COURSE SCHEME
FOR
M. Sc. (Mathematics)
1st to 4th Semester

Marks distribution for all types of courses:
Theory: Mid Semester Evaluation-50 Marks, End Semester Evaluation -100 Marks
Practical/Project/Training: Mid Semester Evaluation-100 Marks, End Semester Evaluation -50 Marks

Department of Applied Mathematics
M. Sc. Mathematics

1st Semester **Contact hours: 31**

Course Code	Course Name	Load Allocated			Credits	Type of Course
		L	T	P		
MSMT-23101	Real Analysis-I	4	1	-	5	Theory
MSMT-23102	Algebra-I	4	1	-	5	Theory
MSMT-23103	Complex Analysis	4	1	-	5	Theory
MSMT-23104	Ordinary Differential equations & Special Functions	4	1	-	5	Theory
MSMT-23105	Mathematical Methods	4	1	-	5	Theory
MSMT-23106	Computer Programming with C	2	-	4	4	Practical
	Total	**22**	**5**	**4**	**29**	

2nd Semester **Contact hours: 29**

Course Code	Course Name	Load Allocated			Credits	Type of Course
		L	T	P		
MSMT-23201	Real Analysis-II	4	1	-	5	Theory
MSMT-23202	Algebra-II	4	1	-	5	Theory
MSMT-23203	Linear Algebra	4	1	-	5	Theory
MSMT-23204	Partial Differential Equations	4	1	-	5	Theory
MSMT-23205	Numerical Analysis	4	1	-	5	Theory
MSMT-23206	Computational Numerical Analysis Lab	-	-	4	2	Practical
	Total	**20**	**5**	**4**	**27**	

3rd Semester **Contact hours: 25**

Course Code	Course Name	Load Allocated			Credits	Type of Course
		L	T	P		
MSMT-23301	Topology	4	1	-	5	Theory
MSMT-23302	Functional Analysis-I	4	1	-	5	Theory
Elective/Optional Courses (choose any three courses)						
MSMT-23303	Probability and Mathematical Statistics-I	4	1	-	5	Theory
MSMT-23304	Discrete Mathematics-I	4	1	-	5	Theory

MSMT-23305	Operations Research-I	4	1	-	5	Theory
MSMT-23306	Mechanics-I	4	1	-	5	Theory
MSMT-23307	Differential Geometry	4	1	-	5	Theory
MSMT-23308	Classical Mechanics and Calculus of Variations	4	1	-	5	Theory
	Total	**20**	**5**	**0**	**25**	

4th Semester **Contact hours: 25**

Course Code	Course Name	Load Allocated			Credits	Type of Course
		L	T	P		
MSMT-23401	Number Theory	4	1	-	5	Theory
MSMT-23402	Functional Analysis-II	4	1	-	5	Theory
Elective/Optional Courses (choose any three courses)						
MSMT-23403	Probability and Mathematical Statistics-II	4	1	-	5	Theory
MSMT-23404	Discrete Mathematics-II	4	1	-	5	Theory
MSMT-23405	Operations Research-II	4	1	-	5	Theory
MSMT-23406	Mechanics-II	4	1	-	5	Theory
MSMT-23407	Fractional Calculus	4	1	-	5	Theory
MSMT-23408	Fourier Analysis	4	1	-	5	Theory
MSMT-23409	Measure Theory	4	1	-	5	Theory
	Total	**20**	**5**	**0**	**25**	

MSMT-23101
REAL ANALYSIS-I

L	T	P	C
4	1	0	5

Course Objectives:

This course is designed to provide a deeper and rigorous understanding of fundamental concepts viz. metric spaces, continuous functions, sequences and series of numbers as well as functions, and the Riemann-Stieltjes integral etc. The main focus of this course will be on theoretical foundation of the above said concepts and it will cultivate the rigorous mathematical logics and skills in the students.

1. Basic Topology: (12)

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.

2. Limits & Continuity: (12)

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

3. The Riemann-Stieltjes integral: (12)

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

4. Sequences and series of functions: (12)

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.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Apply the knowledge of concepts of real analysis in order to study theoretical development of different mathematical techniques and their applications.
- Deal with axiomatic structure of metric spaces and generalize the concepts of sequences and series, and continuous functions in metric spaces.
- Use theory of Riemann-Stieltjes integral in solving definite integrals arising in different fields of science and engineering.

Reference Books:

1. Walter Rudin : Principles of Mathematical Analysis (3rd Edition) McGraw-Hill Ltd.
2. Simmons : Introduction to Topology and Modern Analysis, McGraw- Hill Ltd.
3. Shanti Narayan & P.K. Mittal : A Course of Mathematical Analysis.
4. S.C. Malik & Savita Arora : Mathematical Analysis, Wiley Eastern Ltd

MSMT-23102
ALGEBRA-I

L	T	P	C
4	1	0	5

Course Objectives:

This course is designed to give students a foundation for all future mathematics courses. The fundamentals of algebraic problem-solving are explained. Students will explore foundations of Algebraic structures. The course also fulfills the objective to make students aware of the applicability of abstract mathematics in real world problems

1. **(12)**

Groups, Subgroups, Equivalence relations and partitions, generators and relations, Homomorphisms, Cosets, Normal subgroups, Simple groups, Quotient groups, Group actions, Lagrange's theorem, Conjugate elements, the Class equation, Isomorphism theorems, Cyclic Groups, Cauchy's theorem.

2. **(12)**

Composition series, the Jordan Holder theorem, Groups of automorphisms, Inner automorphisms, Symmetric groups, Alternating groups, Sylow's theorems, p-groups.

3. **(12)**

Nilpotent groups, Simplicity of An $n \geq 5$, Cayley's theorem, the imbedding theorem, Commutator subgroup, Characteristic subgroup, Solvable groups, Sequences of subgroups.

4. **(12)**

Direct product and semi direct product of groups, Fundamental theorem of finitely generated Abelian groups, Free groups, groups of symmetries, Groups of small order.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Apply the knowledge of Algebra to attain a good mathematical maturity and enables to build mathematical thinking and skill.
- Utilize the class equation and Sylow theorems to solve different related problems.
- Identify and analyze different types of algebraic structures such as Solvable groups..
- Identify the challenging problems in modern mathematics and find their appropriate solutions.

Reference Books:

1. M. Artin : Algebra, Prentice-Hall
2. D.S. Dummit : Abstract Algebra, John-Wiley & Sons, Students Edition- 1999 & Foote
3. Surjit Singh, and Qazi Zameerudin : Modern Algebra.
4. J. Gallian : Contemporary Abstract Algebra

MSMT-23103
COMPLEX ANALYSIS

L	T	P	C
4	1	0	5

Course Objectives:

The objective of this course is to introduce and develop a clear understanding of the fundamental concepts of Complex Analysis such as analytic functions, Cauchy-Riemann relations and harmonic functions and to make students equipped with the understanding of the fundamental concepts of complex variable theory

1. **(12)**

Functions of complex variables, limit, continuity and differentiability, Analytic functions, Conjugate function, Harmonic function, Cauchy Riemann equations (Cartesian and Polar form), Construction of analytic functions.

2. **(12)**

Complex line integral, Cauchy's theorem, Cauchy's integral formula and its generalized form. Cauchy's inequality. Poisson's integral formula, Morera's theorem, Liouville's theorem, Power Series and its circle of convergence.

3. **(12)**

Taylor's theorem, Laurent's theorem. Zeros and Singularities of an analytic function, Residue at a pole and at infinity, Cauchy's Resiude theorem, Integration round unit circle, Evaluation of integrals of the type $\int^{\infty}$.

4. **(12)**

Jordan's lemma, Fundamental theorem of algebra, Argument principle, Rouche's theorem, Conformal transformations, Bilinear transformations, critical points, fixed points, cross ratio, Problems on cross ratio and bilinear transformation.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Know the fundamental concepts of complex analysis.
- Evaluate complex integrals and apply Cauchy integral theorem and formula
- Solve the problems using complex analysis techniques applied to different situations in engineering and other mathematical contexts

Reference Books:

1. Copson, E.T.: Theory of functions of complex variables.
2. Ahlfors, D. V.: Complex analysis.
3. Titchmarsh, E.C. :Theory of functions of a complex variable.
4. Kumar, R.R. : Complex Analysis, Pearson Education.

MSMT-23104

ORDINARY DIFFERENTIAL EQUATIONS AND SPECIAL FUNCTIONS

L	T	P	C
4	1	0	5

Course Objectives:

The objective of this course is to introduce ordinary differential equations and fundamental theorems for existence and uniqueness. This course further explains the analytic techniques in computing the solutions of various ordinary differential equations appearing in various fields of science and technology.

1. **(12)**

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.

2. **(12)**

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.

3. **(12)**

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.

4. **(12)**

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

Course Outcomes (COs):

On the completion of course, students will be able to:

- Understand ordinary differential equations of various types, their solutions, and fundamental concepts about their existence.
- Understand the concept and applications of eigen value problems
- Understand differential equations of Strum Liouville type.
- Apply various power series methods to obtain series solutions of differential equations

Reference 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. Raisinghania, M.D., Advanced Differential Equations. S. Chand Publications, 1995

MSMT-23105
MATHEMATICAL METHODS

L	T	P	C
4	1	0	5

Course Objectives:

The objective of the course is to acquaint the students with the knowledge of mathematical techniques frequently applied in various branches of engineering and sciences. Also, one of the objectives of this course is to equip the students with the mathematical background required for the development of such techniques.

1. **(12)**

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

2. **(12)**

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.

3. **(12)**

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.

4. **(12)**

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.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Understand the theory and applications of integral transforms
- Explain how integral transforms can be used to solve a variety of differential equations.
- Solve integro-differential equations of Fredholm and Volterra type.
- Understand the properties of various kinds of integral equations

Reference Books:

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

MSMT-23106

COMPUTER PROGRAMMING WITH C

L	T	P	C
2	0	4	4

Course Objectives:

The objective of this course is to help the students in finding solutions to various real life problems and converting the solutions into computer program using C language (structured programming).Students will learn to write algorithm for solutions to various real life problems.

1. **(6)**

Basic Structure of C-Program, constants, variables, Data types, Assignments, console I/O statements, Arithmetical, Relational and logical operators, Control statements: if, switch.

2. **(6)**

While, do while, for, continue, goto and break. Function definition and declaration, Arguments, return values and their types, Recursion. One and two-dimensional arrays, Initialization, Accessing array elements, Functions with arrays.

3. **(6)**

Address and pointer variables, declaration and initialization, pointers and arrays, pointers and functions.

4. **(6)**

Structure initialization, structure processing, nested structure, Array of structures, structure and functions. Union, defining and opening a file, closing a file, Input/Output operations on files.

Laboratory Assignments (do any Six from the list below)

1. Find average of N numbers.
2. Calculate the real roots of quadratic equation.
3. To check the given number is even and odd.
4. Input / Output using nested loops.
5. Input / Output with array using loop structures.
6. Find the average of any N numbers using linear array.
7. Find sum of two numbers using argument with return.
8. Find solution of linear equation using return.

Instructions for students :

Students are required to give written exam during practical examination.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Understand the right statement for the program.
- Understand the logic building used in Programming.
- Write algorithms for solving various real life problems.
- To convert algorithms into programs using C .

Reference Books:

1. Norton Peter: Introduction to Computers, Tata McGraw Hill .
2. R. Singh and I. Singh,: Expert C++ programming, Khanna Book Publisher.
3. Yashavant Kanetkar: Let us C.
4. E Balagurusamy: Programming in ANSI C.

MSMT-23201
REAL ANALYSIS-II

L	T	P	C
4	1	0	5

Course Objectives:

This course is designed to consider theoretical foundations of concepts of mathematical analysis, viz. derivative, mean value theorems, functions of several variables, Lebesgue Measure theory, Lebesgue Differentiation and Integration that have many important applications in different branches of pure and applied mathematics. Further, the objective is enable students familiar with these concepts and their fruitful applications

1. **(10)**

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.

2. **(10)**

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

3. **(10)**

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.

4. **(15)**

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.

Course Outcomes(COs):

On the completion of course, students will be able to:

- Understand the nature of abstract mathematics and explore the concepts in further details.
- Utilize the concepts of derivative, MVTS for vector-valued functions and measure theory in various fields like management, industry and economics etc.
- Extend their knowledge of Lebesgue theory of integration by selecting and applying its tools for further research in related areas.

Reference Books:

1. Royden, H.L. and Fitzpatrick, P.M.: Real Analysis, 4th Edition. New Delhi: Pearson
2. Barra, G. de.: Measure Theory and Integration, New Delhi: Woodhead Publishing
3. Rudin, W.: Principles of Mathematical Analysis, 3rd Edition. New Delhi: McGraw-Hill Inc.

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.

MSMT-23202
ALGEBRA-II

L	T	P	C
4	1	0	5

Course Objectives:

This course is designed to give students a foundation for advanced study in Algebra. The fundamental theorems of algebraic structures are explained. Students will explore the concepts of Polynomial rings, UFD, ED, PID, Field extensions,modules etc. Throughout the course, Advanced Core standards are taught and reinforced as the student learns how to apply the concepts in real-life situations.

1. (**10)**

Rings, Subrings, Ideal, Factor Rings, Homomorphisms, Integral domains, Maximal and Prime Ideals, The field of quotients of an integral domain, Chinese Remainder Theorem, Simple Rings, Ideals of Matrix rings.

2. (**10)**

Principal Ideal domains, Euclidean rings, The ring of Gaussian Integers, Unique factorization domains, Gauss Lemma, Polynomial rings, Division algorithm, factorization in polynomial rings over unique factorization domains.

3. (13)

Modules, submodules, free modules, quotient modules, Homomorphism theorems, direct sums, finitely generated modules, Simple modules, cyclic modules, differences between modules over rings and vector spaces.

4. (12**)**

Modules over PID's, structure theorem of modules over PID's, Torsion modules, Torsion free modules, Artinian and Noetherian Modules, Artinian And Noetherian rings, modules of finite length.

Course Outcomes(COs):

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

- Apply the knowledge of Algebra to attain a good mathematical maturity and enables to build mathematical thinking and reasoning.
- Utilize the Polynomial rings, UFD, ED, PID to solve different related problems.
- Design, analyze and implement the concepts of Gauss Lemma, Einstein's irreducibility criterion, separable extensions etc.
- Identify the challenging problems in advanced Algebra to pursue further research.

Reference Books:

1. Fraleigh, J.B, : A First Course in Abstract Algebra 7th edition, Narosa Publishing House, New Delhi.
2. Singh, S. and Zameeruddin, Q.: Modern Algebra, Vikas Publishing House, New Delhi.
3. Dummit, D.S. and Foote, R.M.: Abstract Algebra, John-Wiley & Sons, Student Edition.
4. Bhattacharya, P.B., Jain, S.K., Nagpal, S.R.: Basic Abstract Algebra, Cambridge University Press.
5. Musili, C.: Rings and Modules, Narosa Publishing House, New Delhi

MSMT-23203
LINEAR ALGEBRA

L	T	P	C
4	1	0	5

Course Objectives:

This course is designed to give students a foundation for fundamentals of algebraic problem-solving. Students will explore about vector spaces, linear transformation, linear operators inner product spaces and so on. The course also fulfills the objective to make students aware of the applicability of linear algebra in solving the real world problems.

1. (**10)**

Vector spaces, Subspaces, Quotient Spaces, Basis and Dimension Theorems, Sum of subspaces, Direct sum decompositions, Linear transformations, The Algebra of linear transformations.

2. (**10)**

Matrices associated with linear transformations, effect of change of ordered bases on the matrix of linear transformations, Elementary matrix operations and Elementary matrices, Row rank, Column rank and their equality, system of linear equations

3. (**13)**

Eigen values and Eigen vectors of linear operators, Characteristic and minimal polynomials, companion matrix, subspaces invariant under linear operators, triangulation, Diagonalization, Linear Functionals, Dual Spaces and dual basis, the double dual

4. (**12)**

Inner Product Spaces, The Gram-Schmidt Orthogonalization, Orthogonal Complements, The Adjoint of a linear operator on an inner product space, Normal and Self-Adjoint Operators, Unitary and Normal Operators, Spectral Theorem

Course Outcomes(COs):

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

- Apply the knowledge of linear Algebra to attain a good mathematical maturity and enables to build mathematical thinking and skill.
- Identify and analyze different types of effect of change of ordered bases on the matrix of linear transformations.
- Identify the challenging problems to find their appropriate solutions using the concepts of linear transformations.
- Extend their knowledge of linear algebra for further exploration of the subject for going into research.

Reference Books:

1. Hoffman, K. and Kunze, R. : Linear Algebra, Second Edition, Prentice Hall.
2. Axler, S.: Linear Algebra Done Right, Second Edition, Springer-Verlag.

3. Friedberg, S.H., Insel, A.J and Spence, L.E. : Linear Algebra, Fourth Edition, Prentice Hall.
4. Lang, S.: Linear Algebra, Third Edition, Springer-Verlag.
5. Sahai,VivekandBist, Vikas: Linear Algebra, Narosa Publishing House.

MSMT-23204
PARTIAL DIFFERENTIAL EQUATIONS

L	T	P	C
4	1	0	5

Course Objectives:

The Objective of this course is to introduce first and higher order partial differential equations and their classification. This course explains various analytic methods for computing the solutions of various partial differential equations and their applications in real physical phenomenon like wave equation of string, diffusion equations, boundary value problems and so on to students.

1. **(15)**

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.

2. **(10)**

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.

3. **(10)**

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.

4. **(10)**

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.

Course Outcomes(COs):

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

- Understand partial differential equations of first order, second and higher order.
- Determine integral surfaces passing through a curve, characteristic curves of second order PDE and compatible systems.
- Apply the knowledge of formation and solve some significant PDEs like wave equation, heat equation, diffusion equation and other physical phenomenon.

Reference Books:

1. Sneddon, I.N., Elements of Partial Differential Equation, 3rd Edition. McGraw Hill Book Company.
2. Copson, E.T., Partial Differential Equations, 2nd Edition. Cambridge University Press.
3. Strauss, W.A., Partial Differential Equations: An Introduction, 2 nd Edition.

4. Sharma, J.N. and Singh, K., Partial differential equations for engineers and scientists, 2 nd Edition. New Delhi: Narosa Publication House.

MSMT-23205
NUMERICAL ANALYSIS

L	T	P	C
4	1	0	5

Course Objectives:

This course is designed to introduce the basic concepts of Numerical Mathematics in order to solve the problems arising in various fields that do not possess analytical solutions. This course addresses development, analysis and application of different numerical methods to solve the problems, viz. system of linear & nonlinear equations, initial and boundary value problems of ordinary differential equations, and interpolation etc.

1. **(15)**

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.

2. **(10)**

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.

3. **(10)**

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.

4. **(10)**

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.

Course Outcomes(COs):

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

- Identity and analyze different types of errors encountered in numerical computing.

- Apply the knowledge of Numerical Mathematics to solve problems efficiently arising in science, engineering and economics etc.
- Design, analyze and implement of numerical methods for solving different types of problems, viz. initial and boundary value problems of ordinary differential equations etc.
- Identify the challenging problems in continuous mathematics (which are difficult to deal with analytically) and find their appropriate solutions accurately and efficiently.

Reference Books:

1. Sharma, J.N.: Numerical Methods for Engineers and Scientists, 2nd Edition. Narosa Publ. House New Delhi/Alpha Science International Ltd., Oxford UK.
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
3. Bradie, B.: A Friendly Introduction to Numerical Analysis. Pearson Prentice Hall.
4. Atkinson, K.E.: Introduction to Numerical Analysis, 2nd Edition. John Wiley.
5. Scarborough, J.B.: Numerical Mathematical Analysis. Oxford & IBH Publishing Co.

MSMT-23206
COMPUTATIONAL NUMERICAL ANALYSIS LAB

L	T	P	C
2	0	4	4

Course Objectives:

This course is designed to provide understanding and implementation of basic numerical methods for solving different problems viz.system of linear and nonlinear equations, interpolation and extrapolation, differentiation and integration, initial and boundary value problems of ordinary differential equations etc. Further, this course will develop programming skills in the students in order to write and implement their own computer programs for solving problems arising in various fields.

Laboratory Assignments (do any eight programs from the list below)

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.

Course Outcomes(COs):

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

- Apply their knowledge of computer programming to develop and implement their own computer codes of numerical methods for solving different types of complex problems.
- Understand different implementation modes of a numerical method in order to solve a given problem efficiently.
- Develop, select and apply numerical methods as a computer code with the understanding of their limitations so that they can be implemented in order to get acceptable results.

Reference Books:

1. R. Singh and I. Singh,: Expert C++ programming, Khanna Book Publisher.
2. Byron S. Gottrfried: Programming with C (Schaum’s outline series).
3. Balagurusamy, E., Object Oriented Programming with C++. New Delhi: Tata McGraw Hill, 1999. R.S. Salaria: Application Programming in C
4. Conte, S.D. and Boor, C.D., Numerical Analysis. New York: McGraw Hill.

MSMT-23301
TOPOLOGY

	L	T	P	C
Course Objectives:	4	1	0	5

The objective of the course on Topology is to provide the knowledge of Topological Spaces and their importance. To acquaint students with the concept of Homeomorphism and the topological properties and important mathematical concepts which can be generalized in topological spaces, so that students may learn and appreciate the nature of abstract Mathematics.

1. **(12)**

Topological spaces, Continuous functions, Homeomorphisms, Countability axioms Productspaces, Quotient spaces, Topological groups.

2. **(12)**

Connectedness, Intermediate value theorem and uniform limit theorem, Local connectedness.

3. **(12)**

Compactness, Finite intersection property (F.I.P.), Cantor's intersection theorem, Uniform continuity, Bolzano-Weierastrass Property, Local compactness, Metrizable topological spaces, The Tychonoff Theorem.

4. **(12)**

Separation axioms, Hausdorff spaces, Regular Spaces, Normal spaces, Urysohn's Lemma, Completely regular spaces, , Urysohn's Metrization Theorem, The Tietze extension theorem, Completely normal spaces.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Understand the concepts of topological spaces and the basic definitions of open sets, neighbourhood, interior, exterior, closure and their axioms for defining topological space.
- Understand the concept of Bases and Subbases, create new topological spaces by using subspace
- Understand continuity, compactness, connectedness, homeomorphism and topological properties.
- Understand how points of space are separated by open sets, Housdroff spaces and their importance.
- Understand regular and normal spaces and some important theorems in these spaces

Reference Books:

1. J. R. Munkres : Topology, Prentice Hall of India, 2007 (Indian reprint)

2. Simmons, G.F., Introduction to topology and Modern Analysis, McGraw Hill Publications, 2017.
3. Joshi, K. D., An introduction to general topology, 2nd edition, Wiley Eastern Ltd., New Delhi, 2002.
4. J. L. Kelley : General Topology, 2008 (Indian reprint).

MSMT-23302
FUNCTIONAL ANALYSIS-I

L	T	P	C
4	1	0	5

Course Objectives:

This course will develop a deeper and rigorous understanding of fundamental concepts of functional analysis, their properties and related theorems.

1. **(12)**

Normed linear spaces, Banach spaces, subspaces, quotient spaces. Continuous linear transformations.

2. **(12)**

Equivalent norms.Finite dimensional normed linear spaces and compactness, Riesz Lemma, The conjugate space N*.

3. **(12)**

The Hahn-Banach theorem and its consequences. The natural imbedding of N into N**, reflexivity of normed spaces. Open mapping theorem, projections on a Banach space, closed graph theorem, uniform boundedness principle.

4. **(12)**

Conjugate operators. Lp-spaces: Holder's and Minkowski's Inequalities, completeness of L_p-spaces.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Explain the fundamental concepts of functional analysis and their role in modern mathematics.
- Utilize the concepts of functional analysis, for example continuous and bounded operators, normed spaces,Hilbert spaces and to study the behavior of different mathematical expressions arising in science and engineering.
- Understand and apply fundamental theorems from the theory of normed and Banach spaces including the Hahn-Banach theorem, the open mapping theorem, the closed graph theorem and uniform boundedness theorem.
- Understand the nature of abstract mathematics and explore the concepts in further details.

Reference Books:

1. G.F. Simmons: Introduction to Topology and Modern Analysis, Ch. 9, Ch.10 (Sections 52-55), McGraw-Hill International Book Company, 1963.
2. Royden, H. L. Fitzpatrick, P.M.: Real Analysis, Ch 6 (Sections 6.1 -6.3), Macmillan Co. 1988.
2. Erwin Kreyszig: Introduction to Functional Analysis with Applications, John Wiley &
3. Balmohan V. Limaye: Functional Analysis, New Age International Limited.
4. P.K.Jain and O.P Ahuja : Functional Analysis, New Age International (P) Ltd, Publishers, 2010.
5. K. Chanrashekhra Rao: Functional Analysis, Narosa, 2002

MSMT-23303
PROBABILITY AND MATHEMATICAL STATISTICS-I

L	T	P	C
4	1	0	5

Course Objectives:

The aim of the course is to enable the students with understanding of various types of probability distributions and testing of hypothesis problems. It aims to equip the students with standard concepts of statistical techniques and their utilization.

1. (**12)**

Nature of Data and methods of compilation: Measurement scales, Attribute and variable, Discrete and continuous variables. Collection, Compilation and Tabulation of data.. Representation of data: Histogram, Frequency Polygon, Frequency Curve, Ogives.

2. (**12)**

Measures of central tendency: Mean, Median, Mode, Geometric Mean, Harmonic Mean and their properties. Measuring variability of data: Range, Quartile deviation, Deciles and Percentiles. Standard deviation, Central and non-central moments, Sample and Population variance. Skewness and Kurtosis, Box and Whisker plot.

3. (**12)**

Probability: Intuitive concept of Probability, Combinatorial problems, conditional probability and independence, Bayes' theorem and its applications. Random Variables and Distributions: Discrete and Continuous random variables. Probability mass function and Probability density function. Cumulative distribution function. Expectation of single and two dimensional random variables. Properties of random variables. Moment generating function and probability generating functions.

4. (**12)**

Distributions: Bernoulli distribution. Binomial distribution. Poisson distribution, Negative Binomial and Hypergeometric distributions. Uniform, Normal distribution. Normal approximation to Binomial and Poisson distributions. Beta, Gamma, Chi-square and Bivariate normal distributions. Sampling distribution of mean and variance (normal population). Chebyshev's inequality, weak law of large numbers, Central limit theorems.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Tackle big data and draw inferences form it by applying appropriate statistical techniques.
- Explore the basic ideas about measures of central tendency, dispersion and their applications in other statistical problems.
- Explain the different types of discrete and continuous distributions and their utilization.
- Deal with formulation of hypotheses as per situations and their testing.
- Apply the knowledge of statistical techniques in various experimental and industrial requirments

Reference Books:

1 Goon, A.M., Gupta, M.K., Dasgupta, B: Fundamentals of Statistics, Vol-I & Vol-II (7th Ed. 1998).
2 Sheldon Ross : A First Course in Probability, 6th edition, Pearson Education Asia (2002).
3 Meyer, P.L: Introductory Probability and Statistical Applications.
4 Hogg, R.V. and Craig, T.: Introduction to Mathematical Statistics (MacMillan 2002).
2010.

MSMT-23304
DISCRETE MATHEMATICS-I

L	T	P	C
4	1	0	5

Course Objectives:

The course seeks to develop students' ability to think critically and apply logical reasoning to solve mathematical problems. Students should be able to analyze problems, formulate mathematical models, and apply appropriate strategies to arrive at solutions.. Also, in this course basic concepts of Graph theory are introduced.

1. **(12)**

Mathematical Logic: Properties and logical operations, Truth function, Logical connections, logically equivalent statements, tautology and contradiction, algebra of proposition, arguments, duality law, Quantifiers, inference rules for quantified statements, predicates calculus, interference theory of predicate logic, valid formula involving quantifiers.

2. **(12)**

Boolean Algebra: Boolean Algebra and its properties, Principle of duality in Boolean Algebra, Algebra of Classes, Isomorphism, Partial Order, Boolean switching circuits, Equivalence of two circuits, simplification of circuit, Boolean polynomial, Boolean expression & function, Fundamental forms of a Boolean function. Disjunctive normal form, Complement function of a Boolean function.

3. **(12)**

Lattices: Partial ordered sets, Hasse diagrams, isomorphism, External elements of partially ordered set, lattices, lattices as algebraic system, sub-lattices, direct product and homomorphism.

4. **(12)**

Graph Theory: Simple Graphs, Incidence and degree, regular graph, isolated vertex, pendent vertex, Null graph, Diagraph, isomorphism's, Eulerian graph, planner and dual graph, planner graph representations, Thickness and crossing numbers, adjancy matrix, incidence matrix, cycle matrix.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Construct mathematical arguments using logical connectives and quantifiers.
- Understand how lattices and Boolean algebra are used as tools and mathematical models in the study of networks.
- Validate the correctness of an argument using statement and predicate calculus.
- Students should develop a thorough understanding of graph theory, including the basic definitions and properties of graphs, such as vertices, edges, degrees, paths, cycles, and connectivity.

Reference Books:

1. Trambley, J.P. and Manohar,R: Discrete Mathematical Structures with Applications to Computer Science.
2. Liu C.L.: Elements of Discrete Mathematics.
3. Alan Doerr and Kenneth Levasseur: Applied Discrete Structures for Computer Science

MSMT-23305
OPERATIONS RESEARCH-I

L	T	P	C
4	1	0	5

Course Objectives:

This course is designed to introduce basic optimization techniques in order to get best results from a set of several possible solutions of different problems viz. linear programming problems, transportation problem, assignment problem and unconstrained and constrained problems etc. The major focus will be on formulation of real world phenomena from its physical considerations and implementation of optimization algorithms for solving these problems.

1. **(12)**

Mathematical formulation of linear programming problem, properties of a solution to the linear programming problem, generating extreme point solution, simplex computational procedure, development of minimum feasible solution, the artificial basis techniques, a first feasible solution using slack variables.

2. **(12)**

Two phase and Big-M method with artificial variables , General Primal-Dual pair, formulating a dual problem, primal-dual pair in matrix form, Duality theorems, complementary slackness theorem, duality and simplex method, economic interpretation of primal-dual problems.

3. **(12)**

The General transportation problem, transportation table, duality in transportation problem, loops in transportation tables, linear programming formulation, solution of transportation problem, test for optimality, degeneracy, transportation algorithm (MODI method), time minimization transportation problem.

4. **(12)**

Assignment Problems: Mathematical formulation of assignment problem, the assignment method, typical assignment problem, the traveling salesman problem. Game Theory: Two-person zero sum games, maximin-minimax principle, games without saddle points (Mixed strategies), graphical solution of $2 \times n$ and $m \times 2$ games, dominance property, arithmetic method of $n \times n$ games, general solution of $m \times n$ rectangular games.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Apply the knowledge of basic optimization techniques in order to get best possible results from a set of several possible solution of different problems viz. linear programming problems, transportation problem, assignment problem and unconstrained and constrained problems etc.
- Formulate an optimization problem from its physical consideration.
- Select and implement an appropriate optimization technique keeping in mind its limitations in order to solve a particular optimization problem.
- Understand theoretical foundation and implementation of similar type optimization techniques available in the scientific literature.
- Continue to acquire knowledge and skills of optimization techniques that are appropriate to professional activities
- Extend their knowledge of basic optimization techniques to do interesting research work on these types of optimization techniques.

Reference Books:

1. Gass, S. L.: Linear Programming
2. Hadley, G.: Mathematical Programming
3. Kambo, N. S.: Mathematical Programming
4. Swarup, Kanti Gupta, P.K. & Man Mohan: Operations Research
5. R.Panneerselvam: Operations Research

MSMT-23306
MECHANICS-I

L	T	P	C
4	1	0	5

Course Objectives:

To demonstrate knowledge of functional and extremum path and the application of the knowledge in solving some fundamental problems. To demonstrate the knowledge and understanding of the fundamental concepts in the dynamics of system of particles and Lagrangian and Hamiltonian formulation of mechanics. To represent the equations of motion for complicated mechanical systems using the Lagrangian and Hamiltonian formulation of classical mechanics.

1. **(12)**

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.

2. **(12)**

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.

3. **(12)**

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.

4. **(12)**

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.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Understand the concept of functional and determine stationary paths of a functional to deduce the differential equation for stationary paths.
- Use Euler-Lagrange equation to find stationary paths and its applications in some classical fundamental problems.
- Define and understand basic mechanical concepts related to discrete and continuous mechanical systems.
- Describe and understand the motion of a mechanical system using Lagrange-Hamilton formalism.

- Connect concepts and mathematical rigor in order to enhance understanding.

Reference 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.

MSMT-23307
DIFFERENTIAL GEOMETRY

L	T	P	C
4	1	0	5

Course Objectives:

The objective of this course is to make students familiar with basic concepts of differential geometry so as to deal with geometry of curves and spaces using the methods of differential calculus.

1. **(12)**

A simple arc, curves and their parametric representation, arc length, Contact of curves, tangent line, osculating plane, curvature, principal normal, binormal, Normal Plane,rectifying plane.

2. **(12)**

Curvature and torsion, Serret-Frenet Formule, Helics, Evolute and Involute of a parametric curve, Osculating circle and osculating sphere, spherical curves.

3. **(12)**

Einstein's Summation Convention, Transformation of coordinates, tensor's law for transformation, Contravariant, covariant and mixed Tensors, addition, outer product, contraction,inner product and quotient law of tensors, Metric Tensor and Riemannian metric, christoffel symbols, Covariants differentiation of tensors.

4. **(12)**

Implicit and Explicit forms for the equation of the surface, two fundamental forms of a surface, Family of surfaces, Edge of regression, Envelops, Ruled surface, Developable and skew surfaces, Gauss and Weingarten formulae.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Understand the basic concepts and results related to space curves, tangents, normals and surfaces.
- Explain the geometry of different types of curves and spaces.
- Explain the physical properties of different curves and spaces.
- Understand principal directions and curvatures, asymptotic lines and then apply their important theorems and results to study various properties of curves and surfaces.
- Utilize Geodesics, it's all related terms, properties and theorems.

Reference Books:

1. Pressley: Elementary Differential Geometry, Springer, 2005.
2. T.J.Willmore: Introduction to Differential Geometry
3. Martin M. Lipschutz: Differential Geometry
4. U.C. De; A.A. Shaikh & J. Sengupta: Tensor Calculus
5. M.R. Spiegel: Vector Analysis
6. D. Somasundaram: Differential Geometry – A First course, Narosa Publishing House

MSMT-23308
CLASSICAL MECHANICS AND CALCULUS OF VARIATIONS

L	T	P	C
4	1	0	5

Course Objectives:

To realize the reduction of a two-body problem to a one-body problem in a central force system and calculus of variations, branch of mathematics concerned with the problem of finding a function for which the value of a certain integral is either the largest or the smallest possible.

1. **(12)**

Generalized coordinates and generalized velocities, virtual work, generalized forces, Lagrange's equations for a holonomic dynamical system, conservative system, holonomic dynamical system for impulsive forces and their applications.

2. **(12)**

Kinetic energy as a quadratic function of velocities, theory of small oscillations. Functional, variation of functional and its properties, fundamental lemma of calculus of variation, Euler's equations, necessary and sufficient conditions for extremum, The Brachistochrone problem, Functionals dependent on higher order derivatives and several dependent variables

3. **(12)**

Variational problems with fixed boundaries, Transversality conditions, Orthogonality conditions. Sturm-Liouville's theorem on extremals, One sided variations, Hamilton's principle, The principle of least action, Langrange's equations from Hamilton's principle.

4. **(12)**

Variational Methods, The Ritz method, Kantorovich Method for Boundary value problems in ODE's & PDE's, Isoperimetric Problems.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Understand what functionals are, and have some appreciation of their applications
- Apply the formula that determines stationary paths of a functional to deduce the differential equations for stationary paths in simple cases
- Use the Euler-Lagrange equation or its first integral to find differential equations for stationary paths
- Solve differential equations for stationary paths, subject to boundary conditions, in straightforward cases.

Reference Books:

1. Chorlton, F.: Text Book of Dynamics.
2. Elsgolts, L: Differential Equations and the Calculus of Variations.
3. Gelfand,I.M. and Fomin, S.V.: Calculus of Variations.

MSMT-23401
NUMBER THEORY

L	T	P	C
4	1	0	5

Course Objectives:

This course is designed to provide students an introduction to classical number theory and enable them to study higher courses in number theory, and to apply the learnt concepts of number theory.

1. **(12)**

The sum of non-negative divisors of an integer, Number of divisors of an integer, Multiplicative functions, The Mobius function, Mobius Inversion formula, The greatest integer function,Euler's Phi-function and its properties.

2. **(12)**

The order of an integer modulo n, primitive roots for primes, Composite Numbers having primitive roots, theory of indices and its applications to solving congruences

3. **(12)**

Quadratic residues modulo a prime, Euler's criterion, The Legendre symbol and its properties, Gauss Lemma, Quadratic reciprocity law, Jacobi's symbol and its properties, Phythagoren triplets, Insolvability of the Diophantine Equations: $x^4 + y^4 = z^4$, $x^4 - y^4 = z^2$ in positive integers.

4. **(12)**

Representation of an integer as a sum of two squares and sum of four squares, Finite and Infinite continued fractions, convergence of a continued fraction and their properties, Pell's equation.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Apply the knowledge of Number theory to attain a good mathematical maturity and enables to build mathematical thinking and skill.
- Understand the concept of various number theoretic functions
- Understand and use Legendre symbols and prove the quadratic reciprocity law
- Compute with primitive roots and multiplicative functions, and prove existence of primitive roots modulo p

Reference Books:

1. Hardy G.H. and Wright E.M.: An Introduction to the Theory of Numbers.
2. David M. Burton: Elementary Number Theory, Mc Graw Hill 2002.

MSMT-21402
FUNCTIONAL ANALYSIS-II

L	T	P	C
4	1	0	5

Course Objectives:

This course will develop a deeper and rigorous understanding of fundamental concepts of functional analysis like inner product spaces, Hilbert spaces, spectral theorem. Normed spaces, their properties and related theorems.

1. (**10)**

Inner product spaces, Hilbert spaces, orthogonal complements, orthonormal sets.

2. (**10)**

The conjugate space H*, Strong and weak convergence in finite and infinite dimensional normed linear spaces, Weak convergences in Hilbert spaces, weakly compact set in Hilbert spaces.

3. (**10)**

The adjoint of an operator, self adjoint operators, positive operators, normal operators, Unitary operators, Projections on a Hilbert space

4. (**10)**

Spectral Theorem for normal operators, Compact linear operators on normed spaces, properties of compact linear operators.

Course Outcomes(COs):

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

- Understand the fundamental concepts of functional analysis and their role in modern mathematics.
- Understand the nature of abstract mathematics and explore the concepts in further details.
- Explain the concept of projection on Hilbert and Banach spaces.

Reference Books:

1. Simmons, G.F.: Introduction to Topology and Modern Analysis Ch. X (Sections 56-59), Ch.XI (Sections 61-62), Mc Graw- Hill (1963)International Book Company.
2. Erwin Kreyszig: Introduction to Functional Analysis with Applications, John Wiley & Sons (1978).
3. Limaye, Balmohan V.: Functional Analysis, New Age International Limited, 1996.
4. Jain, P.K. & Ahuja, O.P.: Functional Analysis, New Age International (P) Ltd. Publishers, 2010.
5. Chandrasekhra Rao, K.: Functional Analysis, Narosa, 2002.
6. Somasundram, D.: A First Course in Functional Analysis, Narosa, 2006.

MSMT-23403
PROBABILITY AND MATHEMATICAL STATISTICS-II

L	T	P	C
4	1	0	5

Course Objectives:

The aim of the course is to enable the students with understanding of various types of probability distributions and testing of hypothesis problems. It aims to equip the students with standard concepts of statistical techniques and their utilization.

1. Point and Interval Estimation:
General concept of Point estimation, unbiasedness, consistency, efficiencyand Sufficiency. Factorization theorem, completeness, Rao-Blackwell theorem, Cramer-Rao inequality. **(10)**

2. Maximum likelihood method of estimation and method of moments. Interval estimation, confidence intervals for means, difference of means and variances. **(10)**

3. Hypothesis Testing:
The basic idea of significance test. Null and alternative hypothesis, Type-I and Type-II errors. Uniformly most powerful tests, Likelihood Ratio tests. t, Chi-square and F-distributions. Tests of significance based on t, Chi-square and F. One way and two way Analysis of Variance (ANOVA). **(10)**

4. Non-Parametric Tests:
Sign test, Wilcoxon signed rank test, Mann-whitney test. **(10)**

Course Outcomes (COs):
On the completion of course, students will be able to:

- Tackle big data and draw inferences form it by applying appropriate statistical techniques.
- Explore the basic ideas about measures of central tendency, dispersion and their applications in other statistical problems.
- Explain the different types of discrete and continuous distributions and their utilization.
- Deal with formulation of hypotheses as per situations and their testing.
- Apply the knowledge of statistical techniques in various experimental and industrial requirments

Reference Books:

1 Goon, A.M., Gupta, M.K., Dasgupta, B: Fundamentals of Statistics, Vol-I (7th Ed. 1998).
2 Dudewicz, E.J and Mishra, S.N: Modern Mathematical Statistics (1988).
3 Goon, A.M., Gupta, M.K., Dasgupta, B: Fundamentals of Statistics, Vol-II (7th Ed. 1998).
4 Deniel, W.W: Aplied Nonparametric Statistics (1999).
5 Rohtagi, V.K and Saleh A.K.M.E.: An Introduction to Probability Theory Mathematical Statistics (2000).

MSMT-23404
DISCRETE MATHEMATICS-II

L	T	P	C
4	1	0	5

Course Objectives:

This course introduces students to various discrete mathematical structures, such as graphs, trees, permutations, combinations, and sequences. Students should gain an understanding of the properties and characteristics of these structures and be able to analyze and manipulate them.

1. **(12)**

Graph Theory: Tree, rooted tree, binary tree, spanning trees, minimal spanning tree, Kruskal's algorithm, Chromatic number, four-column problem (statement only)

2. **(12)**

Directed Graphs: Directed paths, directed cycles, acyclic graph, network flow, Max flow, min-cut theorem, K-flow.

3. **(12)**

Recurrence relation & Generating functions: Order & Degree of recurrence relation, telescopic form, recursion theorem, solution of linear recurrence relation, Homogenous solution, closed form expression, Generating function, solution of recurrence relation using generating function.

4. **(12)**

Combinatorics: Principle of Mathematics Induction, the basic of counting, inclusion and exclusion principle, pigeonhole principles, Polya's counting theorem.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Understand the concept of graph coloring
- Understand the properties and characteristics of trees, including rooted trees, binary trees, and spanning trees
- understand how graphs and trees are applied in computer science fields, such as network analysis
- Learn how to work with some of the discrete structures which include sets, relations, functions, graphs and recurrence relation.
- Calculate numbers of possible outcomes of elementary combinatorial processes such as permutations and combinations.

Reference Books:

1 Trambley, J.P. and Manohar,R: Discrete Mathematical Structures with Applications to Computer Science.
2 Liu C.L.: Elements of Discrete Mathematics.
3 Alan Doerr and Kenneth Levasseur: Applied Discrete Structures for Computer Science
4 Narsingh Deo: Graph Theory with Applications to Engineering and Computer Sciences
5 Harary, F., Graph Theory, Narosa, 1995

MSMT-21405
OPERATIONS RESEARCH-II

L	T	P	C
4	1	0	5

Course Objectives:

This course is designed to introduce basic optimization techniques in order to get best results from a set of several possible solutions of different problems viz. Queuing problems, inventory control problem, replacement problem and simulation of various operation research problems. The major focus will be on formulation of real world phenomena from its physical considerations and implementation of optimization algorithms for solving these problems.

1. **(10)**

Queuing Theory: Introduction, Queuing System, elements of queuing system, distributions of arrivals, inter arrivals, departure service times and waiting times, Classification of queuing models, Queuing Models**:** (M/M/1): (∞/FIFO), (M/M/1): (N/FIFO), Generalized Model: Birth-Death Process, (M/M/C): (∞/FIFO), (M/M/C) (N/FIFO).

2. **(10)**

Inventory Control: The inventory decisions, costs associated with inventories, factors affecting Inventory control, Significance of Inventory control, economic order quantity (EOQ), Deterministic inventory problems without shortage and with shortages, EOQ problems with price breaks, Multi item deterministic problems.

3. **(10)**

Replacement Problems: Replacement of equipment/Asset that deteriorates gradually, replacement of equipment that fails suddenly, Mortality Theorem, recruitment and promotion problem, equipment renewal problem.

4. **(10)**

Simulation: Need of simulation, methodology of simulation. Simulation models, event-type simulation, generation of random numbers, Monte Carlo simulation. Simulation of inventory problems, queuing system, maintenance problems and job sequencing.

Course Outcomes(COs):

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

- Understand theoretical foundation and implementation of available optimization techniques..
- Formulate mathematically an optimization problem from its physical consideration.
- Apply the knowledge of basic optimization techniques in order to get best possible results from a set of several possible solutions of well defined problem.
- Extend their knowledge of basic optimization techniques to do interesting research work on these types of optimization techniques.

Reference Books:

1. R.Panneerselvam: Operations Research
2. Taha, H.A.: Operations Research
3. Chaddrasekhara, Rao & Shanti Lata Mishra: Operations Research
4. Kanti Swarup, Gupta, P.K. & Man Mohan: Operations Research
5. Mustafi, C.K.: Operations Research

MSMT-23406
MECHANICS-II

L	T	P	C
4	1	0	5

Course Objectives:

To demonstrate knowledge of functional and extremum path and the application of the knowledge in solving some fundamental problems. To demonstrate the knowledge and understanding of the fundamental concepts in the dynamics of system of particles and Lagrangian and Hamiltonian formulation of mechanics. To represent the equations of motion for complicated mechanical systems using the Lagrangian and Hamiltonian formulation of classical mechanics.

1. Tensors:

Introduction, Range and Summation Conventions, Free and dummy suffixes, results in vector algebra and matrix, the symbol δij & εijk , Coordinate transformations, cartesian tensors, Properties of tensors, Isotropic tensors, Isotropic tensor of order four, Tensors as linear operators, Transpose of a tensor. **(10)**

2. Tensor Continued:

Symmetric and skew tensors, Dual vector of a skew tensor, Invariants of a tensor, Deviatoric tensors, Eigenvalues and eigenvectors, Polar decomposition **(10)**

3. 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. **(10)**

4. 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. **(10)**

Course Outcomes (COs):

On the completion of course, students will be able to:

- Understand the concept of functional and determine stationary paths of a functional to deduce the differential equation for stationary paths.
- Use Euler-Lagrange equation to find stationary paths and its applications in some classical fundamental problems.
- Define and understand basic mechanical concepts related to discrete and continuous mechanical systems.
- Describe and understand the motion of a mechanical system using Lagrange-Hamilton formalism.
- Connect concepts and mathematical rigor in order to enhance understanding.

Reference Books:

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

MSMT-23407
FRACTIONAL CALCULUS

L	T	P	C
4	1	0	5

Course Objectives:

The objective of this course to cover the basics of the fractional calculus, or more aptly called the calculus of derivatives and integrals to an arbitrary order. Then introduce the concept of fractional differential equations and consider some of their applications. Also, study the numerical solution of fractional differential equations

1. **(12)**

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.

2. **(12)**

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.

3. **(12)**

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.

4. **(12)**

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.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Understand the Riemann-Liouville fractional integral and evaluate fractional integrals of some common functions
- Define the Riemann-Liouville and Caputo fractional derivatives and find the fractional derivatives of some common functions
- State sufficient conditions under which the fractional integrals and derivatives exist
- Investigate some applications of the fractional calculus to the real world.
- Solve linear fractional differential equations using the Laplace transform and Fourier Transforms

Reference Books:

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.

MSMT-23408
FOURIER ANALYSIS

L	T	P	C
4	1	0	5

Course Objectives:

The objective of this course is to describe the basic concepts of Fourier analysis. They know properties of the discrete and the continuous Fourier transform and are able to apply them to different problems. In addition to a basic understanding of the theoretical issues, they can describe the associated algorithms of Fourier analysis and apply them to more advanced problems in analysis

1. **(12)**

Trigonometric Series, Basic Properties of Fourier Series, Riemann-Lebesgue Lemma, The Dirichlet and Fourier Kernels, Continuous and Discrete Fourier Kernels.

2. **(12)**

Lebesgue's pointwise convergence theorem, Finite Fourier Transforms, Convolutions, the exponential form of the Lebesgue's theorem.

3. **(12)**

Pointwise and Uniform, convergence of Fourier Series, Cesaro and Abel Summability, Fejer's Kernel, Fejer's theorem, a continuous function with divergent Fourier series, term wise integration, term wise differentiation.

4. **(12)**

The Fourier Transforms and Residues, inversions of the trigonometric and exponential forms, Fourier Transformations of derivatives and integrals.

Course Outcomes (COs):

On the completion of course, students will be able to:

- Understand and apply concepts and methods from the theory of Fourier series
- Calculate the Fourier coefficients of a given function and hence write its Fourier series
- Analyze the convergence of an obtained series and distinguish the different convergence definitions
- emphasize relating the theoretical principles of the Fourier transform to solve practical problems

Reference Books:

1. R. Strichartz, A Guide to Distributions and Fourier Transforms, CRC Press.
2. E.M. Stein and R. Shakarchi, Fourier Analysis: An Introduction, Princeton University Press, Princeton 2003.
3. G. Bachman, L. Narici, E. Beckenstein; Fourier and Wavelet Analysis, (Universitext) Springer-Verlag, New York, 2000.

MSMT-21409
MEASURE THEORY

L	T	P	C
4	1	0	5

Course Objectives:

This course will develop a deeper and rigorous understanding of fundamental concepts of measure theory like lebesgue measures and their properties, Measurable Functions, various Characterizations and Properties of Measurable functions,Lebesgue Integral.

1. **(10)**

Lebesgue Outer Measure, Measurable Sets and their properties, Non Measurable Sets, Outer and Inner Approximation of the Lebesgue Measurable Sets, Borel Sigma Algebra and The Lebesgue Sigma Algebra, Countable Additivity, Continuity and the Borel-Cantelli Lemma.

2. **(10)**

The motivation behind Measurable Functions, various Characterizations and Properties of Measurable functions: Sum, Product and Composition, Sequential Pointwise Limits and Simple Approximations to Measurable Functions. Littlewood's three Principles.

3. **(10)**

Lebesgue Integral: Lebesgue Integral of a simple function and bounded measurable function over a set of finite measure. Comparison of Riemann and Lebesgue Integral. Bounded Convergence Theorem, Integral of a non-negative measurable function, Fatou's Lemma, Monotone convergence Theorem.

4. **(10)**

General Lebesgue Integral, Lebesgue Dominated Convergence Theorem, Countable Additivity and Continuity of Integration, Vitali Covers and Differentiability of Monotone Functions, Functions of Bounded Variation, Jordan's Theorem, Absolutely Continuous Functions, Absolute Continuity and the Lebesgue Integral.

Course Outcomes(COs):

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

- Understand the fundamental concepts of lebesgue measures, their properties and role in modern mathematics.
- Understand the nature of abstract mathematics and explore the concepts in further details.
- Explain the concept of General Lebesgue Integral, Comparison of Riemann and Lebesgue Integral.

Reference Books:

1. Royden, H.L. and Fitzpatrick, P.M.: Real Analysis (Fourth Edition), Pearsoon Education Inc. New Jersey, U.S.A.(2010).

2. R. A. Gordon, The integrals of Lebesgue, Denjoy, Perron and Henstock, Amer. Math. Soc. Province, RI, (1994).
3. Barra, G. De. : Introduction to Measure Theory, Van Nostrand and Reinhold Company.
4. Jain, P.K. and Gupta, V.P.: Lebesgue Measure and Integration.