Equations-II** Introduction, Regula-Falsi method and Secant method.
Block 5	**Numerical Differentiation and Integration**

Unit X	**Numerical Differentiation-I** Introduction, derivatives using forward difference formula, derivatives using backward difference formula.
Unit XI	**Numerical Differentiation-II** Introduction, derivatives using Stirling difference formula, derivatives using Newton's Divided difference formula.
Unit XII	**Numerical Integration** Introduction, general quadrature formula for equally spaced arguments, Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule.
Unit XIII	**Numerical Solution of Ordinary Differential Equations-I** Introduction, Euler's method, Euler's modified method, Taylor Series method.
Unit XIV	**Numerical Solution of Ordinary Differential Equations-II** Introduction, Picard's method. Runge-Kutta method for fourth order, Milne's predictor-corrector method.

Suggested Text Book Readings:

1. Atkinson, K. and Han, W. Theoretical Numerical Analysis, Springer Science & Business Media, 2010.
2. Jain, M.K., Iyengar, S.R.K and Jain, R.K.: Numerical Methods for Scientific and Engineering Computations, New Age International (P) Ltd. New Delhi, 2014.
3. Sastry, S.S.: Introductory Methods of Numerical Analysis, UBS Publishers, 2012.
4. Bradie, B. A friendly introduction to Numerical Analysis. Pearson Education, 2007.
5. Gupta. R. S., Elements of Numerical Analysis, 2nd Edition, Cambridge University Press, 2015

This course can be opted as an elective by the students of following subjects:
MCA/M.Sc. (Data Science & Analytics/Statistics)

Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: None		
Programme: M.Sc./M.A.	**Year:** I	**Semester:** I
Subject: Statistics		
Course Code: ***PGBR-01***	**Course Title:** ***Basics in Research***	
Course Objectives: The main objective of this course is to develop a research orientation among the scholars and to acquaint them with fundamentals of research methods, survey, Plagiarism and copyright issue.		
Course Outcomes: **CO1:** To write a good qualitative research statement and design the research questions. **CO2:** To know about the hypothesis, conduct the survey and a qualitative case study. **CO3:** Able to know the Plagrism and copyright issue for writing research paper and project.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

BLOCK 1	Basic of Research
Unit 1	Introduction to Research: Knowledge and the Approaches of Acquiring knowledge (deductive, inductive and scientific), Meaning of Research, Objectives of Research, Motivation in Research, Significance of Research, Importance of knowing How Research is Done?, Criteria of Good Research
Unit 2	APPROACHES OF RESEARCH: Types of Research, Research Approaches, Research Methods versus Methodology, Research and Scientific Method, Research Process
Unit 3	DEFINING THE RESEARCH PROBLEM: What is a Research Problem?, Selecting the Problem, Necessity of Defining the Problem, Technique involved in Defining a Research Problem.
Unit 4	RESEARCH DESIGN: Need for Research Design, Features of Good Design, Important Concepts Relating to Research Design, Different Research Design, Basic Principles of Experimental Designs.
BLOCK 2	LITERATURE SURVEY, REVIEW, AND SYNOPSIS PREPARATION
Unit 5	Literature Survey: Introductions: Sources of information, need for reviewing literature, primary-secondary and tertiary sources, journals, abstracts, text books, Web resources, E-journals, journal access, case study alerts. Citation index, UGC infonet, E-books, Impact Factors, Search engines- Google scholar, Science Direct, SciFinder, Scopus, web of science.
Unit 6	Literature Review: Establishing the Context, Identifying Gaps in Knowledge, Formulating Research Questions or Hypotheses, Defining Key Concepts and Terms, Selecting Research Methods, Supporting Research Design and Methodology, Evaluating Research Methods, Citing Relevant Studies, Avoiding Redundancy, Synthesizing Knowledge, Demonstrating Scholarly Engagement, Guiding the Organization of Your Research Paper, Providing a Theoretical Framework, Supporting Ethical Research, Contributing to the Research Conversation, Types of Review of literature.
Unit 7	Preparation of Research Synopsis: The structure of synopsis- Title, Introduction, Literature Review, Research Questions or Hypotheses, Methodology, Data Collection, Data Analysis, Expected Outcomes and Significance, Timeline, References, Budget, Appendices.
BLOCK 3	ETHICS AND IPR
Unit 8	Research Ethics: Regulatory bodies, practices and compliances, Good Laboratory Practices (GLP), Research Ethics & Misconduct.
Unit 9	Intellectual Property Rights: Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties. Plagiarism, Patents, Fundamentals of patents, Product and process patent, Patent Treaties and Convention, process of filing patent (Search and retrieval), copyrights, geographical indications, design and layout, trademarks.

Unit 10	Ethical consideration for research: Informed Consent, Privacy and Confidentiality, Minimizing Harm and Risks, Beneficence, Justice and Fairness, Deception, Publication Ethics, Peer Review, Conflict of Interest, Animal Welfare, Data Management and Sharing, Community and Stakeholder Involvement, International Research Ethics.
BLOCK 4	RESEARCH REFERENCE, REPORT AND PAPER WRITING
Unit11	Reference Writing: APA Style (American Psychological Association), MLA Style (Modern Language Association), Chicago Style, IEEE Style (Institute of Electrical and Electronics Engineers), AMA Style (American Medical Association), Harvard Style, Vancouver Style, Turabian Style, CSE Style (Council of Science Editors), Bluebook Style. Tips for writing references.
Unit12	Report writing in academics and research: Various kinds' of academic and research activities. Necessity of report writing for achievement of academic and research goals. Various kinds of reports / presentations. Characteristics of academic and research reports / presentations. Conclusions. Scientific Writing – Introduction to Technical writing, definition, types, characteristics, Report Writing, Research proposal writing.
Unit13	Research paper writing: Choose a Topic, Conduct a Literature Review, Formulate a Research Question or Hypothesis, Plan Your Research, Gather Data, Organize Your Research, Write an Outline, Write the Introduction, Literature Review, Methodology, Results, Discussion, Conclusion, Cite Your Sources, Proofread and Edit, Formatting and References, Finding a Suitable Journal, Submit Your Paper, Peer Review and Revision, Final Proofreading.
Block 5	RESEARCH TOOLS AND STATISTICAL METHODS
Unit 14	Basics of Data, Research Tools, and Types of Variables- Research Tools for Data Collection-Questionnaire, Structured vs. Semi-structured, Open-ended and closed-ended questions, Interview Schedule-Face-to-face, telephonic, or digital, Observation Method, Participant and non-participant observation-Checklist and Rating Scale, Likert scales, semantic differential scales, Dietary Assessment Tools, 24-hour recall, food frequency questionnaire (FFQ), food diary, Anthropometric Measurement Tools, Weighing scale, stadiometer, measuring tape, MUAC, BMI chart. Types of Data and Variables-Qualitative vs. Quantitativ, Nominal, Ordinal, Interval, Ratio, Dependent and Independent Variables. *Understanding Data Distributions*-Normal and skewed distributions, checking normality: Histogram, Q-Q Plot, Shapiro-Wilk test.
Unit 15	Parametric Statistical Tools and Applications- Descriptive Statistics (Parametric), Mean, Median, Mode, Standard Deviation, Variance, Percentiles and Z-scores, Inferential Parametric Tests, t-tests, One-sample t-test, Independent samples t-test, Paired samples t-test, One-way ANOVA, F-test, post-hoc interpretation, Correlation and Regression, Pearson correlation, Simple Linear Regression (assumptions, interpretation, R^2), Confidence Intervals and p-values, Interpretation and significance, Tools Used: MS Excel, SPSS, Examples: Comparing mean hemoglobin between groups, Predicting BMI from daily calorie intake.
Unit 16	Non-Parametric Statistics and Risk Estimation Tools-Descriptive Statistics (Non-Parametric), Median, Mode, Interquartile Range, Non-Parametric Tests, Chi-square Test, Test of independence using contingency tables, Mann-Whitney U Test, Comparison of two independent groups, Wilcoxon Signed-Rank Test, Paired samples, Kruskal-Wallis Test, Non-parametric ANOVA alternative, Risk Estimation Tools, Odds Ratio (OR), Use in case-control studies, Interpretation, Relative Risk (RR), Use in cohort studies, 2x2 tables, Manual and SPSS calculation, Tools Used: SPSS, Manual calculation using examples, Examples: Association between junk food and obesity, Risk of anemia based on dietary habits.

Suggested Text Book Readings:

1. C.R. Kothari, Gaurav Garg. Research Methodology: Methods and Techniques, New Age International Publishers, 2019.
2. Kumar. R: Research Methodology: A Step-by-Step Guide for Beginners, (3rd Edition), SAGE, Inc., 2011.
3. https://onlinecourses.swayam2.ac.in/cec22_ge28/preview

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** I	**Semester:** II
Subject: Mathematics		
Course Code: PGMM-106N/MAMM-106N	**Course Title:** Advanced Algebra	
Course Objectives: Acquiring ability for defining set, relation, function, algebraic structures, groups, subgroups, ring, Extension Fields, Galois Theory and their applications.		
Course Outcomes: **CO1:** The student will be able to know about set theory and its applications. **CO2:** The student shall understand the group theory with their applications. **CO3:** Ability to apply advanced algebra to solve problems in other branches of mathematics and in other disciplines. **CO4:** Processing pre-requisites for pursuing research in group theory and cryptography.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Group Theory**
Unit I	**Basic Set Theory** Introduction, Representation of sets, types of sets, subset, universal set, Venn diagram, operations on sets, and algebra of sets, relations, equivalence relation, and partial order relation, functions.
Unit II	**Introduction of Group Theory** Introduction, algebraic structure, group, Abelian group, finite and infinite group, composition tables for finite sets.
Unit III	**Permutations Groups** Introduction, permutations, groups of permutations, cyclic permutations, even and odd permutations.
Unit IV	**Order of an element and Isomorphism Groups** Introduction, order of an element of a group, isomorphism on groups.
Unit V	**Subgroup and Cosets** Introduction, complexes and subgroups of a group, intersection of subgroups, cosets, Lagrange's theorem, Fermat's theorem, Cayley's theorem.
Unit V	**Cyclic Group** Introduction, Cyclic groups, subgroup generated by a subset of a group, generating system of a group.
Block 2	**Advanced Group Theory**
Unit VI	**Cyclic Group** Introduction, Cyclic groups, subgroup generated by a subset of a group, generating system of a group.
Unit VII	**Normal Subgroup** Introduction to Normal subgroup, simple group, conjugate element, centre of a group, conjugate subgroup and quotient groups.
Unit VIII	**Homomorphism** Introduction, Homomorphism on groups, Kernel of a homomorphism, fundamental theorem on homomorphism of groups, automorphisms and inner automorphisms, Maximal subgroup, Composition series of a group, Jordon Holder's theorem, Solvable groups, Direct products, Sylow's theorem.
Block 3	**Rings and Field Theory**

Unit IX	**Rings** Introduction, Rings, elementary properties of a ring, ring with or without zero divisors, integral domain, field, subrings and subfields.
Unit X	**Ideals** Introduction, ideals, principal ideal, divisibility in an integral domain, greatest common divisor, polynomials rings, unique factorization domain and reminder theorem.
Unit XI	**Advanced Rings Theory** Introduction. Quotient rings, homomorphism on rings, kernel of a ring homomorphism, maximal ideals, prime ideals and Euclidean rings.
Block-4	**Extension Fields and Galois Theory**
Unit XII	**Extension Fields** Introduction, field extensions, field adjunctions, simple and algebraic field extensions, separable extension and perfect field.
Unit XIII	**Galois Theory-I** Introduction, The elements from Galois theory, fixed field, normal extension.
Unit XIV	**Galois Theory-II** Introduction, Galois group, fundamental theorem of Galois theory

Suggested Text Book Readings:

1. David S. Dummit & Richard M. Foote (2008). Abstract Algebra (2nd edition). Wiley.
2. P. B. Bhattacharya, S. K. Jain & S. R. Nagpaul (2003). Basic Abstract Algebra (2^{nd} edition). Cambridge University Press.
3. Khanna, Vijay K & Bhambri, S K A Course in Abstract Algebra, S Chand and Company Ltd; 5^{th} edition,2022.
4. John B. Fraleigh, A First Course in Abstract Algebra (7th edition). Pearson, 2007.
5. Joseph A. Gallian, Contemporary Abstract Algebra (9th edition). Cengage, 2017.
6. I. N. Herstein, Topics in Algebra (2nd edition). Wiley India, 2006.

This course can be opted as an elective by the students of following subjects: NA

Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.

Programme: M.Sc.	**Year:** I	**Semester:** II
Subject: Mathematics		
Course Code: PGMM-107N/MAMM-107N	**Course Title:** Complex Analysis	

Course Objectives: The main aim of this course is provide the basic concepts of complex analysis, derivatives and integrals of functions of a complex variable, conformal mapping and use of complex analysis to evaluate complicated real integrals via residue calculus.

Course Outcomes:

CO1: The student will be able to know about fundamental concepts of complex analysis.

CO2: The student shall understand the Cauchy-Riemann equations and apply them to complex functions in order to determine whether a given continuous function is complex differentiable.

CO3: Ability to apply complex analysis techniques in engineering and science.

CO4: Processing pre-requisites for pursuing research in complex analysis.

Credits: 4	**Type of Course:** Core

Max. Marks: 100	**Min. Passing Marks:** 36
Block 1	**Function of Complex Variables**
Unit I	**Complex Numbers** Introduction, Graphical representation, exponential functions of complex numbers, circular and hyperbolic functions of complex numbers.
Unit II	**Analytic Functions** Introduction, single and multivalued functions, analytic functions, Cauchy Riemann equations, Polar form of C-R equation, Derivative of w in polar form.
Unit III	**Harmonic Functions** Orthogonal system, Laplace equations, harmonic functions, conjugate functions, Milne's Thomson method.
Block 2	**Conformal Mappings**
Unit IV	**Introduction to Conformal Mappings** Mappings or Transformations, Jacobian of a transformations, ordinary and critical points, conformal mappings, some general transformations: Translation, Rotation, Magnification, Inversion.
Unit V	**Bilinear Transformations** Bilinear transformations, Fixed points of the Bilinear Transformations, Some important properties of Bilinear Transformations, Special conformal transformations, Joukowski's transformation and Schwarz-Christoffel transformation.
Block 3	**Complex Integration and Series**
Unit VI	**Introduction to Complex Integration** Complex integration, Arc, Regular Arc, Contour, Connected and Non-connected region, simple and multi connected region,
Unit VII	**Cauchy's Theorem** Cauchy Fundamental theorem, and Cauchy-Goursat theorem.
Unit VIII	**Cauchy's Integral Formula and its Applications** Cauchy's integral formula, An extension of the Cauchy's integral formula, Cauchy's integral formula for derivative, Cauchy's inequality.
Unit IX	**Important Theorems in Complex Integration** Morera's Theorem, Liouville's theorem and its applications, The fundamental theorem of Algebra, Maximum modulus principle.
Unit X	**Series** Introduction, Entire functions, Taylor's theorem and its applications, Laurent's Theorem and its applications.
Block 4	**The calculus of residues**
Unit XI	**Singularities and Residues** Zero of analytic functions, singularities of analytic functions, isolated and non-isolated singularities, removable singularities, pole, residue at pole, Cauchy's Residue theorem.
Unit XII	**Applications of Complex Integration-I** Evaluation of real definite integrals, Integration round the unit circle, Jorden's inequality, Jordan's lemma, Evaluation of integrals in which poles lie on the real axis.
Unit XIII	**Applications of Complex Integration-II** Introduction, Evaluation of integrals in which poles lie on the real axis, integral involved many valued functions.

Unit XIV	**Meromorphic Functions** Meromorphic functions, Mittag Leffler's expansion theorem, number of poles and zeroes of a meromorphic function, Principle of argument, Rouche's theorem.

Suggested Text Book Readings:

1. Ponnusamy, Foundations of Complex Analysis. 2nd Edition, Narosa Book Publication, 2008.
2. K.P. Gupta, Functions of complex variable, Sixteen Edition, Pragati Prakashan, 2002.
3. J. B. Conway, Functions of One Complex Variable, Narosa Publishing House, New Delhi, 2002.
4. Priestly, H. A.: Introduction to Complex Analysis, Oxford University Press, 2008.
5. Ahlfors, L.V.: Complex Analysis, McGraw Hill Education; 3rd Edition, 2017.
6. M. Spiegel, J. Schiller, S. Lipschutz, Schaum's Outline of Complex Variables, 2ed (Schaum's Outlines)
7. James W. Brown & R. V. Churchill: Complex variables and applications, McGraw-Hill, 2006.

Suggested online link:

1. https://epgp.inflibnet.ac.in/Home/ViewSubject?catid=ZLCHeZEhCZ8yCri36nSF3A==

This course can be opted as an elective by the students of following subjects: M.Sc. (Data Science & Analytics/Statistics)

Suggested equivalent online courses (MOOCs) for credit transfer:

https://archive.nptel.ac.in/courses/111/103/111103070/ by Prof. P. A. S. Sree Krishna IIT Guwahati

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** I	**Semester:** II
Subject: Mathematics		
Course Code: PGMM-108N/MAMM-108N	**Course Title:** Mathematical Statistics	
Course Objectives: The aim of this course is to extend the students' knowledge of statistical methods and to provide theoretical background for studying advanced statistical methods.		
CO1: The student will be able to know about fundamental concepts of statistical methods. **CO2:** The student shall understand the data collection, measures of central tendency and dispersion and apply them in various day-to day life problems. **CO3:** Ability to apply the correlation and regression techniques in engineering and science. **CO4:** The students will be able to study, correctly apply and interpret different statistical methods.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Data Collection and its Representation**
Unit I	**Data Collection and Tabulation** Meanings, Definitions and Applications of Statistics, Measurements and Scale, Measurements of qualitative data, Methods of data collection, Types of data.
Unit II	**Representation of Data- I (Diagrammatical representation)** Frequency distribution, Tabulation of data, Diagrammatical Representation of data, Bar diagram, Multiple bar diagram, Divided bar diagram, Percentage bar diagram, Pie chart, Pictogram, leaf chart.
Unit III	**Representation of Data- II (Graphical representation)** Graphical representation of frequency distribution, Histogram, Frequency polygon, Frequency curve, Ogive.
Block 2	**Measures of Central Tendency and Dispersion**
Unit IV	**Measures of Central Tendency-I** Types of measures of central tendency, Arithmetic mean, Fundamental Theorems on Arithmetic mean, Geometric mean, Harmonic mean.
Unit V	**Measures of Central Tendency-II** Median, Mode, Percentiles, Deciles, and Quartiles.
Unit VI	**Measures of Dispersion** Types of measures of Dispersion, Range, Mean Deviation, Variance and Standard deviation, Effect of change of origin and scale, Relationship between measures of central tendency and measures of dispersion, Coefficient of variation.
Block 3	**Moments, Skewness and Kurtosis**
Unit VII	**Moments, Raw Moments** Definition of moments, raw moments for ungrouped data, raw moments for grouped data.
Unit VIII	**Moments, Raw Moments and Central Moments** Central moments, Factorial moments, Interrelationship between various moments, effect of change of origin and scale on moments, Charlier's checks, Sheppard's correction for moments.
Unit IX	**Skewness and Kurtosis** Definition of skewness, Measures of skewness, Pearson's coefficient, Bowley's coefficients, Kurtosis, Measures of Kurtosis, effect of change of origin and scale.
Block 4	**Correlation and Regression**

Unit X	**Bivariate Data and Correlation** Scatter Diagram, Karl Pearson's coefficient of correlation, Properties of correlation coefficient, limits of correlation coefficient, Effect of change of origin and scale on correlation coefficient
Unit XI	**Regressions-I** Regressions, linear regression model, principal of least square.
Unit XII	**Regressions-II** Regression lines, Regression coefficient, Properties of Regression coefficients.
Unit XIII	**Correlation and Intra Class Correlation** Rank correlation coefficient, Spearman's rank correlation coefficients, rank correlation coefficient for tied ranks, Intra-class correlation, some remarks on Intra-class correlation.
Unit XIV	**Theory of Attributes** Combinations, Classes and Class frequencies of Attributes, Dichotomous Classification, Consistency of data, joint distribution of attributes, Contingency tables, Independence and Association of Attributes, Measures of Association, Yates Correction.

Suggested Text Book Readings:

1. Irwin Miller & Marylees Miller, John E. Freund's Mathematical Statistics with Applications (8^{th} edition). Pearson. Dorling Kindersley Pvt. Ltd. India, 2014.
2. Robert V. Hogg, Joseph W. McKean & Allen T. Craig, Introduction to Mathematical Statistics (7^{th} edition), Pearson Education, 2013.
3. Sheldon M. Ross, Introduction to Probability Models (11^{th} edition). Elsevier, 2014.
4. V.K. Kapoor and S. C. Gupta, Fundamental of Mathematical Statistics, S. Chand & Sons, 2018.
5. Gupta, C. B., Malik, A. K., Kumar, V., Random-Variables and Stochastic Processes, Neelkanth Publisher Jaipur, 2011.
6. Mood, A.M. and Grayville, F.: Introduction to the Theory of Statistics**,** McGraw Hill Education; 3^{rd} edition, 2017.

This course can be opted as an elective by the students of following subjects:
M.Sc. (Data Science & Analytics/Statistics)

Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** I	**Semester:** II
Subject: Mathematics		
Course Code: PGMM-109N/MAMM-109N	**Course Title:** Topology	
Course Objectives: This course puts forward some basic concepts of topology and its applications. The main emphasis on the explanations of some important concepts; metric spaces and topological spaces; to show how the theory and concepts grow naturally from idea of distance.		
Course Outcomes: **CO1:** Able to use this theory and concepts, development naturally from the idea of distance. **CO2:** To apply the metric space, pseudo and discrete metric space, and its properties. **CO3:** To know about the concepts of topological spaces and its use in solving engineering and science problems. **CO4:** To understand the sequentially compact spaces, countable compactness, compactness, and Separation Axioms in Topological Spaces.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Metric Spaces-I**
Unit I	**Elements of Set Theory** Sets, subset, index set, power set, operations on set, relations, functions, finite and infinite sets, Countable and uncountable sets.
Unit II	**Introduction to Metric Spaces** Metric space, Pseudo Metric Space, Discrete Metric Space, Bounded and Unbounded Metric Space, Usual and Quasi Metric Space, inequalities.
Unit III	**Bounded and Unbounded Metric Space** Bounded and Unbounded Metric Space, Usual and Quasi Metric Space, inequalities.
Block 1I	**Metric Spaces-II**
Unit IV	**Spaces in Metric** Sequence spaces l^{∞}, Function space, sequence space l^{p}, Hilbert sequence space l^{2}, Open and closed ball, sphere, neighbourhood of a point, limit point, equivalent Metrics.
Unit V	**Sequence in Metric Spaces** Sequence in a Metric Space, Convergent Sequence in a Metric Space, Bounded Set, Cauchy Sequence, Continuity and Homeomorphism of metric spaces, Homeomorphic Spaces.
Unit VI	**Complete Metric Spaces** Complete Metric Space, Incomplete Metric Space, Contor's Intersection theorem, Completeness of C.
Block 2	**Introduction to Topological Spaces**
Unit VII	**Topological Spaces-I** Topological Spaces, Trivial topology, Non-Trivial topologies, Comparison of Topologies, Algebra of Topologies, Open Set, Neighbourhood, Usual Topology, Limit Points, Derived Set, Closed Sets, Door Space.
Unit VIII	**Topological Spaces-II** Closure of a Set, Separated Set, Interior points and the Interior of a Set, Exterior of a Set, Boundary Points, Dense Set.
Unit IX	**Base and Sub-base** Relative Topology, Subspace, Base for a topology, Sub-bases, Local base, First Countable Space, Second Countable Space, Topologies Generated by Classes of Sets, Separable Space, Cover of a Space, Lindelof Space.

Unit X	**Continuous Maps and Homeomorphism** Continuous Function, Open Mapping, Closed Mapping, Bicontinuous Mapping, Bijective Mapping, Sequential Continuity, The pasting Lemma, Homeomorphism.
Block 3	**Separation Axioms on Topological Spaces**
Unit XI	**Separation Axioms-I** Separation axioms – T_0, T_1, T_2, T_3, $T_{3/2}$, regular space, completely regular space, their characterizations and basic properties.
Unit XII	**Separation Axioms-II** Separation axioms: normal space, completely normal space, T_4 and T_5, their characterizations and basic properties. Urysohn's lemma and Teitze Extension Theorem, Urysohn's Metrization Theorem.
Unit XIII	**Connectedness** Separated Sets, Connected Set, Disconnected Set, Connectedness on the Real Line, components, Maximal Connected Set, Locally Connected Space and Totally Disconnected Set.
Unit XIV	**Compactness** Cover, Open Cover, Compact Space, Compact Set, Finite Intersection Property, Locally Compact Space, Lindelof Space, Bolzano Weierstrass Property, Sequentially Compact, Uniformly Continuous, Lebesgue Covering Lemma, Heine-Borel Theorem, Product Topology, Projection Mappings.

Suggested Text Book Readings:

1. G. F. Simmons: Introduction to Topology and Modern Analysis, McGraw Hill, 1963.
2. Singh, S. R. & Malik, A. K. Topology Dreamtech Press, 2020.
3. James R Munkres, Topology, A first course, Prentice Hall, New Delhi, 2000
4. J. L. Kelly, Topology, Von Nostrand Reinhold Co. New York, 1995.
5. K.D. Joshi, Introduction to General Topology, Wiley Eastern Ltd.
6. J. V. Deshpande, Introduction to Topology, Tata McGraw Hill, 1988.

This course can be opted as an elective by the students of following subjects:
M.Sc. (Data Science & Analytics/Statistics)

Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: None			
Programme: M.Sc./M.A.		**Year:** I	**Semester:** III
Subject: Mathematics			
Course Code: ***PGED-02***	**Course Title:** Entrepreneurship Development		
Credits: 4		**Type of Course:** Core	
Max. Marks: 100		**Min. Passing Marks:** 36	
Unit 1	**Entrepreneurship** Introduction, Meaning, Evolution & Concept Of Entrepreneurship, Nature Of Entrepreneurship, Importance Of Entrepreneurship, Elements Of Entrepreneurship Characteristics Of Entrepreneurship, Need Of Entrepreneurship, Functions Of Entrepreneurship Types Of Entrepreneurship, Merits Of Entrepreneurship, Demerits Of Entrepreneurship, Entrepreneurship And Environment The Need Of Entrepreneurship For Indian Economy ,Introduction, Views Of Leading Thinkers, Drucker's Views On Entrepreneur Walker's Views On Entrepreneur.		
Unit 2	**Entrepreneur** Meaning, Concept, Characteristics Of An Entrepreneur Qualities Of Entrepreneur, Difference Between Entrepreneurship And Entrepreneur, Difference Between Entrepreneur, Intrapreneur And Manager, Difference Between Entrepreneurship And Intrapreneurship		
Unit 3	**Functions And Types Of Entrepreneur** Introduction, Basic Functions Of An Entrepreneur, Process To Setup An Enterprise, Difference Between Managerial Functions And Entrepreneurial Functions Of An Entrepreneur, Types Of Entrepreneurs,		
Unit 4	**Theories Of Entrepreneurship** Introduction, Economic Theories, Neoclassical Economic Theories Of Entrepreneurship , Sociological Theories Of Entrepreneurship, Psychological Theories Of Entrepreneurship, Cultural Theories Of Entrepreneurship		
Unit 5	**Entrepreneurship Development Programme:** Introduction, Evolution And Concept Of Entrepreneurship Development Programme , Meaning, Features Of Entrepreneurship Development Programme , Need Of Entrepreneurship Development Programme , Objectives Of Entrepreneurship Development Programme , Formulation Of Entrepreneurship Development Programme , Outline Of Entrepreneurship Development Programme , Achievements Of Entrepreneurship Development Programme		
Unit 6	**Entrepreneurship Development In India:** Meaning, Sustainable Entrepreneurship Development, Phases Of Entrepreneurship Development In India, Emergence Of Entrepreneurial Class In India, Locational Mobility Of Entrepreneurs, The Key Factors Influencing The Mobility Of Entrepreneurs , Entrepreneurial Performance In India, Entrepreneurship Development Cycle, Institutions For Entrepreneurship Development		
Unit 7	**Women Entrepreneurship:** Introduction, Meaning, Characteristics Of Women Entrepreneurship, Factors Affecting The Need For Women Entrepreneurship, Problems Of Women Entrepreneurs, Remedies/ Overcoming/Solutions To The Problems Of Women Entrepreneurs, Steps To Promote Women Entrepreneurs, Traits Of Successful Women, Benefits Of Women Entrepreneurship		
Unit 8	**Promotion Of Ventures:** Meaning And Concept Of Projects, Characteristics Of Project, Types Of Projects, The Boundaries Of A Project, Project Life Cycle – Stages, Success Of A Project, Implementation Of A Project, Benefits Of Project Management, Project Management, .Task Management, Difference Between Task		

	Management And Project Management , Uses Of Project Management And Task Management, Project Identification, Identification Stage Diagram, Formulation And Report, Project Appraisal, Product Selection And Technique, Criteria And Factors To Be Considered In New Product Selection Stages, Phases Involved In New Product Selection Exercise
Unit 9	**Project Management:** Introduction, Meaning And Concept Of A Project, Characteristics Of A Project, Importance Of Project Management, Tools And Techniques Of Project Management, Classification Of Project, Project Life Cycle And Its Phases, The Project Manager, Roles And Responsibilities Of Project Manager
Unit 10	**Raising Funds:** Introduction, Concept & Relevance Of Finance For The Entrepreneur, Choices Between Sources Of Financial Capital, Sources Of Funds, The Advantages And Disadvantages Of The Different Sources Of Finance, Steps In Managing Finance, Objectives Of Financial Planning For The Entrepreneur
Unit 11	**Legal Requirements For Establishment Of New Business Unit:** Introduction, Formalizing A Business Structure And Founders Agreement, . Applying For Business Licenses, Understanding Taxation And Accounting Laws. Adhering To Labour Law. Ensuring Protection Of Intellectual Property. Ensuring Effective Contract Management. Details About Winding Down The Business
Unit12	**Financial Institution's Aid To Entrepreneurs** Introduction, Assistance Of Financial Institutions To Entrepreneurs, Comprehensive Promotion Structure Of MSME Sector, Financial Institutions Supporting And Assisting Small Scale Industries (SSI) In India
Unit13	**Network Analysis** Meaning And Concept Of Network Analysis, Importance Of Network Analysis/Network Technique, Classification Of Network Techniques, Programme Evaluation And Review Technique (PERT),Procedure Followed In PERT ,Advantages Of Pert ,Limitations Of Pert ,Critical Path Method (CPM): ,Identification Of The Critical Path, Advantages Of Critical Path Method ,Limitations Of CPM ,Similarities Between Pert And CPM, Comparison Between Pert And CPM ,Differences Between PERT And CPM Financial Support System: Forms of Financial support, Long term and Short term financial support, Sources of Financial support, Development Financial Institutions, Investment Institutions
Unit14	**Marketing Assistance To Entrepreneurs** Introduction, Meaning, Types Of Markets Available To An Entrepreneur, Traditional Marketing, Entrepreneurial Marketing, Differences Between Traditional And Entrepreneurial Marketing
Unit15	**Entrepreneurship Development: Intellectual Property Rights And MSME** Introduction, IPR And MSME's, Patents ,The Patent Process, Types Of Patents, Who Can File For A Patent?, Trademarks, Types Of Trademarks, Registration Of Trademark, Copyrights ,Objectives Of Copyrights, Geographical Indications ,Industrial Designs ,Trade Secrets ,Integrated Circuits, Protection Of New Plant Variety, Need Of IPR For MSME
Unit16	**Small Business** Introduction, Meaning Of Small Business, Types Of Small Business, Nature Of Small Business, Characteristics Of Small Business Enterprises, Objectives Of Small Business, Importance Of Small Business, Process Of Establishing Small Business,
Unit 17	**Project Budgeting/Capital Budgeting** Introduction, Meaning And Definition Of Project/Capital Budgeting, Features Of Capital Budgeting, Importance And Need Of Capital Budgeting, Types Of Capital

	Expenditure, Factors Affecting Capital Investment Decisions
Unit 18	**Project Control** Introduction, Control Process, Scope Of Project Control, Techniques Of Schedule Control ,Techniques Of Cost Control
Unit 19	**Entrepreneurial Consultancy** Meaning, Entrepreneurial Consultancy: Process And Methods, Motives Or Reasons For Using Advisory Services, Approaches To Modern Ounselling, Marketing Counselling
Unit 20	**E Commerce And Entrepreneurship** Introduction, Meaning And Concept Of E-Commerce , Approaches Of E-Commerce , Relevance Of E-Commerce , Advantages Of E-Commerce, Disadvantages Of E-Commerce, Difference Between Traditional Commerce And E-Commerce
Unit 21	**Planning Of Capital Structure** Introduction, Meaning Of Capital Structure, Types Of Capital Structure, Importance Of Capital Structure, Factors Determining Capital Structure, Capital Gearing, Planning Of Capital Structure, Optimal Capital Structure, Determinants Of Capital Structure

Suggested Text Book Readings:

1. C.R. Kothari, Gaurav Garg. Research Methodology: Methods and Techniques, New Age International Publishers, 2019.
2. Kumar. R: Research Methodology: A Step-by-Step Guide for Beginners, (3rd Edition), SAGE, Inc., 2011.
3. https://onlinecourses.swayam2.ac.in/cec22_ge28/preview

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** II	**Semester:** III
Subject: Mathematics		
Course Code: PGMM-111N/MAMM-111N	**Course Title:** Advanced Differential Equations	
Course Objectives: The main objective of this course is to develop the student level to understand the use of ordinary differential equation in real-life problems.		
Course Outcomes: **CO1:** To study the power series and special function with its applications. **CO2:** The student will be able to understand the basic concepts of partial differential equation and its applications. **CO3:** Able to understand the two-dimensional Laplace equation, one-dimensional heat equation and wave equation and its applications in boundary value problems. **CO4:** Able to formulate and solve the difference equation and use of calculus of variations in science and engineering.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Ordinary Differential Equations**
Unit I	**Power Series-I** Introduction to power series method, Ordinary points, Series solutions about ordinary points.
Unit II	**Power Series-II** Introduction, Singularities, Regular and Irregular singular points, Frobenius method, Series solutions about regular singular points.
Unit III	**Legendre's Function** Introduction, Legendre's function, generating function, orthogonal properties of Legendre's function, recurrence relations, Rodrigues's formula.
Unit IV	**Bessel's Function** Introduction, Bessel's Function of first and second kind, generating function, orthogonal properties of Bessel's function, recurrence relations.
Block 2	**Partial Differential Equations of First Order**
Unit V	**Partial Differential Equations of First Order and First Degree** Introduction to Partial Differential Equations, Order and Degree of Partial Differential Equations, Derivation of Partial Differential Equations.
Unit VI	**Lagrange Method** Introduction, Standard form of Linear Partial Differential Equations of order one, Lagrange method for solving first order Partial Differential Equations.
Unit VII	**Standard Form** Introduction, Non-linear Partial Differential Equations, Standard form, Standard form-I, II, III & IV (Clairaut's form).
Unit VIII	**Charpit's Method** Introduction, Charpit's method for first order Partial Differential Equations, working procedure for solving Partial Differential Equations using Charpit's Method.
Block 3	**Partial Differential Equations of Higher Order**
Unit IX	**Partial Differential Equations of Higher Order-I** Introduction, Partial differential equations of higher order, classification of linear Partial differential equations, Separation of variable method.
Unit X	**Partial Differential Equations of Higher Order-II** Introduction, Two-dimensional Laplace equation in Cartesian coordinates, one-

	dimensional Heat equation, one-dimensional Wave equation.
Block 4	**Difference Equations and Calculus of Variations**
Unit XI	**Introduction to Difference equations** Introduction to difference equations, order and degree of difference equations, formulation of difference equations.
Unit XII	**Application of Difference Equations** Introduction, Linear difference equations, homogeneous linear difference equations with constant coefficient, non-homogeneous linear difference equations with constant coefficient.
Unit XIII	**Calculus of Variations-I** Introduction, functional, Euler's equation, equivalent forms of Euler's equation, solution of Euler's equations.
Unit XIV	**Calculus of Variations-II** Introduction, strong and weak variations, isoperimetric problems, variational problems involving several dependent variables, functional involving second order derivatives.

Suggested Text Book Readings:

1. Shepley L. Ross, Differential Equations (3rd edition), Wiley India, 2007.
2. E.A. Coddington and N. Levinson, Theory of Ordinary Differential Equations, Tata McGraw-Hill, 2016.
3. Ross. S. L., Differential Equations, 3rd Edition, Wiley, 1980.
4. Rai, B., Chaudhary, D.P. and Freedman, H.I., A Course in Ordinary Differential Equations, NarosaPublishing House, New Delhi 2013.
5. George F. Simmons, Differential Equations with Applications and Historical Notes (3rd edition). CRC Press. Taylor & Francis, 2017.

This course can be opted as an elective by the students of following subjects:
M.Sc. (Data Science & Analytics/Statistics)

Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** II	**Semester:** III
Subject: Mathematics		
Course Code: PGMM-112N/MAMM-112N	**Course Title:** Functional Analysis	
Course Objectives: The main objective of this course is to introduce the concepts of vector space, normed linear space, Banach space, Hilbert space, fixed-point theory and Housdorff space. This course lays a foundation for solving many research problems in different areas such as quantum physics and dynamical system theory.		
Course Outcomes: **CO1:** To study the different concepts of vector and normed linear space with its applications. **CO2:** The student will be able to understand the basic concepts of linear operators, linear functional on Banach and Hilbert spaces. **CO3:** Able to understand the basic tool to solve the problems of integral equations, fluid dynamics and optimization theory. **CO4:** Processing pre-requisites for pursuing research in pure and applied mathematics.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Vector Space and Normed Linear Space**
Unit I	**Vector Space** Introduction, Vector or Linear Space, linear subspace, linear combination, linear span, linear dependence and linear independence, basis, finite and infinite dimensional vector spaces, dimension of a subspace.
Unit II	**Normed Linear Space** Normed linear space, sequence of series, l^p space, l^∞ space, unit sphere, closed and open ball, subspace of a Banach space.
Unit III	**Completeness** Introduction, completeness, closeness, equivalent norms, completeness and finite dimension, compactness, Friesz's lemma.
Unit IV	**Linear Operators** Introduction, linear operators, null space, linear operator, identity operator, zero operator, inverse of a linear operator, bounded linear operator.
Unit V	**Linear Functional** Continuity and null space, linear functional, bounded linear functional, dot product, algebraic dual space, isomorphic.
Unit VI	**Hilbert Spaces** Inner product spaces, Hilbert spaces, some properties of Hilbert spaces, orthonormal sets, conjugate space and adjoint of an operator.
Block 2	**Fixed Point Theory**
Unit VII	**Banach Fixed Point** Introduction, Banach fixed point, contraction, Banach fixed point theorem, Kannon contraction theorem, Reich contraction, Hardy and Rogers's contraction theorem.
Unit VIII	**Applications of Banach Theorem-I** Applications of Banach theorem to linear equations, Applications of Banach theorem to differential equations, Picard's existence and uniqueness theorem, Applications of Banach theorem to integral equations.
Unit IX	**Applications of Banach theorem-II** Applications of Banach theorem to linear equations, Applications of Banach theorem to differential equations, Picard's existence and uniqueness theorem,

	Applications of Banach theorem to integral equations.
Unit X	**Approximation in Normed Spaces** Introduction, best approximation, polynomials, uniqueness, convexity.
Unit XI	**Housdorff Space** Introduction, distance, Housdorff metric space, Nadler's contraction theorem.
Block 3	**Applied Functional Analysis**
Unit XII	**Differentiation and Integration in normed space** Integration, Gateaux derivative, Frechet derivative, Bochner integral.
Unit XIII	**Spectral Theory of Linear Operators in Normed Space-1** Introduction, Eigen values and Eigen vectors, resolvent operators, regular value, resolvent set, spectrum.
Unit XIV	**Spectral Theory of Linear Operators in Normed Space-II** Introduction, spectral properties of bounded linear operators, holomorphic, local holomorphy.

Suggested Text Book Readings:

1. Goffan, C. and Pedrick, G.: A First course in Functional Analysis, AMS Chelsea Publishing: AnImprint of the American Mathematical Society, New York, 1983.
2. Jain, P.K. and Ahuja, O.P.: Functional Analysis, New Age (International P, Ltd,) New Delhi, 2010.
3. Kreyszig, E.: Introductory Functional Analysis with Applications, John Wiley and Sons, New York, 2007.
4. Simmons, G.F.: Introduction to Topology and Modern Analysis, McGraw Hill Book Co., New York, 2013.
5. Taylor, A.E. Introduction to Functional Analysis, John Wiley and Sons, New York, 2013.
6. Bollobas, B.: Linear Analysis, An Introductory Course, Cambridge University Press, Cambridge, 1999.
7. Berbarian, S.K.: Introduction to Hilbert Spaces, Oxford University Press, New York, 1961.
8. Fixed Point Theory Andrzej Granas Springer-Verlag, New York Volume I (see below) and the unpublished Volume II (in a major Volume) and will be appearing in the Spring of 2003.

This course can be opted as an elective by the students of following subjects: NA

Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** II	**Semester:** III
Subject: Mathematics		
Course Code: PGMM-113N/MAMM-113N	**Course Title:** Measure Theory and Integration	
Course Objectives: The objective of the course is to give an introduction to Lebesgue measure on the set of real numbers R and the concept of measure in general, indicating its role in the theory of integration.		
Course Outcomes: **CO1:** To study the basic concepts of sets, relations, functions and countability of sets. **CO2:** The student will be able to understand the concept of Lebesgue measure is used in developing the theory of Lebesgue integration, which gives better results as compared to the theory of Riemann integration. **CO3:** Understand the basic tool to solve the problems of integral equations, fluid dynamics and optimization theory. **CO4:** Able to understand the measure and integration has numerous applications in other branches of pure and applied mathematics like as probability theory, partial differential equations, and functional analysis.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Set Theory**
Unit I	**Sets** Introduction, Representation of sets, types of sets, subset, universal set, Venn diagram, operations on sets, and algebra of sets.
Unit II	**Relations** Introduction, inverse relation, representation of relations, types of relations, equivalence relation, and partial order relation.
Unit III	**Functions** Introduction, inverse function, types of functions, real valued function, identity function, constant function, composition of functions.
Unit IV	**Countability of Sets** Introduction, cardinality of a set, Schroder-Bernstein's equivalence theorem, Finite and infinite sets, countable and uncountable sets, cardinal numbers, Cantor's theorem, Continuum hypothesis, Algebraic and Transcendental numbers.
Unit V	**Advanced Set Theory** Introduction, axiom of choice, Zorn Lemma, ordinal numbers.
Unit VI	**Open and Closed Sets** Introduction, Open and closed sets, Bolzano-Weierstrass theorem.
Block 2	**Lebesgue Measure**
Unit VII	**Measure** Introduction, Length of an interval, measure of interval, Borel set, Boolean Ring, Boolean algebra, measure, Outer Measure, Carathedory's Postulates for Outer Measure.
Unit VIII	**Lebesgue Measure** Introduction, Exterior Measure, Measurable space and Measurable sets, First Fundamental Theorem, Interior Measure, Cantor's Ternary set.
Unit IX	**Measurable Functions** Introduction, Measurable function, Borel Measurability, pointwise convergence, convergence in measure, uniform convergence, F. Riesz theorem, Egoroff's theorem and Lusin's theorem.

Block 3	**Lebesgue Integral**
Unit X	**Lebesgue Integral** Introduction, Riemann Theory of Integral, Lebesgue integral, First Mean Value Theorem, Lebesgue Bounded Convergence Theorem, Fatou's Lemma, Monotone convergence Theorem, Beppo-Levi's Theorem and Lebesgue Dominated Convergence Theorem.
Unit XI	**Differentiation and Integration** Introduction, Vitali's Lemma, Function of bounded variation, Fundamental Theorem of Integral Calculus, Lebesgue point and Lebesgue set.
Unit XII	**The L^p -Space** Introduction, Conjugate number, Riesz-Holder's Inequalities, Cauchy-Schwarz's Inequality, Minkowski's Inequality, L^p -space, Convergent sequence and Cauchy sequence, Properties of L^p -spaces.
Block 4	**Signed measures and Product measures**
Unit XIII	**Signed measures** Introduction, Signed measures, Elementary properties, Hahn Decomposition theorem, Lebesgue Decomposition theorem, Radon Nikodym theorem, some important results.
Unit XIV	**Product measures** Introduction to product measures, Fubini's theorem, Tonelli's theorem.

Suggested Text Book Readings:

1. Malik, A.K., Kumar, S., Singh, S. R, Malik, S. C., Measure Theory and Integration, Dreamtech Press, 2020.
2. Barra, G de: Measure Theory and Integration, 2nd Edition, New Age International (P) Ltd., 2011.
3. Goldberg, Richard R: Real analysis, Oxford and IBH, 2012.
4. Jain, P.K. & Gupta, V.P.: Lebesgue Measure and Integration, New Age International (P) Ltd., New Delhi.
5. Rana, Inder K., An Introduction to Measure and Integration, Narosa Publishing House, 2007
6. Royden, H.L.: Real analysis, 4th Edition, Pearson, 2018.
7. Rudin, Walter, Real & Complex Analysis, McGraw Hill Education, 3rd Edition, 2017.

This course can be opted as an elective by the students of following subjects:
M.Sc. (Data Science & Analytics/Statistics)

Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** II	**Semester:** III
Subject: Mathematics		
Course Code: PGMM-114N/MAMM-114N	**Course Title:** Theory of Probability	
Course Objectives: The main aim of this course is to extend and master students' knowledge of probability theory and to provide theoretical background for studying advanced probabilistic and statistical method.		
Course Outcomes: **CO1:** To study the fundamental concepts of probability theory. **CO2:** The student will be able to understand the concept of random variable and probability distributions, expectation. **CO3:** Able to understand the discrete and continuous distribution with their applications in other branches of pure and applied mathematics. **CO4:** Understand the basic tool to solve the problems related to statistical interference and check the test of significance.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Introduction to Probability Theory**
Unit I	**Random experiments and Probability** Deterministic and random experiments, Sample space, Events, Algebra of Events, Axiomatic definition of Probability, Classical definition of Probability, Statistical definition of probability, Addition Theorem of Probability.
Unit II	**Conditional Probability** Conditional probability, Multiplicative theorem of Probability, Independent events, Partition of sample space, Baye's Theorem.
Block 2	**Probability Distributions and Expectations**
Unit III	**Random Variables and Probability Distributions** Definition and types of random variables, Cumulative distribution function and its properties, Probability Mass Function, Probability Density Function.
Unit IV	**Expectation** Definition and types of Mathematical Expectation, Moments in terms of expectation, Mathematical and Multiplication theorems of Expectation, other theorems on expectation.
Unit V	**Inequalities for Moments** Cauchy-Schwartz Inequality, Markov's inequality, Chebyshev's inequality.
Block 3	**Concept of Probability Distributions**
Unit VI	**Univariate Distributions** Bernoulli Distribution, Binomial Distribution, mean and variance of binomial distribution, Moments, Moments Generating Function, Additive and Multiplicative property, Recurrence relation for moments, Fitting of Binomial Distribution, Poisson Distribution, Poisson Distribution as a limiting case of Binomial Distribution, mean and variance of Poisson distribution, Moments, Moment Generating Function, Additive and Reproductive property, Recurrence relation for moments, fitting of Poisson Distribution.
Unit VII	**Discrete Distributions** Geometric Distribution, mean and variance, moment generating function of geometric distribution, Negative Binomial Distribution, Moment Generating Function, Mean and Variance, Recurrence formulae for negative Binomial Distribution, Poisson Distribution as a limiting case of Negative Binomial

	Distribution, Hyper Geometric Distribution, Mean and Variance, Recurrence relation for Hyper Geometric distribution.
Unit VIII	**Normal Distribution** Normal Distribution and its parameters, Standard Normal Distribution, Moments, Moments Generating Function, Area Property, properties of normal curve, Standard Scores, Advantages and Characteristics of Z Scores.
Unit IX	**Continuous Distributions** Uniform Distribution, Moment Generating Function, Distribution Function, Moments of Uniform Distribution, Exponential Distribution, Moments, Moment Generating Function, Lack of Memory Property.
Unit X	**Sampling Distribution** Sampling distribution of a statistic, Parameter, Derivation of χ^2, t, F, z distributions, Beta, Gamma, Cauchy densities.
Block 4	**Basic Principles of Statistical Inference**
Unit XI	**Estimation** Point Estimation, properties of a good estimators, Consistency, Unbiasedness, Efficiency, Sufficiency, Confidence Interval Estimation.
Unit XII	**Method of Estimation** Procedures of Estimation, Method of Moments, method of Maximum Likelihood, Method of Scoring, Properties of Estimators
Unit XIII	**Testing of Hypothesis** Statistical Hypothesis, Simple and Composite Hypothesis, Critical Region, Two kinds of Error, One-tailed and Two-tailed tests, Test of Significance, Most Powerful Test, Uniformly Most Powerful Test.
Block 4	**Test of Significance**
Unit XIV	**Exact Tests and Fisher's transformations** Tests of Significance based on Chi-Square Distribution, Tests of Significance based on t–Distribution, Tests of Significance based on F–Distribution, Tests of Significance based on Fisher's Z–Distribution.
Unit XV	**Large Sample Tests** Testing Significance of Mean, Testing Equality of Means, Testing Significance of Proportion, Testing Equality of Proportions, Testing Significance of Standard Deviation, Testing Equality of Standard Deviation.
Unit XVI	**Non-Parametric Tests** Non-Parametric Tests, Sign Test, Wilcoxon Signed- Rank Test, Mann- Whitney U-Test, Run Test.

Suggested Text Book Readings:

1. Rohatgi, V.K., Saleh, A.K. Md. Ehsanes, An Introduction to Probability and Statistics, Second Edition Wiley-Inderscience, 2008.
2. Mayer, P.L., Introductory Probability and Statistical Applications, IBH. 2nd Edition, 1970.
3. Sheldon M. Ross, Introduction to Probability Models (11th edition), Elsevier, 2014.
4. V.K. Kapoor and S. C. Gupta, Fundamental of Mathematical Statistics, S. Chand & Sons, 2018.
5. Gupta, C. B., Malik, A. K., Kumar, V., Random-Variables and Stochastic Processes, Neelkanth Publisher Jaipur, 2011.

This course can be opted as an elective by the students of following subjects:
M.Sc. (Data Science & Analytics/Statistics)

Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: Basics in Research		
Programme: M.Sc./M.A.	**Year:** II	**Semester:** III
Subject: Statistics		
Course Code: ***PGRT-03***	**Course Title:** ***Basics Research Tools***	
Course Objectives: The main objective of this course is to develop a research orientation among the scholars and toacquaint them with fundamentals of basic computer tools,research tools, indexing of research paper and scientific report writing.		
Course Outcomes: **CO1:** To know about the research tools and indexing of a research paper. **CO2:**To know about the fundamentals of basic computer tools and how to use it in research. **CO3:** Able to know the writing the research paper and scientific report writing.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Introduction**
Unit 1	**MEASURES OF CENTRAL TENDENCY MEASURES:** Introduction, Definition. Objectives of Average .Characteristics of Good Average . Types of Average. Arithmetic Mean. Weighted Arithmetic Average .Median .Mode .Geometric Mean .Harmonic Mean
Unit 2	**MEASURES OF DISPERSION:** Introduction. Definition .Objectives of Measuring Dispersion. Different Measures of Dispersion. Range .Standard Deviation .**Lorenz Curve .** Skewness . Kurtosis
Block 2	**PROBABILITY**
Unit 3	**PROBABILITY – 1:** Introduction . **Meaning and Definition of Probability. Probability Defined.** Experiment. Sample Space (S). Event. Types of events in probability. Probability Measure. Probability Rules**:. Probability Theorems. Addition Theorem. Multiplication Theorem**
Unit 4	**PROBABILITY 2:** Conditional Theory. Key Concepts of conditional theory. Applications of conditional theory . Bayes' Theorem. Application of Bayes' Theorem. . Theoratical distribution . Uses of Theoretical Distributions. Types of Theoretical Distributions. Benefits Of Theoretical Distributions. Introduction. Binomial Distribution in Statistics . What Is The Binomial Distribution Formula?. Assumption For Binomial Distribution . Common Applications of Binomial Distribution. Poisson Distribution. Key Characteristics of Poisson distribution. Probability Mass Function (PMF). Applications of Poisson distribution. Assumptions of Poisson distribution. Common Uses of Poisson distribution. How to Solve Problems of Poisson distribution?
Unit 5	**PROBABILITY 3:** Introduction;. Binomial Distribution in Statistics . What Is The Binomial Distribution Formula?. Assumption For Binomial Distribution . Common Applications of Binomial Distribution. Poisson Distribution, Key Characteristics of Poisson distribution, Probability Mass Function (PMF), Applications of Poisson distribution, Assumptions of Poisson distribution, Common Uses of Poisson distribution, How to Solve Problems of Poisson distribution?, Introduction, Key Characteristics of Normal Distribution, Properties of Normal Distribution, Application of Normal Distribution, Types of Normal Distribution
Block 3	**SAMPLING**
Unit 6	**SAMPLING:** Introduction: Meaning of Sampling, Need of Sampling, Advantages of Sampling, Limitations of Sampling

Unit 7	**SAMPLING METHODS OF DATA COLLECTION:** Sampling, Data Collection, **Methods For Collecting Statistical Data ,** Types Of Data, Primary And Secondary Data, **Primary Data, Secondary Data**
Unit 8	**SAMPLING DISTRIBUTION:** Probability and Non-Probability Sampling, Sampling Techniques, Probability or Random Sampling, Simple Random Sampling, Stratified Sampling , Systematic Sampling , Cluster Sampling, Area Sampling, Probability-proportional-to-size sampling, Double Sampling and Multiphase Sampling, Non-probability or Non Random Sampling, Quota sampling, Convenience or Accidental sampling, Purposive (or judgment) Sampling, Snow-ball Sampling
Unit 9	**SOURCES OF DATA COLLECTION:** Introduction: Meaning and Importance of Data, Primary Sources of Data, Advantages of Primary Data, Disadvantages of Primary Data, Methods of Collecting Primary Data, Secondary Sources of Data, Features and Uses of Secondary Data, Advantages of Secondary Data, Disadvantages of Secondary Data, Methods of Collecting Secondary Data, Difference between Primary Data and Secondary Data, Questionnaire and Schedule Construction, Basic Rules for Questionnaire Item Construction
Block 4	**STATISTICAL INVESTIGATION AND ESTIMATION**
Unit 10	**STATISTICAL ESTIMATION:** Introduction, Point estimation , Types of point estimators , Properties of point estimator, Point estimation methods , Advantages of Point estimation:, Disadvantages of Point estimation , Errors in Point Estimation, Uses of Point Estimation , Interval estimation Types of Interval estimation, Properties of Interval estimation, Interval estimation methods , Advantages of Interval estimation, Disadvantages of Interval estimation, Errors in Interval estimation, Uses of Interval estimation
Unit 11	**SAMPLING TEST:** Introductions , Types of Sampling , Sampling Methods, Sampling Test Statistics: Hypothesis Testing:, Common Sampling Tests, Large sample, Benefits of Large sample, Limitation of Large Sample , Test for large sample , Some specific tests for large samples include , Small Sample , Benefits of Small Sample, Limitations of Small Sample, Types of Small Sample , Test For Small Sample
Unit 12	**HYPOTHESIS TESTING:** Introduction or Conceptual Framework of Hypothesis, Uses of Hypothesis, Scientific Hypothesis, Measures of Hypothesis, Statistical Hypothesis testing, Hypothesis Error
Unit 13	NON **PARAMETRIC TEST:** Non parametric test, Wilcoxon rank-sum test (Mann-Whitney U test), The Wilcoxon signed-rank test, The Kruskal-Wallis H test, Spearman's rank correlation, Chi-square test
Block 5	**Statistical Tools**
Unit 14	**CORRELATION AND REGRESSION:** Introduction, Definitions, Types of Correlation, Methods of Determining Correlation, Calculation of Coefficient of Correlation, Rank Correlation, Regression, Utility of Regression, Methods of Studying Regression, Regression Equation, Comparison of Correlation and Regression
Unit 15	**STATISTICAL QUALITY CONTROL (SQC):** Introduction, Key components of SQC, Benefits of SQC, Uses of SQC, Limitations of Statistical Quality Control, Functions of Statistical Quality Control
Unit 16	**CONSTRUCTION OF CONTROL CHARTS:** Introduction to Control Charts, Key Components of a Control Chart,How Control Charts Work, Types of Control Charts, Construction of Control Charts, Formula to calculate control chart,Control Chart Constants
Unit 17	**CHI SQUARE TEST**: Introduction, Chi-Square as Non-Parametric Test, Test of Goodness of Fit

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** II	**Semester:** IV
Subject: Mathematics		
Course Code: PGMM-116N/MAMM-116N	**Course Title:** Operations Research	
Course Objectives: The main objective of the course is to presents the theory and techniques of solving operations research problems in linear programming, inventory, simulation, queuing and reliability theory.		
Course Outcomes: **CO1:** To solve the linear programming problem with revised simplex method, which is very useful for in given problem having large number of variables or constrains involved. **CO2:** To have deep insight in solving linear programming problem with duality and sensitivity analysis of the linear programming problem. **CO3:** The formulation and solving of applications of operations research like as sequencing, project scheduling, simulation and reliability theory. **CO4:** Able to know the inventory, queuing and replacement models with their real life applications.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Introduction to Operations Research**
Unit I	**History of Operations Research** Introduction, Historical development, Scope and phases of Operation Research, applications of operations research.
Unit II	**Simplex method** Introduction, Simplex method, Computational procedure for solving linear programming problem by Simplex method.
Unit III	**Big-M and Two-Phase Method** Introduction, Big-M method, Two-Phase method, Difference between Big-M method and Two-Phase method.
Block 2	**Revised Simplex Method and Sensitivity Analysis**
Unit IV	**Revised Simplex method** Introduction, Revised Simplex method, Computational procedure for solving linear programming problem by Revised Simplex method.
Unit V	**Duality in Linear Programming Problem** Introduction, Symmetric form, dual of linear programming problem, primal dual relationship, fundamental theorem of duality, Dual Simplex method.
Unit VI	**Sensitivity Analysis** Introduction, Sensitivity analysis, Change in c_{ij}'s (the coefficients of x_{ij}'s in the objective function), Change in b_{ij}'s (the right hand side of constraints), Change in a_{ij}'s (the columns of coefficient matrix, deletion and addition of constraints, deletion and addition of decision variables.
Block 2	**Applications of Operations Research**
Unit VII	**Sequencing** Introduction, sequencing, Johnson's algorithm for processing n jobs through two machines, Johnson's algorithm for processing n jobs through k machines, processing two jobs through k machines.
Unit VIII	**Project Scheduling-I** Introduction, network, project development, network, activity, event, Fulkerson's rule for numbering events.
Unit IX	**Project Scheduling-II**

	Introduction, program evaluation and review techniques, optimum scheduling by critical path method, time-cost optimization algorithm.
Unit X	**Simulation** Introduction, random numbers and pseudo random numbers, Monte Carlo simulation, applications of simulation.
Unit XI	**Reliability Theory** Introduction, basic concept of reliability, Hazard rate function, system reliability: series and parallel, redundancy, reliability of preventive maintenance.
Block 3	**Models in Operations Research**
Unit XII	**Inventory Models** Introduction, inventory, inventory control, inventory costs, economics order quantity, deterministic inventory models with shortages.
Unit XIII	**Queuing Models** Introduction, markovian queues, probability distribution of n arrivals, distribution of inter-arrivals time, birth and death process.
Unit XIV	**Replacement Models** Introduction, replacement policy model, replacement policy when the value of money does not change with time, replacement policy when the value of money changes with time.

Suggested Text Book Readings:

1. Yadav, S. R. and Malik, A. K., Operations Research, Oxford University Press, 2014.
2. Malik, A. K, Yadav, S. K. and Yadav, S. R. and., Optimization Techniques, Dreamtech Press, 2020.
3. Taha, H. A. Operation Research: An Introduction. 9 th edition, Pearson, 2010.
4. Gupta, P.K. and Hira, D.S. Introduction to Operations Research, S. Chand & Co. 2008.
5. Hardy, G.: Nonlinear and Dynamic Programming (4^{th} edition), Addison-Wesley, Reading Mass, 1974.
6. Sharma, J. K., Mathematical Model in Operation Research, Tata McGraw Hill, 1989.
7. Swarup, K., Gupta, P.K. and Mohan Man: Operations Research (9^{th} Edition), S.Chand and Sons, NewDelhi, 2002.
8. Frederick S. Hillier & Gerald J. Lieberman (2015). Introduction to Operations Research (10th edition). McGraw-Hill Education.

This course can be opted as an elective by the students of following subjects:
MBA/M.Sc. (Data Science & Analytics/Statistics)

Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** II	**Semester**: IV
Subject: Mathematics		
Course Code: PGMM-117N/MAMM-117N	**Course Title:** Fluid Dynamics	
Course Objectives: The main aim of this course is to develop the fundamental knowledge and understanding of the mechanics of fluid at rest and in motion to develop the ability to demonstrate and formulate the physical problems encountered in different branches of engineering in mathematical form and arrive at useful solutions.		
Course Outcomes: **CO1:** Able to understand and apply the basic concepts of fluid mechanics. **CO2:** To convert the physical laws of conservation of mass, momentum, moment of momentum and energy into mathematical equations and apply them to describe the fluid motion. **CO3:** To describe the motion of ideal and real fluids with different techniques including complex variable technique. **CO4:** Able to know and apply the basic flow equations, such as the Navier-Stokes equations to evaluate velocity, pressure drop in simple geometries like laminar flows between parallel plates, axial and transverse flows in pipes and flows in annular region produced.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Motion in One Dimension**
Unit I	**Kinematic (Equations of Motion)** Introduction, Hydrodynamics, Shearing stress, Viscosity, Lagrangian method, Eulerian method, Local and Individual time rates of change, Acceleration, Kinds of motion, Definition of some curves , Stream line ,Path line, Streak line, Velocity potential, Vorticity vector, Beltrami flow.
Unit II	**Kinematic of Fluid in Motion** Introduction, Boundary surface, Lagrangian and Eulerian Equation of continuity, Equation of Continuity in different co-ordinates, Symmetrical forms of the equation of continuity.
Unit III	**Equation of Motion** Introduction, Equation of motion, Pressure equation, Lagrangian equation of motion, Bernoulli`s equation of motion.
Unit IV	**Equation of Motion of Inviscid Fluid** Introduction, Helmholtz vorticity equation, Cauchy`s integrals, Equations for impulsive action, Kelvin`s circulation theorem, Equation of energy.
Block 2	**Motion in Two Dimension**
Unit V	**Source, Sink & Doublets (I)** Introduction, Motion in two dimension, Lagrange`s stream function, Irrotational motion in two dimensions, Complex potential, Definition of Source, sinks, doublets, Complex potential due to a source, Complex potential due to doublet.
Unit VI	**Source, Sink & Doublets (II)** Introduction, Image w.r.t straight line, Images w.r.t. to circle, Circle theorem of Milne –Thomson, Blasius Theorem.
Unit VII	**Motion of Sphere** Introduction, Equation of continuity, ϕ for the motion of a sphere with velocity U in a liquid, liquid streaming past a fixed sphere, Equation of sphere.
Unit VIII	**Motion of Cylinder**

	Introduction, General motion of a cylinder, Kinetic energy, motion of circular cylinder, liquid streaming past a fixed circular cylinder.
Unit IX	**Motion of Elliptic & Parabolic Cylinder** Introduction, Elliptic co-ordinate, Motion of an elliptic cylinder, liquid streaming past a fixed elliptic cylinder, Motion of a parabolic cylinder, liquid streaming past a fixed parabolic cylinder.
Block 3	**Applications of Fluid Dynamics**
Unit X	**The Navier Stokes Equations** Introduction, The Navier-stokes equation of motion of a viscous fluid(Fundamental equation of motion).
Unit XI	**The Energy Equation** Introduction, The energy equation- conservation of energy, Equation of state for perfect fluid, Diffusion of vorticity, equation for vorticity and circulation, Dissipation of energy, Dissipation of energy in Cartesian form.
Unit XII	**Elementary Notions of Fluid Flow** Introduction, Body forces and surface forces, Nature of stresses, Transformation of stress components, Stress invariants, Principal stresses, Nature of strains, Rates of strain components, Relation between stress and rate of strain components, General displacement of a fluid element, Newton's law of viscosity, Navier- Stokes equation (sketch of proof).
Unit XIII	**Normal and Oblique Shock** Introduction, Normal and oblique shocks. Plane Poiseuille and Couette flows between two parallel plates.
Unit XIV	**Dynamical similarity, Inspection analysis and dimensional analysis** Introduction, Unsteady flow over a flat plate, Reynold's number.

Suggested Text Book Readings:

1. O'Neil, M. E., and Chorlton, F. Ideal and Incompressible Fluid Dynamics. John Wiley & Sons, 1986.
2. Kundu, P. K., Cohen, I. M. and Dowling, R. David. Fluid Mechanics, 6th edition, Academic Press, 2015.
3. Raisinghania, M.D.: Fluid Dynamics: with Complete Hydrodynamics and Boundary Layer Theory, S. ChandPublishing, 2014
4. Yuan, S. W. Foundations of Fluid Mechanics. Prentice Hall of India Private Limited, New Delhi, 1976.
5. Betchelor, G.K. An Introduction of Fluid Mechanics, Oxford University Books, NewDelhi, 2000.
6. Besaint, W.H. and Ramsey, A. S. A Treatise on Hydromechanics, Part II. CBS Publishers, Delhi, 1988.
7. Curle, N. and Davies, H. J. Modern Fluid Dynamics. Vol 1, D Van Nostrand Company Ltd, London, 1968.

This course can be opted as an elective by the students of following subjects: NA
Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year: I**I	**Semester:** IV
Subject: Mathematics		
Course Code: PGMM-122N/MAMM-122N	**Course Title:** Dissertation with viva-voce	
Course Objectives: In the last semester of Masters the main objectives of the exposure of students towards project/dissertation is to elevate their understanding into the applications areas of Mathematics. This course will develop their analytical ability, will provide them an apt exposure to work in any research group, and will motivate them to execute research in the area of their interest in Mathematical sciences.		
Course Outcomes: **CO1:** Students will be able to plan and strategize a scientific problem, and implement it within a reasonable time frame. **CO2:** It is expected that after completing this project dissertation, students will learn to work independently and how to keep accurate/readable record of assigned project. **CO3:** In addition, students will be able to know the library search and handle the data in a meaningful way. Also, the students will be able to interpret the spectral data independently. **CO4:** Subsequently, the students should be able to critically examine research articles, and improve their scientific writing/communication skills and power point presentation.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	
Unit I	For project work and dissertation, the area of the work to be decided by the advisor/mentor. On completion of the project work, students have to submit the work in the form of a dissertation followed by oral presentation in the presence of faculty members of the School in the University Campus Prayagraj.	
Suggested Text Book Readings: 1. Use different searching engine to get relevant information (Google scholar, Wiki-databases, Science Direct, SciFinder, Scopus, and YouTube. 2. Access to different online research library and research portal (Web resources, E-journals, journal access, TOC alerts)		
This course can be opted as an elective by the students of following subjects: Open for all		
Suggested equivalent online courses (MOOCs) for credit transfer: NA		

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** II	**Semester:** IV
Subject: Mathematics		
Course Code: PGMM-118N/MAMM-118N	**Course Title:** Soft Computing	
Course Objectives: The aim is to equip students with some state-of-the-art artificial intelligence and soft computing technology to prepare them in a better way for the rapidly evolving high-tech information-based modern industry and market.		
Course Outcomes: **CO1:** The students will be able to know about the concepts of artificial intelligence and implement it. **CO2:** This theory provides an excellent tool to handle the vagueness in modern science and technology problems such as optimization techniques, computer science, statistics, economics and medical science. **CO3:** Able to know and apply the fuzzy theory, neural network and genetic algorithm in solving applications of real life situations. **CO4:** On the basis of this theory many real-life based problems can be solved such as robotics, industrial, management etc.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Artificial Intelligence & Soft Computing**
Unit I	**Introduction of Artificial Intelligence** Definitions, Theoretical background, AI problem domain, General AI techniques, Underlying assumptions, possible goal of AI, Criteria of success. Problem state, state space, search space, State space representation, Production system, control strategy, water jug problem, 8-puzzle problem, Heuristic searching.
Unit II	**Knowledge Representation Model** First order predicate logic, clauses, inference, rule base system, natural deduction and resolution, monotonic reasoning.
Unit III	**Non-Monotonic Reasoning** Uncertainty, Bay's theorem, Bayesian network, dependency network, limitation of probabilistic reasoning, Soft computing definition, soft computing paradigm, applications, Pattern recognition, pattern classification, association and mapping.
Block 2	**Fuzzy Set Theory**
Unit IV	**Introduction of Fuzzy Logic** Uncertainty, Fuzzy set, Crisp vs. fuzzy sets, Membership function, Fuzzy sets and operations, Operations and relations; fuzzy relations, cardinalities, membership functions.
Unit V	**Fuzzy Relations** Fuzzy Cartesian product, fuzzy membership function formulation and parameterization, Fuzzy rules and reasoning, Formulation on fuzzy rules, extension principle and nested fuzzy relations.
Unit VI	**Fuzzy Rule Base System** Fuzzy if-then rules, fuzzy inference, Fuzzy inference system, Defuzzification methods, Fuzzy control systems, and Applications of Fuzzy control systems.
Block 3	**Neural Network**
Unit VII	**Introduction of Neural Networks** Limitations of Rule based system, characteristics of neural networks, simple structure of biological neuron and modeling of artificial neuron. Difference between ANN and biological neural networks, artificial neuron models, artificial neural networks terminology, topology of ANN, Characteristics of ANN and its applications.

Unit VIII	**Activation and Synaptic Dynamics** Basic learning laws, Artificial neural network architectures, Basic artificial neural network models, perceptron architecture, Perceptron learning rule, ADLINE architecture, LMS learning rule, Linear classifier, convergence theorem, limitation of perceptron learning, Multi-layer perceptron architecture.
Unit IX	**Pattern Mapping Network** Multilayer feed forward neural network architecture, Generalized delta learning rule, Backpropagation learning algorithm and issues, limitation of Backpropagation learning rule, improvement in BP algorithms, momentum term, conjugate descent, reuse gradient, generalization and approximation, ill posing, Radial basis network.
Block-4	**Genetic Algorithm**
Unit X	**Introduction of Genetic Algorithm** Fundamental and basic concepts, terminology, Applications and advantages, Representation of chromosomes and gens, Population representation, working principle, search space, solution state, global vs local optimization, encoding methods.
Unit XI	**Population Representation** Selection criteria and methods, fitness evaluation function, reproduction, basic genetic operators, Mutation, selection, crossover. Fitness criteria, convergence of GA, combinatorial optimization.
Unit XII	**Problem Solution and Genetic Modeling**, Inheritance operator, crossover operator and its various forms, inversion & deletion, mutation operator, bitwise operator, Generation cycle, Differences & similarities between GA & other traditional method.

Suggested Text Book Readings:

1. Dubosis Didler and Prade, Henri, Fuzzy Sets and systems Theory and Applications, Academioc Press, NewYork, 1980
2. Klir . Georage. J and Yuan Bo, Fuzzy Sets and Fuzzy Logic: Theory and Applications, Prentice Hall of India, New Delhi. 2009
3. Lee, Kwang H., First Course on Fuzzy Theory and Applications, Springer International Edition, 2009.
4. Ross, Timothy J., Fuzzy Logic with Engineering Applications, McGraw Hills inc., 2004 New Delhi
5. Roger, Jyh-Shing; Sun, Chuen-Tsai; Mizutani, Eiji, Neuro-fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence, MATLAB curriculum series, illustrated, reprint, Prentice Hall, 1997
6. Zimmermann,H.J. Fuzzy Set Theory & its Applications, Allied Publishers Ltd. New Delhi, 2006.
7. Bart Kosko, Neural Network and Fuzzy Systems- Prentice Hall, Inc., Englewood Cliffs, 1992.
8. Simon Haykin, Neural Network- A Comprehensive Foundation- Prentice Hall International, Inc.1998.
9. Sivanandam, S.N., Deepa, S. N., Introduction to Genetic Algorithms, Springer India, 2013.

This course can be opted as an elective by the students of following subjects:
MCA/M.Sc. (Data Science & Analytics)

Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** II	**Semester:** IV
Subject: Mathematics		
Course Code: PGMM-119N	**Course Title:** Number Theory and Cryptography	
Course Objectives: The main aim of the course is to provide the knowledge of number theory and cryptography and how to apply them in solving real life problems.		
Course Outcomes: **CO1:** The student will be able to understand about the basics concept of number theory. **CO2:** The student shall understand the importance and applications of the Fermat's little theorem and Wilson's theorem. **CO3:** The student will get to know about Riemann Zeta Function and Algebraic Number Theory. **CO4:** The student shall understand the Secret key cryptography and Public key cryptography.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Introduction to Number Theory**
Unit I	**Divisibility** Introduction, Definition of divisibility, the division algorithm, Greatest common divisor, Euclidean algorithm in Z, Diophantine equation ax + by = C, Primes and their distribution, Fundamental Theorem of Arithmetic.
Unit II	**Congruence's** Introduction, Congruence's, Properties of Congruence's, linear congruence's, Special divisibility tests, Fermat's factorization method, Fermat's little theorem, Wilson's theorem.
Unit III	**Theoretical Function-I** Introduction, Definition and properties of the Dirichlet's product, Arithmetic and Number theoretic functions, functions τ and σ.
Unit IV	**Theoretical Function-II** Introduction, Mobius Inversion formula, greatest integer function, Euler's Generalization of Fermat's theorem Euler's $\phi(n)$ function, Euler's theorem, properties of $\phi(n)$ function.
Unit V	**Primitives** Introduction, Primitive roots, the order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots, the theory of Indices.
Block 2	**Fermat Numbers**
Unit VI	**Fermat numbers and Mersenne numbers** Introduction, Primes in certain arithmetical progressions, Fermat numbers and Mersenne numbers, System of linear congruence's Chinese Remainder Theorem, Congruence to prime power modulus.
Unit VII	**Quadratic residue and non-residue** Introduction, Legendre's Symbol, Gauss Lemma and its applications, Quadratic Law of Reciprocity Jacobi's Symbol, arithmetic in Zp, group Un, Primitive roots, group Upn (p-odd) and U_2n, existence of primitive roots, group of quadratic residue, Quadratic residue for prime power modulii and arbitrary modulii.
Unit VIII	**Riemann Zeta Function** Introduction, Riemann Zeta Function $\xi(s)$ and its convergence, Application to prime numbers, ξ (s) as Euler's product, Evaluation of $\xi(2)$ and $\xi(2k)$, Dirichlet's series with simple properties, Dirichlet's series as analytic function and its derivative, Euler's products, Introduction to modular forms.

Block 3	**Algebraic Number Theory**
Unit IX	**Diophantine equations** Introduction, Diophantine equations, $x^2 + y^2 = z^2$ and $x^4 + y^4 = z^4$, representation of number by two or four squares, Waring's problem, Four square theorem, number g(k) & G(k), Lower bounds for g(k) & G(k).
Unit X	**Algebraic number and Integers** Introduction, Gaussian integers and its properties, Primes and fundamental theorem in the ring of Gaussian integers, Integers and fundamental theorem in $Q(\omega)$ where ω is third root of unity, algebraic fields.
Unit XI	**Primitive Polynomials** Introduction, Primitive polynomials, general quadratic field $Q(\sqrt{m})$, Units of $Q(\sqrt{2})$, Fields in which fundamental theorem is false, Real and complex Euclidean fields, Fermat's theorem in the ring of Gaussian integers, Primes of Q(2) and Q(5), Luca's test for the primality of the Mersenne number.
Block 4	**Cryptography**
Unit XII	**Public Key Cryptography** Introduction, Public-Key Cryptography Principles, RSA, Key Management: Diffi-Hellman key exchange.
Unit XIII	**Message Authentication and Hash Functions** Introduction, Authentication requirements, Authentication Functions, Message Authentication codes, Hash Functions, SHA-1 and MD5.
Unit XIV	**Digital Signatures** Introduction, Digital signatures, Authentication protocols, Digital Signature standard.

Suggested Text Book Readings:

1. Burton, D. M. Elementary Number Theory. Tata McGraw Hill Publishing House, 2006.
2. Apostol, T. M. Introduction to Analytic Number Theory. Springer 2014.
3. Davenport, H. Higher Arithmetic. Cambridge University Press, 1999.
4. Hardy, G. H. and Wright, E. M. Theory of Numbers. Oxford Science Publications, 2003.
5. Niven, I. and Zuckerman, H. S. Introduction to the Theory of Numbers. John Wiley & Sons, 2008.

This course can be opted as an elective by the students of following subjects:
MCA/M.Sc. (Data Science & Analytics)

Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** II	**Semester:** IV
Subject: Mathematics		
Course Code: PGMM-120N/MAMM-120N	**Course Title:** Machine Learning Techniques	
Course Objectives: The aim is to equip students with some state-of-the-art machine learning techniques to prepare them in a better way for the rapidly evolving high-tech information-based modern industry and market.		
Course Outcomes: **CO1:** The students will be able to know about the concepts of machine learning techniques and implement it. **CO2:** This theory provides an excellent tool to handle the vagueness in modern science and technology problems such as optimization techniques, computer science, statistics, economics and medical science. **CO3:** Able to know and solve many research problems and real-world problems by using machine-learning techniques. **CO4:** This course has high rate of employability due to its great applicability in engineering.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	
Block 1	**Artificial Intelligence & Soft Computing**	
Unit I	**Introduction** What is machine learning; Types of learning, Problems, Definition of learning systems. Goals and applications of machine learning. Aspects of developing a learning system: training data, concept representation, function approximation.	
Unit II	**Computational Learning Theory** Data, probably approximately correct (PAC) learning model, Probabilistic Data Model, Loss Function and Expected Risk, Stability, Overfitting, Regularization, Bias variance, Cross validation, Nearest centroid, Least squares. Computational complexity.	
Unit III	**Memory based methods** Nearest neighbour, k-nearest neighbours, Feature maps, Representer theorem, Kernels, Hypothesis space, Loss function, Target function.	
Unit IV	**Regression** Introduction to regression, usage of regression, types of regression, linear regression, multi-linear regression, Logistic regression, Polynomial regression, Ridge and Lasso regression, Evaluation of regression.	
Unit V	**Classification** Introduction to classification, Multi-class classification, Decision boundaries; Probability and classification, Bayes optimal decisions, Naive Bayes and Gaussian class-conditional distribution, Linear classifiers, Bayes' Rule and Naive Bayes Model, Gradient descent.	
Unit VI	**Decision Tree Learning** Representing concepts as decision trees, Recursive induction of decision trees, Picking the best splitting attribute: entropy and information gain, Searching for simple trees and computational complexity, Overfitting, noisy data, and pruning.	
Unit VII	**Ensemble Learning** Standard ensemble learning strategies, Bagging, Boosting, Stacking, Decorate, Active learning with ensembles, Boosting: Concept of boosting, weak learnability, AdaBoost, AdaBoost for classification, Model selection, Validation, Train-validation split, Regularization, Stability.	

Unit VIII	**Bagging and Random Forest** Bagging for classification, Issues with Bagging, Introduction to Random forest, Bagging vs. Random Forest, Out-of-Bag (OOB) error estimation, Variable importance measures, Majority voting, Soft Majority Voting, Random Forest Algorithm, Tuning random forest, Random forest issues.
Unit IX	**Support Vector Machines** Support vectors, Hyperplane, Kernel for learning non-linear functions, Different types of kernels, Parameter tuning, Generative vs. discriminative training, Multi-class support vector machine (SVM), SVM for classification, Support vector for regression.
Unit X	**Clustering and Unsupervised Learning** Learning from unclassified data. Clustering. Hierarchical Aglomerative clustering, k-means clustering, partitional clustering, Expectation maximization (EM) for soft clustering, Semi-supervised learning with EM using labeled and unlabled data.
Unit XI	**Language Learning** Classification problems in language: word-sense disambiguation, sequence labeling. Hidden Markov models (HMM's). Veterbi algorithm for determining most-probable state sequences. Forward-backward EM algorithm for training the parameters of HMM's. Use of HMM's for speech recognition, part-of-speech tagging, and information extraction.
Unit XII	**Programming Languages for Machine Learning** Python Ecosystem for Machine Learning: Python, SciPy, scikit-learn, Python Ecosystem Installation. Crash Course in Python: Assignment, Flow Control, Data Structures. NumPy Crash Course: Create Array, Access Data, and Arithmetic. Matplotlib Crash Course: Line Plot, Scatter Plot. Pandas Crash Course: Series, Data Frame.

Suggested Text Book Readings:

1. Goldberg D.E., Genetic Algorithms in Search, Optimization, and Machine Learning, Addison Wesley, 1989.
2. Deisenroth, M. P., Faisal, A, A, Ong, C. S., Mathematics for Machine Learning, Cambridge University Press, 2020
3. Shing, Jyh., Jang Roger, Mizutani Eiji., Sun, Chuen-Tsai, Neuro-fuzzy and Soft Computing: A Computational, Prentice Hall, Inc., 2007
4. Miroslav Kubat, An Introduction to Machine Learning, Springer International Publishing AG, 2016.
5. Roger, Jyh-Shing; Sun, Chuen-Tsai; Mizutani, Eiji, Neuro-fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence, *MATLAB curriculum series*, illustrated, reprint, Prentice Hall,1997
6. Zimmermann, H.J. Fuzzy Set Theory & its Applications, Allied Publishers Ltd. New Delhi, 2006.

This course can be opted as an elective by the students of following subjects:
MCA/M.Sc. (Data Science & Analytics)

Suggested equivalent online courses (MOOCs) for credit transfer: NA

Course prerequisites: To study this course, a student must have qualified graduation with Mathematics.		
Programme: M.Sc.	**Year:** II	**Semester:** IV
Subject: Mathematics		
Course Code: PGMM-121N/MAMM-121N	**Course Title:** Vedic Mathematics	
Course Objectives: The aim of this course is to develop fast mathematical thinking and enhance computational abilities.		
Course Outcomes: **CO1:** The students will be able to know about the concepts of Vedic mathematics and use it. **CO2:** This theory is provide in order to speed up calculations in internet security and cryptographic algorithms, Vedic mathematics division, exponentiation, and multiplication are being used. **CO3:** Able to know the arithmetic and logic unit in a computer handles all aspects of logical and mathematical calculations. Various sutras including udharvtriyakbhyam and nikhilam are used for multiplication methods. **CO4:** Students will be able to utilize Vedic sutras to enhance their skills for competitive exams and able to solve examinations more efficiently.		
Credits: 4	**Type of Course:** Core	
Max. Marks: 100	**Min. Passing Marks:** 36	

Block 1	**Indian Mathematicians and their contributions**
Unit I	**Contribution of the Indian Mathematicians-I** (1) Baudhayana (2) Aryabhata (3) Varahmihir
Unit II	**Contribution of the Indian Mathematicians-II** (1) Bhaskaracharya-II (2) Srinivas Ramanujan (3) Bharti Krishna Tirtha.
Block 2	**Vedic Arithmetic**
Unit III	**Basic Vedic Mathematics** Introduction, Vedic Mathematics Sutra and Subsutra with explanation.
Unit IV	**Introduction of Vedic Mathematics** Introduction, Sankalan, Vyavkalan, Friend and Fast Friend, Complements, Beejank, Deviation Methods.
Unit V	**Simple Calculation on Vedic Mathematics** Introduction, Forward Counting, Backward Counting, Addition, Subtraction, Vinculum, Tables Writing, Introduction to Meruprastara.
Unit VI	**Multiplication in Vedic Mathematics** Introduction, Multiplication by Vedic Sutras (ekadhikenpurvena, vertically and crosswise etc.).
Unit VII	**Division in Vedic Mathematics** Introduction, Division by Vedic Sutras, Flag Method, Test of Divisibility.
Unit VIII	**Squaring and Cubing Method** Introduction, Square of Numbers and Square roots of perfect square numbers. Cubing: Cube of Numbers and Cube roots of perfect cube numbers, mixed operation.
Block 3	**Vedic Algebra**
Unit IX	**Introduction to Vedic Algebra** Introduction, Addition, Subtraction, Multiplication, Division of Algebraic Expression, Mixed operations in Vedic algebra.
Unit X	**Introduction to Partial Fractions** Introduction, LCM, HCF of algebraic expressions, Partial Fractions.

Unit XI	**Solution of Algebraic Equations** Introduction, Solution of linear, quadratic, cubic equations.
Block 4	**Vedic Geometry, Trigonometry and Calculus**
Unit XII	**Baudhayana Numbers** Introduction, Baudhayana triplet of angle, multiplication of triplet by constant, triplet of compliment angle, triplet of the sum and difference of angles. Baudhayana Numbers and its application to find trigonometrical ratios and identities.
Unit XIII	**Vedic Co-ordinate Geometry** Introduction, Baudhayana form of Co-ordinate, Introduction of line and its Baudhayana form, angle between two lines, perpendicular distance from points to line.
Unit XIV	**Introduction of Vedic Mathematics in Calculus** Introduction of Differentiation and Integration, derivative of sum and product, applications in derivative, integration by parts, integration using partial fractions.

Suggested Text Book Readings:

1. Bharti Krishna Trith Ji "Vedic Ganit" Moti Lal Banarasi Das , Delhi, India, 1991,First Edition.
2. Uppadhya B.L. "Prachin Bharatiya Ganit" Vigyan Bharti, New Delhi, India.
3. Mohan Braj "History of Mathematics" Hindi Samiti Information Department U.P., India.
4. Handa Nidhi "Ancient Hindu Mathematics an Introduction" Oshina Publications, Indore (MP), India, 2018, FirstEdition.
5. "Vedic Ganit Nirdeshika" Vidya Bharti Sanskriti Shiksha Sansthan, Haryana, India, 2017, Seventh Edition.
6. Singh Shivraj , Kumar Anil ,Gupta Soniya ,Yadav Rashmi "Vedic Ganit", Pragati Prakashan, Meerut,India,2022, First Edition.
7. Chauthaiwale, Shriram" "Enjoy Vedic Mathematics" Art of Living international Bangluru, India
8. Chauthaiwale, Shriram, Verma, Deviprasadand and Deshmukh, Devendra, "Eminent Bharatiya Mathematicians".

This course can be opted as an elective by the students of following subjects: Open for all

Suggested equivalent online courses (MOOCs) for credit transfer: NA