Syllabus

M. Sc. MATHEMATICS

(Specialization: Applied Mathematics)

BABAGHULAM SHAH BADSHAH UNIVERSITY
Rajouri -185131, (J&K), INDIA

PROGRAMME SPECIFIC OUTCOMES (PSO)

M. Sc. MATHEMATICS

(Specialization: Applied Mathematics)

After completing this program successfully, we expect a student

PSO1. to have sufficient understanding of some core areas of Applied Mathematics such as Real and Complex Analysis, Functional Analysis, Abstract and Linear Algebra, Numerical Analysis, ODE and PDE, Harmonic Analysis and wavelets, Mathematical Programming, Graph theory, Financial and Biological Mathematics etc.

PSO2. to have sufficient knowledge of applications of above mentioned areas in various areas of Science and Technology, banking sectors, industries etc.

PSO3. to have a fair knowledge of the methodology involved in case studies of real life problems.

PSO4. to have deep understanding of that part of Mathematics which he or she encounters in National and State Level Eligibility tests(NET/ SET).

PSO5. to have a training of surfing internet for research purposes and to do team work through projects undertaken by the students in final semester.

PSO6. is prepared with such a strong background of the subject that he/she can do quality research of international repute in core areas of Mathematics.

PSO7. is prepared with such a strong background of the subject that he / she can acquire advanced knowledge of the subject independently.

PSO8. is enabled with good communication skills in both verbal and written forms.

PSO9. gets enough confidence to speak before gatherings by making him to go through a series of presentations in the class room during his / her course of the study.

PSO10. have sufficient computer skills which he / she requires in his / her further studies in the subject.

PSO11. have sufficient introduction to Mathematical softwares MATLAB, LATEX and SPSS.

SEMESTER I

Course Code	Course Title	No. of Credits	Distribution of Marks		
			SA	**UE**	**Total**
Core Courses					
MS- 101	Topology and its Applications	04	40	60	100
MS -102	Techniques in Differential Equations	04	40	60	100
MS -103	Real Analysis	04	40	60	100
MS -104	Applied Numerical Analysis	04	40	60	100
MS -105	Computer Fundamentals and C-Programming	04	40	60	100
MS -106	Lab Course on MS-104 and MS-105	04	50	50	100
	Total	**24**	**250**	**350**	**600**

SA: Sessional Assessment
UE: University Examination

SEMESTER - I

Course Title: Topology and its Applications
Course Code: ***MS-101***
Credits: ***4***

Maximum Marks: 100
University Examination: 70
Sessional Assessment: 30
Duration of Exam: ***3 hours***

Objectives

The aim of this course is to introduce the students to the basic ideas of metric and topological spaces and make them appreciate their applications.

Unit I

Elements of point set topology in $\mathbb{R}^n$: Norm and its properties; Open and closed sets; structure of open sets in $\mathbb{R}$; accumulation points; Bolozano- Weirstrass theorem; Cantor intersection theorem; Lindelof covering theorem; Heine Borel theorem; compactness in $\mathbb{R}^n$.

Unit II

Metric spaces: Definition and examples–$\mathbb{R}^n$, $\mathbb{C}^n$, l^p; point set topology; compact sets; convergent and Cauchy sequences; complete metric spaces–$\mathbb{R}^n$, $\mathbb{C}^n$, l^p; continuity of a function; relation between continuity and inverse images of open/closed sets and convergence of sequences; error correcting codes – Hamming distance; DNA sequences.

Unit III

Topological spaces: Definition and examples; Basis of a Topology; Closed sets; Hausdorff space; modeling of digital image displays in digital topology by topological spaces; interior and closure of a set with their basic properties; limit points; applications to geo information system.

Unit IV

Sub-spaces, quotient spaces and continuous functions: Subspace topology; open and closed sets in subspaces; product of two topological spaces – annulus, solid torus; Quotient spaces – Klein bottle, projective plane; open set definition of continuity and its various equivalent conditions; Pasting lemma; Homeomorphism; Homeomorphic image of a Hausdorff space.

Unit V

Connectedness and compactness: Connected, path connected spaces and their continuous images; arbitrary union and finite product of connected spaces; totally disconnected spaces; connectedness of $\mathbb{R}^n$; general version of intermediate theorem; applications to population model; Compact spaces, subspaces and their continuous images; finite union, product and arbitrary intersection of compact spaces; tube lemma.

Course Outcomes:

On successful completion of this course, we expect that a student

1. Should be able to explain the concepts of Euclidean, Metric & Topological spaces with standard examples.

2. Should be able to explain the concepts and properties of interior & accumulation points, open, closed, connected & compact sets in Euclidean, Metric & Topological spaces.
3. Should be able to explain the concepts of closure & interior of a set in a topological space and their various properties.
4. Should know the fundamental theorems such as Bolzano- Weirstrass theorem(BWT), Cantor's intersection theorem(CIT), Lindeloof covering theorem(LCT), Heine - Borel theorem(HBT) in $\mathbb{R}^n$ and also should be able to explain the validity of these theorems (as usually been stated in $\mathbb{R}^n$) in general metric spaces.
5. Should be able to explain the connection between metric spaces and error correcting codes and DNA sequences.
6. Should be able to explain the connection between topological spaces and modeling of digital image displays and applications to geo information system.
7. Should be able to explain the concept of convergence of a sequence and Cauchy sequence and their various properties in Topological spaces.
8. Should be able to explain the concept of Continuity with its various versions in Topological spaces and its connections with connected and compact sets.

Note for Paper Setting:
The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Adams, C. and Franzosa, R. (2009),** Introduction to Topology – Pure and Applied, **Pearson.**
2. **Apostol, Tom M., (2002),** Mathematical Analysis, 1st edition, **Narosa Publishing House.**

REFERENCE BOOKS:

1. **Willard, S., (1976),** General Topology **(1970)**, **Dover Publications New York..**
2. **Searcoid, M. O., (2007),** Metric Spaces, **Springer.**
3. **Munkers J.R. ,(2000),** Topology, 2nd Edition, **PHI.**

SEMESTER I

Course Title: Techniques in Differential Equations
Course Code: ***MS -102***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives

The main objective of this course is to introduce students to the techniques of solving various differential equations.

Unit I

Higher order linear differential equations-I: Basic existence theorem (Proof not included); basic theorems on linear homogenous equations; concept of Wronskian; reduction of order method; general solution of a homogeneous linear differential equation with constant coefficients.

Unit II

Higher order linear differential equations-II: Method of undetermined coefficients; method of variation of parameters; Cauchy–Euler equation; power series about an ordinary point; singular point; method of Frobenius; Bessel's equation and Bessel's functions.

Unit III

Systems of linear differential equations: Types of linear systems; differential operator; operator method for linear systems with constant coefficients; basic theory of linear systems in normal form; matrix method of solving homogenous linear system with constant coefficients.

Unit IV

Laplace transform: Definition, examples and basic properties of Laplace transform; existence of Laplace transform; step function; inverse Laplace transform and convolution theorem; solution of linear differential equations with constant coefficients by using Laplace transform; linear systems.

Unit V

Sturm-Liouville boundary value problems: Sturm-Liouville problems; characteristic values; characteristic functions; orthogonality of characteristic functions; expansion of a function in a series of orthogonal functions; expansion problem; trigonometric Fourier series and its convergence.

Course Outcomes:

After studying this course we expect a student have understood

1. The concept of homogeneous and non-homogeneous linear differential equations and the method of finding its general solution.
2. How to find the power series solution of homogeneous differential equations at singular points and ordinary points.
3. How to find the solution of linear system by operator method.
4. The basic theory of linear system of differential equations in normal form & matrix method for solving homogeneous linear system with constant coefficients.
5. The concept of Laplace transform &its basic properties.
6. How to find the solution of linear differential equation by using Laplace transform.
7. The concept of sturm- Liouville problem, orthogonalitiy of characteristic functions & expansion of functions in a series of orthogonal functions.
8. The concept of trigonometric Fourier series and its convergence.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Ross, S., (1984),** Differential Equations, 3rd Edition**, Wiley India (P) Ltd, New Delhi.**

REFERENCE BOOKS:

1. **Boyce,W.E.,DiPrima, R.C., (2007),**Elementary Differential Equations and Boundary Value Problem, 8th edition, **John wiley and sons.**
2. **Edward, P., (2005),** Differential Equation and Boundary Value Problems; Computing and Modeling, 3rd edition, **Pearson Education**.
3. **Simmons, G. F., (2003),** Differential Equation with Applications and Historical Notes, 2nd edition, **Tata McGraw Hill edition.**

SEMESTER I

Course Title: Real Analysis
Course Code: ***MS -103***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives

The objective of this course is to introduce students to Riemann and Lebesgue Integration, and make them learn the convergence issues of sequences and series of functions.

Unit I

Riemann integral: Upper and lower sums; Riemann integral and basic criterion for its existence; basic properties of Riemann integral; connection of monotonicity and continuity with the existence of Riemann integral; fundamental theorem of calculus.

Unit II

Sequences and series of functions: Point-wise and uniform convergence; Cauchy criterion for uniform convergence; Weirstrass M-test; connection of uniform convergence with differentiation, integration and continuity; example of a continuous and nowhere differentiable function; Weirstrass approximation theorem.

Unit III

Improper integrals and the Lebesgue Measure: Definition, examples and convergence of improper integrals of type-I and type-II; absolute convergence and comparison tests; Outer measure; outer measure of an interval in IR; measureable sets, Lebesgue measure; Borel sets.

Unit IV

Measureable real functions: Non-measureable sets; measureable functions and their sum, difference and product; sequence of measureable functions; the concept of almost everywhere; Integral of a simple function; integral of a bounded measureable function; connection between Riemaan and Lebesgue integral; bounded convergence theorem.

Unit V

Lebesgue integration: Integral of a non-negative function; Fatou's Lemma; monotone convergence theorem; Lebesgue integral of general function; Lebesgue convergence theorem; Vitali theorem(statement only); Functions of bounded variation; differentiation of an integral – equality of the derivative of an indefinite integral of an integrable function and the integrand a.e.

Course Outcomes:

After going through this course a student must be able to

1. Explain upper & lower sums, Upper & lower integral & hence Riemann integral.

2. Develop the basic criterion for the existence of Riemann integral and connection between the existence of Riemann integral with monotonicity & continuity.
3. Differentiate between point wise & uniform convergence of sequences & series of functions.
4. Elaborate Cauchy criterion for uniform convergence of sequences & series of functions & hence connection of uniform convergence with differentiation integration & continuity.
5. explain the convergence and absolute convergence of improper integral of both type –I & II
6. explain the concepts of measurable sets, measurable functions with their basic properties.
7. Describe the integral of a a measureable function with their properties.
8. Explain the fundamental theorems such as Fatou's lemma, monotone convergence theorem, vitalis theorem, Lebesgue convergence theorem etc.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

1. **Bilodeau, G. G., Thie, P. R. and Keough, G.E (2010),** An Introduction to Analysis**, second edition, Joes and Bartlett Learning.**
2. **Royden, H.L., (2006),** Real Analysis, **3rd edition**, **Prentice-hall of India Private Limited**

TEXT BOOKS:

Reference Books:

1. **Denlinger, C. G. (2011),** Elements of Real Analysis**, First Indian edition, Joes and Bartlett Learning.**
2. **Rudin, W., (1976),** Principles of Mathematical Analysis, 3rd edition, **McGraw Hill International Edition**.
3. **Yeh, J., (2000),** Lectures on Real Analysis**, World Scientific.**

SEMESTER I

Course Title: Applied Numerical Analysis
Course Code: ***MS -104***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives:

The aim of this course is to train students in numerical analysis techniques and their applications.

Unit I

Error analysis and solutions of non-linear equations: Binary and machine numbers; computer accuracy; computer floating point numbers; errors and their propagation; order of approximation; method of fixed point iteration for solving non-linear equations; Bisection method of Bolzano; method of false position; initial approximation and convergence criteria.

Unit II

Solutions of non-linear equations continued: Slope method for finding roots; Newton-Raphson theorem; Secant method; Aitken's process; Jacobian; Siedel and Newton's method for system of non-linear equations.

Unit III

Interpolation and polynomial approximation: Taylor series and calculations of functions; Horner's method for evaluating a polynomial; interpolation, Lagrange's approximation, error terms and error bounds for Lagrange's interpolation; Newton polynomials; divided differences; Pade approximation.

Unit IV

Curve fitting: Least square line; power fit method; data linearization; non-linear least squares method; least squares parabolas; Polynomial niggles; interpolation; piece wise cubic splines; existence and construction of cubic splines clamped; parabolic terminates and end point curvature adjusted spline; minimum property of cubic splines; Bernstine and their properties; Bezier curves.

Unit V

Numerical differentiation and integration: Approximation of derivative; central differentiation formulas; error analysis and step size; Richardson extrapolation; differentiation of Lagrange's and Newton polynomials; Newton-Cotes quadrature formulae; composite Trapezoidal and Simpson's rules and their error analysis ; recursive trapezoidal and Simpson's rules; Boole rules; Romberg Integration; adoptive curvature; Gauss - Legender integration.

Course Outcomes:

After studying this course a student should be able to

1. Solve algebraic transcendental equation using an appropriate numerical method.
2. Approximate a function using an appropriate numerical method.
3. explain how to fit experimental data into different curves.

4. explain the concept of Spline, Bernstein's Polynomials and Bezier curve.
5. Perform an error analysis for a given numerical method.
6. explain central differentiation formulas, Richardson's extrapolation, differentiation of Lagrange's and Newton's polynomials.
7. Explain Newton's cotes quarantine formulae such as, Trapezoidal, Simpson's rules, Boole's rules, Romberg integration and their error analysis.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Curtis, F. G. and Patrick, O. W., (1999),** Applied Numerical Analysis**,** 6th edition**, Pearson Education.**
2. **John, H. M. and Kurtis, D. F., (2007),** Numerical Methods using Matlab,4th edition, **Prentice Hall of India Pvt. Limited, New Delhi.**

REFERENCE BOOKS:

1. **Burden, R. L. and Faires, J. D.,(2009),** Numerical Analysis, 7th edition, **CENAGE Learning India (Pvt) Ltd.**
2. **Golub, G. and Loan, C. V.**, **(1996),**Matrix Computations,3rd edition, **John Hopkins University Press.**
3. **Jain, M.K., Iyenger, S.R.K. and Jain, R.K.**, **(2007),**Numerical Methods for Scientific and Engineering Computation, 5th edition,**New Age International Publication, New Delhi.**

SEMESTER I

Course Title: Computer Fundamentals and C-Programming
Course Code: ***MS -105***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives:

The aim of this course is to create awareness among students about computer applications and programming through C-language that will enable them to solve mathematical models.

Unit I

Computer fundamentals: Block diagram of computer; characteristics of a computer; generation of computers; I/O devices; memory and its types; number system & conversions; disk operating system (DOS); working with DOS commands (Internal and External).

Unit II

Introduction to windows: Customize desktop; working with folders; add printer; add &removing programs; working with word pad; fundamentals of MS-word; creating and formatting MS-word documents; creating &customizing tables; mail merge and using math equations; overview of MS-Excel; working with cells; creating and formatting worksheets; working with formulae bar; creating charts.

Unit III

Programming languages: Introduction; history of C language; structure of C program; variables, constants, keywords, operators and data types in C; decision making statements– (if, if else, else if ladder, nested if, switch–case, break, continue, goto).

Unit I V

Array and function: Loops in C; arrays (one dimensional and multidimensional arrays);string array; introduction to function-element of user-defined function (declaration, function calling, function definition);functions call by value & call by reference; recursive function.

Unit V

Structure and pointer: Definitions; declaration structure variable; accessing structure members; array of structures; introduction to pointers-accessing the address of variables; declaration pointer variables; initialization of pointer variable; pointer arithmetic.

Course outcomes: After completing this course a student

1. should be able to explain the concepts of input and output devices of computer and their working.
2. should know the uses of different types of worksheets like WordPad, MS- office and excel sheet.
3. should be able to design programs connecting decision structures, loops and functions.
4. should be able to explain the difference between call by value and call by address.
5. should be able to explain the dynamic behavior of memory by the use of pointers.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Balaguruswamy, E., (2004),** Programming in ANSI C, 4th edition, **Tata McGraw Hill**.
2. **Saxena, S., (2007),**MS- Office for Everyone, 1st edition, **Vikas Publications, New Delhi**.
3. **Sinha, P.K., (2007),** Computer Fundamentals, 4th edition, **BPB Publications, New Delhi**.
4. **Taxali, R.K., (2007),**PC Software for Windows, 1st edition, **TMH, New Delhi.**

REFERENCE BOOKS:

1. **Basandra, K., (2008),** Computers Today, 1st edition, **Galgotia publication, New Delhi.**
2. **Schiltz, H.,(2004),** C: The Complete Reference,4th edition**, Tata McGraw Hill.**

SEMESTER I

Course Title: Lab course on MS-104 & MS-105
Course Code: *MS -106*
Credits: 4

Maximum Marks: 100
University Examination: 50
Sessional Assessment: 50
Duration of Exam: 3 *hours*

Each student is required to maintain a practical record book .

The course carries 100 marks. Two practical tests, one Internal and one External, are to be conducted, each carrying 50 marks. The marks in practical test will be divided into 4 parts, program code, program execution , Viva-Voce and practical record book as per the choice of examiner. The student has to pass both internal and external practical test separately scoring a minimum of 20 marks for each test.

Course outcomes:

After completing this course a student

1. Should be able to appreciate the use of computers in engineering industry.
2. Should have developed in him / her the basic understanding of computers, the concept of algorithms and algorithmic thinking.
3. Should have developed in him / her the ability to analyze a problem and develop an algorithm to solve it.
4. Should know the use of the C - programming language to implement various algorithms.

SEMESTER II

Course Code	Course Title	No. of Credits	Distribution of Marks		
			SA	UE	Total
Core Courses					
MS- 201	Numerical Linear Algebra	04	40	60	100
MS -202	Functional Analysis with Applications	04	40	60	100
MS -203	Abstract Algebra with Applications	04	40	60	100
MS -204	Complex Analysis with Applications	04	40	60	100
Choice based open elective courses(Students are required to opt any one of the following courses)					
IT. 202	Soft skills in Information Technology	04	40	60	100
Comp. 203	Computer Applications and Operations	04	40	60	100
Bio. 204	Fundamentals of Biotechnology	04	40	60	100
Bot. 205	Mysteries of Green Plants	04	40	60	100
Bot. 206	Botany in Rural Development	04	40	60	100
Zol. 207	Nutrition, Health and Hygiene	04	40	60	100
Arab. 208	Fundamentals of Arabic Language	04	40	60	100
Eng. 209	Fundamentals of English	04	40	60	100
Edu. 210	Higher Education	04	40	60	100
Eco. 211	Principles of Banking	04	40	60	100
HT. 212	Basics of Tourism and Travel Agencies	04	40	60	100
HT. 213	Tourism Resources of J and K	04	40	60	100
Mgt. 214	Business communication and soft skills	04	40	60	100
Edu-215	Instructional technology	04	40	60	100
Lab Course					
MS -205	MatLab	04	50	50	100
Total		**24**	**250**	**350**	**600**

SA: Sessional Assessment
UE: University Examination

SEMESTER II

Course Title: Numerical Linear Algebra
Course Code: ***MS-201***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives

The main objective of this course is to introduce students to the fundamentals of linear algebra and numerical solutions of problems of linear algebra.

Unit I
Matrices: Review of fundamental concepts of vector space; Matrix of a linear transformation; matrix of sum and composition of linear transformations; change of basis matrix; similar matrices; determinant of a matrix and its basic properties; permutation and its signature; uniqueness of determinant map.

Unit II
Spectral theory: Eigen values and eigen vectors of a matrix and a linear transformation; algebraic and geometrical multiplicities of an eigen value; diagonalizable linear mapping/matrix; Cayley-Hamilton theorem; minimum polynomial of a matrix and its properties; invariant subspaces of a vector space; primary decomposition theorem (statement only) and its special cases; necessary and sufficient conditions for simultaneous diagonalization of two matrices.

Unit III
Canonical and bilinear forms: Nilpotent linear transformations; existence of triangular matrix; Jordan decomposition theorem (statement only); index of a nilpotent linear transformation and its elementary properties; Jordan Block matrix; Jordan form; Jordan basis; bilinear form; symmetric and skew symmetric bilinear forms; quadratic form and its properties; Sylvester's theorem; positive definite quadratic form.

Unit IV
Numerical methods for linear systems: Gauss elimination method; Gauss Jordan elimination method; pivoting; LU factorization method; Doolittle method; Crout's method; Cholisky's method; Jacobi iteration method; Gauss Seidel iteration method; matrix norms; introduction to ill conditioning; well conditioning and condition number of a matrix.

Unit V
Numerical methods for finding eigen values and eigenvectors: Power method; shifted inverse power method; Jacobi's method; Householder's method; Householder's reflection theorem; Householder's transformation and its computation; QR method; Gerschgorian's theorem; Peron's theorem; Schur's theorem.

Course outcomes
On successful completion of this course we expect a student will be able to

1. explain vector space, linear dependence / independence, basis and dimension, linear transformation, change of basis matrix, permutation and its signature.
2. explain the concept of characteristic polynomial to compute the eigen values and eigen vectors of a square matrix and Cayley-Hamilton theorem.
3. explain the concept of minimum polynomial of a matrix and its properties, primary decomposition theorem and diogonalization.

4. explain the concept of Nilpotent linear transformations, Jordan decomposition theorem, Jordan Block Matrix, Jordan form, Jordan basis.
5. explain the concept of bilinear forms, symmetric and skew symmetric bilinear forms, quadratic form and its properties.
6. explain the numerical methods such as Gauss- Jordan elimination method, LU factorization method, Doolettle method, Crout's method, Cholisky's method, Gauss-Seided iteration method for solving the system of linear equations.
7. explain the numerical methods such as power method, Jocabi's method, Household's method, QR method and theorems such as Gerschgorian's theorem, person's theorem.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Blyth, T.S. and Robertson, E. F., (2007),** Basic Linear Algebra, 2nd Edition, **Spinger.**
2. **Blyth, T.S. and Robertson, E. F., (2008),** Further Linear Algebra, 2nd Edition, **Spinger.**
3. **John, H. M. and Kurtis, D. F., (2007),** Numerical Methods using Matlab, 4th edition, **Prentice Hall of India Pvt. Limited, New Delhi.**

REFERENCE BOOKS:

1. **Burden, R. L. and Faires, J. D., (2009),** Numerical Analysis, 7th edition, **CENAGE Learning India (Pvt) Ltd.**
2. **Golub, G. and Loan, C. Van**, **(1996),**Matrix Computations, 3rd edition, **John Hopkins University Press.**
3. **Jain, M.K., Iyenger, S.R.K. and Jain, R.K.**, **(2007),** Numerical Methods for Scientific and Engineering Computation, 5th edition, **New Age International Publication, New Delhi.**
4. **Kreyszig, E.,** Advanced Engineering Mathematics, 8th Edition, **Wiley India Private limited.**

SEMESTER II

Course Title: Functional Analysis with Applications
Course Code: ***MS -202***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives

The main objective of this course is to introduce students to the fundamentals of functional analysis and make them aware of its applications.

UNIT I

Normed spaces: Definition, examples and basic properties of normed spaces; completeness and equivalence of norms on finite dimensional normed spaces; characterization of compact sets in finite dimensional normed spaces; Riesz lemma; introduction to $\mathbb{L}^p$ –spaces.

UNIT II

Linear operators on normed spaces: Definition and basic properties of bounded linear operators; connection between continuity and boundedness of linear operators; continuity of linear operators on finite dimensional spaces; completeness of normed space of operators; dual spaces of $\mathbb{R}^n$ and l^p spaces, Hahn Banach extension theorem for normed spaces and its consequences.

UNIT III

Inner product spaces(IPS): Definition and basic properties of IPS; Hilbert spaces; existence of minimizing vector; orthogonality; Projection theorem; orthogonal complement of a set and its basic properties; Bessel's inequality; total orthonormal sets; Parseval's relation; connection between separability and orthonormal sets; isomorphism of Hilbert spaces of same dimension.

UNIT IV

Inner product spaces and Banach fixed point Theorem: Riesz theorem; sesquilinear forms; Riesz representation for sesquilinear forms; Hilbert adjoint operator and its basic properties; basic properties of self adjoint, unitary and normal operators; Banach fixed point theorem and its applications to differential and integral equations −Picard's existence and uniqueness theorem, Fredholm and Volterra integral equations.

UNIT V

Reflexive spaces and fundamental theorems: Reflexive spaces; Hilbert spaces and finite dimensional normed spaces as examples of reflexive spaces; separability of dual normed space as a sufficient condition for the separability of the normed space; Baire's Category theorem; uniform boundedness theorem and its application to space of polynomials and Fourier Series; Open mapping and closed graph theorems.

<u>Course Outcomes</u>:

On successful completion of this course, we expect a student

1. should be able to explain the concept of inner product and norm on a vector space.

2. should be able to explain the concept of normed, Banach & Hilbert spaces with standard examples and relation between them.
3. should be able to explain the concepts of bounded linear operator & bounded linear functional with standard examples.
4. should be able to explain the properties of linear operators on finite and infinite dimensional normed spaces.
5. should be able to explain the dual spaces of $\mathbb{R}^n$ and l^p spaces and completeness of the normed space of operators.
6. should know the Banach contraction principle with applications to differential & integral equations.
7. should know the fundamental theorems such as Riez Lemma, Hahn Banach extension theorem, closed graph theorem, open mapping theorem, Principle of uniform boundedness, Bessel's inequality, projection theorem, Pansevals relation, Baire Category theorem and Riesz theorem with applications.
8. should be able to explain the concept of separable and reflexive normed spaces.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Kreyszig, E., (2006),** Introductory Functional Analysis with Applications, 1st edition, **Wiley Student edition.**

REFERENCE BOOKS:

1. **Bachman, G. and Narici, L., (1966),** Functional Analysis, **Academic Press New York.**
2. **Cheney, W., (2000),** Analysis for Applied Mathematics, **Springer.**
3. **Rynne, B. P. and Youngson, M. A., (2008),** Linear Functional Analysis, 2nd edition, **Springer.**
4. **Siddiqi, A. H., (2004),** Applied Functional Analysis, **Marcel-Dekker, New York.**

SEMESTER II

Course Title: Abstract Algebra with Applications
Course Code: ***MS -203***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Internal Assessments: 40
Duration of Exam: ***3 hours***

Objectives

The main objective of this course is to introduce students to the fundamentals of abstract algebra- group and ring theory with their applications to coding theory.

Unit I

Class equation and Syllow's theorem with applications: Conjugate of an element of a group; class equation and its applications – non-triviality of centre of a group of order p^n, Cauchy's theorem; number of a conjugate classes in S_n; 1st part of Syllow's theorem (Proof by induction); 2nd and 3rd parts of Syllow's theorem(Proofs not included); Applications of Syllow's theorem in the determination of simplicity of groups of order 72, 20449, 225, 30, 385, 108, p^2q (p, q primes) and 60.

Unit II

Ring theory: Definition and examples of rings; special classes of rings – integral domain, field; characteristic of an integral domain; Homomorphism; ideals and quotient rings; maximal ideals; the field of quotient of an integral domain.

Unit III

Euclidean rings: Euclidean ring (ER); ideals in a ER; principle ideal ring; concept of division, gcd, units, associate and prime elements in a ER; relation between prime elements and maximal ideals in a ER; ring of Gaussian integers and ring of polynomials F[x], F a field as examples of ERs.

Unit IV

Polynomial Rings and UFD: Polynomials over the rational field; primitive polynomials; content of a polynomial; Gauss lemma; Einstein's criteria; polynomial rings over commutative rings; UFD and its relation with ER; R[x] as a UFD when R is a UFD; relation between PIR and UFD**.**

Unit V

Algebraic coding theory: Classification, structure and subfields of a finite field; Linear codes; Hamming distance and weight with properties; correcting capability of a linear code; orthogonality relation; Parity check matrix decoding; coset decoding; syndrome.

Course Outcomes

After completing this course, we expect a student have understood

1. Class equation with applications, Cauchy theorem, Syllow's theorems with applications to find simplicity of a group.
2. The concept of ring with standard examples, different classes of rings such as Integral domain, field, ideal and quotient ring.
3. The concept of ideal with standard examples, maximal and prime ideals and quotient field of an Integral domain.
4. The concept of Unique factorization domain, Euclidean ring and Principal Integral domain and relation between them.
5. The concept of Ring of Gaussian integers and polynomials with properties.
6. Gauss lemma and Einstein's criteria.
7. the characterization of subfields of a finite field.
8. The concept of linear code, Hamming distance, coding, decoding, and syndrome.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Gallian, J. A. (1998),** Contemporary Abstract algebra, **Fourth edition**, **Narosa.**
2. **Herstein, I.N,(2004),** Topics in Algebra**,** 2nd edition**, Wiley.**

REFERENCE BOOKS:

1. **Artin, M., (2010),** Algebra, 2nd edition, **Springer.**
2. **Farmer, D.W., (1963),** Groups and Symmetry: A Guide to Discovering Mathematics**, American Mathematical Society.**
3. **Jacobs, H. R., (1979),** Elementary Algebra, 1st edition,**W. H. Freeman.**
4. **Levinson, N., (1970),** Coding Theory: A Counter Example to G. H. Hardy's Conception of Applied Mathematics, AMS Monthly 77: 249-258

SEMESTER II

Course Title: Complex Analysis with Applications
Course Code: ***MS -204***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives

The objective of this course is to introduce students to the fundamentals of Complex analysis (with applications) which is a tool with remarkable and almost mysterious utility in applied mathematics.

Unit I

Analytic functions: Extended complex plane; derivate of a complex function and its basic properties; C-R equations in both cartesian and polar form; analytic and harmonic functions; exponential, trigonometric and hyperbolic functions; branch of a multi-valued function; logarithmic function; complex exponents.

Unit II

Integral of a complex function-I: Contour integral and its basic properties; ML-inequality; primitives; Cauchy-Goursat theorem for triangles, open convex sets and simply connected domains; winding number; Cauchy's integral formula; derivative of an analytic function; Morera's theorem; Cauchy's inequality; Liouville's theorem; fundamental theorem of Algebra.

Unit III

Integral of a complex function-II: Convex Hull; Gauss theorem; Luca's theorem; Gauss mean value property; max/min modulus principle; Taylor's series; Parseval's formula; zeros of an analytic function; Schwartz lemma; Borel Caratheodary theorem; reflection principle; Laurant's series.

Unit IV

Singularities and residues: Isolated singularities; Riemann theorem; residues; residue theorem; connection between zeroes and poles; Casorati-Weirstrass theorem; meromorphic functions; argument principle; Rouche's theorem; Hurwitz theorem; definite integral involving sines and cosines; improper integrals involving rational functions; improper integrals involving sines and cosines; Jordan's inequality and Jordan's lemma.

Unit V

Conformal mapping: Linear and reciprocal transformations; square map, conformal and isogonal maps; conformality theorem; Bi-linear transformation and its basic properties; fixed points of a bilinear transformation; cross ratio; exponential and trigonometric transformations; Riemann mapping theorem (proof not included); construction of harmonic functions; Poission integral formula.

Course Outcomes

After the completion of this course a student must be able to

1. Explain the concept of extended complex plane, derivative of a complex function with its basic properties, analytic function, Cauchy Riemann equations.

2. Explain in detail the elementary complex functions such as exponential, trigonometric, hyperbolic, logarithmic, etc.
3. Describe contour integral, convex hull, open convex sets, simple connected domains & winding number etc.
4. Provide the proof of theorems like Cauchy-Gourmet theorem, Cauchy integral formula, Cauchy inequality, Morear's theorem, Liouville's theorem, fundamental theorem of Algebra, maximum, minimum modulus theorem, Schwarz lemma Borel caratheodary theorem, reflection principle etc.
5. Differentiate between isolated and non- isolated regularities, zeroes and poles and should be able to find residues.
6. Explain the theorems like Riemann theorem, Residue theorem, casorti Weirstrass theorem, argument principle, Hurwitz theorem, Jordan's lemma, Poisson integral formula, Riemann mapping theorem etc.
7. find real integrals by using complex analysis techniques and construction of harmonic functions.
8. Describe Bi-linear transformation with its basic properties and the concept of cross ratios.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books recommended:

TEXT BOOKS:

1. **Kasana, H. S., (2012),** Complex Variables, Theory and Applications, 2nd Edition, **PHI learning Private limited, New Delhi-110001.**
2. **Mathews, J. H. & Howell, R. W., (2006),** Complex Analysis for Mathematics and Engineering, 5th edition**, B Jones and Bartlett Publishers**

REFERENCE BOOKS:

1. **Brown, J. W. and Churchill, R. V., (2009),** Complex Variables and Applications, 8th Edition, **McGraw-Hill International.**
2. **Conway, J. B., (1973),** Functions of one Complex Variable, 2nd edition**,Springer International Student edition.**
3. **Rudin, W., (1987),** Real and Complex Analysis, 3rd edition, **McGraw Hill International Edition**.

SEMESTER II

Course Title: MatLab
Course Code: *MS -205*
Credits: 4

Maximum Marks: 100
University Examination: 50
Sessional Assessment: 50
Duration of Exam: 3 *hours*

Objectives

The Lab course has been designed to train students of Mathematics in using MatLab and computers in evolving solutions to problems of Numerical Analysis and linear algebra.

Each student is required to maintain a practical record book .

The course carries 100 marks. Two practical tests, one Internal and one External, are to be conducted, each carrying 50 marks. The marks in practical test will be divided into 4 parts, program code, program execution , Viva-Voce and practical record book as per the choice of examiner. The student has to pass both internal and external practical test separately scoring a minimum of 20 marks for each test.

Course Outcomes

After studying this course, we expect a student have understood

1. the applicability of MATLAB in Mathematics in particular and engineering applications in general.
2. the commands of MATLAB which one uses to solve elementary problems of numerical Analysis.
3. the concept of M-file and Script file along with control flow programming.
4. the plotting of graphs of functions by using syntax and semantics.

SEMESTER III

Course Code	Course Title	No. of Credits	Distribution of Marks		
Core Courses			**SA**	**UE**	**Total**
MS-316	Computational methods for ODE and PDE	04	40	60	100
MS-317	Applied Multivariable Calculus	04	40	60	100
MS-318	Applied Harmonic Analysis	04	40	60	100
MS-319	LATEX and Lab course on MS-316	04	50	50	100
Choice based Complementary Electives Students are required to choose any two of the following courses					
MS-320	Mathematical Finance	04	40	60	100
MS-321	Graph and Network Theory	04	40	60	100
MS-322	Modeling and Simulation	04	40	60	100
MS-323	Applied Probability and Random Processes	04	40	60	100
MS-324	Mathematical Programming	04	40	60	100
MS-325	Modeling of Real World Problems by Variational Inequalities	04	40	60	100
Total		**24**	**250**	**350**	**600**

SA: Sessional Assessment
UE: University Examination

SEMESTER III

Course Title: Computational Methods for ODE and PDE
Course Code: ***MS-316***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives

The objective of this course is to introduce students to numerical methods for solving ordinary and partial differential equation and their computer implementation.

Unit I

Numerical solutions of ordinary differential equations-I: Euler's method; Heun's method; Taylor's series method; Runge-Kutta methods; Adam- Bash forth- Moulton method; Milne-Simpson method; Hamming method.

Unit II

Numerical solutions of ordinary differential equations-II: Shooting method; finite difference methods; collocation method; BVPs; basic existence theorem for BVPs (statement only); numerical solutions of systems and higher order differential equations.

Unit III

Partial Differential equation of first order: Introduction; Formation of Partial Differential equation, Solution of Partial Differential equation of first order, Lagrange Linear Equation of the type Pp +Qq = R Partial Differential equation non linear in p & q, Charpit's Method, Cauchy problem for first order.

Unit IV

Partial Differential equation of 2nd order: Classification of second order Partial Differential equation, Laplace equation solution by the method of separation of variable, Dirichlet problem for a rectangular, Neumann problem for a rectangular solution of Laplace equation in Cylindrical & spherical coordinates.

Unit V

Heat & Wave equation: Heat equation solution by the method of separation of variables, Solution of heat equation in Cylindrical & spherical coordinates Wave equation solution by the method of separation of variables, solution of wave equation in spherical coordinates.

<u>Course Oucomes:</u>

After studying this course a student should be able to

1. *explain the methods of obtaining numerical solutions of differential equations by using different numerical methods such as , Euler's method, Heun's method, Taylors series method, Runge Kutta methods, Adam Bashforth method, Adam Moulton method, Milne simpson method, Hamming method etc.*
2. explain the concept and existence of solutions of a BVPs.
3. *explain the methods of obtaining numerical solutions of BVPs by using different numerical methods such as, shooting method, Finite difference method etc. and their error analysis.*

4. *explain the method of formation of a partial differential equations and the methods of finding solutions of linear and non – linear(such as Charpit's method) of partial differential equations.*
5. explain various classes of second order Partial Differential equations.
6. *explain Cauchy problem for first order.*
7. explain the methods of solutions of Heat and wave equations by the method of separation of variables
8. explain the methods of solutions of Heat and wave equations in Cylindrical and spherical coordinates.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books recommended:

TEXT BOOKS:

1. **Kharab, A. and Guenther, R. B., (2006),** An Introduction to Numerical Methods A MATLAB Approach, **Chapman and Hall/CRC.**
2. **Rao, K. Sankara,** Introduction to Partial Differential equation, PHI Learning Private limited 2013**.**
3. **Sneddon, I.N., Elements of** Partial Differential equation **,Mcgran Hill Book Company 1957**

REFERENCE BOOK:

1. **John, H. M. and Kurtis, D. F., (2007),** Numerical Methods using Matlab, 4th edition, **Prentice Hall of India Pvt. Limited, New Delhi.**
2. **Burden, R. L. and Faires, J. D.,(2009),** Numerical Analysis, 7th edition, **CENAGE Learning India (Pvt) Ltd.**
3. **Evans, G., Blackledge, J. M. and Yardley, P. ,(2000),** Numerical Methods for Partial Differential Equations, **Springer.**

SEMESTER III

Course Title: Applied Multivariable Calculus
Course Code: ***MS-317***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives

The aim of this course is to introduce the students differential and integral calculus of several variables and their applications to real world.

Unit I

Derivatives and partial derivatives: The concept, examples and elementary properties of derivative of a function from $\mathbb{R}^n$ to $\mathbb{R}^m$; Partial Derivatives and the Jacobian matrix; Chain rule; Higher derivatives – examples and exercises; gradient of a function

Unit II

Taylor's formula and optimization: Taylor's formula; sufficient condition for differentiability of a function in terms of derivatives of the coordinate functions; equality of mixed Partial derivatives; quadratic forms; Maxima and minima of a function in terms of Hessian and its applications

Unit III

Optimization and Riemann integrability: The method of Lagrange multipliers; The inverse function theorem(statement only); The implicit function theorem(statement only); Riemann integral of a function of n variables – criterion of its existence, sum rule, scalar multiple rule; integrability of a continuous function; Fubini theorem

Unit IV

Riemann integrability and line integrals: Integrals over nonrectangular regions; Differentiating under the integral sign; The change of variable formula (statement only); Line integral of a function; independence of line integral on parameterization; sum and scalar multiple rule; Line integrals of vector fields and its independence on parameterization; Conservative vector fields

Unit V

Green's theorem; the concept of surface; surface area; surface integrals – sum and scalar multiple rules; oriented surfaces and independence of the surface integral on parameterization of oriented surfaces; Stoke's theorem(without proof) and its applications

<u>Note for Paper Setting:</u>

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Course outcomes

After studying this course we expect a student have understood

1. the concept, examples and basic properties of continuity and differentiability of vector functions.
2. the concept of Taylor series and equality of mixed partial derivatives.
3. the concept and examples of extrema in terms of Hessain matrix and the method of Lagrange's multiplier
4. the concept of Riemann integral of a function of n variable and its various properties.
5. the fundamental results such as inverse function theorem, the implicit function theorem, Fubni's theorem and their applications.
6. The concept of Line and surface integrals and their various properties.
7. Green theorem, Strokes theorem and their applications.

Books Recommended:

TEXT BOOKS:

3. **Corwin, J. L. and Szczarba, R. H. (2015),** Calculus in Vector spaces, 2nd edition, **CRC press**

REFERENCE BOOKS:

4. **Ghorpade, S.R and Limaye, V.B.,(2010),** A course in Multivariable calculus and Analysis, **Springer.**
5. **Rudin, W., (1976),** Principles of Mathematical Analysis, 3rd edition, **McGraw Hill International Edition.**

SEMESTER III

Course Title: Applied Harmonic Analysis
Course Code: *MS-318*
Credits: *4*

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: *3 hours*

Objectives:

The main objective of this course is to introduce students various techniques of solving partial differential equations and Fourier analysis with applications.

Unit I

L^p - spaces: Minkowski and Holder inequalities; Riesz-Fischer theorem; approximation in L^p-spaces; Bounded linear functionals on L^p - spaces; Riesz representation theorem.

Unit II

Fourier series: Fourier series, Fourier sine and cosine series, Riemann- Lebesgue and Cantor- Lebesgue lemma, Dirichlet and Fourier kernels, convergence of Fourier series – Dini's test, Lipschitz condition, Riemann localization principle, Drichlet's point-wise convergence theorem, Relation between a convergent trigonometric series and Fourier series, Gibbs phenomenon

Unit III

Fourier series & Fourier Transform: Term wise differentiation and integration of Fourier series, Lebesgue point-wise convergence theorem(statement only), Fourier transform of $L^1(\mathbb{R})$ functions and its basis properties, convolution theorem, Fejer-Lebesgue inversion theorem (statement only), inversion formula when $\hat{f} \in L^1(\mathbb{R})$ and when f is of BV, the Fourier map an its properties.

Unit IV

Fourier transform: Fourier transform of derivates and integrals, Parseval's identities, Fourier transform of $L^2(\mathbb{R})$ functions, Plancherel's theorem, Shannon sampling theorem, applications of FT to ODEs and integral equations.

Unit V

The Discrete and Fast Fourier transforms: The discrete Fourier transform(DFT) and its basis properties, the DFT map, inversion theorem for DFT, Parseval's identities, DFT of cyclic convolution of two maps, fast Fourier transform for N= 2^k and fast Fourier transform for N=RC.

<u>Note for Paper Setting:</u>

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Course Outcomes

After studying this course we expect a student have understood

1. The concept of L^p – spaces and some of the fundamental results connected with them such as Minkowski inequality, Holder inequality, Riesz-Fischer theorem and Riesz representation theorem.
2. Fourier series and its convergence issues including its relation with a convergent trigonometric and Drichlet's point-wise convergence theorem.
3. Riemann - Lebesgue and Cantor- Lebesgue lemmas and Riemann localization principle.
4. term wise differentiation and integration of Fourier series and Lebesgue point-wise convergence theorem.
5. The concept of Fourier transform of $L^1(\mathbb{R})$ functions with its basic properties and some connected results such convolution theorem, Fejer- Lebesgue inversion theorem, inversion formula, Parseval's identities.
6. The concept of Fourier transform of $L^2(\mathbb{R})$ functions with its basic and connected results such as Plancherel's theorem, Shannon sampling theorem.
7. Applications of FT to ODEs and integral equations.
8. The concept of Discrete and Fast Fourier transforms with applications.

Books Recommended:

TEXT BOOKS:

1. **Bachman. G, Narici. L, Beckenstein. E (2010), Fourier and Wavelet Analysis, Springer**

REFERENCE BOOKS:

1. **Kreyszig, E., (2010),** Advance Engineering Mathematics, 10th Edition, **Wiley India Private limited.**

Pinsky, M. A., (1994), Partial Differential Equations and Boundary-Value Problems with Applications, 3rd Edition, **McGraw Hill.**

SEMESTER III

Course Title: LATEX and *Lab course on MS-316*
Course Code: *MS-319*
Credits: 4

Maximum Marks: 100
University Examination: 50
Sessional Assessment: 50
Duration of Exam: 3 *hours*

Objectives:

The objective of this course is to train the students of mathematics to use LATEX and the computer implementation of numerical methods studied in MS-316.

Each student is required to maintain a practical record book .

The course carries 100 marks. Two practical tests, one Internal and one External, are to be conducted, each carrying 50 marks. The marks in practical test will be divided into 4 parts, program code, program execution , Viva-Voce and practical record book as per the choice of examiner. The student has to pass both internal and external practical test separately scoring a minimum of 20 marks for each test.

Course Outcomes

After studying this course, we expect a student have understood

1. Typeset mathematical formulae using latex.
2. Use the preamble of Latex file to define document class and layout options.
3. Use nested list and enumerate environment within a document.
4. Use tabular and array environment within latex document.
5. Use various methods to either create or import graphics into a Latex document.

SEMESTER III

Course Title: Mathematical Finance
Course Code: ***MS-320***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives:

The objective of this course is to study applications of Mathematical methods to the world of finance.

Unit I

Option theory: Introduction to options and markets; European and American options; asset price random walks; a simple model for asset prices; Itô's lemma; elimination of randomness.

Unit II

Black-Scholes model-I: Arbitrage; option values; payoffs and strategies; put-call parity formula; the Black-Scholes analysis; the Black-Scholes equation; boundary and final conditions for European options; the Black-Scholes formulae for European options; hedging in practice; implied volatility.

Unit III

Black-Scholes model-II: The Black-Scholes formulae; similarity solutions; derivation of Black-Scholes formulae; binary options; risk neutrality; variations on Black-Scholes model – option on dividend-paying assets; time dependent parameters in the Black-Scholes equation.

Unit IV

American options-I: Introduction; the obstacle problem; American option as free boundary value problems; the American put; other American options; a linear complimentarily problem for the American put option; the American call with dividends.

Unit V
American options-II: Methods for American options- Introduction ;finite difference formulation; the constrained matrix problem; projected SOR; the time stepping algorithm; numerical examples; convergence of the method.

<u>Course Outcomes</u>

After studying this course we expect a student have understood

1. The concepts of options and markets.
2. the European and American Options, asset price random walk and Itô's lemma.
3. the concept of Arbitrage, the put call parity formula and binary options.
4. the Black-Scholes formulae and their derivation.
5. the obstacle problem.

6. American option as free boundary value problems, the Americal put and American call.
7. the concept of linear complementarily problem for the American put option.
8. Some numerical methods for American options such as finite difference methods, projected SOR method, the time stepping algorithm and their convergence issues.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Wilmott,P., Howison, S. and Dewynne**, **J., (1995),**The Mathematics of Financial Derivatives-A student Introduction, **Cambridge University Press.**

REFERENCE BOOKS:

1. **Duffie, D., (2001),**Dynamic Asset Pricing Theory, 3rd edition, **Princeton.**
2. **Hull,J., (1993),**Options, Futures and other Derivative Securities,2nd edition, **Prentice-Hall.**
3. **Siddiqi, A. H., Manchanda, P. and Kocvara**, **M., (2007)** An Iterative two Step Algorithm for American Option Pricing, **IMA Journal of Mathematics Applied to Business and Industry.**
4. **Wilmot, P., Dewynne, J.N. and Howison**, **S. D., (1993),**Option Pricing Mathematical Models and Computation, **Oxford Financial Press.**

SEMESTER III

Course Title: Graph and Network Theory
Course Code: ***MS-321***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives
The aim of this course is to introduce students fundamentals of Graph Theory and their applications to real world problems.

Unit I
Fundamentals of a graph: Graphs; vertices and edges of a graph; order and size of a graph; isomorphisms of graphs; complete graphs; matrices associated with a graph; subgraph; induced subgraph; clique and maximal clique; clique number of a graph ;bipartite and R-partite graphs ;complement of a graph: union, intersection, join and cartesian product of two graphs; degree of vertex; graphical and valid graphical collection of integers.

Unit II
Walks, paths and cycles: Basic ideas of walks; paths and cycles; a necessary and sufficient condition for a graph to be bipartite; radius ,diameter, eccentricity, girth and circumference of a graph; weighted distance; shortest path problem; Euler walks; necessary and sufficient condition for a graph to be Eulerian graph; Hamiltonian cycles and Hamiltonian graphs; ore's theorem; Dirac's theorem; the travelling salesman problem; connected graphs; cut-point and cut edge of a graph; vertex connectivity and edge connectivity of a graph and relation between them.

Unit III
Trees, vector spaces associated with a graph: Trees, characterization of trees, spanning trees, counting of spanning trees in a graph, problem of finding minimal spanning trees, basics of finite field and vector spaces, the power set as a vector space, the vector space associated with a graph, the cycle subspace, the cutest subspace and their bases.

Unit IV
Factorizations, graph colorings and planarity: One factorization of a graph; standard factorization of a complete bipartite graph; one factorization theorem; factorization of regular graphs; Petersen's theorem and its generalization; vertex coloring; greedy algorithm for vertex coloring Zrook's theorem(without proof);counting of vertex colorings and chromatic polynomial and its basic results; edge-coloring; chromatic index; and k-paintings of a graph; edge coloring of a bipartite graph; Relationship of edge chromatic number with maximum degree of graph; representations of a graph; crossing number of a representation; planar graph; Euler's formula ;five color problem & four color problem.

Unit V
Digraphs and network flows: Basics ideas; orientations, tournaments and directed Euler walks; transportation networks and flows; maximal flow in a network; the maximal flow minimal cut theorem; the max flow min cut algorithm.

<u>Course Outcomes</u>

After studying this course we expect a student have understood

1. the concept of a graph and fundamental ideas connected to the graph such as vertices, edges, order and size of a graph, sub graph, clique and maximal

clique, complement of graph, union, intersection, join and Cartesian of two graphs.

2. the concept of walk, Euler walk, path, cycle and their basic properties.
3. the concept of a connected graph, vertex connectivity, edge connectivity and relation between them.
4. the concept of a tree, spanning tree, minimal spanning tree, vector space associated with a graph.
5. the concept of factorization of a graph, standard factorization of complete bipartite graph, Petersen's theorem and its generalization.
6. the concept of vertex coloring, chromatic polynomial, chromatic index, crossing numbe, planar graph and edge-coloring.
7. the concept of directed graphs and transportation networks and flows.
8. some basic results such as relationship of edge chromatic number with maximum degree of graph, Euler's formula, Five color problem, four color problem, greedy algorithm for vertex coloring and Zrook's theorem, the maximal flow minimal cut theorem; the max flow min cut algorithm.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Gary, C. and Ping, Z.,(2005),** Introduction to graph theory, **McGraw Hill.**
2. **Wallis, W.D., (2006),** A Beginner's guide to graph theory, 2nd edition,**Springer**.

REFERENCE BOOKS:

1. **Deo, N., (2007),** Graph Theory with Applications to Engineering and Computer Science, **Prentice Hall of India Pvt. Ltd. New Delhi.**
2. **West**,**D. B., (2005),**Introduction to Graph Theory, 2nd edition, **Prentice Hall of India Pvt. Ltd. New Delhi.**

SEMESTER III

Course Title: Modeling and Simulation
Course Code: ***MS-322***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives:

The objective of this course is to study methods of model formation and their simulation techniques.

Unit I

Systems and models: Definition and classification of systems; classification and limitations of mathematical models and relation to simulation; methodology of model building; modeling through differential equations; linear growth and decay models; nonlinear growth and decay models; compartment models.

Unit II

Monte Carlo simulation and case studies: Barterning model; basic optimization theory; Monte-Carlo simulation approaches to differential equations; local stability theory; classical and continuous models; case studies in problems of engineering and biological sciences.

Unit III

Real world models: Checking of model validity; verification of models; stability analysis; basic model relevant to population dynamics, ecology, environment biology through ordinary differential equations; partial differential equations and differential equations

Unit IV

Simulation of random variables: General techniques for simulating continuous random variables, simulation from normal and Gamma distributions, simulation from discrete probability distributions, simulating a non – homogeneous Poisson process and queuing system.

Unit V

Numerical method for continuous simulation: Basic concepts of simulation languages, overview of numerical methods used for continuous simulation, Stochastic models, Monte Carlo methods.

<u>Course Outcomes</u>

After studying this course we expect a student have understood

1. the concept and various classes and limitations of mathematical models and their relation to simulation.
2. the technique of modeling through differential equations with special focus on linear and non – linear growth and decay models.
3. the concept of Barterning model, classical and continuous models and Monte-Carlo simulation approaches to differential equations.

4. the methodology involved in case studies of problems of engineering and biological sciences.
5. The method of checking of model validity, verification of models and related stability analysis.
6. general techniques for simulating continuous and discrete random variables with emphasis on normal, Gamma, non – homogeneous Poisson distributions.
7. the basics of simulation languages and a general overview of numerical methods used for continuous simulation.
8. basics of Stochastic models and Monte Carlo methods.

Note for Paper Setting:

*The question paper will be divided into two sections. **Section A** will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units. **Section B** will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Edward A. B., (2000),** An Introduction to Mathematical Modeling, **John Wiley.**
2. **Fowler, A. C., (1997),** Mathematical Models in Applied Sciences, **Cambridge University Press.**
3. **Ross, S.M., (2012),** Simulation, **India Elsevier Publication.**

REFERENCE BOOKS:

1. **Kapoor, J. N., (1988)**, Mathematical Modeling, **New Age.**
2. **Fishwick, P.,(1995),** Simulation Model Design and Execution, **PHI.**
3. **Law, M., Kelton, W. D., (1991),** Simulation Modeling and Analysis, **McGraw-Hill.**
4. **Geoffrey, G., (1982)**, System Simulation, **PHI.**

SEMESTER III

Course Title: Applied Probability and Random Processes
Course Code: ***MS-323***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives:

The aim of the course is to study Probability distribution, stochastic processes and their applications to real world problems.

Unit I

Random variables: Random variable; distribution function; discrete and continuous random variables; expectation and moments of a random variable; conditional expectation; the Chebyshev and Morkov inequality.

Unit II

Special probability distributions: Bernoulli distribution; binomial distribution; geometric distribution; Pascal distribution; hyper geometric distribution; Poission distribution; exponential distribution; Erlang distribution; uniform distribution; normal distribution; the Hazard function.

Unit III

Multiple random variables: Joint CDFs of BRVs; discrete and continuous random variables; determination of probabilities from a joint C
DF; conditional distributions; co-variance and correlation coefficients; expectation of a function of one random variable; sum of IRVs; minimum and maximum of two IRVs; functions of two random variables; law of large numbers and the central limit theorem.

Unit IV

Random processes: Classification and characterization of random processes; cross correlation and cross covariance functions; stationary and Ergodic random processes; power spectral density; discrete-time random processes.

Unit V

Models of random processes: Bernoulli process; random walk; the Gaussian process; Poisson process; Markov process; discrete and continuous-time Markov chains; Gambler's ruin as a Markov chain.

<u>Course Outcomes</u>

After studying this course we expect a student have understood

1. the concept of a Random variable(discrete and continuous random variables), its distribution function and moments.
2. various discrete and continuous distributions such as Bernoulli, Binomial Geometric, Pascal, Poission, Exponential, Normal etc.
3. the concept of joint CDFs of BRVs and the method of determination of probabilities from a joint CDF.

4. The concept of co-variance and correlation coefficients and expectation of a function of a random variable.
5. Some fundamental theorems such as Chebyshev inequality, Morkov inequality, law of large numbers and the central limit theorem.
6. the concept of a random process and their classifications and characterizations.
7. various models of random processes such as Bernoulli, Gaussian Poisson and Markov.
8. the concept of discrete and continuous-time Markov chains.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books recommended:

TEXT BOOKS:

1. **Geoffrey, G. and David, S., (2001),**Probability and Random Processes, 3rd edition, **Oxford.**
2. **Oliver, C. I. , (2010),** Fundamentals of Applied Probability and Random Processes, **Elsevier.**

REFERENCE BOOKS:

1. **Koralov, L. B. and Sinai, Y. G.,(2007),** Theory of Probability and Random Processes, **Springer.**
2. **SKorokhod, A. V., (2005),** Basic Principles and Applications of Probability Theory, **Springer.**

SEMESTER III

Course Title: Mathematical Programming
Course Code: ***MS-324***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives:

The objective of this course is to study various types of Programming and their applications to real world problems.

Unit I

Linear programming: Definition of operation research; simplex method; degenerate solution ; basic feasible solution; reduction of a feasible solution to a basic feasible solution; two phase method; big-M method; inverting a matrix using simplex method; applications of simplex method; duality in linear programming; duality and simplex method; dual simplex method.

Unit II

Integer programming: Introduction; fractional cut method; applications of integer programming; transportation problem-general transportation problem; duality in transportation problem; loops in transportation; stepping stone solution method; LP formulation of the transportation problem.

Unit III

Dynamic programming: Introduction; Bellman's principle of optimality; characteristics of dynamic programming; applications of dynamic programming; finding solutions of linear programming problems by dynamic programming.

Unit IV

Network analysis: Introduction; network and basic components; rules of network construction; critical path method (CPM); probability consideration in PERT; distinction between PERT and CPM.

Unit V

Non linear programming: General nonlinear programming problem; necessary and sufficient conditions for a general non linear programming problem; Kuhn Tucker condition of non linear programming problem; saddle points problem; quadratic programming-general quadratic programming; Kuhn Tucker conditions of quadratic programming problem; example based on Wolfe's method and Beale's method.

Course Outcomes

After studying this course we expect a student have understood

1. the concept of linear programming, feasible solution, basic feasible solution and reduction of feasible solution to a basic feasible solution.

2. how to find feasible solution of linear programming problem by different methods such as simplex method, dual simplex method, two phase method and Big-M method
3. the concept of Integer programming and its applications.
4. the concept of transportation problem and related ideas such as duality and loops and the stepping stone solution method.
5. the concept of networking Analysis and various rules of network construction.
6. the critical path method (CPM), probability consideration in PERT and distinction between PERT and CPM.
7. the concept of nonlinear programming, the quadratic programming saddle points and Kuhn Tucker conditions.
8. How to solve the problems based on Wolfe's method and Beale's method.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Sharma, S. D., (2006),** Operation Research**, KedarNath Ram Nath and co.**

REFERENCE BOOKS:

1. **Hamady, T., (1995),** Operation Research, **Mac Milan Co**
2. **Kanti S., Gupta, P. K. and Manmohan, (2008),** Operation Research, 4th edition,**S. Chandand Co.**

SEMESTER III

Course Title: Modeling of Real World Problems by Variational Inequalities
Course Code: MS-325
Credits: 4

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives:
Modeling, discretization, algorithms and visualization of solutions are vital components of Industrial Mathematics. The knowledge of calculus, matrices and differential equations is sufficient for studying modeling of problems of physics, engineering, economics, business and trade. The theory of variational inequalities is one of such branches of mathematics which has been applied in the above mentioned areas. Moreover, it models free boundary value problems.

Unit I
Minimization of convex functionals: Fundamental theorem; the general problem of minimization; the search of good hypothesis; minimization of quadratic functional; variational formulation of a minimization problem; variational inequalities; variational equation; projection on convex sets; projection Operators.

Unit II
Variational inequalities: Fundamental theorem; bilinear forms; minimization and variational problems; Lions-Stampacchia theorem; Gateaux derivative; functionals defined on Hilbert spaces; Gateaux differential; G-derivative of a quadratic functional; general results on the equivalence of minimization and variational problems; indicatrix functions; fundamental result of existence and uniqueness;the concept of sub – differentials; right and left derivatives and subdifferential; multi-valued equations.

Unit III
Variational problems in one dimensions: Variational formulation of the obstacle problem; interpretation of the variational problem as a boundary value problem; equivalence of the two formulations of the obestacle problem; results of regularity; some considerations regarding second order linear problems; variational formulation of a boundary value problem; more general operators; eigenvalue problems.

Unit IV
Differential operators: General comments on differential operators; differential operators -quasi-linear, semi-linear and linear; differential equations - quasi-linear, semi-linear and linear; classification of second order differential operators; some classical operators; initial value problems and boundary value problems; Cauchy problem; the operator L.

Unit V
Linear problems: Variational formulation of the homogeneous Dirichlet problem on the coerciveness of the bilinear form; the Riesz-Fredholm theorem(statement only);general formulation in variational terms - the data and variational problem; intrepretation of the variational problem; examples of boundary value problems-the data, the differential operator, decomposition of the Laplace operator; examples - Dirichlet problems, Neuman problems, non-homogeneous Neuman problem, problem for Laplace operator.

Course Outcomes
After studying this course we expect a student have understood

1. the concept of a convex functional, the general minimization problem and variational formulation of minimization problem.

2. the concept of projection Operators and their properties.
3. the concept of a bilinear form, Gateaux derivative, indicatrix function and sub – differential.
4. fundamental results on the equivalence of minimization and variational problems and existence and uniqueness.
5. the variational formulation of the obstacle problem, its interpretation as a boundary value problem and some connected results.
6. the concept of a differential operator, its various types such as quasi-linear, semi-linear and linear and classification of second order differential operators.
7. Variational formulation of various problems such as Cauchy problem, Dirichlet problem, Neuman problems and non-homogeneous Neuman problem.
8. some basic results such as Lions-Stampacchia theorem and Riesz-Fredholm theorem.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Baiocchia, C. and Capalo**, **A., (1984),** Variational and Quasi Variational Inequalities, Application to Free Boundary Problems, **John Wiley and sons Chechter.**

REFERENCE BOOKS:

1. **Durant, G. and Lions, J.L.,(1976),** Inequalities in Mechanics and Physics, **Berlin, New York, Spring-Verlag.**
2. **Kikuchi, N. and Oden, J.I, (1988),**Contact Problems in elasticity: A Study of Varitional Inequalities and Finite Element Methods, **Philadelphia, SIAM.**
3. **Lehrer, D., Kinder, S. and Stampacchia**, **G., (1980),**Introduction to Variational Inequalities, **Academic Press, New York.**
4. **Siddiqi, A. H., (2004),** Applied Functional Analysis, **Marcel-Dekker, New York.**

SEMESTER IV

Course Code	Course Title	No. of Credits	Distribution of Marks		
Core courses			**SA**	**UE**	**Total**
MS-416	Dissertation/ Major Project	08	50 (D=30; V=20)	150 (D=100; V=50)	200
MS-417	Technical Communication	02	20	30	50
MS-418	Lab course on SPSS	02	25	25	50
Choice based Complementary Electives The students are required to choose any three of the following courses					
MS-419	Wavelets and Applications	04	40	60	100
MS-420	Mathematics of Insurance	04	40	60	100
MS-421	Fluid Dynamics	04	40	60	100
MS-422	Algorithmic optimization	04	40	60	100
MS-423	Integral Equations and Applications	04	40	60	100
MS-424	Bio Mathematics	04	40	60	100
MS-425	Finite Fields and Coding Theory	04	40	60	100
MS-426	Applied Functional Analysis	04	40	60	100
MS-427	Dynamical Systems	04	40	60	100
	Total	**24**	**210**	**390**	**600**

SA: Sessional Assessment
UE: University Examination
D: Dissertation
V: Viva-Voce

SEMESTER IV

Course Title: Dissertation/Major Project
Course Code: ***MS-419***
Credits: ***8***

Maximum Marks: 200
University Examination: 150
Sessional Assessment: 50

Objectives:

The objective of this course is to assess the ability of the students to solve real world problems.

Each student has to submit a project on a topic of his/her own choice under the supervision of a teacher selected as guide by the student's choice from the Departmental faculty or under the joint supervision of a teacher from the Department and an appropriate member from any other Department or industry but after the permission of the Departmental guide. The marks by internal /external examiner will be assigned on the basis of the project report submitted by the student and the viva-voce examination. The breakup for the dissertation and viva-voce marks is as follows:

	Dissertation	viva-voce	Total
Supervisor:	30	20	50
External Examiner:	100	50	150

Course Outcomes:

After a student completes the Major project, we expect a student have understood

1. the method of searching literature, on a particular topic, form the internet.
2. the various potential areas of research, in a particular field, that can lead to a research degree(M. Phil/ Ph. D).
3. various ethics of good research.
4. how to read a research paper and present it in his / her own words.
5. the use of various concepts from different courses for studying a research paper.
6. how to employ the skills learned through different courses to simplify complicated situations.
7. the value of teamwork.

SEMESTER IV

Course Title: Technical Communication
Course Code: ***MS-417***
Credits: 2

Maximum Marks: 50
University Examination: 30
Sessional Assessment: 20
Duration of Exam: 2 ***hours***

Objectives:

The objective of teaching English to the students of Mathematics is to make them acquainted with English language which is now considered a global language. Acquaintance with English language will increase their prospects of employability and increase their communication skill as well.

Unit I

Communication-I: Scope and importance of communication; barriers to communication; verbal, non-verbal, oral and written communication; techniques to improve communication; presentation skills -effective use of presentation software and overhead, practical sessions.

Unit II

Communication-II: Parts of speech; words frequently miss pelt; formation of words; tenses; one word substitutions; use of preposition; précis writing; narration; change of voices; paragraph writing; punctuation.

Unit III
Writing skills, group discussion and interview: Rules of good writing; principles of letter writing - structure and layout; curriculum vitae; letter of acceptance; letter of resignation; application / letters with bio-data; notice; agenda; minutes; *group discussion* -definition, methodology, helpful expression and evaluation with practical sessions; *interview* -types of interview and interview skills with practical session.

Course Outcomes:
After completing this course we expect a student should

1. be able to explain the importance of good communication skills in verbal, non-verbal, oral and written communication.
2. be able to explain the techniques to improve communication and presentation skills.
3. be able to write reports etc in a precise and correct way.
4. be able to explain the basic principles of good writing.
5. be able to explain the method of presenting one's curriculum vitae.
6. be able to write various official and unofficial letters, notices, agendas, minutes of meetings etc.
7. know how to behave in a group discussion with better expressions.
8. know how to behave in an interview with better expressions.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 06 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 06 long answer type questions, two*

from each unit and the candidate will be required to answer one from each unit. Each question carries 08 marks.

<u>Books Recommended:</u>

TEXT BOOKS:

1. **Balasubramanian, T., (1981),** A Textbook of English Phonetics for Indian students**, MacMillan India Ltd.**
2. **Eastwood, J., (1999),** Oxford Practice Grammar, **Oxford University Press.**
3. **Jones, L.,(1998),** Cambridge Advanced English, **Cambridge University Press.**

REFERENCE BOOKS:

1. **Lesikar, R. V. and Pettir, Jr., (2004),** Business Communication Theory and Applications, 6th edition, **A. I. T. B. S, New Delhi.**

2. **Thakar, P. K., Desai, S.D. and Purani, J. J., (1998),** Developing English Skills, **Oxford University Press.**

SEMESTER IV

Course Title: Lab course on SPSS
Course Code: *MS-418*
Credits: 0

Maximum Marks: 50
University Examination: 25
Sessional Assessment: 25
Duration of Exam: 3 *hours*

Objectives:

The objective of this course is to introduce the basic working of the SPSS software.

Each student is required to maintain a practical record book .

The course carries 50 marks. Two practical tests, one Internal and one External, are to be conducted, each carrying 25 marks. The student has to pass both internal and external practical test separately scoring a minimum of 10 marks for each test.

Course Outcomes

After studying this course, we expect a student

1. would be able to perform a wide range of data management tasks in SPSS application.
2. have understood the basic working of SPSS and performing of basic statistical analysis.
3. would be able to perform database management tasks, descriptive statistical tasks, graphic tasks and basic inferential statistical tasks for comparisons and correlations.
4. To perform advanced analysis in SPSS.

SEMESTER IV

Course Title: Wavelets and Applications
Course Code: ***MS-419***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives:
Wavelet analysis is an exciting new method having applications in many areas like Image Processing (data compression, signal analysis, pattern recognition), Medical Sciences (analysis of echography and tomography), Financial Sector (analysis of stock price fluctuation), Atmospheric Sciences (analysis of climatic variation and global warming) and Applied Mathematics (wavelet series expansion). This course is introduced taking into account its wide application and acceptance among researchers of various domains. This, in true sense, will promote inter-disciplinary studies and help students in job market.

Unit I
Multi-resolution analysis: Definition and examples of multiresolution analysis (MRA); dilation equation, Mother wavelet, Haar wavelets, orthonormality of translates of an $L^2(R)$ function, filters, filter equality, scaling identity, representation of the filter m_g for $g \in W_0$, Mother wavelet theorem

Unit II
Scaling functions: Compactly supported scaling functions φ, Properties of m_φ, Fourier transform of scaling functions, non sufficiency of trigonometric polynomials to generate wavelets, sufficient conditions for orthonormality of translates of scaling functions, Shannon wavelets, Riesz basis, characterization of Riesz basis, Riesz MRA, construction of an orthonormal basis from a Riesz basis.

Unit III
Frames: Franklin wavelets, Frames- tight and exact, Frame operator and its properties, Dual frame and its properties, equivalence of exact frames and Riesz basis in separable Hilbert spaces, Weyl- Heisenberg frames and their generation, splines and their basic properties.

Unit IV
Continuous Wavelet Transform: Disadvantages of Fourier transform, Window function, centre, radius and width of a window function, windowed Fourier transform, Gabor transform and Short- Time Fourier transform, The uncertainty principle, basic wavelets and their examples, Continuous wavelet transform and its basic properties, Parseval's formula, reconstruction formula, Discrete wavelet transform, numerically stable recovery of a function through it DWCs.

Unit V
Applications:, Introduction to applications of wavelets to Numerical Analysis – ODE and PDE; Signal analysis – audio compression, image and video compression, JPEG 2000, Texture classification, de-noising, finger prints; audio applications – audio structure decomposition, speech recognition, speech enhancement, audio de-noising.

Note for Paper Setting:
The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two*

from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.

Course Outcomes

After studying this course, we expect a student have understood

1. the concepts and various examples of Multiresolution Analysis (MRA), filters and wavelets.
2. various equations, identities and results such as dilation equation, filter equality, scaling identity and Mother wavelet theorem.
3. the concept and properties of scaling functions and Riesz basis.
4. the concept of a Frames and various terms connected with it such as tight and exact frame, Frame operator, Dual frame and Weyl- Heisenberg frame.
5. various transforms such as Fourier transform, Windowed transform, Gabor transform, Short- Time Fourier transform, wavelet transform and advantageous of one over the other.
6. fundamental results connected with wavelet transform such as Parseval's formula, reconstruction formula etc.,
7. the concept of Discrete wavelet transform and the numerically stable recovery of a function through its DWCs.
8. importance of wavelets in various areas of mathematics and other sciences such as Numerical Analysis, Signal analysis etc.

Books Recommended:

TEXT BOOKS:

1. **Bachman. G, Narici. L, Beckenstein. E (2010), Fourier and Wavelet Analysis, Springer**
2. **Siddiqi, A. H., (2004),** Applied Functional Analysis, **Marcel-Dekker, New York.**

REFERENCE BOOKS:

1. **Daubechies, I.,(1992),** Ten Lectures on Wavelets, **CBS-NSF Regional Conferences in Applied Mathematics, 61, SIAM, Philadelphia, PA.**
2. **Hernandez, E., and Weiss, G.,(1996),** A First Course on Wavelets, **CRC Press, New York.**
3. **Teolis**, **A., (1998),** Computation Signal Processing with Wavelets, 1st edition, **Birkhauser, Boston, Basel.**

SEMESTER IV

Course Title: Mathematics of Insurance
Course Code: MS-420
Credits: 4

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives:

The aim of this course is to learn the applications of mathematics in the world of insurance.

Unit I

Fundamentals of insurance: Concept of insurance; the claim number process; the claim size process; solvability of the portfolio; reinsurance and ruin Problem.

Unit II

Premium and ordering of risks and distribution of aggregate claim amount: Premium calculation principles and ordering distributions; individual and collective model; compound distributions; claim number of distributions.

Unit III

Distribution of aggregate claim amount: Various recursive computation methods; results on Lundberg bounds; approximation by Compound distributions.

Unit IV

Risk processes: Various time dependent risk models; Poisson arrival processes; idea of ruin probabilities and bounds; asymptotics and approximation.

Unit V

Time dependent risk models: Ruin problems and computations of ruin functions; dual queuing model; risk models in continuous time and numerical evaluation of ruin functions.

Course Outcomes:

After going through this course, we expect a student have understood

1. the concept of insurance, ruin problem, the claim number and claim size process, and solvability of the portfolio.
2. the concepts and terms connected with the Premium calculation principles and ordering distributions.
3. Various recursive computation methods and basic results on Lundberg bounds.
4. Various time dependent risk models.

5. the concept of ruin probabilities and bounds.
6. Ruin problems and computations of ruin functions.
7. the dual queuing models.
8. the risk models in continuous time and numerical evaluation of ruin functions.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **John, C. H., (2012),** Option, Futures, and Other Derivatives, 6th edition, **Prentice Hall of India Private Limited.**
2. **Sheldon, M. R., (1999),** An Introduction to Mathematical Finance, **Cambridge University Press.**
3. **Salih, N. N., (2000),** An Introduction to Mathematical Finance Derivatives, 2nd edition, **Academic Press, Inc.**
4. **Robert, J. E. and Kopp, P. E., (2004),** Mathematics of Financial Markets, **Springer- Verlag, New York inc.**

REFERENCE BOOKS:

1. **Duffie, D., (2001),** Dynamic Asset Pricing Theory, 3rd edition, **Princeton.**
2. **Wilmot, P., Dewynne, J.N. and Howison**, **S.D., (1993),** Option pricing Mathematical models and computation, **Oxford Financial Press.**

SEMESTER IV

Course Title: Fluid Dynamics
Course Code: ***MS-421***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives:

The objective of this course is to introduce students to the fundamentals of fluid dynamics.

Unit I

Kinematics of fluids in motion: Real fluids and ideal fluids; velocity of a fluid at a point; streamlines and path lines; steady and unsteady flows; the velocity potential; the velocity vector; local and particle rates of change; the equation of continuity at a rigid boundary.

Unit II

Equations of motion of a fluid: Pressure at a point in a fluid at rest and in a moving fluid; condition at a boundary of two in viscid immiscible fluids; Euler's equation of motion; Bernoulli's equation; steady motion under conservative body force; basic theorems on steady ir-rotational in-compressive flows for which the velocity potential satisfies $\nabla^2\emptyset = 0$ at all points within moving fluid; flows involving axial symmetry.

Unit III

Two dimensional flows: The stream function; the complex potential for two dimensional ir-rotational and incompressible flow; complex velocity potentials for standard two dimensional flows; lines sources; line sinks; line doublets and line vertices; two dimensional image systems; the Milne Thomson circle theorem and its applications; electrostatic form of Milne Thomson's theorem.

Unit IV

Thermodynamics: The equation of state of a substance; the first law of thermodynamics; internal energy of a gas; specific heat of a gas; functions of state; Maxwell's thermodynamics relations; isothermal, adiabatic and isotropic process; the second law of thermodynamics; Carnot's theorem.

Unit V

Gas dynamics: Compressibility effects in real fluids; the one dimensional wave equation; wave equations in two and in three dimensions; spherical waves; progressive and stationary waves; the speed of sound in a gas; equations of motion of a gas; Mach number; subsonic, sonic and supersonic flows; isotropic gas flow: shock waves and their formation; elementary analysis of normal shock waves.

Course Outcomes

After going through this course a student must be able to

1. explain the concepts of real fluids and ideal fluids, stream lines and path lines, steady and unsteady flows, lines sources, line sinks, line doublets and line vertices.

2. explain velocity of a fluid at a point, the equation of continuity at a rigid boundary, pressure at a point in a fluid at rest and in a moving position.
3. Euler's equation of motion, Bernoulli's equation, flows involving axial symmetry, the stream function, the complex potential for two dimensional ir-rotational and incompressible flow.
4. explain basic theorems on steady ir-rotational, in-compressive, flows for which the velocity potential satisfies $\nabla^2\emptyset = 0$ at all points within moving fluid, Milne Thomson circle theorem and its applications, electrostatic form of Milne Thomson's theorem and Carnot's theorem.
5. explain the equation of state of a substance, the first law of thermodynamics, internal energy and specific heat of a gas, Maxwell's thermodynamics relations, isothermal, adiabatic and isotropic process, the second law of thermodynamics and Carnot's theorem.
6. explain wave equations in one two and three dimensions;
7. explain waves of different types like spherical, progressive and stationary waves etc.
8. Discuss in detail various types of flows like subsonic, sonic and supersonic flows; isotropic gas flow etc.

Note for Paper Setting:

*The question paper will be divided into two sections. **Section A** will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units. **Section B** will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Chorlton F.,(2009),** Textbooks of Fluid Dynamics**, G. K. publication.**

REFERENCE BOOK:

1. **Ern, A. and Guermond, J. L., (2004),**Theory and Practice of Finite Elements, **Springer- Verley New York, LLC.**

SEMESTER IV

Course Title: Algorithmic Optimization
Course Code: ***MS-422***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives:

The objective of this course is to introduce students to solve different problems by using optimization techniques.

Unit I
Calculus in normed spaces: Frechet derivative --- definition, examples, chain rule, mean value theorem, implicit function theorem (proof not included); second derivative; Taylor's formulae for first and second derivatives; Gateaux derivative and its relation with Frechet derivative.

Unit II
Extrema of real valued functions on normed spaces: Euler's equation; necessary conditions for constrained relative extremum– Lagrange's multiplier ; necessary and sufficient condition for relative minimum in terms of second derivative; convex functions and their relation with first and second derivatives ; convexity and relative minima; Newton's method(convergence proofs not included).

Unit III
General results on optimization problems: Gradient of a functional on a Hilbert space; special classes of optimization problems; existence of solution of optimization problem for coercive and quadratic functional; examples of optimization problems; relaxation and gradient methods for unconstrained problems(convergence proofs not included)– properties of elliptic functional; conjugate gradient method for unconstrained problems (convergence proofs not included).

Unit IV
Non linear programming: Relaxation and gradient penalty–function methods for constrained problems (convergence proofs not included); introduction to non-linear programming problems; Farkas lemma ; Kuhan-Tuckar conditions – cone of feasible directions and its important properties; necessary and sufficient condition for the existence of a minimum in non-linear programming; properties of saddle points; Lagrangian associated with the optimization problems; duality; Uzawa's method (convergence proofs not included).

Unit V
Linear programming: General results on linear programming; examples of linear programming problems; the simplex method – polyhedron and its properties; duality and linear programming – necessary and sufficient conditions for the existence of a minimum in linear programming; duality in linear programming; Lagrangian; relation between duality and simplex method.

Course outcomes

After studying this course we expect student have understood

1. the concept of Frechet derivative, Gateaux derivative and relation between them.
2. basic results such Mean value theorem, chain rule, implicit function theorem, Taylor's formulae for first and second derivatives.

3. the concept of relative extremum, the Lagrange's multipliers and the Euler's equation.
4. the concept of convex functions and their relation with first and second derivatives.
5. the concept of Gradient of a functional on a Hilbert space, elliptic functional, saddle points, Lagrangian associated with the optimization problems, duality and classification of optimization problems.
6. the basic results connected with the existence of solution of optimization problem for coercive and quadratic functional, relaxation, gradient and conjugate gradient methods for unconstrained problems.
7. Basic results connected with non – linear Programming such as Farkas lemma, Kuhan-Tuckar conditions, necessary and sufficient condition for the existence of a minimum, Uzawa's method.
8. the basic results on linear programming, the simplex method, necessary and sufficient conditions for the existence of a minimum and the relation between duality and simplex method.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Ciarlet**, **P. G., (1989),** Introduction to Numerical Algebra and Optimization, **Cambridge University Press Cambridge.**

REFERENCE BOOKS:

1. **Cheney, W., (2001),** Analysis for Applied Mathematics, **Springer**, **New York.**
2. **Neunzert, H. and Siddiqi**, **A. H., (2000),** Topics in Industrial Mathematics-case Studies and Related Mathematical Methods, **Kluwer Academic Publishers, Dordrecht, Boston, London.**
3. **Polok**, **E., (1997),** Optimization Algorithms and Consistent Approximations Applied Mathematical Sciences Series, **Springer, New York.**

SEMESTER IV

Course Title: Integral Equations and Applications
Course Code: ***MS-423***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives:

The objective of this course is to introduce students to the fundamentals of Integral Equations and their Applications.

Unit I

Classification of integral equation: Definition and classification of integral equations; regularity conditions; special kind of kernels; integral equation with separable kernels; reduction to a system of algebraic equation; Fredholm alternate; an approximate method.

Unit II

Method of successive approximations: Introduction; iterative scheme; Volterra integral equation; some results about the resolvent kernel; classical Fredholm theory; the method of solution of Fredholm ; Fredholm's first theorem.

Unit III

Application to ordinary differential equation: Initial value problems; boundary value problems; Dirac- delta function; Green's function approach; Green's function for nth order ordinary differential equations.

Unit IV

Symmetric kernels: Introduction, fundamental properties of eigen values and Eigen functions for symmetric kernel, expansion in eigen function and bilinear form, Hilbert-Schmidt theorem & consequences, solution of symmetric integral equation.

Unit V

Singular integral equation: Introduction; the Abel integral equation; Cauchy principal value for integrals; the Cauchy type integrals; solution of the Hilbert kernels; solution of the Hilbert type singular integral equation.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two*

from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.

Course Outcomes

After studying this course we expect a student have understood

1. the concept and classification of integral equations and kernels.
2. how to solve the volterra integral equation and Fredhlom integral equations by different techniques.
3. Applications of integral equations to Initial value and boundary value problems.
4. the concept of Dirac- delta function and Green's function.
5. the concept of eigen values and eigen functions for symmetric kernels and their fundamental properties.
6. the concept of bilinear form, Hilbert-Schmidt theorem and its consequences.
7. the Abel integral equation, Cauchy principal value for integrals and Cauchy type integrals.
8. How to solve Hilbert type singular integral equation?

Books Recommended:

TEXT BOOK:

1. **Kanwal**, **R. P., (1997),** Linear Integral Equations (Theory and Technique), 2nd edition, **Academic Press Birkhauser**.

REFERENCE BOOK:

1. **Porter, D., and Stirling, D. S. G., (1990),** Integral Equations a Practical Treatment from Spectral Theory to Applications, **Cambridge University Press.**

SEMESTER IV

Course Title: Bio-Mathematics
Course Code: *MS-424*
Credits: *4*

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: *3 hours*

Objectives:

The objective of this course is to study the fundamental of mathematical modeling biology.

Unit I

Continuous population models for single species: Growth and decay models in Biology; population in natural and laboratory environments; intoxicants and nutrients; stability analysis interacting population with predation; basic models and their solutions; compartmental model.

Unit II

Deterministic compartmental models: Epidemic models; deterministic models with and without removal; general deterministic models with removal and immigration; control of an epidemic; stochastic epidemic model without removal.

Unit III

Models for interacting population: Models in genetics; basic models for inheritance; further discussion of basic model for inheritance of genetic characteristics; models for genetic improvement; selection and mutation; models for genetic inbreeding.

Unit IV

Drug absorption and flow problems: Pharmaco-kinetics; compartmental models in terms of system of differential equations; bio-diffusion; diffusion of drugs; trans-capillary exchange; oxygenation and de-oxygenating of blood; cardio vascular flow patterns; temperature regulation in human subjects.

Unit V

Empirical laws and curve fitting: Curve fitting and biological modeling; fitting curves to data; the method of least squares; polynomial curve fitting.

<u>Course outcomes</u>

After studying this course we expect a student to

1. have a deep knowledge of basic models such as growth and decay models, compartmental models, epidemic models, deterministic and stochastic epidemic models.

2. Have a deep knowledge of Models in genetics such as inheritance model, genetic improvement model, genetic inbreeding models etc.
3. Explain the concepts of Pharmaco-kinetics, bio-diffusion, trans-capillary exchange, oxygenation and de-oxygenating of blood, cardio vascular flow patterns and temperature regulation in human subjects.
4. the concepts of Curve fitting and biological modeling.
5. Explain the method of least squares.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Cullen, M.R., (1985),** Linear Models in Biology (Pharmacy), **E. Horwood, University of California.**
2. **Murray, J. D.,(2003),** Mathematical Biology, 3rd edition, **Springer.**

REFERENCE BOOKS:

1. **Allman, E. S. and Rhodes, J. A., (2004),** An Introduction Mathematical Models in Biology, **Cambridge University press**.
2. **Rubinow, S. I., (1997),** Introduction to Mathematical Biology, **John Willey and Sons Publication**.

SEMESTER IV

Course Title: Finite Fields and Coding Theory
Course Code: ***MS-425***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives:

The objective of this course is to study various techniques of coding theory.

Unit I

Field Extensions and finite fields: Field; prime field; algebraic and simple extension; minimal polynomial of an algebraic element; finite extension: transitivity of finite extensions; simple algebraic extension; splitting field; finite fields; number of elements in a finite field; existence and uniqueness of finite fields; subfields of a finite field.

Unit II

Roots of irreducible polynomials over finite fields and traces: Roots of an irreducible polynomials over finite fields; relation between splitting field of two irreducible polynomials of same degree; automorphisms of a finite field; definition and basic properties of trace; relation between trace and linear transformation; transitivity of trace; norm and its basic properties; transitivity of norm; bases; dual bases ;normal bases; Artin lemma normal basis theorem.

Unit III

Cyclotomic and irreducible polynomials: Cyclotomic field; primitive nth root of unity; cyclotomic polynomial; cyclotomic field as simple algebraic extension; finite fields as cyclotomic fields; different ways of writing the elements of a finite field; Moebius function; Moebius inversion formula; number of monic irreducible polynomials of a given degree over a finite field; product of all monic irreducible polynomials of a given degree over a finite field.

Unit IV

Codes: Code; coding and decoding schemes; linear codes; Hamming distance and weight; error-correcting codes; decoding of linear codes; Hamming bound; Poltkin bound; Gilbert-Varshamov bound; dual code.

Unit V

Cyclic codes: Definition and characterization of cyclic code in terms of an ideal; generator polynomial of cyclic code; parity-check polynomial of cyclic code; relation between code polynomial and the roots of generator polynomial; BCH code; minimum distance of BCH codes; decoding algorithm for BCH codes.

Course outcomes

After studying this course we expect a student have understood

1. The concept of a Field, prime field, splitting field and various kinds of field extensions such as algebraic, simple, finite, simple algebraic.
2. The concept of a finite field, their order, existence and uniqueness.

3. The concept of an irreducible polynomial and relation between splitting field of two irreducible polynomials of same degree.
4. the concept and basic properties of trace and norm.
5. the concept of Cyclotomic fields and their relationship with simple algebraic extensions and finite fields.
6. the concept of monic irreducible polynomials and the cardinality and product of monic irreducible polynomials of a given degree over a finite field.
7. the concept of Code and various related terms such as linear codes, Hamming distance and weight, error-correcting codes; decoding, Hamming bound, Poltkin bound, Gilbert-Varshamov bound etc.
8. the concept of cyclic code in terms of an ideal and related terms and algorithms such as decoding algorithm for BCH codes etc.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books recommended:

TEXT BOOKS:

1. **Lidl,R. and Niederreiter,H., (1994)**Introduction to Finite Fields and Applications, **Cambridge University Press**.
2. **Rndolf, P. and Gunter, P., (1998),** Applied Abstract Algebra, 7th edition, **Spinger.**

REFERENCE BOOKS:

1. **Hill, R., (1986),** A first Course in Coding Theory, Oxford Appl. Math and Comp. Sci. Series, **Clarendon Press, Oxford.**
2. **Lidl, R. and Niederreiter, H., (1997),**Finite Fields, revised Edition **Cambridge University Press.**
3. **Mullen, G. L. and Mummert, C. , (2012),** Finite Fields and Application, **American Mathematical Society, Indian Edition.**

SEMESTER III

Course Title: Applied Functional Analysis
Course Code: ***MS-426***
Credits: ***4***

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: ***3 hours***

Objectives:

The main objective of this course is to introduce students Distribution theory , Sobolev spaces, Schwartz spaces and their applications.

Unit I
Distribution theory-I: Definition and examples of a test function; convergence in the space D(IR^n) of test functions; definition and examples of distributions---regular; Dirac delta; Heaviside distribution; derivative of a distribution; convergence of distributions; product of a c^∞(IR^n) function and a distribution.

Unit II
Distribution theory and fundamental solution of Laplacian: Convolution of a test function and a distribution; differential operators--- fundamental solution of the Laplacian operator; Support of a distribution--- partitions of unity; ε' as a subset of $D'(IR^n)$;convolution of two distributions.

Unit III
Schwartz and Sobolev spaces-I: Schwartz space; tempered distribution and its Fourier transform; definition and first properties of $W^{k,p}(\Omega)$, $k \in NI$, $1 \le p \le \infty$ --- completeness; embedding of $W^{1,2}(IR)$ in $W^{0,\infty}(IR)$; other embedding theorems(without proofs); denseness of C^∞ functions of $W^{k,p}(\Omega)$ in $W^{k,p}(\Omega)$.

Unit IV
Sobolev spaces continued: Definition and first properties of $H^s(IR^n)$, $s \in IR$ --- competenees; distribution with compact support as an element of $H^s(IR^n)$; $\overline{D(IR^n)} =$ $H^s(IR^n)$; dual of $H^s(IR^n)$;Sololev's embedding theorem; density and trace theorems for $H^m(\Omega)$ (without proofs);coincidence of $H^{-m}(\Omega)$; $m \in NI$ with E_m; Poincare's and convexity inequalities(without proofs).

Unit V
Symmetric and non-symmetric variational problems: Formulation of symmetric variational problems- bilinear forms; Ritz-Galerkin approximation problem; fundamental Galerkin orthogonality; Ritz method; formulation of non-symmetric variational problems-Galerkin approximation problem; Lax- Milgram theorem ;Cea's theorem; variational formulation of Poisson's equation and pure Neumann boundary value problems; boundary value problems in science and technology.

Course outcomes

After studying this course we expect a student have understood

1. the concept, examples and properties of test function and distributions(such as regular, Dirac delta and Heaviside)
2. the concept of derivative of a distribution, convergence of a sequence of distributions and product of a c^∞(IR^n) function with a distribution.

3. the concept of convolution of a test function and a distribution, fundamental solution of the Laplacian operator, Support of a distribution, partitions of unity and convolution of two distributions.
4. The concept of tempered distribution and its Fourier transform.
5. The definition and basic properties of Sobolev spaces $W^{k,p}(\Omega)$, $k \in NI$, $1 \leq p \leq \infty$ --- such as completeness, embedding of $W^{1,2}(IR)$ in $W^{0,\infty}(IR)$, denseness of C^{∞} functions of $W^{k,p}(\Omega)$ in $W^{k,p}(\Omega)$.
6. fundamental results such as Sololev's embedding theorem, density and trace theorems, Poincare's and convexity inequalities.
7. formulation of symmetric and non – symmetric variational problems.
8. the Lax- Milgram theorem, Cea's theorem and variational formulation of Poisson's equation and pure Neumann boundary value problems.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books Recommended:

TEXT BOOKS:

1. **Berner, S. C. and Scott, L. R.,(2000),** The Mathematical Theory of Finite element methods**,** 3rd edition**, Springer.**
2. **Cheney**, **W., (2000),** Analysis for Applied Mathematics, **Springer, New York.**
3. **Dautary, R. and Lions, J. L.**, **(2000),** Mathematical Analysis and Numerical Methods for Science and Technology, **Vol. 2 Function and variational Methods, Springer, Berlin, Heidelberg, New York.**

REFERENCE BOOKS:

1. **Chipot**, **M., (2000),** Elements of Non Linear Analysis, **Birkhauser, Basel, London, Boston.**
2. **Siddiqi, A. H., (2004),** Applied Functional Analysis, **Marcel-Dekker, New York.**
3. **Zeidler, E., (1991),** Applied Functional Analysis and its Applications, **II/ A, Springer, Berlin, Heidelberg, New York.**

SEMESTER IV

Course Title: Dynamical Systems
Course Code: ***MS-427***
Credits: 4

Maximum Marks: 100
University Examination: 60
Sessional Assessment: 40
Duration of Exam: 3 ***hours***

Objectives:

The objective of this course is to introduce the students of the fundamental of dynamical systems.

Unit I

Continuous autonomous systems- I: Terminology related to first order continuous autonomous systems; classification of fixed points of autonomous systems; attractors and repellors; natural boundaries; case studies- population growth.

Unit II

Continuous autonomous systems- II: Autonomous second order systems; constant coefficient equations; phase curves and fixed points; classification of fixed points of linear systems; analyzing non-linear systems; case studies - lead absorption in the body, interacting species.

Unit III

Discrete systems: Definitions examples and terminology related to discrete systems ;classification of discrete systems - linear discrete systems, non-linear discrete systems; quadratic maps.

Unit IV

Flows- I: Concept of Bifurcations in one-dimensional flows; various bifurcations - saddle-node bifurcation, trans critical bifurcation, Pitchfork bifurcation.

Unit V

Flows- II: Concept of bifurcations in two-dimensional flows – saddle-node; various bifurcations – trans critical, pitch for bifurcations and Hop bifurcations.

Course outcomes

After studying this course we expect a student have understood

1. the basic terminology related to first order continuous autonomous systems and classification of fixed points of autonomous systems.
2. the concept of Autonomous second order systems and the classification of fixed points of linear systems.
3. some case studies related to lead absorption in the body.
4. the basic terminology related discrete systems and their classification such as linear discrete systems and non-linear discrete systems etc.
5. the concept of Bifurcations in one dimensional flows and its various types such as saddle-node bifurcation, trans critical bifurcation, Pitchfork bifurcation.

6. the concept of Bifurcations in two dimensional flows and its various types such as trans critical, pitch for bifurcations and Hop bifurcations.

Note for Paper Setting:

The question paper will be divided into two sections. ***Section A*** *will be compulsory and will contain 10 very short answer type questions eliciting answers not exceeding 20 words/ multiple choice questions/ fill in the blanks, each carrying one mark equally distributed from all units.* ***Section B*** *will contain 10 long answer type questions, two from each unit and the candidate will be required to answer one from each unit. Each question carries 10 marks.*

Books recommended:

TEXTBOOKS:

1. **Berry, J. and Arnold,(1996),**Introduction to Non-Linear Systems, **Great Britain.**
2. **Strogatz S. H., (1994),**Non Linear Dynamics and Chaos, **Addison- Wesley Publishing Company, USA.**

REFERENCE BOOKS:

1. **Wiggins, S., (1990),** Introduction to Applied Non-Linear Dynamical systems and Chaos (Vol-2),**TAM, Springer-Verlag, NewYork.**
2. **Hirsch, M. W., Smale, S., and Devaney, R. L. , (2004),**Differential Equations, Dynamical Systems and an Introduction to Chaos , **Elsevier.**