Scheme and Syllabus of

M.Sc. Mathematics Batch 2017 onwards

M.Sc. Mathematics is a postgraduate level course of the Department of Mathematics which is a 2-years course. It is consisting of semester system (4 semesters) with two semesters per year.

Program Code: MSM (Masters of Science in Mathematics)

Eligibility: B.A./B.Sc. with Honors in Mathematics or B.A./B.Sc. (pass course) with Mathematics as one of the subjects having at least 50% marks in aggregate.

First Semester **Contact Hours: 27 Hrs.**

Course Code	Course Title	Load Allocation			Marks Distribution			Credits
		L	T	P	Internal	External	Total	
MSM-101	Algebra-I	4	1	0	20	80	100	5
MSM -102	Real Analysis-I	4	1	0	20	80	100	5
MSM -103	Complex Analysis	4	1	0	20	80	100	5
MSM -104	Ordinary Differential Equations and Special Functions	4	1	0	20	80	100	5
MSM -105	Mathematical Methods	4	1	0	20	80	100	5
MSM -106	Introduction to Computer Algebra System (Lab)	0	0	2	50	00	50	1
Total		20	05	02	150	400	550	26

Second Semester **Contact Hours: 27 Hrs.**

Course Code	Course Title	Load Allocation			Marks Distribution			Credits
		L	T	P	Internal	External	Total	
MSM -201	Algebra-II	4	1	0	20	80	100	5
MSM -202	Real Analysis-II	4	1	0	20	80	100	5
MSM -203	Mechanics-I	4	1	0	20	80	100	5
MSM -204	Partial Differential Equations	4	1	0	20	80	100	5
MSM -205	Numerical Analysis	4	1	0	20	80	100	5
MSM -206	Numerical Analysis (Lab)	0	0	2	50	00	50	1
Total		20	05	02	150	400	550	26

Third Semester **Contact Hours: 27 Hrs.**

Course Code	Course Title	Load Allocation			Marks Distribution			Credits
		L	T	P	Internal	External	Total	
MSM -301	Topology	4	1	0	20	80	100	5
MSM -302	Number Theory and Cryptography	4	1	0	20	80	100	5
MSM -303	Mathematical Statistics-I	4	1	0	20	80	100	5
MSM -304	Functional Analysis	4	1	0	20	80	100	5
MSM -XXX	Elective-I	4	1	0	20	80	100	5
MSM -305	Seminar	0	0	2	50	-	50	1
Total		20	05	02	150	400	550	26

Fourth Semester **Contact Hours: 27 Hrs.**

Course Code	Course Title	Load Allocation			Marks Distribution			Credits
		L	T	P	Internal	External	Total	
MSM -401	Mechanics-II	4	1	0	20	80	100	5
MSM -402	Mathematical Statistics-II	4	1	0	20	80	100	5
MSM-403	Differential Geometry	4	1	0	20	80	100	5
MSM -YYY	Elective-II	4	1	0	20	80	100	5
MSM -ZZZ	Elective-III	4	1	0	20	80	100	5
MSM -404	Seminar	0	0	2	50	-	50	1
Total		20	05	02	150	400	550	26

Elective-I MSM XXX (Any one subject to be opted)

MSM -501 Coding Theory

MSM -502 Operations Research

Note1: Student is to adopt one course from the list of Elective-II and one course from list of Elective-III

Elective-II Courses: MSM-503, MSM-504, MSM-505, MSM-506

Elective-III Courses: MSM-507, MSM-508, MSM-509, MSM-510, MSM-511

MSM -503 Advanced Complex Analysis

MSM -504 Advanced Operations Research

MSM -505 Advanced Fluid Mechanics

MSM -506 Advanced Solid Mechanics

MSM -507 Theory of Linear Operators

MSM -508 Advanced Numerical Methods

MSM -509 Topological Vector Spaces

MSM -510 Fractional Calculus

MSM -511 Discrete Mathematics

Note 2:

Instructions for paper setters and candidates:

a) The entire question paper should be distributed into three sections viz. Section-A, Section-B, Section-C.
b) The Section-A should cover the entire syllabus, the Section-B should cover Unit-I & II and the Section-C should cover Unit-III & IV of the syllabus.
c) Section-A should contain eight questions of two marks each. This section should cover the entire syllabus. All questions in this section should be compulsory.
d) Section-B and Section-C should contain three questions each carrying 16 (sixteen) marks.
e) Student should be asked to attempt at least two questions from Section-B and Section-C each.
f) The awards for internal and external examination should be in 20:80 ratio.
g) The Duration of examination is three hours.

Course Title: Algebra-I
Course Code: MSM-101

L	T	P
4	1	0

Course Objectives: The main aim of the course:

- is to introduce basic topics of algebra like groups, sylow groups, rings, ideals, etc.
- to make the students learn about operations on algebraic structures which are quite significant in modern mathematics.
- to make the students understand the theorems of group isomorphisms and ring isomorphisms.

UNIT-I

Groups: Groups, homomorphisms, Subgroups and Cosets, Cyclic groups, Permutation groups, Normal subgroups and quotient groups, Isomorphism theorems, Automorphisms, Dihedral groups, Symmetric groups, Conjugacy. [Ref 2: Unit 1]

UNIT-II

Normal series, Derived Series, Composition Series, Solvable Groups, Simple groups and their examples, Alternating group A_n, Simplicity of A_n. [Ref 2: Unit 1]

UNIT-III

Direct Products, Finite Abelian Groups, Fundamental Theorem on Finitely generated Abelian Groups, Invariants of a finite abelian groups, Sylow's Theorems and their applications, Groups of order p^2, pq. [Ref 2: Unit 1]

UNIT-IV

Rings: Ring, Subring, Ideals, Homomorphism and Algebra of Ideals, Maximal and prime ideals, Ideals in quotient rings, Nilpotent and nil ideals. [Ref 2: Unit 2]

RECOMMENDED BOOKS:

1. Bhattacharya, P. B., Jain, S.K. and Nagpaul, S.R., *Basic Abstract Algebra*, *2nd Edition.* U.K.: Cambridge University Press, 2004.
2. Dummit, David. S., and Foote, Richard M., *Abstract Algebra, 3rd Edition*. New Delhi: Wiley, 2011.
3. Herstein, I.N., *Topics in Algebra, 2nd Edition*. New Delhi: Wiley, 2006.
4. Singh, Surjeet, and Zameeruddin, Q., *Modern Algebra, 7th Edition*. New Delhi: Vikas Publishing House, 1993.
5. Artin, M., *Algebra, 2nd Edition*. Pearson Publications, 2010.
6. Fraleigh, J. B., *A First Course in Abstract Algebra, 7th Edition*. Pearson Publications, 2002.

Course Outcomes:

- The students will be able to learn the basic concepts like groups, rings, etc.

- They will be acquainted with prerequisite knowledge required to learn advanced algebra.
- They will be able to apply the learnt techniques in modern algebra

Course Title: Real Analysis-I
Course Code: MSM-102

L	T	P
4	1	0

Course Objectives: This course will develop

- a deeper and rigorous understanding of fundamental concepts viz. metric spaces, some important sets, continuous functions, sequences and series of numbers as well as functions, and the Riemann-Stieltjes integral in analysis.
- to introduce theoretical foundations of the above said concepts to students
- to develop their rigorous mathematical thinking and writing.

UNIT-I

Finite, Countable and Uncountable sets, Metric spaces, Compact sets, Perfect sets, Connected sets, Convergent sequences, Sub sequences, Cauchy sequences, Power series, Absolute convergence, Algebra of series, Rearrangements of elements in a series.

UNIT-II

Limits of functions, Continuous functions, Compactness, Connectedness, Monotonic functions, Infinite limits and Limits at infinity.

UNIT-III

The Riemann-Stieltjes integral: Definition and existence of the Riemann-Stieltjes integral, Properties of the integral, Integration and differentiation, Integration of vector-valued functions, Rectifiable curves.

UNIT-IV

Sequences and series of functions: Interchanging order of limits for sequences of functions, Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation, Equicontinuous families of functions, Stone Weierstrass Theorem.

RECOMMENDED BOOKS:

1. Rudin, W., *Principles of Mathematical Analysis, 3rd Edition*. New Delhi: McGraw-Hill Inc., 2013.
2. Royden, H.L. and Fitzpatrick, P.M., *Real Analysis, 4th Edition.* New Delhi: Pearson, 2010.
3. Carothers, N. L., *Real Analysis*, Cambridge University Press, 2000.
4. Apostol, T.M., *Mathematical Analysis –A modern approach to Advanced Calculus*. New Delhi: Narosa Publishing House, 1957.
5. Abbott, S., *Understanding Analysis, 2nd Edition.* Springer, 2016.

Course Outcomes: After completion of the course, the student will be able to

- Understand hypotheses and writing mathematical proofs.

- Understand the theoretical structures of basic concepts in analysis.
- Understand axiomatic structure of metric spaces and consideration of sequences and series, continuous functions in metric spaces.
- Understand the theoretical foundation and properties of the Riemann-Stieltjes integral.

Course Title: Complex Analysis
Course Code: MSM-103

L	T	P
4	1	0

Course Objectives: The objective of this course is

- to introduce and developing a clear understanding of the fundamental concepts of Complex Analysis such as analytic functions, Cauchy-Riemann relations and harmonic functions etc.
- to make students equipped with the understanding of the fundamental concepts of complex variable theory.
- in particular, to enable students to acquire skill of contour integration to evaluate complicated real integrals via residue calculus.

UNIT-I

Function of complex variable, continuity and differentiability, Analytic functions, Cauchy Riemann equation (Cartesian and polar form). Harmonic functions, Harmonic conjugate, Construction of analytic functions. Exponential function, Trigonometric and inverse trigonometric functions, Logarithmic function, Complex powers, Branches of multivalued functions with reference to arg(z), log(z), z^c. Stereographic projection and the spherical representation of the extended complex plane.

Unit-II

Complex line integral, Cauchy-Goursat theorem, independence of path; Cauchy's integral formulas and their consequences, Cauchy inequality, Liouville's theorem, Fundamental theorem of algebra, Morera's theorem, Maximum modulus principle, Schwarz lemma, Poisson's integral formula.

Unit-III

Power series: circle of convergence, radius of convergence. Taylor's series and Taylor's theorem, Laurent'z series and Laurent theorem, Zeros and singularities of complex functions, classification of singularities: removable singularity, poles, essential singularities, Residue at a pole and at infinity, Cauchy's Residue theorem and its applications in evaluation of real integrals: integration around unit circle, integration over semi-circular contours (with and without real poles), integration around rectangular contours, Argument principle, Rouche's theorem

Unit-IV

Conformal transformations, Bilinear transformations, Critical points, Fixed points, Problems on cross-ratio and bilinear transformation.

RECOMMENDED BOOKS:

1. Ahlfors, L.V., *Complex Analysis, 2nd Edition*. McGraw-Hill International Student Edition, 1990.
2. Copson, E.T., *An Introduction to the Theory of functions of a complex Variable*. Oxford university press, 1995.
3. Shastri, A.R., *An Introduction to Complex Analysis*. Macmillan India Ltd., 2003.
4. Ponnusamy, S. and Silverman, H., *Complex Variables and Applications*. Birhkäuser, 2006.

5. Churchill, R. and Brown, J.W., *Complex Variables and Applications, 6th Edition*. New- York: McGraw-Hill, 1996.

Course Outcomes: After the completion of this course the student will be able to

- represent complex numbers algebraically and geometrically.
- Evaluate Complex integrals and applying Cauchy integral.
- evaluate limits and checking the continuity of complex function & apply the concept and consequences of analyticity and the Cauchy-Riemann equations and of results on harmonic and entire functions including the fundamental theorem of algebra.

Course Title: Ordinary Differential Equations and Special Functions
Course Code: MSM-104

L	T	P
4	1	0

Course Objectives: The objective of this course is

- to introduce ordinary differential equations and fundamental theorems for existence and uniqueness.
- to learn analytic techniques for computing solutions of various ordinary differential equations with and without initial and boundary conditions.
- to explore the use of series methods about ordinary and regular-singular points.

UNIT-I

Review of linear differential equations with constant & variable coefficients, Fundamental existence and uniqueness theorem for system and higher order equations (Picard's and Piano theorems), System of linear differential equations, an operator method for linear system with constant coefficients, Phase plane method.

UNIT-II

Homogeneous linear system with constant coefficients, Eigenvalues and eigen functions, orthogonality of eigen functions, Complex eigenvalues, repeated eigenvalues, Ordinary differential equations of the Sturm-Liouville problems, Expansion theorem, Extrema properties of the eigen values of linear differential operators, Formulation of the eigen value problem of a differential operator as a problem of integral equation, Linear homogeneous boundary value problems

UNIT-III

Power series solution of differential equations: about an ordinary point, solution about regular singular points, the method of Frobenius, Bessel equation and Bessel functions, Recurrence relations and orthogonal properties., Series expansion of Bessel Coefficients, Integral expression, Integral involving Bessel functions, Modified Bessel function, Ber and Bei functions, Asymptotic expansion of Bessel Functions, Legendre's differential equations, Legendre Polynomials , Rodrigue's formula, Recurrence relations and orthogonal properties.

UNIT-IV

The Hermite polynomials, Chebyshev's polynomial, Laugrre's polynomial: Recurrence relations, generating functions and orthogonal properties.

RECOMMENDED BOOKS:

1. Ross, S.L., *Differential Equations, 3rd Edition.* John Wiley & Sons, 2004.
2. Boyce, W.E. and Diprima, R.C., *Elementary Differential Equations and Boundary Value problems, 4th Edition*. John Wiley and Sons, 1986.

3. Sneddon, I.N., *Special Functions of Mathematical Physics and Chemistry.* Edinburg: Oliver & Boyd, 1956.
4. Bell, W.W., *Special Functions for Scientists and Engineers.* Dover, 1986.

Course Objectives: Students will be able to:

- classify ordinary differential equations according to their order and linearity, as well as distinguish between initial value problems and boundary value problems.
- determine regions of the plane in which a given first-order differential equation will have a unique solution.
- obtain solutions for system of ordinary differential equations and eigen value problems by using various tools of linear algebra.

Course Title: Mathematical Methods
Course Code: MSM-105

L	T	P
4	1	0

UNIT I

Laplace Transforms: Laplace Transform, Properties of Laplace Transform, Inverse Laplace Transform, Convolution theorem, Laplace transform of periodic functions, unit step function and impulsive function, Application of Laplace Transform in solving ordinary and partial differential equations and Simultaneous linear equations;

UNIT II

Fourier Transforms: Fourier transform, properties of Fourier transform, inversion formula, convolution, Parseval's equality, Fourier transform of generalized functions, application of Fourier transforms in solving heat, wave and Laplace equation. Fast Fourier transform.

UNIT III

Integral Equations: Relations between differential and integral equations, Green's function, Linear equations in cause and effect, Integral equations of Fredholm and Volterra type, solution by successive substitution and successive approximation, integral equations with degenerate kernels.

UNIT IV

Integral equations of convolution type and their solutions by Laplace transform, Fredholm's theorems, integral equations with symmetric kernel, Solutions with separable kernels, Characteristic numbers, Resolvent kernel, Eigen values and Eigen functions of integral equations and their simple properties.

RECOMMENDED BOOKS:

1. Sneddon, I.N., *The Use of Integral Transforms*. McGraw Hill, 1985.
2. Goldberg, R.R., *Fourier Transforms.* Cambridge University Press, 1970.
3. Smith, M.G., *Laplace Transform Theory*. Van Nostrand Inc., 2000.
4. Elsegolc, L., *Calculus of Variation*. Dover Publications, 2010.
5. Kenwal, R.P., *Linear Integral Equation; Theory and Techniques*. Academic Press, 1971.
6. Hildebrand, F.B., *Methods of Applied Mathematics **(Latest Reprint)***. Dover Publications.

7. Pal, S. and Bhunia, S.C., *Engineering Mathematics*. Oxford University Press, 2015.

Course Title: Introduction to Computer Algebra System
Course Code: MSM-106

L	T	P
0	0	2

Course Objectives: This course

- introduces computer algebra systems (CAS) viz. MATLAB and MATHEMATICA that are widely used in scientific computing.
- enables the students to be familiar with the CAS so that they can apply these systems to solve real world problems more efficiently and accurately.

UNIT-I

The MATLAB environment, scalars, variables, arrays, mathematical operations with arrays, built-in and user defined functions, graphics: two-dimensional and three-dimensional, m-files: script and function files, functions: input; disp and fprintf, relational and logical operators, symbolic math: symbolic objects and expressions; collect; expand; factor; simplify; simple; pretty; solve; diff and int commands, Programming: if-end structure; if-else-end structure; if-elseif-else-end structure; loops: for-end and while-end.

UNIT-II

The structure of MATHEMATICA, notebook interfaces, constants, variables, algebraic calculations, four kinds of brackets, lists, tables, expressions, functions, built-in functions, functional operations, graphics, patterns, manipulating lists, transformation rules, evaluation of expressions, modularity, manipulating notebooks, relational and logical operators, symbolic math commands: D; Integrate; Sum; Product; Solve; Eliminate; Reduce; Series; Limit; Minimize; basic numerical mathematics, Programming: conditionals; loops: Do; For and While.

RECOMMENDED BOOKS:

1. Higham, D.J. and Higham, N.J., *MATLAB Guide, 2nd Edition.* Society for Industrial and Applied Mathematics (SIAM), 2005.
2. Gilat, A., *MATLAB: An Introduction with Applications, 5th Edition*. John Wiley & Sons, 2014.
3. Wolfram, S., *The MATHEMATICA Book, 5th revised edition*. Wolfram Media Inc, 2004.
4. Abell, M. and Braselton, J., *Mathematica by Example, 5th Edition*. Academic Press, 2017.

Course Outcomes: After completion of this course, the students will be able to

- use symbolic tools of MATLAB and MATHEMATICA for doing mathematics more efficiently and rapidly.
- understand basic loops and conditional structures that can be used to develop their own computer programs.
- visualize functions in 2-D and 3-D.
- use these CAS for solving applied problems in science and engineering.

Course Title: Algebra-II
Course Code: MSM-201

L	T	P
4	1	0

Course Objectives: The main aim of this course

- is to introduce the students to advanced ideas such as Polynomial rings, Field theory, Algebraic closures, splitting fields and Galois theory.
- To make the students learn about Eisenstein's irreducibility criterion which is quite helpful in the study of solvability of a polynomial.
- To make the students understand about the applications of Galois theory in other branches of mathematics.

UNIT-I

Polynomial rings, factorization of polynomials in one variable over a field. Unique factorization domains, unique factorization in R[x], where R is a Unique Factorization Domain. Euclidean and Principal ideal domain. [Ref 2: Unit 2]

UNIT-II

Gauss Lemma, irreducible polynomials and Eisenstein's Irreducibility Criterion, Fields, Adjunction of roots, Algebraic extensions of field. [Ref 2: Unit 2,4]

UNIT-III

Algebraically closed fields, Splitting fields, normal extensions, finite fields, separable extensions. [Ref 2: Unit 4]

UNIT-IV

Automorphism of groups and fixed fields, Galois extensions. The fundamental theorem of Galois Theory, Fundamental theorem of algebra. [Ref 2: Unit 4]

RECOMMENDED BOOKS:

1. Bhattacharya, P.B., Jain, S.K. and Nagpaul, S.R., *Basic Abstract Algebra, 2nd Edition.* U. K.: Cambridge University Press, 2004.
2. Dummit, David. S., and Foote, Richard M., *Abstract Algebra, 3rd Edition*. New Delhi: Wiley, 2011.
3. Herstein, I.N., *Topics in Algebra, 2nd Edition*. New Delhi: Wiley, 2006.
4. Singh, Surjeet, and Q. Zameeruddin. *Modern Algebra, 7th Edition*. New Delhi: Vikas Publishing House, 1993.
5. Ash, R., *Abstract Algebra: The Basic Graduate Year*, Dover Publications Inc, 2006.

Course Outcomes:

• The students will be able to learn the advanced concepts of algebra which will develop their interest to pursuit study in advanced algebra.

• They will acquire abstract and rational thinking by understanding the concepts such as Eisenstein's irreducibility criterion.

• They will be encouraged to do further research in advanced algebra.

Course Title: Real Analysis-II
Course Code: MSM-202

L	T	P
4	1	0

Course Objectives: This course aims

- to lay theoretical foundations of important aspects of mathematical analysis viz. derivative, mean value theorems (MVTs), functions of several variables, measure theory and integration that have many important applications in different branches of pure and applied mathematics.
- to make students familiar with these concepts, their properties and also some of their fruitful applications.

UNIT-I

Differentiation of Real functions, Mean value theorems, Taylor's theorem, Differentiation of vector-valued functions, Functions of several variables: Linear transformations, Differentiation, Contraction principle, The Inverse function theorem, The implicit function theorem. [Ref. 3]

UNIT-II

Lebesgue Measure: Introduction, Lebesgue outer measure, Measurable sets and Lebesgue measure, non-measurable set, Measurable functions, Borel and Lebesgue measurability, Littlewood's three principles.

UNIT-III

Lebesgue Integral: The Riemann integral, The Lebesgue integral of a bounded function over a set of finite measure, the integral of a nonnegative function, The general Lebesgue integral, Convergence in measure.

UNIT-IV

Differentiation and Integration: Differentiation of monotone functions, The Four derivatives, Functions of bounded variation, differentiation of an integral, Lebesgue Differentiation Theorem. Absolute continuity. Convex Functions.

RECOMMENDED BOOKS:

1. Royden, H.L. and Fitzpatrick, P.M., *Real Analysis*, *4th Edition*. New Delhi: Pearson, 2010.
2. Barra, G. de., *Measure Theory and Integration*, New Delhi: Woodhead Publishing, 2011.
3. Rudin, W., *Principles of Mathematical Analysis*, *3rd Edition*. New Delhi: McGraw-Hill Inc., 2013.
4. Carothers, N. L., *Real Analysis*, Cambridge University Press, 2000.
5. Apostol, T.M., *Mathematical Analysis –A modern approach to Advanced Calculus*. New Delhi: Narosa Publishing House, 1957.

Course Outcomes After completing the course, the student will

- understand derivative, MVTs and functions of several variables that would be the basis for rigorous understanding of advanced analysis and its applications.
- understand how Lebesgue measure is defined and its properties.
- understand how the measures may be used in the development of integrals.
- become familiar with deep understanding and application of Lebesgue theory of integration.

Course Title: Mechanics-I
Course Code: MSM-203

L	T	P
4	1	0

UNIT-I

Functional and its properties, Variation of a functional, Motivating problems: Brachistochrone, isoperimetric, Geodesics. Fundamental lemma of calculus of variation, Euler's equation for one dependent function of one and several variables. Generalization to *n* dependent functions and dependence on several derivatives. Invariance of Euler's equation, Moving end points problem, extremum under constraints.

UNIT-II

Constraints, Generalized coordinates, Generalized velocity, Generalized force, Generalized potential, D'Alembert principle, Lagrange's equation of first kind and second kind, uniqueness of solution, Energy equation for conservative field. Examples based on solving Lagrange's equation.

UNIT-III

Legendre transformation, Hamilton canonical equation, cyclic coordinates, Routhian procedure, Poisson bracket, Poisson's identity, Jacobi-Poisson theorem, Hamilton's principle, Principle of Least action, Small oscillations of conservative system, Lagrange's equation for small oscillations, Nature of roots of frequency equation, Principle oscillations. Normal coordinates.

UNIT-IV

Canonical transformations, Hamilton-Jacobi equation. Method of Separation of variables, Lagrange's bracket, Hamilton's equations in Poisson bracket, Canonical character of transformation through Poisson bracket. Invariance of Lagrange's bracket and Poisson's bracket. Action-Angle Variables.

RECOMMENDED BOOKS:

1. Elsegolc, L.D., *Calculus of Variation*, Dover Publication, 2007.
2. Gantmacher, F., *Lectures in Analytic Mechanics*, Moscow: Mir Publisher, 1975.
3. Goldstien, H., Poole, C. and Safco, J.L., *Classical Mechanics, 3rd Edition*. Addison Wesely, 2002.
4. Landau, L.D. and Lipshitz, E.M., *Mechanics*, Oxford: Pergamon Press, 1976.
5. Marsden, J.E., *Lectures on Mechanics*, Cambridge University Press, 1992.
6. Biswas, S. N., *Classical Mechanics*, Books and Applied (P) Ltd., 1999.

Course Title: Partial Differential Equations
Course Code: MSM-204

L	T	P
4	1	0

Course Objectives: the objective of this course is

- to introduce first and higher order partial differential equations and their classification
- to study analytic methods for computing solutions of various partial differential equations.
- to study applications of partial differential equations which appear in real life and physical phenomena like as wave equation of string, diffusion equation and heat flow equation etc.

UNIT-I

First Order PDE: Partial differential equations; its order and degree; origin of first-order PDE; determination of integral surfaces of linear first order partial differential equations passing through a given curve; surfaces orthogonal to given system of surfaces; non-linear PDE of first order, Cauchy's method of characteristic; compatible system of first order PDE; Charpit's method of solution, solutions satisfying given conditions, Jacobi's method of solution.

UNIT-II

Second and Higher Order PDE: Origin of second order PDE; linear second and higher order PDE with constant and variable coefficients; characteristic curves of the second order PDE; Monge's method of solution of non-linear PDE of second order.

UNIT-III

Separation of Variable Method: Separation of variables for PDE; wave, diffusion and Laplace equations and their solutions by Separation of variables method; Elementary solutions of Laplace equations.

UNIT-IV

Applications of PDE: Vibrations governed by one and two-dimensional wave equations; vibrations of string and membranes; three dimensional problems; diffusion equation; resolution of boundary value problems for diffusion equations and elementary solutions of diffusion equations.

RECOMMENDED BOOKS:

1. Sneddon, I.N., *Elements of Partial Differential Equation, 3rd Edition.* McGraw Hill Book Company, 1998.
2. Copson, E.T., *Partial Differential Equations, 2nd Edition.* Cambridge University Press, 1995.
3. Strauss, W.A., *Partial Differential Equations: An Introduction, 2nd Edition*. 2007.
4. Sharma, J.N. and Singh, K., *Partial differential equations for engineers and scientists, 2nd Edition*. New Delhi: Narosa Publication House, 2009.

Course Outcomes: Students will be able to:

- understand the mathematical derivation of the methods and partial differential equations.
- learn analytic techniques for computing solutions of various partial differential equations.
- learn the behavior of partial differential equations as parabolic, elliptic and hyperbolic and the applications of partial differential equations.

Course Title: Numerical Analysis
Course Code: MSM-205

L	T	P
4	1	0

Course Objectives: The objective of this course includes

- the study the basic numerical methods and their convergence properties for solving nonlinear equations, linear system of equations, initial value problems and boundary value problems.
- the study of numerical methods for differentiation, integration, including Romberg integration.
- the course will also develop an understanding of the elements of error analysis for numerical methods.

UNIT-I

Numerical computation and Error analysis: Numbers and their accuracy, Floating point arithmetic, Errors in numbers, Error estimation, General error formulae, Error propagation in computation. Inverse problem of error analysis and Numerical instability. Algebraic and transcendental equations: Bisection method, Iteration method, Regula-Falsi method, Secant method, Newton-Raphson's method. Convergence of these methods. Lin-Bairstow's method, Muller's method, Graeffe's root squaring method, Solution of system of nonlinear equations, Complex roots by Newton-Raphson's method.

UNIT-II

System of linear algebraic equations: Gauss elimination method without pivoting and with pivoting, Gauss-Jordon method, LU-factorization method, Jacobi and Gauss-Seidal methods, Convergence of iteration methods, Round-off errors and refinement, ill-conditioning, Partitioning method, Inverse of matrices. Eigen values and eigen vectors: Rayleigh Power method, Given's method and Householder's method.

UNIT-III

Interpolation: Finite differences, Newton's interpolation formulae, Gauss, Stirling's and Bessel's formulae, Lagrange's, Hermite's and Newton's divided difference formulae. Numerical differentiation and integration: differentiation at tabulated and non-tabulated points, Maximum and minimum values of tabulated function, Newton-Cotes Formulae-Trapezoidal, Simpson's, Boole's and Weddle' rules of integration with errors, Romberg integration, Gaussian integration, Double integration by Trapezoidal and Simpson's rules.

UNIT-IV

Ordinary differential equations: Taylor series and Picard's methods, Euler's and modified Euler methods, Runge-Kutta methods, Predictor-Corrector methods: Adams-Bashforth's and Milne's methods. Error analysis and accuracy of these methods. Solution of simultaneous and higher order equations, Boundary value problems: Finite difference and Shooting methods.

RECOMMENDED BOOKS:

1. Sharma, J.N., *Numerical Methods for Engineers and Scientists, 2nd Edition*. Narosa Publ. House New Delhi/Alpha Science International Ltd., Oxford UK, 2007, Reprint 2010.
2. Jain, M.K., Iyengar, S.R.K. and Jain, R.K., *Numerical Methods for Scientific and Engineering Computation, 5th Edition. New Age International Publ.* New Delhi, 2010
3. Bradie, B., *A Friendly Introduction to Numerical Analysis*. Pearson Prentice Hall, 2006.
4. Atkinson, K.E., *Introduction to Numerical Analysis, 2nd Edition*. John Wiley, 1989.
5. Scarborough, J.B., *Numerical Mathematical Analysis.* Oxford & IBH Publishing Co., 2001.

Course Outcomes: Upon successful completion of this course, the student will be able to:

- apply the numerical methods (such as Bisection, False position, Newton-Raphson, Secant, to solve equations.
- apply the numerical methods (such as Gauss Elimination, Gauss Jordan, LU factorization, Cholesky Factorization, Jacobi and Gauss Seidel) for linear system of equations.
- apply the numerical methods (such as Newton forward and backward difference interpolation formula- Lagrange interpolation formula) for differentiation and integration.

Course Title: Numerical Analysis (LAB)
Course Code: MSM-206

L	T	P
0	0	2

Course Objectives: This course

- provides understanding of implementations of basic numerical methods for solving problems viz. nonlinear equations, system of equations, interpolation, extrapolation, differentiation, integration and ordinary differential equations.
- to enable students to develop their own computer programs of the numerical methods for solving different problems.

The following programs of following methods are to be practiced:

1. To find a real root of an algebraic/ transcendental equation by using Bisection method.
2. To find a real root of an algebraic/ transcendental equation by using Regula-Falsi method.
3. To find a real root of an algebraic/ transcendental equation by using Newton-Raphson method.
4. To find a real root of an algebraic/ transcendental equation by using Iteration method.
5. Implementation of Gauss- Elimination method to solve a system of linear algebraic equations.
6. Implementation of Jacobi's method to solve a system of linear algebraic equations.
7. Implementation of Gauss-Seidel method to solve a system of linear algebraic equations.
8. To find differential coefficients of 1st and 2nd orders using interpolation formulae.
9. To evaluate definite integrals by using Newton - Cotes integral formulae.
10. To evaluate definite integrals by using Gaussian Quadrature.
11. To evaluate double integrals by using Trapezoidal and Simpson method.
12. To compute the solution of ordinary differential equations with Taylor's series method.
13. To compute the solution of ordinary differential equations by using Euler's method.
14. To compute the solution of ordinary differential equations by using Runge -Kutta methods.
15. To compute the solution of ordinary differential equations by using Milne-Simpson method.
16. To compute the solution of Boundary value problems of Ordinary Differential Equations by using Finite Difference method.
17. To compute the solution of Boundary value problems of Ordinary Differential Equations by using Shooting method.

RECOMMENDED BOOKS:

1. Fausett, L.V., *Applied Numerical Analysis using MATLAB, 2nd Edition.* Pearson Prentice Hall, 2007.
2. Mathews, J.H. and Fink, K.D., *Numerical Methods using MATLAB, 4th Edition.* Pearson Prentice Hall, 2004.
3. Balagurusamy, E., Object Oriented Programming with C++. New Delhi: Tata McGraw Hill, 1999.
4. Conte, S.D. and Boor, C.D., *Numerical Analysis*. New York: McGraw Hill, 1990.

Course Outcomes: After completion of this course, the students will be able to

- Understand different implementation modes of numerical methods.
- Develop and implement their own computer programs.
- Solve problems more accurately and efficiently.

Instructions for paper setters and candidates:
Candidates are required to perform at least 10-12 Practical in a semester.

Course Title: Topology
Course Code: MSM-301

L	T	P
4	1	0

UNIT-I

Introduction topological spaces, closed sets, Closure, Dense subsets, neighborhoods, interior, exterior and boundary, Accumulation points and derived sets.
Bases and subbases, Subspaces and relative Topology, Alternative methods of defining a Topology in terms of Kuratowski closure operator and neighborhood systems.

UNIT-II

Open mappings and closed mappings, Continues functions and homomorphism's, Compactness and local Compactness. One-point compactification, connected and arc-wise connected spaces, Components and Locally connected spaces.

UNIT-III

T0 and T1 spaces, T2 spaces and sequences. Hausdorffness of one-point compactification, Axioms of Countability and Seperability, Equivalence of Separable, second Axiom and Lindel of properties in a metricspaces. Equivalence of compact and countably compact sets in metric spaces.

UNIT-IV

Regular and completely regular, Normal and completely normal spaces. Metric spaces as T2, completely normal and first axiom spaces, Urysohn's Lemma, Tietze Extension Theorem.

BOOKS RECOMMENDED

1. Munkres, J. R., *Topology, a first course*, Prentice-Hall of India Ltd., New Delhi, 2000.
2. Joshi, K. D., *An introduction to general topology, 2nd edition*, Wiley Eastern Ltd., New Delhi, 2002.
3. Simmons, G.F., *Introduction to topology and Modern Analysis*, McGraw Hill Publications, 2017.
4. Kelley, J. L., *General Topology*, Springer Verlag, New York, 1990.
5. Armstrong, M.A., *Basic Topology*, Springer International Ed., 2005.

Course Title: Number Theory and Cryptography
Course Code: MSM-302

L	T	P
4	1	0

Course Objectives: The main objectives of this course:

- is to teach the basic foundations of Number Theory, namely, Prime Numbers, Division algorithm, Arithmetic functions, Diophantine equations and Cryptography.
- To make the students learn about the interrelation of various concepts of number theory such as Fermat's Last theorem, Reciprocity law, etc. with other branches of mathematics.

- To make students understand the various techniques such as Division tests, Chinese remainder theorem, etc.
- To make the students learn about coding and decoding processes using Discrete log, public key cryptography and RSA cryptography.

UNIT-I

Divisibility, Greatest common divisor, Euclidean Algorithm, The Fundamental Theorem of arithmetic, congruences, Special divisibility tests, Chinese remainder theorem, residue classes and reduced residue classes, Fermat's little theorem, Wilson's theorem, Euler's theorem.

UNIT-II

Arithmetic functions $\phi(n)$, $d(n)$, $\sigma(n)$, $\mu(n)$, Mobius inversion Formula, the greatest integer function, perfect numbers, Mersenne primes and Fermat numbers,

UNIT-III

Primitive roots and indices, Quadratic residues, Legendre symbol, Gauss's Lemma, Quadratic reciprocity law, Jacobi symbol, Diophantine equations: $ax + by = c$, $x^2 + y^2 = z^2$, $x^4 + y^4 = z^2$, sums of two and four squares, [Ref. 2]

UNIT-IV

Cryptography: some simple cryptosystems, need of the cryptosystems, Discrete log, the idea of public key cryptography, RSA cryptosystem. [Ref. 4]

RECOMMENDED BOOKS:

1. Burton, D.M., *Elementary Number Theory, 7th Edition*. McGraw-Hill Education, 2010.
2. Hardy, G.H. and Wright, E.M., *An introduction to the Theory of Numbers, 4th Edition*. Oxford University Press, 1975.
3. Niven, I., Zuckerman, H.S. and Montgomery, H.L., *Introduction to Theory of Numbers, 5th Edition*. John Wiley & Sons, 1991.
4. Koblitz N., *A Course in Number Theory and Cryptography, Graduate Texts in Mathematics, No.114*. New-York: Springer-Verlag, 1987.
5. Stallings, W., *Cryptography and Network Security, 5th Edition.* Pearson, 2010.

Course Outcomes:

- The students will learn fundamental theorems and results in number theory.
- They will be able to apply the learnt techniques in different fields of mathematics.
- They will be acquainted with prerequisite knowledge required to learn advanced course in Number Theory.
- They will be able to construct codes and decode the encrypted code using the learnt techniques.

Course Title: Mathematical Statistics-I
Course Code: MSM-303

L	T	P
4	1	0

Course Objectives: The main objectives of this course is:

- To cover the basic concepts of mathematical statistics, random experiments and their applications.
- To make the students to learn the theory of probability, one dimensional and two-dimensional random variables, expectation etc. to study the random experiments.
- To enhance the statistical thinking of the students.

UNIT-I

Classical, empirical and axiomatic approaches to the theory of probability, the probability set function, algebra of events, conditional probability, addition and multiplicative theorems of probability and their generalizations to n events. Total probability theorem and Bayes' theorem and their applications.

UNIT-II

Random variables (discrete and continuous) and their density functions. Cumulative distribution function and its properties. Different methods to derive the distribution of the function of a random variable. Non-central and central moments of a random variable, expected value of functions of random variable.

UNIT-III

Two dimensional random variables, joint, marginal and conditional density functions, distribution function, independence of random variables. Distribution of the functions of two-dimensional random variables. Joint moments of a two-dimensional random variable.

Unit -IV

Cauchy-Schwartz inequality, Jenson's inequality, product moment correlation coefficient, conditional expectation and variance, probability generating function, moment generating function and its properties. Characteristic function and its elementary properties. Chebychev's inequality, Convergence in probability, weak law of large numbers.

BOOKS RECOMMENDED:

1. Hogg R. V., McKean J. W. and Craig A. T., Introduction to Mathematical Statistics, Pearson, 2005, Sixth Edition.
2. Gupta S. C. and Kapoor V. K., Fundamentals of Mathematical Statistics, Sultan Chand & Sons, 2014, Eleventh Edition.
3. Fisz M., Probability Theory and Mathematical Statistics, John Wiley & Sons, 1967, Third Edition.
4. Gun A. M., Gupta M. K. and Dasgupta B., Fundamentals of Statistics (Vol-I), World Press, 2013.
5. Feller W., An Introduction to Probability Theory and Its Applications (Vol-I), John Wiley & Sons, 2003, Third Edition.
6.

Course Outcomes After completion of this course, the students will

- Learn the basic concepts of mathematical statistics.
- Be able to apply statistical methods in solving real life problems.
- Be able to analyze the different possible inferences for a given physical situation.

Course Title: Functional Analysis
Course Code: MSM-304

L	T	P
4	1	0

UNIT-I

Normed linear spaces, Banach spaces, properties of normed spaces, finite dimensional normed spaces and subspaces, linear operators, bounded and continuous linear operators, linear functionals, normed spaces of operators

UNIT-II

Equivalent norms, conjugate spaces, Reflexivity. Hahn-Banach theorems for real/complex vector spaces and normed spaces, Applications to bounded linear functionals on C [a,b].

UNIT-III

Uniform boundedness theorem, open mapping theorem, closed graph theorem, Projections on Banach spaces.

UNIT-IV

Inner product spaces, Hilbert spaces, properties of inner product spaces, orthogonal complements, orthonormal sets, Hilbert – adjoint operator, self-ad joint, unitary and normal operators, projections on Hilbert spaces.

RECOMMENDED BOOKS:

1. Simmons, G.F., *Introduction to Topology and Modern Analysis*, 2008.
2. Rudin, W., *Functional Analysis, International Series in Pure and Applied Mathematics*, McGraw-Hill inc.,1991.
3. Kreyszig, E., *Introductory Functional Analysis with Applications*, John Wiley and Sons(Asia) Pvt. Ltd., 2006.
4. Bachman, G. and Narici, L., *Functional Analysis*, Dover, 2000.
5. Conway, J.B., *A Course in Functional Analysis, 2nd Edition*. Springer-Verlag, 2006.

Course Title: Mechanics-II
Course Code: MSM-401

L	T	P
4	1	0

Unit I

Tensors: Introduction, Range and Summation Conventions, Free and dummy suffixes, results in vector algebra and matrix, the symbol δ_{ij} & ε_{ijk} , Coordinate transformations, cartesian tensors, Properties of tensors, Isotropic tensors, Isotropic tensor of order four, Tensors as linear operators, Transpose of a tensor.

Unit II

Tensor Continued: Symmetric and skew tensors, Dual vector of a skew tensor, Invariants of a tensor, Deviatoric tensors, Eigenvalues and eigenvectors, Polar decomposition, Scalar, vector and tensor functions, Comma notation, Gradient of a scalar, divergence and curl of a vector, Gradient of a vector, divergence and curl of a tensor, Integral theorems for vectors and tensors.

Unit III

Continuum Hypothesis: Notation of a continuum, Configuration of a continuum, Mass and density, Descriptions of motion, Deformation: Material and special coordinates, Deformation gradient tensor, Stretch and rotation, Strain tensors, Strain-displacement relations, Infinitesimal strain tensor, Infinitesimal stretch and rotation, Compatibility conditions., Principal strains, Strain-deviator.

Unit IV

Motion and Stress: Material and local time-derivatives, Stretching and vorticity, path lines, stream lines, and vortex lines, Transport formulas, Circulation and vorticity, Body forces and surfaces forces, Stress components, Stress tensor, Normal and shear stresses, stress-deviator, Boundary conditions for stress tensor, Piola-Kirchhoff stress tensors.

BOOKS RECOMMENDED:

1. Jog, C.S., *Foundations and Applications of Mechanics: Volume-I Continuum Mechanics*. Narosa Publishing House, New delhi.
2. Chandrasekharaiah, D.S. and Lokenath, D., *Continuum Mechanics*, Academic Press, London (Prism Books Pvt. Ltd., Bangalore-India).

Course Title: Mathematical Statistics-II
Course Code: MSM-402

L	T	P
4	1	0

Course Objectives: The main objectives of this course are:

- To introduce various types of distributions, descriptive statistics, theory of estimation and testing of hypothesis etc.
- To make the students learn estimation and testing of hypotheses of parameters of distributions and their applications in real life situations.

Unit-I

Study of various discrete and continuous distributions: Binomial, Poisson, Geometric, Hyper geometric, Multinomial; Uniform, Exponential, Normal, Cauchy, exponential, Beta and gamma distributions, Bivariate normal distribution. Convergence in distribution (law), Central limit theorems (Laplace-Demoiver and Lindeber-Levy).

Unit-II

Introduction to statistical methods, frequency distributions, measures of central tendency and dispersion, moments and measures of Skewness and Kurtosis. Fitting of Binomial, Poisson and Normal distributions. Theory of attributes independence and association, bivariate correlation and regression.

Unit-III

General concept of Point estimation, unbiasedness, consistency, efficiency, sufficient statistics, Factorization Theorem (without proof), Cramer Rao Inequality (without proof) and their applications. Maximum Likelihood method of estimation and method of moments.

Unit-IV

Concept of sampling distribution and its standard error. Derivation of sampling distributions of Chi-square, t and F. Distribution of sample mean and sample variance from normal distribution. Test of significance, Type I and Type II errors, level of significance. Tests of significance using Chi-square, t and F distributions. Analysis of variance: One way and two-way classifications (one and multiple but equal observations per cell).

BOOKS RECOMMENDED:

1. Hogg R. V., McKean J. W. and Craig A. T., *Introduction to Mathematical Statistics*, Pearson, 2005, Sixth Edition.
2. Gupta S. C. and Kapoor V. K., *Fundamentals of Mathematical Statistics*, Sultan Chand & Sons, 2014, Eleventh Edition.
3. Fisz M., *Probability Theory and Mathematical Statistics*, John Wiley & Sons, 1967, Third Edition.
4. Gun A. M., Gupta M. K. and Dasgupta B., *Fundamentals of Statistics (Vol-I)*, World Press, 2013.
5. Feller W., *An Introduction to Probability Theory and Its Applications (Vol-I)*, John Wiley & Sons, 2003, Third Edition.

Course Outcomes After completion of this course, the students will

- Learn the different distributions, estimation theory and testing of hypothesis.
- Be able to use efficiently statistical tools in solving real life problems.
- Be able to analyze the hypothesis/hypotheses using different tests of significance.

Course Title: Differential Geometry
Course Code: MSM-403

L	T	P
4	1	0

Unit I

Theory of Space Curves: Tangent, principal normal, bi-normal, curvature and torsion. Serretfrenet formulae.Contact between curves and surfaces. Locus of centre of curvature, spherical curvature, Helices.

Unit II

Spherical indicatrix, Bertrand curves, surfaces, envelopes, edge of regression, developable surfaces, two fundamental forms.

Unit III

Curves on a surface, Conjugate Direction, Principle Directions, Lines of Curvature, Principal Curvatures, Asymptotic Lines. Theorem of Beltrami and Enneper, Mainardi- Codazzi equations.

Unit IV

Geodesics, Differential Equation of Geodesic, torsion of Geodesic, Geodesic Curvature, Clairaut's theorem, Gauss- Bonnet theorem, Joachimsthal's theorem, Geodesic Mapping, Tissot's theorem.

BOOKS RECOMMENDED:

1. Weatherburn, C.E., *Differential Geometry of Three Dimensions*, Cambridge University Press, 2016.
2. Willmore, T.J., *Introduction to Differential Geometry*, Dover Publications Inc., United States, 2012.
3. Bansi Lal, *Differential Geometry, 4th Edition.* Atma Ram & Sons, India, 1976.

Elective Subjects

Course Title: Coding Theory
Course Code: MSM-501

L	T	P
4	1	0

Unit-I

Introduction to Coding Theory: Code words, distance and weight function, Nearest-neighbour decoding principle, Error detection and correction, Matrix encoding techniques, Matrix codes, Group codes, decoding by coset leaders, Generator and parity check matrices, Syndrome decoding procedure, Dual codes.

Unit-II

Linear Codes: Linear codes, Matrix description of linear codes, Equivalence of linear codes, Minimum distance of linear codes, Dual code of a linear code, Weight distribution of the dual code of a binary linear code, Hamming codes.

Unit-III

BCH Codes: Polynomial codes, Finite fields, Minimal and primitive polynomials, Bose-Chaudhuri-Hocquenghem codes.

Unit-IV

Cyclic Codes: Cyclic codes, Algebraic description of cyclic codes, Check polynomial, BCH and Hamming codes as cyclic codes. Maximum distance separable codes, Necessary and sufficient conditions for MDS codes, Weight distribution of MDS codes, An existence problem, Reed-Solomon codes.

BOOKS RECOMMENDED

1. Vermani L R, *Elements of Algebraic Coding Theory*, Chapman and Hall, 1996.
2. Vera P.**,** *Introduction to the Theory of Error Correcting Codes*, John Wiley and Sons, 1998.
3. Roman Steven, *Coding and Information Theory*, Springer Verlag, 1992.
4. Garrett Paul, *The Mathematics of Coding Theory*, Pearson Education, 2004.

Course Title: Operations Research
Course Code: MSM-502

L	T	P
4	1	0

UNIT-I

Formulation of linear programming problem (LPP) -graphical method, Basic Feasible Solution, Extreme Points, Convex set, Convex linear combination, optimal solution of LPP using Simplex, Big-M and two-phase methods, Exceptional cases in LPP i.e., Infeasible, unbounded, alternate and degenerate solutions.

UNIT-II

General Primal-Dual pair, Formulating a dual problem, Weak and strong duality theorems, Complementary slackness theorem, Dual simplex method, Economic interpretation of primal-Dual problems. Sensitivity analysis: change in right hand side of constraints, change in the objective function and coefficient matrix addition and deletion of constraint and variables.

UNIT-III

Initial basic Feasible solution of transportation problem, Balanced and unbalanced transportation problems, Optimal solutions of transportation problem using U-V /MODI methods, Assignment problems; Mathematical formulation of assignment problem, typical assignment problem, the traveling salesman problem, Test for optimality, degeneracy, Project management with critical path method.

UNIT-IV

Concept of convexity and concavity, Maxima and minima of convex functions, Single and multivariate unconstrained problems, constrained programming problems, Kuhn-Tucker conditions for constrained programming problems, Quadratic programming, Wolfe's method.

BOOKS RECOMMENDED

1. Taha, H.A., *Operations Research-An Introduction*, PHI, 2007.
2. Kanti Swarup, Gupta, P.K. and Man Mohan, *Operations Research*, Sultan Chand & Sons, Ninth Edition, 2002.
3. Hillier, F.S. and Lieberman, G.J., *Operations Research, Second Edition,* Holden-Day Inc, USA, 1974.
4. Bazaraa, M.S., Sherali, H.D., Shetty, C.M., *Nonlinear Programming: Theory and Algorithms,* John Wiley and Sons, 1993.
5. Chandra, S., Jayadeva, and Mehra, A., *Numerical Optimization and Applications,* Narosa Publishing House, 2013.

Course Title: Advanced Complex Analysis
Course Code: MSM-503

L	T	P
4	1	0

Unit-I

Analytic continuation, Analytic continuation by power series method, Natural boundary, Schwarz reflection principle, Analytic continuation along a path, Monodromy theorem, Runge's theorem, simple connectedness, Mittag-Leffler's theorem.

Unit-II

Maximum principle, Schwarz's Lemma, Hadamard's three circle theorem, Phragmen-Lindelof theorem, Weierstrass factorization theorem, Factorization of sine function, Gamma function. Entire functions, Jensen's formula, the genus and order of an entire function, Hadamard factorization theorem.

Unit-III

Harmonic functions, Basic properties, Harmonic functions on a disc, Subharmonic and Superharmonic functions, The Dirichlet problem, Green's function.

Unit-IV

Normal families of analytic functions, Montel's theorem, Hurwitz's theorem, Riemann mapping theorem, Univalent function, Distortion and Growth theorem for the class of normalized univalent functions, Covering theorem, starlike functions, convex functions, Subordination principle.

BOOKS RECOMMENDED

1. Nihari, Z., Conformal Mapping, Conformal Mapping, McGraw-Hill,1952.
2. Conway, J.B., Functions of One Complex Variable, Springer-Verlag,1973
3. Gamelin, T.W., Complex Analysis, Springer, 2004.
4. Tutschke, W. and Vasudeva, H.L., An Introduction to Complex Analysis- Classical and Modern Approaches, Chapman & Hall/CRC, 2005
5. Copson, E.T., An Introduction to Theory of Functions of a Complex Variable.

Course Title: Advanced Operations Research
Course Code: MSM-504

L	T	P
4	1	0

Unit I

Advanced Linear Programming: Revised simplex method, Sensitivity analysis, Parametric programming, Integer programming branch and bond algorithm, Goal programming, Standard form of LGPP, Partitioning algorithm.

Unit II

Game Theory: Two person zero sum games pure strategies (minmax and maximum principles), Game with saddle point, Mixed strategies: Game without saddle point, Rule of Dominance, Solution methods for games without saddle point: Graphical method, Linear programming method.

Unit III

Dynamic Programming: Characteristics of dynamic programming, Recursive relations, continuous and discrete cases, forward recursion, linear programming versus dynamic programming, Dynamic programming approach for Priority Management employment smoothening, capital budgeting, Stage Coach/Shortest Path, cargo loading and Reliability problems.

Unit IV

Inventory Models: Deterministic models: Classic EOQ (Economic order quantity) models, EOQ with price brakes, Multi item EOQ with storage limitation, Dynamic EOQ models(b) Probabilistic models: Probabilistic EOQ models, Single period models and multiperiod models.

Books Recommended

1. Taha, H.A., *Operations Research- An introduction*, 8th Edition, PHI, 2007.
2. Sharma, J.K, *Operation research: Theory & Applications*, 3rd Edition, Macmillan India, 2007.
3. Kasana, H.S and Kumar K.D, *Introductory Operations Research: Theory & Applications*, Springer, 2005.
4. Pant, J.C, Introduction to Optimization and Operations Research, Jain Brothers, 2004.

Course Title: Advanced Fluid Mechanics
Course Code: MSM-505

L	T	P
4	1	0

UNIT-I

Basic Concepts: Continuum Hypothesis, Viscosity, Most general motion of a fluid element, Rate of strain quadric, stress at a point, Tensor character of stress matrix, Symmetry of stress matrix, stress quadric, Stress in a fluid at rest, stress in a fluid in motion, Relation between stress and rate of strain components (Stoke's law of friction), Thermal conductivity, Generalized law of heat conduction, Fundamental equations of the flow of viscous fluids: Equation of state, equation of continuity - Conservation of mass, Equation of motion- Navier-Stoke's equations, Equation of energy- Conservation of energy, Symmetry of fundamental equations, Vorticity and circulation in a viscous incompressible fluid motion, (a) velocity transport equation, (b) Circulation

UNIT-II

Dynamical similarity and Dynamical Analysis: Dynamical similarity, Reynold's law, Inspection analysis, Dimensional analysis, Buckingham π-theorem. Method of finding out the pi-products, Application of pi- theorem to viscous and compressible fluid. Physical importance of non-dimensional parameters. Reynolds number, Eckert Number, Froude Number, Mach Number, Pecklet Number, Grashoff Number, Prandtl Number, Brinkman Number, Nussel Number. Exact Solution of Navier-Stoke's equations of motion- Flow between parallel plates (Velocity and temperature distributions), (i) Plane Couette flows (ii) Plane Poiseulle Flow and (iii) Generalized Couette flow.

UNIT-III

Flow in a circular pipe (Hagen Poiseuille flow) -Velocity and temperature distribution, Flow through tubes of uniform cross section in the form of circle, annulus, ellipse and equilateral triangle under constant pressure gradient. Flow between two concentric rotating cylinders (Couette flow) , Flow in convergent and divergent channels,

UNIT-IV

Steady incompressible flow with variable viscosity: Variable viscosity plane Couette flow and plane poiseulle flow. Unsteady incompressible flow with constant fluid properties: Flow due to a plane wall suddenly set in motion, flow due to an oscillating plane wall, starting flow in plane Couette motion, Starting flow in pipes, Plane coquette flow with transpiration cooling.

Books Recommended

1. Bansal, J L, *Viscous Fluid Dynamics*, OXFORD & IBH Publishing Company Pvt. Ltd., New Delhi, 1992.

2. Chorlton, F., *Textbook of Fluid Dynamics*, C.B.S. Publishers, Delhi, 1985.

3. Schlichting, H., *Boundary Layer Theory*, McGraw Hill Book Company, New York, 1979.

4. Young, A. D., *Boundary Layers*, AIAA Education Series, Washington DC, 1989.

5. Yuan, S.W., *Foundations of Fluid Mechanics*, Prentice Hall of India Private Limited, New Delhi, 1976

Course Title: Advanced Solid Mechanics
Course Code: MSM-506

L	T	P
4	1	0

Unit-I

Basics and Extension of Beams: Hooke's law, generalized Hooke's law, Elastic moduli and their relationship, strain-energy density function and its connection with Hooke's law, Saint-Venant's principle. Extension of beams: extension of beams by longitudinal forces, beam stretched by its own weight and bending of beams by terminal couples.

Unit-II

Torsion and flexure of beams: Torsion of a circular shaft, cylindrical bars, and elliptic cylinder. Stress function, conformal mapping, solution of torsion problem by conformal mapping. Flexure of beams by terminal loads, bending of rectangular beams.

Unit-III

Two-and Three-dimensional Problems: Plane deformation, plane stress, plane elastostatic problems, Airy's stress function, solution of the bi-harmonic equation, stress and displacement formulae basic problems of circular region: uniform pressure, uniform radial displacement and concentrated loads. Spherical shell under external and internal pressures.

Unit-IV

Thermoelastic problems and Variational Methods: Thermal stresses in spherical bodies, two-dimensional thermoelastic problems. Variational methods: Theorems of potential energy, minimum

complementary energy, work and reciprocity, Ritz method for one- and two-dimensional problems and Galerkin's method. Kantorovich and Trefftz methods. Application of Treffz method.

Books Recommended

1. Sokolnikoff, I.S., *Mathematical Theory of Elasticity*, TMH, New Delhi 1978.

2. Timoshenko.S. and Young D.H., *Elements of strength of materials Vol. I & Vol. II*, T. Van Nostrand Co-Inc Princeton, N.J., 1990.

3. Love, A.E.H, *A Treatise on the Mathematical theory of Elasticity*, Cambridge University Press, 1963.

Course Title: Theory of Linear Operators
Course Code: MSM-507

L	T	P
4	1	0

Unit I

Spectral theory in normed linear spaces, resolvent set and spectrum, spectral properties of bounded linear operators. Properties of resolvent and spectrum. Spectral mapping theorem for polynomials.

Unit II

Elementary theory banach algebra, Spectral radius of a bounded linear operator on a complex banach space.

Unit III

General properties of compact linear operators. Spectral properties of compact linear operators on normed spaces. Behaviors of compact linear operators with respect to solvability of operator equations. Fredholm type theorems. Fredholm alternative theorem. Fredholm alternative for integral equations.

Unit IV

Spectral properties of bounded self-adjoint linear operators on a complex Hilbert space. Positive operators. Monotone Sequences theorem for bounded self-adjoint operators on a complex Hilbert space, Square roots of a positive operator.

Books Recommended

1. Kreyszig E., *Introductory functional analysis with applications*, Johan-Wiley & Sons, New York, 1978.

2. Halmos P.R., *Introduction to Hilbert space and the theory of spectral multiplicity*, 2nd Edition. Chelsea Pub., Co., N.Y. 1957.

3. Dunford N. and Schwartz, J.T., *Linear operators-3 parts*, Inter-science Wiley, New York, 1958-71.

4. Bachman G. and Narici, L., *Functional analysis*, Academic Press, New York, 1998.

Course Title: Advanced Numerical Methods
Course Code: MSM-508

L	T	P
4	**1**	**0**

Unit-I

Iterative Methods for Linear Systems: The classical iterative methods (Jacobi, Gauss-Seidel and Successive Over Relaxation (SOR) methods), Krylov subspace methods; Conjugate gradient, Bi-conjugate-gradient (BiCG), BiCG stability methods, Preconditioning techniques, parallel implementations.

Unit-II

Finite Difference Methods: Explicit and implicit schemes, consistency, stability and convergence, Lax equivalence theorem, numerical solutions to elliptic, parabolic and hyperbolic partial differential equations.

Unit-III

Approximate methods of solution: Rayleigh-Ritz, collocation and Galerkin methods, properties of Galerkin approximations, Petrov-Galerkin method, Generalized Galerkin method.

Unit-IV

Finite Element Method (FEM): FEM for second order problems, One- and two-dimensional problems, The finite elements (elements with a triangular mesh and a rectangular mesh and three-dimensional finite elements), Fourth-order problems, Hermite families of elements, iso-parametric elements, numerical integration.

BOOKS RECOMMENDED:

1. Jain, M.K, Iyengar, S.R.K. and Jain, R.K., *Numerical Methods for Scientific and Engineering Computation*, 5th Edition, New Age international, 2008.

2. Hoffman Joe D., *Numerical methods for Engineers and Scientists*, McGrow-Hill, 1993.

3. Atkinson, K.E, *An Introduction to Numerical Analysis*, 2nd Edition, *John Wiley*, 2004.

4. Gupta R.S., *Elements of Numerical Analysis*, McMillan India, 2009

5. Seshu P., *Textbook of Finite Element Analysis*, Prentice Hall India, 2003.

Course Title: Topological Vector Spaces
Course Code: MSM-509

L	T	P
4	1	0

Unit-I

Review of basic concepts of topological spaces and vector spaces. Prodect topological spaces, projection maps, compactness of prodect topological spaces-Tichonov's theorem.

Topological vector spaces (TVSs), examples of TVSs, Normed vector spaces as TVSs, Translation and multiplication maps, Neighborhood of 0, separated TVS, linear maps between TVSs, Bounded subsets of a topological vector space.

Unit-II

Locally convex topological spaces, normable and metrizable topological vector spaces, complete topological vector spaces

Unit-III

Frechet spaces, Uniform boundedness principle, open mapping and closed graph theorems for Frechet spaces.

Unit-IV

Banach-Alaoglu theorem, Variational inequalities, Lion-Stampacchia theory, Physical phenomenon represented by variational inequalities, points and external sets-Krein Miliman theorem.

BOOKS RECOMMENDED:

1. Munkres J. R., *Topology – A First Course*, Prentice-Hall of India, 1978.

2. Kelley, J.L., *Linear topological spaces*, Van Nostrand East West Press, New Delhi.

3. Wilansky A., *Modern Methods in Topological Vector Spaces*, McGraw Hill, 1978.

4. Simmons G. F., *Introduction to Topology and Modern Analysis*, McGraw-Hill, 1963.

5. Rudin W., *Functional Analysis*, 2nd Edition, McGraw Hill, 1973.

Course Title: Fractional Calculus
Course Code: MSM-510

L	T	P
4	1	0

Unit-I

Special Functions of the Fractional Calculus. Gamma Function. Mittag-Leffler function, Fractional Derivatives and Integrals. Grunwald-Letnikov Fractional Derivatives. Riemann Liouville Fractional Derivatives. Some Other Approaches.

Unit-II

Geometric and Physical Interpretation of Fractional Integration and Fractional Differentiation. Sequential Fractional Derivatives. Left and Right Fractional Derivatives. Properties of Fractional Derivatives. Laplace Transforms of Fractional Derivatives. Fourier Transforms of Fractional Derivatives. Mellin Transforms of Fractional Derivatives.

Unit-III

Linear Fractional Differential Equations. Fractional Differential Equation of a General Form. Existence and Uniqueness Theorem as a Method of Solution. Dependence of a Solution on Initial Conditions. The Laplace Transform Method. Standard Fractional Differential Equations. Sequential Fractional Differential Equations. Fractional Green's Function. Definition and Some Properties. One-Term Equation. Two Term Equation. Three-Term Equation. Four-Term Equation. General Case: n-term Equation.

Unit-IV

Other Methods for the Solution of Fractional-order Equations. The Mellin Transform Method. Power Series Method. Babenko's Symbolic Calculus Method. Method of Orthogonal Polynomials. Numerical Evaluation of Fractional Derivatives. Approximation of Fractional Derivatives. Order of Approximation. Computation of Coefficients. Higher-order Approximations.

Books Recommended

1. Podlubny, I., *Matrix approach to discrete fractional calculus vol. 3*, Fractional Calculus and Applied Analysis, 2000.

2. Carpinteri A, Mainardi F, editors. *Fractals and fractional calculus in continuum mechanics*, New York, Springer-Verlag Wien, 1997.

3. Mandelbrot B.B., *The fractal geometry of nature*, New York, W. H. Freeman, 2000.

4. Miller K.S., Ross B., *An introduction to the fractional calculus*. New York, John Wiley, 1993.

5. Oldham KB, Spanier J., *The fractional calculus*, New York, Academic Press; 1974.

Course Title: Discrete Mathematics
Course Code: MSM-511

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Unit-I

Mathematical Logic: Basic logical operations, conditional and bi-conditional statements, tautologies, contradiction, predicate calculus and its inference theory.

Recursion and Recurrence Relations: Polynomial expressions, telescopic form, recursion theorem, closed form expression, generating function, solution of recurrence relation using generating function, recursion.

Unit-II

Lattices and Boolean Algebra: Introduction to Binary relations, equivalence relations and partitions, Partial order relations, Hasse diagram. Lattices as partially ordered sets, properties, lattices as algebraic systems, sub lattices, direct products, Homomorphism, some special lattices. Boolean algebra as lattices, Boolean identities, sub-algebra, Boolean forms and their equivalence, sum of product, product of some canonical forms. Applications of Boolean algebra to circuit theory.

Unit-III

Graph Theory: Directed graphs, undirected graphs, paths, circuits, cycles, sub-graphs, induced Sub graphs, degree of vertex, connectivity, planner graph, complete, bi-partite complete graph, matrix representation of graph, adjacency and incidence matrix for graph, Eulerian paths and circuits, Trees and Coloring of the graph, Rooted tree, search tree, tree traversals, spanning trees, minimal spanning trees, Kruskal's algorithm. Chromatic number and polynomial, four-color problem (statement only).

Unit-IV

Algebraic Structures: Review of groups, codes and group codes, cyclic codes and coding methods based on entropy, Application of algebraic structure to error corrections and detection codes, discrete codes and first coding theorem.

BOOKS RECOMMENDED:

1. Tremblay, J.P. and Manohar, R.P., *Discrete Mathematics with Applications to Computer Science*, Tata McGraw Hill, 2008.
2. Ram, Babu, *Discrete Mathematics*, Pearson Education, 2007.
3. Harary, F., *Graph Theory*, Narosa, 1995
4. Doerr, Alan and Levsseur, K., *Applied Discrete Structures for Computer Science*, Galgotia Publication, 2005.
5. Liu, C.L, *Elements of Discrete Mathematics*, 3rd Edition, Tata McGraw Hill, 2008.
6. Grimaldi, R.P and Ramana, B.V., *Discrete and Combinatorial Mathematics-An Applied Introduction*, Pearson education, 5th Edition, 2004.
7. Lipschultz, S., *Theory and Practice of Data Structures*, McGraw-Hill, 1988.