VIDYASAGAR UNIVERSITY

Paschim Midnapore, West Bengal

PROPOSED CURRICULUM & SYLLABUS (DRAFT) OF

BACHELOR OF SCIENCE (HONOURS)
MAJOR IN MATHEMATICS

4-YEAR UNDERGRADUATE PROGRAMME

(w.e.f. Academic Year 2023-2024)

Based on

Curriculum & Credit Framework for Undergraduate Programmes (CCFUP), 2023 & NEP, 2020

VIDYASAGAR UNIVERSITY
BACHELOR OF SCIENCE (HONOURS) MAJOR IN MATHEMATICS
(under CCFUP, 2023)

Level	YR.	SEM	Course Type	Course Code	Course Title	Credit	L-T-P	Marks		
								CA	ESE	TOTAL
B.Sc. (Hons.)	1st	I	**SEMESTER-I**							
			Major-1	**MATHMJ101**	**T: Calculus, Geometry & Ordinary Differential Equation**	**4**	**3-1-0**	**15**	**60**	**75**
			SEC	**MATSEC01**	**P: MATLAB-1**	**3**	**0-0-3**	**10**	**40**	**50**
			AEC	**AEC01**	Communicative English -1 (***common for all programmes***)	**2**	**2-0-0**	**10**	**40**	**50**
			MDC	**MDC01**	Multidisciplinary Course -1 (***to be chosen from the list***)	**3**	**3-0-0**	**10**	**40**	**50**
			VAC	**VAC01**	ENVS (***common for all programmes***)	**4**	**2-0-2**	**50**	**50**	**100**
			Minor MAT (Disc.-I)	**MATMI01**	**T: Calculus, Geometry & Ordinary Differential Equation** ***(To be taken by students of other Disciplines)***	**4**	**3-1-0**	**15**	**60**	**75**
					Semester-I Total	**20**				**400**
		II	**SEMESTER-II**							
			Major-2	**MATHMJ102**	**T: Algebra**	**4**	**3-1-0**	**15**	**60**	**75**
			SEC	**MATSEC02**	**P: MATLAB-2**	**3**	**0-0-3**	**10**	**40**	**50**
			AEC	**AEC02**	MIL-1 (***common for all programmes***)	**2**	**2-0-0**	**10**	**40**	**50**
			MDC	**MDC02**	Multi Disciplinary Course-02 (***to be chosen from the list***)	**3**	**3-0-0**	**10**	**40**	**50**
			VAC	**VAC02**	Value Added Course-02 (***to be chosen from the list***)	**4**	**4-0-0**	**10**	**40**	**50**
			Minor (Disc.-II)	**MATMI02**	**T: Algebra** ***(To be taken by students of other Disciplines)***	**4**	**3-1-0**	**15**	**60**	**75**
			Summer Intern.	**CS**	Community Service	**4**	**0-0-4**	**-**	**-**	**50**
					Semester-II Total	**24**				**400**
					TOTAL of YEAR-1	**44**				**800**

MJ = Major, MI = Minor Course, SEC = Skill Enhancement Course, AEC = Ability Enhancement Course, MDC = Multidisciplinary Course, VAC = Value Added Course; CA= Continuous Assessment, ESE= End Semester Examination, T = Theory, P= Practical, L-T-P = Lecture-Tutorial-Practical, MIL = Modern Indian Language, ENVS = Environmental Studies

MAJOR (MJ)

MJ-1: Calculus, Geometry & Ordinary Differential Equation Credits 04 (Full Marks: 75)

MJ-1T: Calculus, Geometry & Ordinary Differential Equation Credits 04

Course contents:

UNIT-1:
Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to problems of typeeax+bsinx, eax+bcosx, (ax+b)nsinx, (ax+b)ncosx, concavity and inflection points, curvature, envelopes, asymptotes, curve tracing in cartesian coordinates, tracing in polar coordinates of standard curves, L'Hospital's rule, applications in business, economics and life sciences.

UNIT-2:
Reduction formulae, derivations and illustrations of reduction formulae of the type ∫sin nx dx, ∫cosnx dx, ∫tan nx dx, ∫sec nx dx, ∫(log x)n dx, ∫sinnx sinmx dx, parametric equations, parameterizing a curve, arc length of a curve, arc length of parametric curves, area under a curve, area and volume of surface of revolution, techniques of sketching conics.

UNIT-3:
Reflection properties of conics, rotation of axes and second degree equations, classification of conics using the discriminant, polar equations of conics.
Spheres. Cylindrical surfaces. Central conicoids, paraboloids, plane sections of conicoids, generating lines, classification of quadrics, illustrations of graphing standard quadric surfaces like cone, ellipsoid.

UNIT-4:
General, particular, explicit, implicit and singular solutions of a differential equation. First order but not first degree. Exact differential equations and integrating factors, and equations reducible to this form, linear equation, Bernoulli equation and special integrating factors and transformations.

Suggested Readings:

1. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
2. M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi, 2007.
3. H. Anton, I. Bivens and S. Davis, Calculus, 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
4. R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer-Verlag, New York, Inc., 1989.
5. S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
6. Murray, D., Introductory Course in Differential Equations, Longmans Green and Co.
7. G.F.Simmons, Differential Equations, Tata Mcgraw Hill.
8. T. Apostol, Calculus, Volumes I and II.
9. S. Goldberg, Calculus and mathematical analysis.

MJ-2: Algebra **Credits 04 (Full Marks: 75)**

MJ-2T: Algebra **Credits 04**

Course contents:

UNIT-1:
Polar representation of complex numbers, nth roots of unity, De Moivre's theorem for rational indices and its applications.
Theory of equations: Relation between roots and coefficients, transformation of equation, Descartes rule of signs, cubic and biquadratic equation.
Inequality: The inequality involving AM≥ GM≥ HM, Cauchy-Schwartz inequality.

UNIT-2:
Equivalence relations. Functions, composition of functions, Invertible functions, one to one correspondence and cardinality of a set. Well-ordering property of positive integers, division algorithm, divisibility and Euclidean algorithm. Congruence relation between integers. Principles of Mathematical induction, statement of Fundamental Theorem of Arithmetic.

UNIT-3:
Systems of linear equations, row reduction and echelon forms, vector equations, the matrix equation Ax=b, solution sets of linear systems, applications of linear systems, linear independence.

UNIT-4:
Definition of vector space of $R^{n:}$, introduction to linear transformations, matrix of a linear transformation, inverse of a matrix, characterizations of invertible matrices. Subspaces of R^n, dimension of subspaces of R^n, rank of a matrix, Eigen values, eigen vectors and characteristic equation of a matrix. Cayley-Hamilton theorem and its use in finding the inverse of a matrix.

Suggested Readings:

1. Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser, 2006.
2. Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint, 2005.
3. David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
4. K.B. Dutta, Matrix and linear algebra.
5. K. Hoffman, R. Kunze, Linear algebra.
6. W.S. Burnstine and A.W. Panton, Theory of equations.

MINOR (MI)

MI – 1: Calculus, Geometry & Ordinary Differential Equation Credits 04

MI – 1T: Calculus, Geometry & Ordinary Differential Equation Full Marks: 75

Course contents:

UNIT-1:
Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to problems of typeeax+bsinx, eax+bcosx, (ax+b)nsinx, (ax+b)ncosx, concavity and inflection points, curvature, envelopes, asymptotes, curve tracing in cartesian coordinates, tracing in polar coordinates of standard curves, L'Hospital's rule, applications in business, economics and life sciences.

UNIT-2:
Reduction formulae, derivations and illustrations of reduction formulae of the type ∫sin nx dx, ∫cosnx dx, ∫tan nx dx, ∫sec nx dx, ∫(log x)n dx, ∫sinnx sinmx dx, parametric equations, parameterizing a curve, arc length of a curve, arc length of parametric curves, area under a curve, area and volume of surface of revolution, techniques of sketching conics.

UNIT-3:
Reflection properties of conics, rotation of axes and second degree equations, classification of conics using the discriminant, polar equations of conics.
Spheres. Cylindrical surfaces. Central conicoids, paraboloids, plane sections of conicoids, generating lines, classification of quadrics, illustrations of graphing standard quadric surfaces like cone, ellipsoid.

UNIT-4:
General, particular, explicit, implicit and singular solutions of a differential equation. First order but not first degree. Exact differential equations and integrating factors, and equations reducible to this form, linear equation, Bernoulli equation and special integrating factors and transformations.

Suggested Readings:

1. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
2. M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi, 2007.
3. H. Anton, I. Bivens and S. Davis, Calculus, 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
4. R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer-Verlag, New York, Inc., 1989.
5. S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
6. Murray, D., Introductory Course in Differential Equations, Longmans Green and Co.
7. G.F.Simmons, Differential Equations, Tata Mcgraw Hill.
8. T. Apostol, Calculus, Volumes I and II.
9. S. Goldberg, Calculus and mathematical analysis.

MI-2: Algebra **Credits 04 (Full Marks: 75)**

MI-2: Algebra **Credits 04**

Course contents:

UNIT-1:
Polar representation of complex numbers, nth roots of unity, De Moivre's theorem for rational indices and its applications.
Theory of equations: Relation between roots and coefficients, transformation of equation, Descartes rule of signs, cubic and biquadratic equation.
Inequality: The inequality involving AM≥ GM≥ HM, Cauchy-Schwartz inequality.

UNIT-2:
Equivalence relations. Functions, composition of functions, Invertible functions, one to one correspondence and cardinality of a set. Well-ordering property of positive integers, division algorithm, divisibility and Euclidean algorithm. Congruence relation between integers. Principles of Mathematical induction, statement of Fundamental Theorem of Arithmetic.

UNIT-3:
Systems of linear equations, row reduction and echelon forms, vector equations, the matrix equation Ax=b, solution sets of linear systems, applications of linear systems, linear independence.

UNIT-4:
Definition of vector space of $R^{n:}$, introduction to linear transformations, matrix of a linear transformation, inverse of a matrix, characterizations of invertible matrices. Subspaces of R^n, dimension of subspaces of R^n, rank of a matrix, Eigen values, eigen vectors and characteristic equation of a matrix. Cayley-Hamilton theorem and its use in finding the inverse of a matrix.

Suggested Readings:

1. Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser, 2006.
2. Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint, 2005.
3. David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
4. K.B. Dutta, Matrix and linear algebra.
5. K. Hoffman, R. Kunze, Linear algebra.
6. W.S. Burnstine and A.W. Panton, Theory of equations.

SKILL ENHANCEMENT COURSE (SEC)

SEC 1: MATLAB-1 **Credits 03**

SEC1P: MATLAB -1 **Full Marks: 50**

Course Outline:

MATLAB interface, data types, variables, Flow control statements, arrays: creating, indexing, operations, Matrix creating, indexing, operations, Input and output function, Mathematical library functions, user-defined function: anonymous function.

Plotting of two dimensional functions: Graph plotting, Graph formatting (title, axis, line styles, colors, etc.), multiple plots, matrix plots, polar plots, 3D plotting (line, surface, mesh, and contour) of three dimensional functions.

I. Find the sum, product, max, min of a list of number in an array, in a sub-array without library function.
II. Find a sub-matrix of the given matrix.
III. Find the column sum, product, max, min of the given matrix without library function.
IV. Find the row sum, product, max, min of the given matrix without library function.
V. Define any transcendental function and then find and show the table of its functional values.
VI. Plotting of graph of functions $e^{\mathrm{ax+b}}$, $\log(\mathrm{ax} + \mathrm{b})$, $\log\frac{1}{\mathrm{ax + b}}$, $sin(ax + b)$, $cos(ax + b)$, $|ax + b|$ and to illustrate the effect of a and b on the graph.
VII. Plotting the graphs of polynomial of degree 4 and 5, the derivative graph, the second derivative graph and comparing them.
VIII. Sketching parametric curves (eg. trochoid, cycloid, epicycloids, hypocycloid).
IX. Tracing of conics in cartesian coordinates/ polar coordinates.
X. Sketching ellipsoid, hyperboloid of one and two sheets, elliptic cone, elliptic, paraboloid, and hyperbolic paraboloid using cartesian coordinates.

SEC 2: MATLAB-2 **Credits 03**

SEC 2P: MATLAB-2 **Full Marks: 50**

Course Outline:

Introduction to M-file: scripts and function, flow control statements, standard arrays library functions, standard matrix library functions, User-defined function: primary function, sub-function, private function, eval function, function handles, function of functions, library functions.

Importing and Exporting data, read spread sheet data, write spread sheet data, MAT-file

I. Fitting a curve for given data.
II. Plotting of given data: Graph plotting, multiple plots, matrix plots, polar plots, 3D plotting (line, surface, mesh, and contour) of three dimensional data.
III. Obtaining surface of revolution of curves.
IV. Find the sum, product, max, min, sort of a list of number in an array, in a sub-array using library function.
V. Find the column sum, product, max, min, sort of the given matrix using library function.
VI. Find the row sum, product, max, min of the given matrix using library function.
VII. Conversion of one number system to another number system among decimal, binary, octal, hexadecimal.
VIII. Solution of a square, under determined and over determined system of linear equation.
IX. Different problems for root, eigenvalues and eigenvectors of the matrix.
X. Plotting of recursive sequences.
XI. Study the convergence of sequences through plotting.
XII. Verify Bolzano-Weierstrass theorem through plotting of sequences and hence identify convergent subsequences from the plot.
XIII. Study the convergence/divergence of in finite series by plotting their sequences of partial sum.
XIV. Cauchy's root test by plotting nth roots.
XV. Ratio test by plotting the ratio of nth and (n+1)th term.

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BACHELOR OF SCIENCE (HONOURS) MAJOR IN MATHEMATICS

4-YEAR UNDERGRADUATE PROGRAMME

(w.e.f. Academic Year 2023-2024)

Based on

Curriculum & Credit Framework for Undergraduate Programmes (CCFUP), 2023 & NEP, 2020

VIDYASAGAR UNIVERSITY
BACHELOR OF SCIENCE (HONOURS) MAJOR IN MATHEMATICS
(Under CCFUP, 2023)

Level	YR.	SEM	Course Type	Course Code	Course Title	Credit	L-T-P	Marks		
								CA	ESE	TOTAL
B.Sc. (Hons.)	2nd	III			**SEMESTER-III**					
			Major-3	**MATHMJ03**	**T: Real Analysis;**	**4**	**3-1-0**	**15**	**60**	**75**
			Major-4	**MATHMJ04**	**T: Differential Equations & Vector calculus**	**4**	**3-1-0**	**15**	**60**	**75**
			SEC	**MATSEC03**	**P: Object Oriented Programming in C++ / Introduction to Python programming (Practical)**	**3**	**0-0-3**	**10**	**40**	**50**
			AEC	**AEC03**	Communicative English -2 (***common for all programmes***)	**2**	**2-0-0**	**10**	**40**	**50**
			MDC	**MDC03**	Multidisciplinary Course -3 (***to be chosen from the list***)	**3**	**3-0-0**	**10**	**40**	**50**
			Minor-3 (Disc.-I)	**MATMIN03**	**T: Algebra**	**4**	**3-1-0**	**15**	**60**	**75**
					Semester-III Total	**20**				**375**
		IV			**SEMESTER-IV**					
			Major-5	**MATHMJ05**	**T: Theory of Real Functions & Introduction to Metric**	**4**	**3-1-0**	**15**	**60**	**75**
			Major-6	**MATHMJ06**	**T: Group Theory – I**	**4**	**3-1-0**	**15**	**60**	**75**
			Major-7	**MATHMJ07**	**T: Numerical Methods; P: Lab**	**4**	**3-0-1**	**15**	**60**	**75**
			AEC	**AEC04**	MIL-2 (***common for all programmes***)	**2**	**2-0-0**	**10**	**40**	**50**
			Minor-4 (Disc.-II)	**MATMNI04**	**T: Calculus, Geometry & Ordinary Differential Equation**	**4**	**3-1-0**	**15**	**60**	**75**
			Summer Intern.	**INT**	**Internship/ Apprenticeship - activities to be decided by the Colleges following the guidelines**	**4**	**0-0-4**	**-**	**-**	**50**
					Semester-IV Total	**22**				**400**
					TOTAL of YEAR-2	**42**				**775**

MJ = Major, MI = Minor Course, SEC = Skill Enhancement Course, AEC = Ability Enhancement Course, MDC = Multidisciplinary Course, CA= Continuous Assessment, ESE= End Semester Examination, T = Theory, P= Practical, L-T-P = Lecture-Tutorial-Practical, MIL = Modern Indian Language

MAJOR (MJ)

MJ-3: Real Analysis **Credits 04 (Full Marks: 75)**

MJ-3T: Real Analysis **Credits 04**

Course contents:

Unit 1:

Review of algebraic and order properties of R, ε-neighborhood of a point in R. Idea of countable sets, uncountable sets and uncountability of R. Bounded above sets, bounded below sets, bounded sets, unbounded sets. Suprema and infima. Completeness property of R and its equivalent properties. The Archimedean property, density of rational (and Irrational) numbers in R, intervals. Limit points of a set, isolated points, open set, closed set, derived set, illustrations of Bolzano-Weierstrass theorem for sets, compact sets in R, Heine-Borel Theorem.

Unit 2:

Sequences, bounded sequence, convergent sequence, limit of a sequence, liminf, lim sup. Limit theorems. Monotone sequences, monotone convergence theorem. Subsequences, divergence criteria. Monotone subsequence theorem (statement only), Bolzano Weierstrass theorem for sequences. Cauchy sequence, Cauchy's convergence criterion.

Unit 3:

Infinite series, convergence and divergence of infinite series, Cauchy criterion, tests for convergence: comparison test, limit comparison test, ratio test, Cauchy's nth root test, integral test. Alternating series, Leibniz test. Absolute and conditional convergence.

Unit 4:

Graphical Demonstration (Teaching aid)

1. Plotting of recursive sequences.
2. Study the convergence of sequences through plotting.
3. Verify Bolzano-Weierstrass theorem through plotting of sequences and hence identify convergent subsequences from the plot.
4. Study the convergence/divergence of in
5. finite series by plotting their sequences of partial sum.
6. Cauchy's root test by plotting nth roots.
7. Ratio test by plotting the ratio of nth and (n+1)th term.

Suggested Readings:

1. R.G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
2. Gerald G. Bilodeau , Paul R. Thie, G.E. Keough, An Introduction to Analysis, 2nd Ed., Jones& Bartlett, 2010.
3. Brian S. Thomson, Andrew. M. Bruckner and Judith B. Bruckner, Elementary

4. Real Analysis, Prentice Hall, 2001.
5. S.K. Berberian, a First Course in Real Analysis, Springer Verlag, New York, 1994.
6. T. Apostol, Mathematical Analysis, Narosa Publishing House
7. Courant and John, Introduction to Calculus and Analysis, Vol I, Springer
8. W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
9. Terence Tao, Analysis I, Hindustan Book Agency, 2006.
10. S. Goldberg, Calculus and mathematical analysis.

MJ-4: Differential Equations & Vector Calculus Credits 04 (Full Marks: 75)

MJ-4T: Differential Equations & Vector Calculus Credits 04

Course contents:

Unit 1

Lipschitz condition and Picard's Theorem (Statement only). The general solution of the homogeneous equation of second order, principle of superposition for homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients, method of variation of parameters.

Unit 2

Systems of linear differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients, Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions.

Unit 3

Equilibrium points, Interpretation of the phase plane, Power series solution of a differential equation about an ordinary point, solution about a regular singular point.

Unit 4

Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions.

Unit 5

Graphical demonstration (Teaching aid)

1. Plotting of family of curves which are solutions of second order differential equation.
2. Plotting of family of curves which are solutions of third order differential equation.

Suggested Readings:

1. Belinda Barnes and Glenn R. Fulford, Mathematical Modeling with Case
2. Studies, A Differential Equation Approach using Maple and Matlab, 2nd Ed., Taylor and Francis group, London and New York, 2009.
3. C.H. Edwards and D.E. Penny, Differential Equations and Boundary Value problems Computing and Modeling, Pearson Education India, 2005.
4. S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
5. Martha L Abell, James P Braselton, Differential Equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.

6. Murray, D., Introductory Course in Differential Equations, Longmans Green and Co.
7. Boyce and Diprima, Elementary Differential Equations and Boundary Value Problems, Wiley.
8. G.F.Simmons, Differential Equations, Tata Mc Graw Hill
9. Marsden, J., and Tromba, Vector Calculus, McGraw Hill.
10. Maity,K.C. and Ghosh, R.K. Vector Analysis, New Central Book Agency (P) Ltd. Kolkata (India).
11. M.R. Speigel, Schaum's outline of Vector Analysis.

MJ-5: Theory of Real Functions& Introduction to Metric Space Credits 04 (75 marks)

MJ-5T: Theory of Real Functions& Introduction to Metric Space Credits 04

Course contents:

Unit 1
Limits of functions (ε - δ approach), the sequential criterion for limits, and divergence criteria. Limit theorems, one-sided limits. Infinite limits and limits at infinity. Continuous functions, the sequential criterion for continuity and discontinuity. Algebra of continuous functions. Continuous functions on an interval, intermediate value theorem, location of roots theorem, preservation of intervals theorem. Uniform continuity, non-uniform continuity criteria, uniform continuity theorem.

Unit 2
Differentiability of a function at a point and in an interval, Caratheodory's theorem, algebra of differentiable functions. Relative extrema, interior extremum theorem. Rolle's theorem. Mean value theorem, intermediate value property of derivatives, Darboux's theorem. Applications of mean value theorem to inequalities and approximation of polynomials.

Unit 3
Cauchy's mean value theorem. Taylor's theorem with Lagrange's form of remainder, Taylor's theorem with Cauchy's form of remainder, application of Taylor's theorem to convex functions, relative extrema. Taylor's series and Maclaurin's series expansions of exponential and trigonometric functions, $\ln(1 + x)$, $1/(ax + b)$ and $(x+1)^n$. Application of Taylor's theorem to inequalities.

Unit 4
Metric spaces: Definition and examples. open and closed balls, neighbourhood, open set, interior of a set. Limit point of a set, closed set, diameter of a set, subspaces, dense sets, separable spaces.

Suggested Readings:

1. R. Bartle and D.R. Sherbert, Introduction to Real Analysis, John Wiley and Sons, 2003.
2. K.A. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2004.
3. Mattuck, Introduction to Analysis, Prentice Hall, 1999.
4. S.R. Ghorpade and B.V. Limaye, a Course in Calculus and Real Analysis, Springer, 2006.
5. T. Apostol, Mathematical Analysis, Narosa Publishing House
6. Courant and John, Introduction to Calculus and Analysis, Vol II, Springer
7. W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill

8. Terence Tao, Analysis II, Hindustan Book Agency, 2006
9. SatishShirali and Harikishan L. Vasudeva, Metric Spaces, Springer Verlag, London, 2006
10. S. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House, 2011.
11. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw- Hill, 2004.

MJ-6: Group Theory 1 **Credits 04 (Full marks 75)**

MJ-6T: Group Theory 1 **Credits 04**

Course contents:

Unit 1
Symmetries of a square, dihedral groups, definition and examples of groups including permutation groups and quaternion groups (through matrices), elementary properties of groups.

Unit 2
Subgroups and examples of subgroups, centralizer, normalizer, centre of a group, product of two subgroups.

Unit 3
Properties of cyclic groups, classification of subgroups of cyclic groups. Cycle notation for permutations, properties of permutations, even and odd permutations, alternating group, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem.

Unit 4
The external direct product of a finite number of groups **(definition and examples only)**, normal subgroups, factor groups, Cauchy's theorem for finite abelian groups **(only statement)**.

Unit 5
Group homomorphisms, properties of homomorphisms, Cayley's theorem, properties of isomorphisms. First, Second and Third isomorphism theorems.

Suggested Readings:

1. John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
2. M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
3. Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999.
4. Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., Springer Verlag, 1995.
5. I.N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.
6. D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra.

MJ-7: Numerical Methods **Credits 04 (Full marks 75)**

MJ-7T: Numerical Methods **Credits 03**

Course contents:

Unit 1
Algorithms. Convergence. Errors: relative, absolute. Round off. Truncation.

Unit 2
Transcendental and polynomial equations: Bisection method, Newton's method, secant method, Regula-falsi method, fixed point iteration, Newton-Raphson method. Rate of convergence of these methods.

Unit 3
System of linear algebraic equations: Gaussian elimination and Gauss Jordan methods. Gauss Jacobi method, Gauss-Seidel method and their convergence analysis. LU decomposition

Unit 4
Interpolation: Lagrange and Newton's methods. Error bounds. Finite difference operators. Gregory forward and backward difference interpolation.
Numerical differentiation: Methods based on interpolations, methods based on finite differences.

Unit 5
Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson's 1/3rd rule, Simpsons 3/8th rule, Weddle's rule, Boole's Rule. Midpoint rule, Composite trapezoidal rule, composite Simpson's 1/3rd rule, Gauss quadrature formula.
The algebraic eigenvalue problem: Power method. Approximation: Least square polynomial approximation.

Unit 6
Ordinary differential equations: The method of successive approximations, Euler's method, the modified Euler method, Runge-Kutta methods of orders two and four.

Suggested Readings:

1. Brian Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India, 2007.
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering
3. Computation, 6th Ed., New age International Publisher, India, 2007.
4. C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education, India, 2008.
5. Uri M. Ascher and Chen Greif, A First Course in Numerical Methods, 7th Ed., PHI Learning Private Limited, 2013.
6. John H. Mathews and Kurtis D. Fink, Numerical Methods using Matlab, 4th Ed., PHI Learning Private Limited, 2012.
7. Scarborough, James B., Numerical Mathematical Analysis, Oxford and IBH

Publishing Co.
8. Atkinson, K. E., An Introduction to Numerical Analysis, John Wiley and Sons, 1978.
9. Yashavant Kanetkar, Let Us C , BPB Publications.
10. M.Pal, Numerical Analysis for Scientists and Engineers: Theory and C Programs, Narosa. 2007.

MJ-7P: Numerical Methods Lab (Using MATLAB/C++/Python) Credits 01

List of problems (using any software):

1. Calculate the sum 1/1 + 1/2 + 1/3 + 1/4 +-----------+ 1/ N.
2. Enter 100 integers into an array and sort them in ascending order.
3. Solution of transcendental and algebraic equations by
   a) Bisection method
   b) Newton Raphson method.
   c) Secant method.
   d) Regula Falsi method.
4. Solution of a system of linear equations
   a) LU decomposition method
   b) Gaussian elimination method iii)
   c) Gauss-Jacobi method
   d) Gauss-Seidel method
5. Interpolation
   a) Lagrange Interpolation
   b) Newton Interpolation
6. Numerical Integration
   a) Trapezoidal Rule
   b) Simpson's one third rule
   c) Weddle's Rule
   d) Gauss Quadrature
7. Method of finding Eigenvalue by Power method
8. Fitting a Polynomial Function
9. Solution of ordinary differential equations
   a) Euler method
   b) Modified Euler method
   c) Runge Kutta method

Note: For any of the CAS (Computer aided software) Data types-simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and logical expressions, control statements and loop statements, Arrays should be introduced to the students.

MINOR (MI)

MI-3: Algebra **Credits 04 (Full Marks: 75)**

MI-3: Algebra **Credits 04**

Course contents:

UNIT-1:
Polar representation of complex numbers, nth roots of unity, De Moivre's theorem for rational indices and its applications.
Theory of equations: Relation between roots and coefficients, transformation of equation, Descartes rule of signs, cubic and biquadratic equation.
Inequality: The inequality involving AM $\geq$ GM $\geq$ HM, Cauchy-Schwartz inequality.

UNIT-2:
Equivalence relations. Functions, composition of functions, Invertible functions, one-to-one correspondence and cardinality of a set. Well-ordering property of positive integers, division algorithm, divisibility and Euclidean algorithm. Congruence relation between integers. Principles of Mathematical induction, statement of Fundamental Theorem of Arithmetic.

UNIT-3:
Systems of linear equations, row reduction and echelon forms, vector equations, the matrix equation Ax=b, solution sets of linear systems, applications of linear systems, linear independence.

UNIT-4:
Definition of vector space of $R^{n;}$, introduction to linear transformations, matrix of a linear transformation, inverse of a matrix, characterizations of invertible matrices. Subspaces of R^n, dimension of subspaces of R^n, rank of a matrix, Eigen values, eigenvectors and characteristic equation of a matrix. Cayley-Hamilton theorem and its use in finding the inverse of a matrix.

Suggested Readings:

1. Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser, 2006.
2. Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint, 2005.
3. David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
4. K.B. Dutta, Matrix and linear algebra.
5. K. Hoffman, R. Kunze, Linear algebra.
6. W.S. Burnstine and A.W. Panton, Theory of equations.

MI – 4: Calculus, Geometry & Ordinary Differential Equation **Credits 04**

MI – 4T: Calculus, Geometry & Ordinary Differential Equation **Full Marks: 75**

Course contents:

UNIT-1:
Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to problems of type $e^{ax}+b$ sinx, $e^{ax}+b$ cosx, $(ax+b)^n$ sinx, $(ax+b)^n$ cosx, concavity and inflection points, curvature, envelopes, asymptotes, curve tracing in Cartesian coordinates, tracing in polar coordinates of standard curves, L'Hospital's rule, applications in business, economics and life sciences.

UNIT-2:
Reduction formulae, derivations and illustrations of reduction formulae of the type $\int \sin nx\, dx$, $\int \cos nx\, dx$, $\int \tan nx\, dx$, $\int \sec nx\, dx$, $\int (\log x)^n\, dx$, $\int \sin^n x \sin^m x\, dx$, parametric equations, parameterizing a curve, arc length of a curve, the arc length of parametric curves, area under a curve, area and volume of surface of revolution, techniques of sketching conics.

UNIT-3:
Reflection properties of conics, rotation of axes and second-degree equations, classification of conics using the discriminant, polar equations of conics.
Spheres. Cylindrical surfaces. Central conicoids, paraboloids, plane sections of conicoids, generating lines, classification of quadrics, illustrations of graphing standard quadric surfaces like cone, ellipsoid.

UNIT-4:
General, particular, explicit, implicit and singular solutions of a differential equation. First order but not first degree. Exact differential equations and integrating factors, and equations reducible to this form, linear equation, Bernoulli equation and special integrating factors and transformations.

Suggested Readings:

1. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
2. M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi, 2007.
3. H. Anton, I. Bivens and S. Davis, Calculus, 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
4. R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer- Verlag, New York, Inc., 1989.
5. S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
6. Murray, D., Introductory Course in Differential Equations, Longmans Green and Co.
7. G.F.Simmons, Differential Equations, Tata Mcgraw Hill.
8. T. Apostol, Calculus, Volumes I and II.
9. S. Goldberg, Calculus and mathematical analysis.

SKILL ENHANCEMENT COURSE (SEC)

SEC 3: Object-Oriented Programming in C++/Introduction to Python programming

[Students will opt for either Object Oriented Programming in C++ or Introduction to Python programming]

Credits 03

SEC3P: Object Oriented Programming in C++ (Practical) **Full Marks: 50**

Course Outline of Object-Oriented Programming in C++:

Unit 1
Programming paradigms, characteristics of object-oriented programming languages, brief history of C++, structure of C++ program, differences between C and C++, basic C++ operators, Comments, working with variables, enumeration, arrays and pointers.

Unit 2
Objects, classes, constructors and destructors, friend function, inline function, encapsulation, data abstraction, inheritance, polymorphism, dynamic binding, operator overloading, method overloading, overloading arithmetic operator and comparison operators.

Unit 3
Working with files. Template class in C++, copy constructor, subscript and function call operator, concept of namespace and exception handling.

Unit 4: Problems to be solved:

1. Generate a list of 50 random numbers between 1 and 100. Find the maximum and minimum values in the list. Calculate the mean and variance of the numbers.
2. Write a function to determine if a given integer is prime or not.
3. Implement the following sorting algorithms:
   - Bubble Sort
   - Insertion Sort
   - Selection Sort
4. Write a program to calculate the sum of the sine, cosine, or exponential series up to a given number of decimal places.
5. Write a function to check if a given square matrix is an identity matrix.
6. Calculate and print the sum of each row and each column of a given matrix.
7. Write a function that checks whether a given string is a palindrome.
8. Count and display the frequency of each word in a given string.
9. Write a function that removes duplicate characters from a given string.
10. Write a program to compare two strings lexicographically and check if they are equal.
11. Write a function to check if a substring exists in a given string.
12. Write a program to find the longest word in a given sentence.
13. Reverse each word in a given string but keep the original word order intact.
14. Write a program to count the number of vowels and consonants in a given string.
15. Write a program to generate Fibonacci sequence using overloading of ++ operator.

16. Write a class for complex numbers and use it to find the sum, difference, multiplication and division of complex numbers. Use operator overloading.
17. Write a class for matrices and use it to find the sum, difference and multiplication matrices. Use operator overloading.

Suggested Readings:

1. A. R. Venugopal, Rajkumar, and T. Ravishanker, Mastering C++, TMH, 1997.
2. S. B. Lippman and J. Lajoie, C++ Primer, 3rd Ed., Addison Wesley, 2000.
3. Bruce Eckel, Thinking in C++, 2nd Ed., President, Mindview Inc., Prentice Hall.
4. D. Parasons, Object Oriented Programming with C++, BPB Publication.
5. Bjarne Stroustrup, The C++ Programming Language, 3rd Ed., Addison Welsley.
6. E. Balaguruswami, Object Oriented Programming In C++, Tata McGraw Hill
7. Herbert Scildt, C++, The Complete Reference, Tata McGraw Hill.

OR

SEC3P: Introduction to Python programming (Practical) **Full Marks: 50**

Course Outline of Introduction to Python programming:

Unit 1:
Python interpreter as a calculator, variable types: int, float, complex, list, tuple, set, string, type() function, basic mathematical operations, logical conditions (if, elif, else), loops (for, while), user defined functions,, lambda function, importing modules with math, c math, random, help and dir commands, name spaces-local and global.

Python scripts, I/O operations, opening and writing to files.

Unit 2:
List: reading, changing elements, slicing, concatenation, list comprehension. 2D list.
range(), len(), sum(), min(), max(), append(), extend(), count(), index(), sort(), insert(), pop(), remove(), reverse().
Array: Difference between Python lists and arrays, array module, NumPy, Insertion, deletion, and modification.
Tuples: compare with lists, packing/unpacking.
Sets: update(), pop(), remove(), union, intersection, difference, symmetric difference.
Strings: single, double, triple quotes, len(). Indexing, slicing, concatenation, strip(), split), join(), find(), count(), replace(), matting with % operator
Dictionary: Make a dictionary, built-in functions, and dictionary methods.
NumPy library

Unit 3:
Matplotlib, basics of XY-plotting of function, exponential functions, trigonometric functions. Define a Python function, plot in a domain, bar chart, histograms, polar plots, pie plots, plot from data file, save, subplots, and multiple plots.

Unit 4: Problems to be solved:

1. Generate a List of Random Numbers:
   - Generate a list of 50 random numbers between 1 and 100.
   - Find the maximum and minimum values in the list.
   - Calculate the mean and variance of the numbers.
2. Prime Number Check:
   - Write a function to determine if a given integer is prime or not.
3. Sorting Algorithms:
   - Implement and compare the performance of the following sorting algorithms:
     - Bubble Sort
     - Insertion Sort
     - Selection Sort
4. Sum of Series (Trigonometric or Exponential Functions):
   - Write a program to calculate the sum of the sine, cosine, or exponential series up to a given number of decimal places. (Example: sin(x)\sin(x), cos(x)\cos(x), exe^x).
5. Matrix Operations using NumPy:
   - Perform matrix addition, multiplication, and find the inverse using NumPy.
6. Finding Determinant of a Matrix:
   - Use NumPy or implement your own logic to find the determinant of a square matrix.
7. Solving a System of Linear Equations:
   - Use the Gaussian elimination method or NumPy to solve a system of linear equations.
8. Checking Identity Matrix:
   - Write a function to check if a given square matrix is an identity matrix.
9. Sum of Each Row and Column of a Matrix:
   - Calculate and print the sum of each row and each column of a given matrix.
10. Matrix Rotation by 90 Degrees:
    - Write a program to rotate a matrix by 90 degrees clockwise.
11. Palindrome Check:
    - Write a function that checks whether a given string is a palindrome.
12. Word Frequency Counter in a String:
    - Count and display the frequency of each word in a given string.
13. Removing Duplicates from a String:
    - Write a function that removes duplicate characters from a given string.
14. String Comparison:
    - Write a program to compare two strings lexicographically and check if they are equal.
15. Substring Search:
    - Write a function to check if a substring exists in a given string.
16. Longest Word in a Sentence:
    - Write a program to find the longest word in a given sentence.
17. Reverse Each Word in a String:
    - Reverse each word in a given string but keep the original word order intact.
18. Counting Vowels and Consonants in a String:
    - Write a program to count the number of vowels and consonants in a given string.
19. Plotting a Polynomial Function:
    - Plot a polynomial (or any transcendental) function. Identify the real roots by plotting.
20. Plotting Sine and Cosine Functions:
    - Plot the graphs of sine and cosine functions for $x \in [0, 2\pi]$. Use different line styles, colors, and a legend.
21. Plotting $y = x$ and $y = \sqrt{x}$:
    - Plot the graphs of $y = x$ and $y = \sqrt{x}$ on the same figure for $x \in [0, 10]$. Use different colors and add a legend.

22. Bar Chart of Student Grades:
    - Create a bar chart to display the grades of five students in three subjects (Math, Science, and English). Label the axes and provide a title.
23. Market Share Pie Chart:
    - Represent the market share of five companies (A, B, C, D, E) as a pie chart. Use percentages and include labels for each slice.
24. Histogram of Exam Scores:
    - Generate random exam scores for 100 students between 0 and 100 and plot a histogram. Divide the scores into bins of size 10.

Suggested Readings:

1. M. Sundarrajan, Mani Deepak Choudhry, S. Jeevanandham, Akshya Jothi, Python Programming: Beginners Guide, 2024.
2. Dave Brueck. Stephen Tanner, Python 2.1 Bible, Hungry Minds, Inc, New York, 2001.
3. Abhijit Kar Gupta, Scientific Computing in Python, Techno World Computational Playsics, Mark Newman, Amazon Digital, 2022.
4. Ch Satyanarayana, M Radhika Mani and B N Jagadesh, *Programming, University Press, 2018.*
5. J.Elkner, C. Meyer, A Downey, Learning with Python- how to think like a computer scientist, Dreamtech Press, 2015.

INTERNSHIP/APPRENTICESHIP (INT)

Credit-04 Marks: 50 **(120 hours, 8 weeks)**

Guideline for internship/apprenticeship:

The internship program will commence at the beginning of the third semester and will be evaluated upon its completion at the end of the fourth semester.

1. Two or more neighbouring colleges can exchange students for internship programs. Mentors at the partnering colleges may offer these students courses related to their curriculum. The program content will vary depending on the mentor. It could include theoretical courses such as Mathematical Analysis, Numerical Analysis, Applied Mathematics, Financial Mathematics, or Industrial Mathematics, or hands-on training using programming techniques.
2. A student may visit an industry for industry-related issues or a research institution, laboratory, or university to engage in research-related activities under the guidance of an industry official, scientist, or professor.
3. A student may work at a company's outlet or similar type of office, hotel, hospital, nursing home, etc. to collect statistical data and analyse it with any statistical method under the supervision of the respective official or a faculty of his/her own college teacher or a teacher from another college/university/industry person.
4. A student may pursue an internship under the supervision of a teacher within their own college, focusing on allied subjects like Statistics, Economics, or Computer Science (for Mathematics majors).
5. Interns may engage in advanced learning in topics beyond their course curriculum, under the guidance of their respective mentor.
6. Interns may be assigned a complex problem to solve using C++, MatLab or Python and will be required to code and run these programs in the computer lab under the mentor's guidance.
7. Interns may be assigned to design a webpage for his/her own college or department under the mentor's guidance.
8. Interns may be assigned to prepare study materials in MS-Word or MS PowerPoint or LaTeX on topics assigned by their mentor.
9. Interns may be assigned to develop a video lecture on any topic of their own choice with a proper title page for the video under the mentor's guidance.
10. Interns may be allowed to work as quantitative researchers in financial institutions such as banks, insurance companies, or financial consulting firms.

General instructions:

a) Each intern must maintain a daily logbook of activities.
b) At the end of the internship, a completion certificate must be obtained from the mentor, supervisor, or concerned authority.
c) Interns are expected to strictly adhere to the assigned tasks and deadlines.

VIDYASAGAR UNIVERSITY

Midnapore, West Bengal

PROPOSED CURRICULUM & SYLLABUS (DRAFT) OF

BACHELOR OF SCIENCE (HONOURS) MAJOR IN MATHEMATICS

4-YEAR UNDERGRADUATE PROGRAMME

(w.e.f. Academic Year 2023-2024)

Based on

Curriculum & Credit Framework for Undergraduate Programmes (CCFUP), 2023 & NEP, 2020

VIDYASAGAR UNIVERSITY

BACHELOR OF SCIENCE (HONOURS) MAJOR IN MATHEMATICS

(under CCFUP, 2023)

<table>
<tr><th rowspan="2">Level</th><th rowspan="2">YR.</th><th rowspan="2">SEM</th><th rowspan="2">Course Type</th><th rowspan="2">Course Code</th><th rowspan="2">Course Title</th><th rowspan="2">Credit</th><th rowspan="2">L-T-P</th><th colspan="3">Marks</th></tr>
<tr><th>CA</th><th>ESE</th><th>TOTAL</th></tr>
<tr><td rowspan="17">B.Sc. (Hons.)</td><td rowspan="17">3rd</td><td rowspan="6">V</td><td colspan="8">SEMESTER-V</td></tr>
<tr><td>Major-8</td><td>MATHMJ08</td><td>T: Riemann Integration and Series of Functions;</td><td>4</td><td>3-1-0</td><td>15</td><td>60</td><td>75</td></tr>
<tr><td>Major-9</td><td>MATHMJ09</td><td>T: Multivariate Calculus;</td><td>4</td><td>3-1-0</td><td>15</td><td>60</td><td>75</td></tr>
<tr><td>Major-10</td><td>MATHMJ10</td><td>T: Ring Theory & Linear Algebra;</td><td>4</td><td>3-1-0</td><td>15</td><td>60</td><td>75</td></tr>
<tr><td>Major Elective-01</td><td>MATHDSE1</td><td>1.A: Linear Programming Problem
1.B: Bio-Mathematics
1.C: Industrial Mathematics</td><td>4</td><td>3-1-0</td><td>15</td><td>60</td><td>75</td></tr>
<tr><td>Minor-5 (Disc.-I)</td><td>MATMIN05</td><td>T: Numerical Methods
(To be taken from other Discipline)</td><td>4</td><td>3-1-0</td><td>15</td><td>60</td><td>75</td></tr>
<tr><td colspan="4">Semester-V Total</td><td>20</td><td></td><td></td><td></td><td>375</td></tr>
<tr><td rowspan="6">VI</td><td colspan="8">SEMESTER-VI</td></tr>
<tr><td>Major-11</td><td>MATHMJ11</td><td>T: Partial Differential Equations & Applications</td><td>4</td><td>3-1-0</td><td>15</td><td>60</td><td>75</td></tr>
<tr><td>Major-12</td><td>MATHMJ12</td><td>T: Group Theory II</td><td>4</td><td>3-1-0</td><td>15</td><td>60</td><td>75</td></tr>
<tr><td>Major-13</td><td>MATHMJ13</td><td>P: Metric Spaces and Complex Analysis</td><td>4</td><td>3-1-0</td><td>15</td><td>60</td><td>75</td></tr>
<tr><td>Major Elective-02</td><td>MATHDSE2</td><td>2.A: Probability & Statistics
2.B: Logic and Graph Theory
2.C: Portfolio Optimization</td><td>4</td><td>3-1-0</td><td>15</td><td>60</td><td>75</td></tr>
<tr><td>Minor-6 (Disc.-II)</td><td>MATMIN06</td><td>T: Numerical Methods
(To be taken from other Discipline)</td><td>4</td><td>3-1-0</td><td>15</td><td>60</td><td>75</td></tr>
<tr><td colspan="4">Semester-VI Total</td><td>20</td><td></td><td></td><td></td><td>375</td></tr>
<tr><td colspan="4">YEAR-3</td><td>40</td><td></td><td></td><td></td><td>750</td></tr>
<tr><td colspan="4">Eligible to be awarded Bachelor of Science in Mathematics on Exit</td><td>126</td><td colspan="3">Marks (Year: I+II+III)</td><td>2325</td></tr>
</table>

MJ = Major, MI = Minor Course, DSE = Discipline Specific Elective Course, CA= Continuous Assessment, ESE= End Semester Examination,
T = Theory, P= Practical, L-T-P = Lecture-Tutorial-Practical

SEMESTER-V

MAJOR (MJ)

Major – 8
Riemann Integration and Series of Functions

[THEORY; TOTAL CREDITS: 04; 60L]

Course contents:

Unit 1

Riemann integration: inequalities of upper and lower sums, Darbaux integration, Darbaux theorem, Riemann conditions of integrability, Riemann sum and definition of Riemann integral through Riemann sums, equivalence of two definitions. Riemann integrability of monotone and continuous functions, properties of the Riemann integral; definition and integrability of piecewise continuous and monotone functions.

Intermediate Value theorem for Integrals; Fundamental theorem of Integral Calculus.

Unit 2

Improper integrals. Convergence of Beta and Gamma functions.

Unit 3

Pointwise and uniform convergence of sequence of functions. Theorems on continuity, derivability and integrability of the limit function of a sequence of functions. Series of functions;

Theorems on the continuity and derivability of the sum function of a series of functions;

Cauchy criterion for uniform convergence and Weierstrass M-Test.

Unit 4

Fourier series: Definition of Fourier coefficients and series, Riemann-Lebesgue lemma, Bessel's inequality, Parseval's identity, Dirichlet's condition. Examples of Fourier expansions and summation results for series.

Unit 5

Power series, radius of convergence, Cauchy Hadamard theorem. Differentiation and integration of power series; Abel's theorem; Weierstrass approximation theorem.

Reference Books

1. K.A. Ross, Elementary Analysis, The Theory of Calculus, Undergraduate
2. Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
3. R.G. Bartle D.R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
4. Charles G. Denlinger, Elements of Real Analysis, Jones & Bartlett (Student
5. Edition), 2011.
6. S. Goldberg, Calculus and mathematical analysis.
7. Santi Narayan, Integral calculus.
8. T. Apostol, Calculus I, II.

Course Outcomes (COs)

After successful completion of this course, students will be able to:

CO1: Develop a clear understanding of Riemann integration, explore different definitions, and apply the conditions of integrability to monotone, continuous, and piecewise functions.

CO2: Gain the ability to evaluate improper integrals and apply the properties of special functions such as Beta and Gamma in problem-solving contexts.

CO3: Understand and compare pointwise and uniform convergence of sequences and series of functions, and use key theorems to study the behavior of their limits with respect to continuity, differentiability, and integrability.

CO4: Learn to construct Fourier series expansions of functions and make use of fundamental results including Bessel's inequality, Parseval's identity, and Dirichlet's condition to analyze functions.

CO5: Apply the theory of power series to determine their convergence, perform term-by-term differentiation and integration, and utilize results like Abel's theorem and the Weierstrass approximation theorem for approximation of functions.

Major – 9
Multivariate Calculus
[THEORY; TOTAL CREDITS: 04; 60L]

Course contents:

Unit 1

Functions of several variables, limit and continuity of functions of two or more variables Partial differentiation, total differentiability and differentiability, sufficient condition for differentiability. Chain rule for one and two independent parameters, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes, Extrema of functions of two variables, method of Lagrange multipliers, constrained optimization problems

Unit 2

Double integration over rectangular region, double integration over non-rectangular region, Double integrals in polar co-ordinates, Triple integrals, triple integral over a parallelepiped and solid regions. Volume by triple integrals, cylindrical and spherical coordinates. Change of variables in double integrals and triple integrals.

Unit 3

Definition of vector field, divergence and curl.

Line integrals, applications of line integrals: mass and work. Fundamental theorem for line integrals, conservative vector fields, independence of path.

Unit 4

Green's theorem, surface integrals, integrals over parametrically defined surfaces. Stoke's theorem, The Divergence theorem.

Reference Books

1. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
2. M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
3. E. Marsden, A.J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer (SIE), Indian reprint, 2005.
4. James Stewart, Multivariable Calculus, Concepts and Contexts, 2nd Ed., Brooks /Cole, Thomson Learning, USA, 2001
5. T. Apostol, Mathematical Analysis, Narosa Publishing House
6. Courant and John, Introduction to Calculus and Analysis, Vol II, Springer
7. W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
8. Marsden, J., and Tromba, Vector Calculus, McGraw Hill.
9. Maity, K.C. and Ghosh, R.K. Vector Analysis, New Central Book Agency (P) Ltd. Kolkata

(India).
10. Terence Tao, Analysis II, Hindustan Book Agency, 2006
11. M.R. Speigel, Schaum's outline of Vector Analysis.

Course Outcomes (COs)

After successful completion of this course, students will be able to:

CO1: Understand the concepts of functions of several variables, continuity, differentiability, and apply methods such as the chain rule, directional derivatives, and Lagrange multipliers to solve optimization problems.

CO2: Evaluate double and triple integrals in Cartesian, polar, cylindrical, and spherical coordinates, and apply them to compute volumes and solve problems involving change of variables.

CO3: Explain the concepts of vector fields, compute divergence and curl, and apply line integrals in practical contexts such as mass and work.

CO4: Apply Green's theorem to plane regions and solve problems involving surface integrals of vector fields.

CO5: Utilize Stoke's theorem and the Divergence theorem to connect line, surface, and volume integrals, and apply these results in solving physical and geometrical problems.

Major – 10
Ring Theory and Linear Algebra-I
[THEORY; TOTAL CREDITS: 04; 60L]

Course contents:

Unit 1
Definition and examples of rings, properties of rings, subrings, integral domains and fields, characteristic of a ring. Ideal, ideal generated by a subset of a ring, factor rings, operations on ideals, prime and maximal ideals.

Unit 2
Ring homomorphisms, properties of ring homomorphisms. Isomorphism theorems I, II and III, field of quotients.

Unit 3
Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, dimension of subspaces.

Unit 4
Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations. Isomorphisms. Isomorphism theorems, invertibility and isomorphisms, change of coordinate matrix.

Reference Books

1. John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
2. M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
3. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra,4th Ed., Prentice- Hall of India Pvt. Ltd., New Delhi, 2004.
4. Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999.
5. S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005.
6. Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
7. S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.
8. Kenneth Hoffman, Ray Alden Kunze, Linear Algebra, 2nd Ed., Prentice-Hall of India Pvt. Ltd., 1971.
9. D.A.R. Wallace, Groups, Rings and Fields, Springer Verlag London Ltd., 1998.
10. D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra.

Course Outcomes (COs)

After successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts of rings, subrings, integral domains, and fields, and analyze their basic properties including ideals, prime ideals, and maximal ideals.

CO2: Apply the concepts of ring homomorphisms, utilize the Isomorphism Theorems, and construct the field of quotients.

CO3: Demonstrate knowledge of vector spaces, subspaces, quotient spaces, and determine bases, dimensions, and linear independence of vectors.

CO4: Examine linear transformations, compute their null space, range, rank, and nullity, and represent them using matrices.

CO5: Apply algebraic properties of linear transformations, explore isomorphisms, and perform coordinate changes through invertible linear maps.

MAJOR ELECTIVE (DSE)

Major Elective-1

Elective 1. A: Linear Programming

[THEORY; TOTAL CREDITS: 04; 60L]

Course Content:

Unit 1

Introduction to linear programming problem. Theory of simplex method, graphical solution, convex sets, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction to artificial variables, two- phase method. Big- M method and their comparison.

Unit 2

Duality, formulation of the dual problem, primal- dual relationships, economic interpretation of the dual.

Transportation problem and its mathematical formulation, northwest- corner method, least cost method and Vogel approximation method for determination of starting basic solution, algorithm for solving transportation problem, assignment problem and its mathematical formulation, Hungarian method for solving assignment problem.

Unit 3

Game theory: formulation of two person zero sum games, solving two person zero sum games, games with mixed strategies, graphical solution procedure, linear programming solution of games.

Reference Books

1. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, Linear Programming and Network Flows, 2nd Ed., John Wiley and Sons, India, 2004.
2. F.S. Hillier and G.J. Lieberman, Introduction to Operations Research, 9th Ed., Tata McGraw Hill, Singapore, 2009.
3. Hamdy A. Taha, Operations Research, An Introduction, 8th Ed., Prentice- Hall India, 2006
4. G. Hadley, Linear Programming, Narosa Publishing House, New Delhi, 2002.

Course Outcomes (COs)

After successful completion of this course, students will be able to:

CO1: Understand the fundamentals of linear programming problems and solve them using the simplex method, graphical method, and artificial variable techniques.
CO2: Apply duality theory to formulate and interpret primal–dual problems with economic significance.
CO3: Formulate and solve transportation and assignment problems using standard algorithms such as Vogel's approximation and Hungarian method.
CO4: Analyze and solve two-person zero-sum games using graphical, simplex, and mixed strategy approaches.
CO5: Develop optimization-based problem-solving skills for decision-making in real-world applications.

OR

Elective 1. B: Bio Mathematics

[THEORY; TOTAL CREDITS: 04; 60L]

Course Content:

Unit 1

Mathematical biology and the modeling process: an overview. Continuous models: Malthus model, logistic growth, Allee effect, Gompertz growth, Michaelis-Menten Kinetics, Holling type growth, bacterial growth in a chemostat, harvesting a single natural population, Prey predator systems and Lotka Volterra equations, populations in competitions, epidemic models (SI, SIR, SIRS, SIC)

Unit 2

Activator-inhibitor system, insect outbreak model: Spruce Budworm. Numerical solution of the models and its graphical representation. Qualitative analysis of continuous models: Steady state solutions, stability and linearization, multiple species communities and Routh-Hurwitz Criteria. Phase plane methods and qualitative solutions, bifurcations and limit cycles with examples in the context of biological scenario.

Spatial models: One species model with diffusion. Two species model with diffusion, conditions for diffusive instability, spreading colonies of microorganisms, Blood flow in circulatory system, travelling wave solutions, spread of genes in a population.

Unit 3

Discrete models: Overview of difference equations, steady state solution and linear stability analysis. Introduction to discrete models, linear models, growth models, decay models, drug delivery problem, discrete prey-predator models, density dependent growth models with harvesting, host-parasitoid systems (Nicholson-Bailey model), numerical solution of the models and its graphical representation. case studies. Optimal exploitation models, models in genetics, stage structure models, age structure models.

Reference Books

1. L.E. Keshet, Mathematical Models in Biology, SIAM, 1988.
2. J. D. Murray, Mathematical Biology, Springer, 1993.
3. Y.C. Fung, Biomechanics, Springer-Verlag, 1990.
4. F. Brauer, P.V.D. Driessche and J. Wu, Mathematical Epidemiology, Springer, 2008.
5. M. Kot, Elements of Mathematical Ecology, Cambridge University Press, 2001.

Graphical demonstration as Teaching aid using any software

1. Growth model (exponential case only).
2. Decay model (exponential case only).
3. Lake pollution model (with constant/seasonal flow and pollution concentration).

4. Case of single cold pill and a course of cold pills.
5. Limited growth of population (with and without harvesting).
6. Predatory-prey model (basic volterra model, with density dependence, effect of DDT, two prey one predator).
7. Epidemic model of infuenza (basic epidemic model, contagious for life,disease with carriers).
8. Battle model (basic battle model, jungle warfare, long range weapons).

Course Outcomes (COs)

After successful completion of this course, students will be able to:

CO1: Understand the process of mathematical modeling in biology and apply continuous models such as population growth, prey–predator, competition, and epidemic models.
CO2: Analyze biological systems using stability analysis, phase plane methods, bifurcations, and diffusion-based spatial models.
CO3: Apply discrete models including growth, decay, prey–predator, and host–parasitoid systems to study biological dynamics.
CO4: Implement numerical and computational methods to solve biological models and visualize their qualitative behavior.
CO5: Develop and simulate case studies such as epidemic spread, drug delivery, ecological interactions, and resource exploitation using mathematical and computational tools.

OR

Elective 1. C: Industrial Mathematics

[THEORY; TOTAL CREDITS: 04; 60L]

Course Content:

Unit 1

Medical Imaging and Inverse Problems. The content is based on Mathematics of X-ray and CT scan based on the knowledge of calculus, elementary differential equations, complex numbers and matrices.

Unit 2

Introduction to Inverse problems: Why should we teach Inverse Problems? Illustration of Inverse problems through problems taught in Pre-Calculus, Calculus, Matrices and differential equations. Geological anomalies in Earth's interior from measurements at its surface (Inverse problems for Natural disaster) and Tomography.

Unit 3

X-ray: Introduction, X-ray behavior and Beers Law (The fundamental question of image construction) Lines in the place.

Unit 4

Radon Transform: Definition and Examples, Linearity, Phantom (Shepp - Logan Phantom - Mathematical phantoms).

Unit 5

Back Projection: Definition, properties and examples.

Unit 6

CT Scan: Revision of properties of Fourier and inverse Fourier transforms and applications of their properties in image reconstruction. Algorithms of CT scan machine. Algebraic reconstruction techniques abbreviated as ART with application to CT scan.

Reference Books

1. Timothy G. Feeman, The Mathematics of Medical Imaging, A Beginners Guide, Springer Under graduate Text in Mathematics and Technology, Springer, 2010.
2. C.W. Groetsch, Inverse Problems, Activities for Undergraduates, The Mathematical Association of America, 1999.
3. Andreas Kirsch, An Introduction to the Mathematical Theory of Inverse Problems, 2nd Ed., Springer, 2011.

Course Outcomes (COs)

After successful completion of this course, students will be able to:

CO1: Understand the mathematical foundations of medical imaging, including X-rays, CT scans, and inverse problems.
CO2: Apply concepts from calculus, matrices, and differential equations to model and analyze inverse problems in science and industry.
CO3: Explain and utilize the principles of X-ray imaging, Beer's law, Radon transform, and back projection for image reconstruction.
CO4: Analyze mathematical phantoms and reconstruction techniques including Fourier transforms and algebraic reconstruction methods.
CO5: Develop problem-solving skills for real-world applications of inverse problems in medical imaging, tomography, and natural disaster modeling.

MINOR (MI)

Minor-5

Numerical Methods

[THEORY, CREDITS: 04; FM-75]

Course contents:

Unit 1

Algorithms. Convergence. Errors: relative, absolute. Round off. Truncation.

Unit 2

Transcendental and polynomial equations: Bisection method, Newton's method, secant method, Regula-falsi method, fixed point iteration, Newton-Raphson method. Rate of convergence of these methods.

Unit 3

System of linear algebraic equations: Gaussian elimination and Gauss Jordan methods. Gauss Jacobi method, Gauss-Seidel method and their convergence analysis. LU decomposition

Unit 4

Interpolation: Lagrange and Newton's methods. Error bounds. Finite difference operators. Gregory forward and backward difference interpolation.

Numerical differentiation: Methods based on interpolations, methods based on finite differences.

Unit 5

Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson's 1/3rd rule,

Simpsons 3/8th rule, Weddle's rule, Boole's Rule. Midpoint rule, Composite trapezoidal rule,

composite Simpson's 1/3rd rule, Gauss quadrature formula.

The algebraic eigenvalue problem: Power method. Approximation:

Least square polynomial approximation.

Unit 6

Ordinary differential equations: The method of successive approximations, Euler's method, the modified Euler method, Runge-Kutta methods of orders two and four.

Suggested Readings:

1. Brian Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India, 2007.
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering

3. Computation, 6th Ed., New age International Publisher, India, 2007.
4. C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education, India, 2008.
5. Uri M. Ascher and Chen Greif, A First Course in Numerical Methods, 7th Ed., PHI Learning Private Limited, 2013.
6. John H. Mathews and Kurtis D. Fink, Numerical Methods using Matlab, 4^{th} Ed., PHI Learning Private Limited, 2012.
7. Scarborough, James B., Numerical Mathematical Analysis, Oxford and IBH Publishing Co.
8. Atkinson, K. E., An Introduction to Numerical Analysis, John Wiley and Sons, 1978.
9. Yashavant Kanetkar, Let Us C , BPB Publications.
10. M.Pal, Numerical Analysis for Scientists and Engineers: Theory and C Programs, Narosa. 2007.

Course Outcomes (COs)

After successful completion of this course, students will be able to:

CO1: Understand sources of error in numerical computation and analyze convergence of numerical algorithms.

CO2: Apply iterative and direct methods to solve nonlinear equations and systems of linear equations with error and convergence analysis.

CO3: Implement interpolation, numerical differentiation, and numerical integration techniques for function approximation and evaluation.

CO4: Analyze and apply methods for solving algebraic eigenvalue problems and least-squares polynomial approximations.

CO5: Solve ordinary differential equations using numerical techniques such as Euler’s method, Runge-Kutta methods, and successive approximations.

SEMESTER-VI

MAJOR (MJ)

Major-11
Partial Differential Equations & Applications
[Credits 04; Full Marks: 75]

Course contents:

Unit 1

Partial differential equations – Basic concepts and definitions. Mathematical problems. First-order equations: classification, construction and geometrical interpretation. Method of characteristics for obtaining general solution of quasi linear equations. Canonical forms of first-order linear equations. Method of separation of variables for solving first order partial differential equations.

Unit 2

Derivation of heat equation, wave equation and Laplace equation. Classification of second order linear equations as hyperbolic, parabolic or elliptic. Reduction of second order linear equations to canonical forms.

Unit 3

The Cauchy problem, Cauchy-Kowalewskaya theorem, Cauchy problem of an infinite string. Initial boundary value problems. Semi-infinite string with a fixed end, semi-infinite string with a free end. Equations with non-homogeneous boundary conditions. Non- homogeneous wave equation. Method of separation of variables, solving the vibrating string problem. Solving the heat conduction problem

Unit 4

Central force. Constrained motion, varying mass, tangent and normal components of acceleration, modelling ballistics and planetary motion, Kepler's second law.

Unit 5

Graphical Demonstration(Teaching aid)

1. Solution of Cauchy problem for first order PDE.
2. Finding the characteristics for the first order PDE.
3. Plot the integral surfaces of a given first order PDE with initial data.
1. Solution of wave equation in different initial and boundary conditions.

Reference Books

1. Tyn Myint-U and Lokenath Debnath, Linear Partial Differential Equations for Scientists and Engineers, 4th edition, Springer, Indian reprint, 2006.
2. S.L. Ross, Differential equations, 3rd Ed., John Wiley and Sons, India, 2004.
3. Martha L Abell, James P Braselton, Differential equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.
4. Sneddon, I. N., Elements of Partial Differential Equations, McGraw Hill.
5. Miller, F. H., Partial Differential Equations, John Wiley and Sons.
6. Loney, S. L., An Elementary Treatise on the Dynamics of particle and of Rigid Bodies, Loney Press.

Course Outcomes (COs)

After successful completion of this course, students will be able to:

CO1: Understand the basic concepts of partial differential equations, classify first-order PDEs, and apply methods such as characteristics and separation of variables to obtain solutions.

CO2: Derive fundamental second-order PDEs like the heat, wave, and Laplace equations, classify them as hyperbolic, parabolic, or elliptic, and reduce them to canonical forms.

CO3: Formulate and solve Cauchy problems and boundary value problems for wave and heat equations, including cases with non-homogeneous conditions, using the method of separation of variables.

CO4: Apply PDE techniques to model problems in mechanics such as central force motion, constrained motion, varying mass systems, and planetary motion governed by Kepler's laws.

CO5: Use graphical demonstrations to visualize solutions of PDEs, characteristics, integral surfaces, and solutions of wave equations under various conditions.

Major-12
Group Theory II
[THEORY, Credits 04; Full Marks: 75]

Course contents:

Unit 1

Automorphism, inner automorphism, automorphism groups, automorphism groups of finite and infinite cyclic groups, applications of factor groups to automorphism groups, Characteristic subgroups, Commutator subgroup and its properties.

Unit 2

Properties of external direct products, the group of units modulo n as an external direct product, internal direct products, Fundamental theorem of finite abelian groups.

Unit 3

Group actions, stabilizers and kernels, permutation representation associated with a given group action. Applications of group actions. Generalized Cayley's theorem. Index theorem.

Unit 4

Groups acting on themselves by conjugation, class equation and consequences, conjugacy in Sn, p-groups, Sylow's theorems and consequences, Cauchy's theorem, Simplicity of An for $n \geq 5$, non-simplicity tests.

Reference Books

1. John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
2. M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
3. Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, 1999.
4. David S. Dummit and Richard M. Foote, Abstract Algebra, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2004.
5. J.R. Durbin, Modern Algebra, John Wiley & Sons, New York Inc., 2000.
6. D. A. R. Wallace, Groups, Rings and Fields, Springer Verlag London Ltd., 1998
7. D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra.
8. I.N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.

Course Outcomes (COs)

After successful completion of this course, students will be able to:

CO1: Understand automorphisms, inner automorphisms, and automorphism groups, and apply properties of factor groups and commutator subgroups in group theory.
CO2: Analyze external and internal direct products of groups, and apply the Fundamental Theorem of Finite Abelian Groups to classify abelian groups.
CO3: Apply the concept of group actions to study stabilizers, kernels, and permutation representations, and use generalized Cayley's theorem and the index theorem in applications.
CO4: Examine groups acting on themselves by conjugation, apply the class equation, and study conjugacy classes in symmetric groups.
CO5: Apply Sylow's theorems, Cauchy's theorem, and results on simplicity and non-simplicity to classify finite groups, including properties of alternating groups.

Major-13
Metric Spaces and Complex Analysis
[THEORY; TOTAL CREDITS: 04; 60L]

Course Content:

Unit 1
Metric spaces: sequences in metric spaces, Cauchy sequences. Complete metric spaces, Cantor's theorem.

Unit 2
Continuous mappings, sequential criterion and other characterizations of continuity. Uniform continuity. Connectedness, connected subsets of R. Compactness: Sequential compactness, Heine-Borel property, totally bounded spaces, finite intersection property, and continuous functions on compact sets. Homeomorphism. Contraction mappings. Banach fixed point theorem and its application to ordinary differential equation.

Unit 3
Limits, limits involving the point at infinity, continuity. Properties of complex numbers regions in the complex plane, functions of complex variable, mappings. Derivatives, differentiation formulas, Cauchy-Riemann equations, sufficient conditions for differentiability.

Unit 4
Analytic functions, examples of analytic functions, exponential function, logarithmic function, trigonometric function, derivatives of functions, and definite integrals of functions. Contours, Contour integrals and its examples, upper bounds for moduli of contour integrals. Cauchy- Goursat theorem, Cauchy integral formula.

Unit 5
Liouville's theorem and the fundamental theorem of algebra. Convergence of sequences and series, Taylor series and its examples.

Unit 6
Laurent series and its examples, absolute and uniform convergence of power series.

Reference Books

1. Satish Shirali and Harikishan L. Vasudeva, Metric Spaces, Springer Verlag, London, 2006.
2. S. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House, 2011.
3. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2004.
4. James Ward Brown and Ruel V. Churchill, Complex Variables and Applications, 8th Ed., McGraw – Hill International Edition, 2009.
5. Joseph Bak and Donald J. Newman, Complex Analysis, 2nd Ed., Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., NewYork, 1997.
6. S. Ponnusamy, Foundations of complex analysis.
7. E.M.Stein and R. Shakrachi, Complex Analysis, Princeton University Press.

Course Outcomes (COs)

After successful completion of this course, students will be able to:

CO1: Understand the concepts of metric spaces, convergence, Cauchy sequences, completeness, and apply Cantor's theorem in analysis.

CO2: Analyze continuity and uniform continuity, connectedness, compactness, and apply important results such as the Heine–Borel property, Banach fixed point theorem, and their applications.

CO3: Explain the fundamental ideas of complex analysis including limits, continuity, differentiability, and apply Cauchy–Riemann equations to identify analytic functions.

CO4: Apply integral theorems of complex analysis such as Cauchy–Goursat theorem and Cauchy's integral formula to evaluate contour integrals and study properties of analytic functions.

CO5: Use Liouville's theorem, the Fundamental Theorem of Algebra, and power series expansions (Taylor and Laurent series) to study convergence properties and represent complex functions.

MAJOR ELECTIVE (DSE)

Major Elective-2

Elective 2. A: Probability and Statistics

[THEORY; TOTAL CREDITS: 04; 60L]

Course contents:

Unit 1

Sample space, probability axioms, real random variables (discrete and continuous), cumulative distribution function, probability mass/density functions, mathematical expectation, moments, moment generating function, characteristic function, discrete distributions: uniform, binomial, Poisson, geometric, negative binomial, continuous distributions: uniform, normal, exponential.

Unit 2

Joint cumulative distribution function and its properties, joint probability density functions, marginal and conditional distributions, expectation of function of two random variables, conditional expectations, independent random variables, bivariate normal distribution, correlation coefficient, joint moment generating function (jmgf) and calculation of covariance (from jmgf), linear regression for two variables.

Unit 3

Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers. Central limit theorem for independent and identically distributed random variables with finite variance, Markov chains, Chapman-Kolmogorov equations, classification of states.

Unit 4

Random Samples, Sampling Diatributions, Estimation of parameters, Testing of hypothesis.

Reference Books

1. Robert V. Hogg, Joseph W. McKean and Allen T. Craig, Introduction to Mathematical Statistics, Pearson Education, Asia, 2007.
2. Irwin Miller and Marylees Miller, John E. Freund, Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia, 2006.
3. Sheldon Ross, Introduction to Probability Models, 9th Ed., Academic Press, Indian Reprint, 2007.
4. Alexander M. Mood, Franklin A. Graybill and Duane C. Boes, Introduction to the Theory of Statistics, 3rd Ed., Tata McGraw- Hill, Reprint 2007
5. Gupta, Ground work of Mathematical Probability and Statistics, Academic publishers.

Course Outcomes (COs)

After successful completion of this course, students will be able to:

CO1: Understand the fundamental concepts of probability, random variables, probability distributions, and their properties.

CO2: Apply discrete and continuous probability models to compute expectations, moments, and solve practical problems.

CO3: Analyze joint distributions, conditional expectations, correlations, and regression for bivariate data.

CO4: Interpret and apply laws of large numbers, central limit theorem, and concepts of Markov chains in stochastic modeling.

CO5: Perform statistical inference through sampling distributions, estimation of parameters, and hypothesis testing.

OR

Elective 2. B: Logic and Graph Theory

[THEORY; TOTAL CREDITS: 04; 60L]

Unit 1

Introduction, propositions, truth table, negation, conjunction and disjunction. Implications, biconditional propositions, converse, contra positive and inverse propositions and precedence of logical operators. Propositional equivalence: Logical equivalences. Predicates and quantifiers: Introduction, quantifiers, binding variables and negations.

Unit 2

Difference and Symmetric difference of two sets. Set identities, generalized union and intersections. Relation: Product set. Composition of relations, types of relations, partitions, equivalence Relations with example of congruence modulo relation. Partial ordering relations, n-ary relations.

Unit 3

Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bipartite graphs isomorphism of graphs.

Unit 4

Eulerian circuits, Eulerian graph, semi-Eulerian graph, theorems, Hamiltonian cycles,theorems Representation of a graph by matrix, the adjacency matrix, incidence matrix, weighted graph,

Unit 5

Travelling salesman's problem, shortest path, Tree and their properties, spanning tree, Dijkstra's algorithm, Warshall algorithm.

Reference Books

1. R.P. Grimaldi, Discrete Mathematics and Combinatorial Mathematics, Pearson Education, 1998.
2. P.R. Halmos, Naive Set Theory, Springer, 1974.
3. E. Kamke, Theory of Sets, Dover Publishers, 1950.
4. B.A. Davey and H.A. Priestley, Introduction to Lattices and Order, Cambridge University Press, Cambridge, 1990.
5. Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 2nd Edition, Pearson Education (Singapore) P. Ltd., Indian Reprint 2003.
6. Rudolf Lidl and Gunter Pilz, Applied Abstract Algebra, 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
7. N. Deo, Graph Theory with Applications to Engineering & Computer Science, Prentice Hall

India Learning Private Limited; New edition (1 January 1979).
8. D. B. West, Introduction to Graph Theory, Pearson. 2000.

Course Outcomes (COs)

After successful completion of this course, students will be able to:

CO1: Understand the fundamentals of propositional and predicate logic, logical equivalences, and quantifiers.

CO2: Apply set theory and relations, including equivalence relations and partial orderings, to solve mathematical problems.

CO3: Analyze properties of different types of graphs and identify isomorphism between graphs.

CO4: Examine Eulerian and Hamiltonian graphs, and represent graphs using matrices and weighted structures.

CO5: Apply graph algorithms such as shortest path, travelling salesman, spanning tree, Dijkstra's and Warshall's algorithms to solve real-world problems.

OR

Elective 2. C: Portfolio Optimization

[THEORY; TOTAL CREDITS: 04; 60L]

Course contents:

Unit 1

Financial markets. Investment objectives. Measures of return and risk. Types of risks. Risk free assets. Mutual funds. Portfolio of assets. Expected risk and return of portfolio. Diversification.

Unit 2

Mean-variance portfolio optimization- the Markowitz model and the two-fund theorem, risk-free assets and one fund theorem, efficient frontier. Portfolios with short sales. Capital market theory.

Unit 3

Capital assets pricing model- the capital market line, beta of an asset, beta of a portfolio, security market line. Index tracking optimization models. Portfolio performance evaluation measures.

Reference Books

1. F. K. Reilly, Keith C. Brown, Investment Analysis and Portfolio Management, 10th Ed., South-Western Publishers, 2011.
2. H.M. Markowitz, Mean-Variance Analysis in Portfolio Choice and Capital Markets, Blackwell, New York, 1987.
3. M.J. Best, Portfolio Optimization, Chapman and Hall, CRC Press, 2010.
4. D.G. Luenberger, Investment Science, 2nd Ed., Oxford University Press, 2013.

Course Outcomes (COs)

After successful completion of this course, students will be able to:

CO1: Understand the structure of financial markets, investment objectives, measures of risk and return, and the role of diversification in portfolio management.

CO2: Apply mean-variance portfolio optimization techniques including the Markowitz model, two-fund theorem, and efficient frontier analysis.

CO3: Analyze the impact of risk-free assets, short sales, and capital market theory on portfolio construction.

CO4: Evaluate asset pricing using the Capital Asset Pricing Model (CAPM), including beta, capital market line, and security market line.

CO5: Assess portfolio performance through index tracking models and performance evaluation measures.

MINOR (MI)

Minor-6

Numerical Methods

[THEORY, CREDITS: 04; FM-75]

Course contents:

Unit 1

Algorithms. Convergence. Errors: relative, absolute. Round off. Truncation.

Unit 2

Transcendental and polynomial equations: Bisection method, Newton's method, secant method, Regula-falsi method, fixed point iteration, Newton-Raphson method. Rate of convergence of these methods.

Unit 3

System of linear algebraic equations: Gaussian elimination and Gauss Jordan methods. Gauss Jacobi method, Gauss-Seidel method and their convergence analysis. LU decomposition

Unit 4

Interpolation: Lagrange and Newton's methods. Error bounds. Finite difference operators. Gregory forward and backward difference interpolation.

Numerical differentiation: Methods based on interpolations, methods based on finite differences.

Unit 5

Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson's $1/3^{rd}$ rule, Simpsons $3/8^{th}$ rule, Weddle's rule, Boole's Rule. Midpoint rule, Composite trapezoidal rule, composite Simpson's $1/3^{rd}$ rule, Gauss quadrature formula.

The algebraic eigenvalue problem: Power method. Approximation: Least square polynomial approximation.

Unit 6

Ordinary differential equations: The method of successive approximations, Euler's method, the modified Euler method, Runge-Kutta methods of orders two and four.

Reference Books

1. Brian Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India, 2007.
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering
3. Computation, 6th Ed., New age International Publisher, India, 2007.
4. C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis,

Pearson Education, India, 2008.
5. Uri M. Ascher and Chen Greif, A First Course in Numerical Methods, 7th Ed., PHI Learning Private Limited, 2013.
6. John H. Mathews and Kurtis D. Fink, Numerical Methods using Matlab, 4th Ed., PHI Learning Private Limited, 2012.
7. Atkinson, K. E., An Introduction to Numerical Analysis, John Wiley and Sons, 1978.
8. Yashavant Kanetkar, Let Us C , BPB Publications.
9. M.Pal, Numerical Analysis for Scientists and Engineers: Theory and C Programs, Narosa. 2007.

Course Outcomes (COs)

After successful completion of this course, students will be able to:

CO1: Understand sources of error in numerical computation and analyze convergence of numerical algorithms.

CO2: Apply iterative and direct methods to solve nonlinear equations and systems of linear equations with error and convergence analysis.

CO3: Implement interpolation, numerical differentiation, and numerical integration techniques for function approximation and evaluation.

CO4: Analyze and apply methods for solving algebraic eigenvalue problems and least-squares polynomial approximations.

CO5: Solve ordinary differential equations using numerical techniques such as Euler's method, Runge-Kutta methods, and successive approximations.