Academic Council Meeting No. and Date : 3 / February 14, 2022

Agenda Number : 2 Resolution Number : 4.7 & 4.16

Vidya Prasarak Mandal's

B. N. Bandodkar College of Science (Autonomous), Thane

Syllabus for

Programme : Bachelor of Science

Specific Programme : Mathematics

[S.Y.B.Sc. Mathematics]

Revised under Autonomy

From academic year 2022 - 2023

This page is intentionally left blank

Preamble

VPM'S B. N. Bandodkar College of Science Autonomous has changed the syllabus of S.Y.B.Sc. Mathematics from the academic year 2022-23.

Mathematics is the most fundamental subject and an essential tool in the field of Science and Technology. The syllabus has been developed to prepare the students in pursuing research in Mathematics as well as to enhance their analytical skills and knowledge of mathematical tools and techniques required in industry for employment.

Inrecentdecades, theextentofapplicationofMathematicstorealworldproblemshasincreasedbyleapsand bounds. Taking into consideration the rapid changes in science and technology and newapproaches in different areas of mathematics and related subjects like Physics, Statistics andComputer Sciences, the board of studies in Mathematics haspreparedthesyllabusofS.Y.B.Sc. Mathematics. The present syllabi of S. Y. B. Sc. for Semester III and Semester IV hasbeendesignedasperU.G.C.ModelcurriculumsothatthestudentslearnMathematicsneeded for these branches, learn basic concepts of Mathematics and are exposed to rigorous methodsgently and slowly. The syllabi would consist of two semesters andeach semester would comprise of three courses for S.Y.B.ScMathematics. Course I is 'Calculus III and Multivariable Calculus I'. Calculus is applied and needed in every conceivable branch of science. Course II, 'Linear Algebra I and Linear Algebra II' develops mathematical reasoning and logical thinking and has applications inscienceandtechnology. Course III is "Ordinary differential equations and Numerical Methods" which is the applied computational technical skill.

Course Outcome

- Givethe studentsasufficientknowledgeoffundamentalprinciples, methodsandaclearperceptionofinnumerouspowerofmathematicalideasand toolsandknowhowtousethembymodeling,solvingandinterpreting.
- Reflectingthebroadnatureofthesubjectanddevelopingmathematicaltoolsforcontinuingfurtherstudyinvariousfieldsofscience.
- Enhancingstudents' overall developmentandtoequipthemwithmathematicalmodelingabilities, problem solvingskills, creative talentandpowerofcommunicationnecessaryforvariouskindsofemployment.
- Astudentshouldgetadequateexposuretoglobalandlocalconcernsthatexplorethem m anyaspectsofMathematicalSciences.

Program Specific Outcomes

- To understand the basic concepts and fundamental theories of Mathematics
- To develop problem solving and computing skills
- To use mathematical concepts learnt for deducing proofs with logical reasoning
- To learn application of theory of Mathematics in related subjects like Physics, Statistics and Computer Science
- To develop analytical skills and understanding of abstract theories of Mathematics
- To learn various mathematical tools and techniques and apply them in real world

VPM's B.N. Bandodkar College of Science (Autonomous), Thane

S.Y.B.Sc. (MATHEMATICS)

Structure of Program

CourseCode	Course Title	No. of lectures	Credits
	SEMESTER III		
BNBUSMT3T1	Calculus III	**45**	**2**
BNBUSMT3T2	Linear Algebra I	**45**	**2**
BNBUSMT3T3	Ordinary Differential Equations	**45**	**2**
BNBUSMT3P3	Practical based on BNBUSMT3T1, BNBUSMT3T2 and BNBUSMT3T3	**35**	**3**
	SEMESTER IV		
BNBUSMT4T1	Multivariable Calculus I	**45**	**2**
BNBUSMT4T2	Linear Algebra II	**45**	**2**
BNBUSMT4T3A	Numerical Methods	**45**	**2**
BNBUSMT4T3B	Graph Theory and its Applications	**45**	**2**
BNBUSMT4P4	Practical based on BNBUSMT4T1, BNBUSMT4T2 and BNBUSMT4T3A /BNBUSMT4T3B	**35**	**3**
Total		**340**	**18**

Semester III

Course Code	Course Title	Credits	No. of lectures
BNBUSMT3T1	**Calculus III**	**2**	**45**

Course Outcomes: Upon completion of this course, students will learn about

- **Entire concept of series in Real numbers**
- **Theoretical concept of Riemann Integration with applications**
- **Improper integral and applications**

Unit I:	**Infinite Series** 1. Infinite series in IR. Definition of convergence and divergence. Basic examples including geometric series. Elementary results such as if $\sum_{n=1}^{\infty} a_n$ converges then $a_n \to 0$ but converse is not true. Cauchy criterion. Algebra of convergent series. 2. Tests for convergence. Comparison Test, Limit Comparison Test, Ratio Test, Root test, Abel Test (without proof), Dirichlet's Test (without proof). Examples. The decimal expansion of real numbers. Convergence of $\sum_{n=1}^{\infty} \frac{1}{n^p} (p > 1)$. Divergence of Harmonic series $\sum_{n=1}^{\infty} \frac{1}{n}$. 3. Alternating series, Leibnitz rule, Examples. Absolute convergence. Absolute convergence implies convergence but not conversely. Conditional convergence.	**15**
Unit II:	**Riemann Integration** 1. Idea of approximating the area under a curve by inscribed circumscribed rectangles. Partitions of an interval. Refinement of a partition. Upper and lower sums for a bounded real valued function on a closed and bounded interval. Riemann integral. 2. Criterion for Riemann Integrability. Characterization of the Riemann integral as the limit of a sum. Examples. 3. Algebra of Riemann Integrable functions. 4. Riemann Integrability of continuous function and more generally of a bounded function whose set of discontinuities has only finitely many points. Riemann Integrability of monotone functions.	**15**
Unit III:	**Application of Integrations and Improper Integrals** 1. Area between the two curves. Lengths of plane curves. Surface area of surfaces of revolution. 2. First and Second Fundamental Theorems of Calculus. 3. Mean Value Theorem. Integration by parts formula. Leibnitz'srule. 4. Definitions of two types of improper integrals. Necessary and sufficient condition for convergence. 5. Absolute convergence. Comparison and Limit form of Comparison	**15**

	test for convergence. 6. Gamma and Beta functions and their properties. Relationship between Gamma and Beta function.	

Course Code BNBUSMT3T2	Course Title Linear Algebra I	Credits 2	No. of lectures 45
Course Outcomes: Upon completion of this course, students will learn about • System of equations, matrices with basic properties • Vector space in IR • Determinants with its theoretical approach			

Unit I:	**System of Equations and Matrices** Systems of homogeneous and non-homogeneous linear equations, Simple examples of finding solutions of such systems. Geometric and algebraic understanding of the solutions. Matrices (with real entries), Matrix representation of system of homogeneous and non-homogeneous linear equations. Algebra of solutions of systems of homogeneous linear equations. A system of homogeneous linear equations with number of unknowns morethan the number of equations, has infinitely many solutions. Elementary row and column operations. Row equivalent matrices. Row reduction (of amatrix to its row echelon form). Gaussian elimination. Applications to solving systems of linear equations. Examples. Elementary matrices. Relation of elementary row operations with elementary matrices. Invertibility of elementary matrices. Consequences such as (i) a square matrix is invertible if and only if its row echelon form is invertible. (ii) Invertible matrices are products of elementary matrices. Examples of the computation of the inverse of a matrix using Gauss elimination method.	**15**
Unit II :	**Vector space over R** 1. Definition of a vector space over R. Subspaces; criterion for a nonempty subset to be a subspace of a vector space. Examples of vector spaces, including the Euclidean space R^n, lines, planes and hyperplanes in R^n passing through the origin, space of systems of homogeneous linear equations, space of polynomials, space of various types of matrices, space of real valued functions on a set. 2. Intersections and sums of subspaces. Direct sum of vector spaces. Quotient space of a vector space by its subspace. 3. Linear combination of vectors. Linear span of a subset of a vector space. Definitionof finitely generated vector space. Linear dependence and independence of subsets of a vector space. 4. Basis of a vector space. Basic results that any two bases of a finitely generated vector space have the same number of elements. Dimension of a vector space. Examples. Bases of a vector space as a maximal linearly independent sets and as minimal generating sets.	**15**

Unit III:

Determinants, Linear Equations (Revisited)

1. Inductive definition of the determinant of a n x n matrix (e. g. in terms of expansion along the first row). Example of a lower triangular matrix. Laplace expansions along an arbitrary row or column. Determinant expansions using permutations

$$\left(\det(A) = \sum_{\sigma \in S_n} \operatorname{sign}(\sigma) \prod_{i=1}^{n} a_{\sigma(i),i}\right).$$

2. Basic properties of determinants (Statements only);
   - (i) det A = det A^T.
   - (ii) Multilinearity and alternating property for columns and rows.
   - (iii) A square matrix A is invertible if and only if det A $\neq$ 0.
   - (iv) Minors and cofactors. Formula for A^{-1} when det A $\neq$ 0.
   - (v) Det (AB) = det A det B.

3. Row space and the column space of a matrix as examples of vector space. Notion of row rank and the column rank. Equivalence of the row rank and the column rank. Invariance of rank upon elementary row or column operations. Examples of computing the rank using row reduction.

4. Relation between the solutions of a system of non-homogeneous linear equations and the associated system of homogeneous linear equations. Necessary and sufficient condition for a system of non-homogeneous linear equations to have a solution [viz., the rank of the coefficient matrix equals the rank of the augmented matrix [A | B]]. Equivalence of statements (in which A denotes an n x n matrix) such as the following.
   - (i) The system Ax = bof non-homogeneous linear equations has a unique solution.
   - (ii) The systemAx= 0 of homogeneous linear equations has no nontrivial solution.
   - (iii) A is invertible.
   - (iv) DetA $\neq$ 0:
   - (v) Rank(A) = n.

Cramer's Rule. LU Decomposition. If a square matrix A is a matrix that can be reduced to row echelon form U by Gauss elimination without row interchanges, then A can be factored as A = LU where L is a lower triangular matrix

15

Course Code	Course Title	Credits	No. of lectures
BNBUSMT3T3	**ORDINARY DIFFERENTIAL EQUATIONS**	**2**	**45**

Course Outcomes: Upon completion of this course, students will learn about

- solving first order exact and non-exact ODEs and linear ODEs
- methods of solving first order linear ODE in allied subjects
- solving second order linear differential equations
- solving higher order linear differential equations
- evaluating inverse differential operators of standard functions

Unit I:	. Higher order Linear Differential equations (15 Lectures) 1. The general nth order linear differential equations, Linear independence, An existence and uniqueness theorem, the Wronskian, Classification: homogeneous and non-homogeneous, General solution of homogeneous and non-homogeneous LDE, The Differential operator and its properties. 2. Higher order homogeneous linear differential equations with constant coefficients, the auxiliary equations, Roots of the auxiliary equations: real and distinct, real and repeated, complex and complex repeated. 3. Higher order homogeneous linear differential equations with constant coefficients, the method of undermined coefficients, method of variation of parameters. 4. The inverse differential operator and particular integral, Evaluation of $\frac{1}{f(D)}$ for the functions like e^{ax}, $\sin ax$, $\cos ax$, x^m, $x^m \sin ax$, $x^m \cos ax$, $e^{ax}V$ and xV where V is any function of x 5. Higher order linear differential equations with variable coefficients: The Cauchy's equation: $x^3\frac{d^3y}{dx^3} + x^2\frac{d^2y}{dx^2} + x\frac{dy}{dx} + y = f(x)$ and The Legendre's equation: $(ax+b)^3\frac{d^3y}{dx^3} + (ax+b)^2\frac{d^2y}{dx^2} + (ax+b)\frac{dy}{dx} + y = f(x)$. First Order First Degree Differential Equations 1. Basics of ordinary differential equations 2. Exact equations of first order and first degree, non-exact equations and rules of finding integrating factors 3. Linear and reducible linear differential equations of first order, Bernoulli's differential equation 4. Applications of first order differential equations	**15**
Unit II:	Systems of First Order Linear Differential Equations (15 Lectures) 1. Existence and uniqueness theorem for the solutions of initial value problems for a system of two first order linear differential equations in two unknown functions x, y of a single independent variable t, of the form $\begin{cases}\frac{dx}{dt} = F(t,x,y)\\ \frac{dy}{dt} = G(t,x,y)\end{cases}$ (Statement only). 2. Homogeneous linear system of two first order differential equations in two unknown functions of a single independent variable t, of the form	**15**

	$\begin{cases} \frac{dx}{dt} = a_1(t)x + b_1(t)y \\ \frac{dy}{dt} = a_2(t)x + b_2(t)y \end{cases}$ 3. Wronskian for a homogeneous linear system of first order linear differential equations in two functions x, y of a single independent variable t. Vanishing properties of the Wronskian. Relation with linear independence of solutions. 4. Homogeneous linear systems with constant coefficients in two unknown functions x, y of a single independent variable t. Auxiliary equation associated to a homogenous system of equations with constant coefficients. Description of the general solution depending on the roots and their multiplicities of the auxiliary equation, proof of independence of the solutions. Real form of solutions in case the auxiliary equation has complex roots. 5. Non-homogeneous linear system of linear system of two first order differential equations in two unknown functions of a single independent variable t, of the form $\begin{cases} \frac{dx}{dt} = a_1(t)x + b_1(t)y + f_1(t) \\ \frac{dy}{dt} = a_2(t)x + b_2(t)y + f_2(t). \end{cases}$ General Solution of non-homogeneous system. Relation between the solutions of a system of non-homogeneous linear differential equations and the associated system of homogeneous linear differential equations. Second Order Linear Differential Equations 1. Homogeneous and Non-homogeneous second order linear differential equations, Wronskian and linear independence of the solutions, General solution of homogeneous and non- homogeneous second order differential equation (with proofs) 2. Second order homogeneous linear differential equations with constant coefficients, the auxiliary equations, Roots of the auxiliary equations: real and distinct, real and repeated, complex conjugates. 3. Second order non-homogeneous linear differential equations with constant coefficients: The method of undermined coefficients and The method of variation of parameters.	
Unit III:	Numerical Solution of Ordinary Differential Equations (15 lectures) 1. Numerical Solution of initial value problem of first order ordinary differential equation using: (i) Taylor's series method, (ii) Picard's method for successive approximation and its convergence, (iii) Euler's method and error estimates for Euler's method,	**15**

	(iv) Modified Euler's Method, (v) Runge-Kutta method of second order and its error estimates, (vi) Runge-Kutta fourth order method. 2. Numerical solution of simultaneous and higher order ordinary differential equation using: (i) Runge-Kutta fourth order method for solving simultaneous ordinary differential equation, (ii) Finite difference method for the solution of two-point linear boundary value problem. Higher order Linear Differential Equations and Linear system of ODEs 1. Higher order homogeneous linear differential equations with constant coefficients, the auxiliary equations, Roots of the auxiliary equations: real and distinct, real and repeated, complex and complex repeated. 2. An existence and uniqueness theorem, Wronskian and linear independence, General solution of homogeneous and non-homogeneous LDE (without proof) 3. The Differential operator and its properties, The inverse differential operator and particular integral, Evaluation of $\frac{1}{f(D)}$	

Course Code BNBUSMT3P3	Course Title Practical based on BNBUSMT3T1, BNBUSMT3T2, BNBUSMT3T3	Credits 3	No. of lectures 35
	Practical based on BNBUSMT3T1		
Practical 1	**Examples of convergent and divergent series and algebra of convergent series.**		**1**
Practical 2	**Tests of Convergence series.**		**1**
Practical 3	**Calculation of upper sum, lower sum and Riemann integral**		**1**
Practical 4	**Problems on properties of Riemann Integral.**		**1**
Practical 5	**Problems on fundamental theorems of Calculus. Mean Value Theorems, Integration by parts, Leibnitz rule.**		**1**
Practical 6	**Convergence of Improper Integrals. Test for convergence. Beta, Gamma functions.**		**1**
Practical 7	**Miscellaneous Theoretical Questions based on full paper**		**1**
	Practical based on BNBUSMT3T2		
Practical 1	**Systems of homogeneous and non-homogeneous linear equations.**		**1**
Practical 2	**Elementary row/column operations and Elementary matrices.**		**1**
Practical 3	**Vector spaces, Subspaces.**		**1**
Practical 4	**Linear Dependence/independence, Basis, Dimension.**		**1**
Practical 5	**Determinant and Rank of a matrix.**		**1**
Practical 6	**Solution to a system of linear equations, LU decomposition**		**1**
Practical 7	**Miscellaneous Theoretical Questions based on full paper**		**1**
	Practical based on BNBUSMT3T3		
Practical 1	**Solving exact and non-exact first order differential equations**		**3**

Practical 2	**Linear and reducible to linear equations, applications of first order differential equations**	**3**
Practical 3	**Solving second order homogeneous equations and Wronskian**	**3**
Practical 4	**Solving second non-homogeneous ODEs using method of undetermined coefficients and method of variation of parameters**	**3**
Practical 5	**Finding the general solution of homogeneous and non-homogeneous higher order linear differential equations**	**3**
Practical 6	**Inverse Differential Operators**	**3**
Practical 7	**Miscellaneous Theoretical Questions based on full paper**	**3**
	Total	**35**

Course Code BNBUSMT4T1	Course Title CALCULUS II		Credits 2	No. of lectures 45
Learning Outcomes: Students would gain enough knowledge of ❖ Functions of several variables ❖ Limits, continuity and derivative of scalar and vector field functions ❖ Applications of Derivatives of Scalar and Vector field function				
Unit I:	**Functions of Several Variables** 1. Review of vectors in $\mathbb{R}^n$ and basic notations such as addition and scalar multiplication, inner product, length (norm), and distance between two points. 2. Real valued functions of several variables (Scalar fields), Vector valued functions of several variables (Vector fields). Component functions. Examples. 3. Sequences, Limits and Continuity: Sequences in $\mathbb{R}^n$ and their limits, Neighborhood's in $\mathbb{R}^n$.Limits and continuity of scalar fields. Composition of continuous functions. Sequential characterizations. Algebra of limits and continuity. Iterated limits. Limits and continuity of vector fields. Algebra of Limits and continuity of vector fields. 4. Partial and directional derivatives of scalar fields. Definitions of directional derivatives and partial derivatives of scalar fields. Mean Value Theorem of scalar fields			**15**
Unit II :	**Differentiation of Scalar Fields** 1.Differentiability of Scalar Fields (in terms of linear transformation). The concept of total derivative. Uniqueness of total derivative of a differentiable function at a point. Examples of a function of two or three variables. Increment theorem. Basic properties including (i) continuity at a point of differentiability, (ii) existence of partial derivatives at a point of differentiability and (iii) differentiability when the partial derivatives exist and are continuous. 2.Gradient. Relation between total derivative and gradient of a function. Chain Rule. Geometric properties of Gradient. Tangent planes. 3.Euler's Theorem. 4.Higher order partial derivatives. Mixed partial theorem (n = 2).			**15**
Unit III:	**Applications of Differentiation of Scalar Fields and Differentiation of Vector Fields** 1. Application of Differentiation of Scalar Fields. The maximum and minimum rate of change of Scalar Field. Taylor's Theorem for twice continuously differentiable function. Notion of local maxima, local minima and saddle points. First Derivative Test. Examples. Hessian Matrix. Second Derivative Test for functions of two variables. Examples. Method of Lagrange Multiplier.			**15**

	2. Differentiation of Vector Fields. Differentiability and the notion of total derivative. Differentiability of a vector field implies continuity. Jacobian Matrix. Relationship between the total derivative and Jacobian matrix. The chain rule for derivative of a vector fields (statements only)	

Course Code **BNBUSMT4T2**	**Course Title** **Linear Algebra II**	**Credits** **2**	**No. of lectures** **45**

Learning Outcomes: Students would gain enough knowledge

- Linear Transformations
- Inner products and orthogonality of vectors
- Eigen values, Eigen vectors and Diagonalization

Unit I:	**Linear Transformations** 1. Definition of a linear transformation of vector spaces; elementary properties. Examples. Sums and scalar multiples of linear transformations. Composites of linear transformations. A Linear transformation of V $\rightarrow$ W; where V and Ware vector spaces over R and V is a finite dimensional vector space is completely determined by its action on an ordered basis of V. 2. Null-space (kernel) and the image (range) of a linear transformation. Nullity and Rank of a linear transformation. Rank-Nullity Theorem (Fundamental Theorem of Homomorphism). 3. Matrix associated with linear transformation of V $\rightarrow$ W where V and Ware finite dimensional vector spaces over R. Matrix of the composite of two linear transformations. Invertible linear transformations (isomorphism), Linear Operator, Effect of change of bases on matrices of linear operator. 4. Equivalence of the rank of a matrix and the rank of the associated linear transformation.	**15**
Unit II:	**Inner Products and Orthogonality** 1. Inner product spaces (overR). Examples, including the Euclidean space Rn and the spaceof real valued continuous functions on a closed and bounded interval. Norm associated toan inner product. Cauchy-Schwarz inequality. Triangle inequality. 2. Angle between two vectors. Orthogonality of vectors. Pythagoras theorem and somegeometric applications in R^2. Orthogonal sets, Orthonormal sets. Gram-Schmidt Orthogonalization process. Orthogonal basis and orthonormal basis for a finite-dimensional innerproduct space. 3. Orthogonal complement of any set of vectors in an inner product space. Orthogonal complement of a set is a vector subspace of the inner product space. Orthogonal decompositionof an inner product space with respect to its subspace. Orthogonal projection of a vectoronto a line (one dimensional subspace). Orthogonal projection of an inner product spaceonto its subspace.	**15**
Unit III :	**Eigenvalues, Eigenvectors and Diagonalization** 1. Eigenvalues and eigenvectors of a linear transformation of a vector space into itself and ofsquare matrices. The eigenvectors corresponding to distinct eigenvalues of a linear transformation are linearly independent. Eigen spaces. Algebraic and geometric multiplicity ofan eigenvalue. 2. Characteristic polynomial. Properties of characteristic polynomials (only	**15**

	statements). Examples. Cayley-Hamilton Theorem. Applications. 3. Invariance of the characteristic polynomial and eigenvalues of similar matrices. 4. Diagonalizable matrix. A real square matrixA is diagonalizable if and only if there is abasis of R^n consisting of eigenvectors of A. (Statement only – A_{nxn} is diagonalizable ifand only if sum of algebraic multiplicities is equal to sum of geometric multiplicities of allthe eigenvalues of A = n). Procedure for diagonalization of a matrix. 5. Spectral Theorem for Real Symmetric Matrices (Statement only). Examples of orthogonaldiagonalization of real symmetric matrices. Applications to quadratic forms and classification of conic sections.	

Course Code BNBUSMT4T3A	Course Title NUMERICAL METHODS	Credits 2	No. of lectures 45

Course Outcomes: Upon completion of this course, students will learn

- To study methods for finding approximate solution of algebraic and transcendental equations
- To learn methods for finding polynomial approximation of a function with analysis
- To understand and find linear and quadratic curve fitting
- To find approximate integration using methods like Trapezoidal Rule, Simpson's 1/3 rd Rule, Simpson's 3/8th Rule.
- To study methods for finding approximate solution of a linear system of equations and Eigenvalue problems

Unit I:	Solution of Algebraic and Transcendental Equations 1. Measures of Errors: Relative, absolute and percentage errors, Accuracy and precision: Accuracy to n decimal places, accuracy to n significant digits or significant figures, Rounding and Chopping of a number, Types of Errors: Inherent error, Round-off error and Truncation error. 2. Iteration methods based on first degree equation: Newton-Raphson method, Secant method, Regula-Falsi method with derivations, geometrical interpretation and rate of convergence. 3. General Iteration method: Fixed point iteration method	**15**
Unit II:	Interpolation, Curve fitting, Numerical Integration 1. Interpolation: Lagrange's Interpolation, Finite difference operators: Forward Difference operator, Backward Difference operator, Shift operator, Newton's forward difference interpolation formula and Newton's backward difference interpolation formula with derivations 2. Curve fitting: Linear and Quadratic 3. Numerical Integration: Trapezoidal Rule, Simpson's 1/3 rd Rule, Simpson's 3/8th Rule with derivations	**15**
Unit III:	Solution Linear Systems of Equations, Eigenvalue problems 1. Linear Systems of Equations: LU Decomposition Method (Dolittle's Method and Crout's Method), Gauss-Seidel Iterative method 2. Eigenvalue problems: Jacobi's method for symmetric matrices, Rutishauser method for arbitrary matrices	**15**

Course Code BNBUSMT4T3B	Course Title GRAPH THEORY AND ITS APPLICATIONS	Credits 2	No. of lectures 45

Course Outcomes: Students would gain enough knowledge

- Basics of Graphs and different types
- Trees and application of trees
- Concepts of coloring of different graphs

Unit I:	**Graphs:** 1. Introduction to graphs: Types of graphs: Simple graph, directed graph, (One example/graph model of each type to be discussed). 2. (a) Graph Terminology: Adjacent vertices, degree of a vertex, isolated vertex Pendant vertex in an undirected graph. (b) The handshaking Theorem for an undirected graph (statement only), Theorem: undirected graph has an even number odd vertices. 3 Some special simple graphs (by simple examples): Complete graph, cycle, wheel, Bipartite graph, regular graph. 4 Representing graphs and graph isomorphism: (a) Adjacency matrix of a simple graph. (b) Incidence matrix of an undirected graph. 5 Connectivity: (a) Paths, circuits, simple paths, simple circuits in a graph (simple examples). (b) Connecting paths between vertices (simple examples). (c) Euler paths and circuits, Hamilton paths and circuits, Dirac's Theorem (Statement only), Ores Theorem (statement only): Problems based on both Theorems to check graph is Hamiltonian. (d) Planar graphs, planar representation of graphs, Eulers formula. Kuratowski's Theorem (statement only). 6 Shortest path problem: Construction of Eulerian path by Fleury's algorithm, the shortest path algorithm - Dijkstra's Algorithm, Floyd's Algorithm to find the length of the shortest path.	**15**
Unit II:	**Trees:** 1 (a) Trees: Definition and Examples. (b) binary trees (c) Trees as models. (d) Properties of Trees. 2 Application of Trees: (a) Binary Search Trees, Algorithm for locating an item in or adding an item to A binary search tree. (b) Decision Trees (simple examples). (c) Algorithm for Huffman's coding, construction of Huffman's code by examples. 3 Spanning tree, Algorithms for spanning tree – BFS and DFS. 4 Minimum Spanning Trees, Prims Algorithm, Kruskal's Algorithm	**15**
Unit III:	**Colorings of graph** 1. Vertex coloring- evaluation of vertex chromatic number of some standard	**15**

	graphs, critical graph. Upper and lower bounds of Vertex chromatic Number-Statement of Brooks theorem. 5 Edge coloring- Evaluation of edge chromatic number of standard graphs such as complete graph, com-plete bipartite graph, cycle. Statement of Vizing theorem. Chromatic polynomial of graphs-Recurrence Relation and properties of Chromatic polynomials. 6 Vertex and Edge cuts vertex and edge connectivity and the relation between vertex and edge connectivity. Equality of vertex and edge connectivity of cubic graphs. Whitney's theorem on 2-vertex connected graphs.	

Course Code **BNBUSMT4P4**	**Course Title** **Practical based on BNBUSMT4T1, BNBUSMT4T2, BNBUSMT4T3A/BNBUSMT4T3B**	**Credits** **3**	**No. of lectures** **35**
	Practical based on BNBUSMT4T1		
Practical 1	**Limits and continuity of Scalar fields and vector fields. Iterated limits.**		**1**
Practical 2	**Computing directional derivatives, Partial derivatives and Mean Value Theorem of scalar fields.**		**1**
Practical 3	**Differentiability of scalar fields. Total derivative. Gradient.**		**1**
Practical 4	**Chain Rule, Higher order derivative and mixed partial derivative of scalar fields.**		**1**
Practical 5	**Maximum and minimum rate of change of scalar fields. Taylor's Theorem. Finding Hessian/Jacobian Matrix. Differentiation of a vector field at a point. Chain rule for vector fields.**		**1**
Practical 6	**Finding maxima, minima, saddle points. Second derivative test, Method of Lagrange multipliers.**		**1**
Practical 7	**MiscellaneousTheoreticalQuestionsbasedonfullpaper**		**1**
	Practical based on BNBUSMT4T2		
Practical 1	**Linear transformation, Kernel, Rank-Nullity Theorem**		**1**

Practical 2	**Linear Isomorphism, Matrix associated with Linear transformations.**	**1**
Practical 3	**Inner product and properties, Projection, Orthogonal complements.**	**1**
Practical 4	**Orthogonal, orthonormal sets, Gram-Schmidt Orthogonalization**	**1**
Practical 5	**Eigenvalues, Eigenvectors, Characteristic polynomial. Applications of Cayley Hamilton Theorem.**	**1**
Practical 6	**Diagonalization of matrix, orthogonal diagonalization of symmetric matrix and applicationto quadratic form.**	**1**
Practical 7	**MiscellaneousTheoreticalQuestionsbasedonfullpaper**	**1**
	Practical based on BNBUSMT4T3A	
Practical 1	**Newton-Raphson method, Secant method**	**3**
Practical 2	**Regula-Falsi method, Iteration Method**	**3**
Practical 3	**Interpolating polynomial by Lagrange's Interpolation, Newton forward and backward difference Interpolation**	**3**
Practical 4	**Curve fitting, Trapezoidal Rule, Simpson's 1/3rd Rule, Simpson's 3/8th Rule**	**3**
Practical 5	**LU decomposition method, Gauss-Seidel Iterative method**	**3**
Practical 6	**Jacobi's method, Rutishauser method**	**3**
Practical 7	**MiscellaneousTheoreticalQuestionsbasedonfullpaper**	**3**
	Practical based on BNBUSMT4T3B	
Practical 1	**Drawing a graph, counting the degree of vertices and number of edges, Handshaking Lemma and Graph Isomorphism.**	**3**
Practical 2	**Shortest Path problems- Dijkstra’s Algorithm, Floyds Algorithm**	**3**
Practical 3	**To determine whether the given graph is a tree. Construction of Binary search tree and application to sorting and searching**	**3**
Practical 4	**Spanning tree, finding spanning tree using Breath First Search and**	**3**

	/or Depth First Search.	
Practical 5	**Coloring of Graphs**	**3**
Practical 6	**Chromatic Polynomials and Connectivity**	**3**
Practical 7	**Miscellaneous Theoretical Questions based on full paper**	**3**
	Total	**35**

Books and References: Semester III paper I

Sr. No.	Title	Author/s	Publisher	Edition	Year
1.	Methods of Real Analysis	R. R. Goldberg	Oxford and IBH		1964
2.	Calculus and Analytic Geometry	Thomas and Finney	Addison-Wesley		1998
3.	Introduction to Real Analysis	R. G. Bartle and D. R. Sherbert	John Wiley & Sons		1994
4.	A course in Calculus and Real Analysis	SudhirGhorpade and BalmohanLimaye	Springer International Ltd.		2000
5.	Calculus Vol.2	T. Apostol	John Wiley		
6.					

Books and References: Semester III paper II

Sr. No.	Title	Author/s	Publisher	Edition	Year
1.	Elementary Linear Algebra	Howard Anton, Chris Rorres	Wiley Student Edition		

2.	Introduction to Linear Algebra	Serge Lang	Springer International Ltd.		
3.	Linear Algebra - A Geometric Approach	S Kumaresan	PHI Learning.		
4.	Linear Algebra done right	Sheldon Axler	Springer International Ltd.		
5.	Linear Algebra with Applications	Gareth Williams	Jones and Bartlett Publishers		
6.	Matrix theory	David W. Lewis			

Books and References: Semester III paper III

Sr. No.	Title	Author/s	Publisher	Edition	Year
1.	Ordinary Differential Equations A First Course	D Somasundaram	Narosa		2005
2.	Differential equations with applications and historical notes	George F. Simmons	McGraw Hill Education	Second	2017
3.	Elementary Differential Equations	Earl D. Rainville, Phillip E. Bedient and Richard E. Bedient	Publisher Pearson Education	Eight	2016
4.	Ordinary And Partial Differential Equations	M. D. Raisinghania	S. Chand		2005
5.	An Introduction to Ordinary Differential Equations	E. A. Coddington	Dover Books		1989
6.	Ordinary Differential Equations: Principles and Applications	A. K. Nandakumaran, P. S. Datti and Raju K. George	Cambridge University Press	First	2017

Books and references: Semester IV paper I

Title	Author/s	Publisher	Edition	Year
Calculus Vol.2	T. Apostol	John Wiley		
A course in Multivariable calculus and Analysis	Ghorpade, Limaye	Springer		

	Principals of Mathematical Analysis	Walter Rudin	McGraw- Hill			
	Calculus	K. Stewart	Brooke/Cole publishing			

Books and References: Semester IV paper II					
Sr. No.	**Title**	**Author/s**	**Publisher**	**Edition**	**Year**
1.	Elementary Linear Algebra	Howard Anton, Chris Rorres	Wiley Student Edition		
2.	Introduction to Linear Algebra	Serge Lang	Springer International Ltd.		
3.	Linear Algebra - A Geometric Approach	S Kumaresan	PHI Learning.		
4.	Linear Algebra done right	Sheldon Axler	Springer International Ltd.		
5.	Linear Algebra with Applications	Gareth Williams	Jones and Bartlett Publishers		
6.	Matrix theory	David W. Lewis			

Books and References: Semester IV paper III (Elective A)					
Sr. No.	**Title**	**Author/s**	**Publisher**	**Edition**	**Year**
1.	An Introduction to Numerical Analysis	Kendall E. and Atkinson	Wiley		
2.	Numerical Methods for Scientific and Engineering Computation	M. K. Jain, S. R. K. Iyengar and R. K. Jain	New Age International Publications		
3.	Introductory methods of Numerical Analysis	S. Sastry	PHI Learning		
4.	Numerical Methods: Fundamentals and Applications	Rajesh Kumar Gupta	Cambridge University Press		2019
5.	Numerical Methods	P. Kandasamy, K. Thilagavathy and K. Gunavati	S Chand		2006

6.	Numerical Methods	E. Bal Guruswamy	McGraw Hill Education		2017

Books and References: Semester IV paper III (Elective B)					
Sr. No.	**Title**	**Author/s**	**Publisher**	**Edition**	**Year**
1.	Discrete Mathematics and its applications	Kenneth H. Rosen	McGraw Hill	Seventh	2011
2.	Graph Theory with Applications.	Bondy and Murty	Elsevier Science ltd		1976
3.	A Textbook of Graph theory	R. Balakrishnan and Ranganathan	Anebooks - Springer		2007
4.	Introduction to graph Theory.	D. B. West	Pearson	Second	2000
5.	Graph Theory	Frank Harary	Narosa Publishing house		2001
6.	Introduction to Graph theory	Robin J. Wilson	Prentice Hall.	Fourth	1996

Evaluation Scheme

Internals

			Attendance & Leadership qualities	**Total**

10	**10**	**10**	**10**	**40**
Certification of Swayam / NPTEL in concern course **Class test 20** **Assignment/Project/courses/achievements 10**				

Internal Examination: **Based on Unit 1 / Unit 2 / Unit 3**
Duration: 1 Hour **Total**
Marks: 20

	Answer the following	**20**
Q. 1		
Q. 2		
Q. 3		
Q. 4		
Q. 5		

Theory Examination: **Suggested Format of Question paper**
Duration: 2 Hours **Total**
Marks: 60

- **All questions are compulsory**

Q. 1	Answer ***any two*** of the following		**16**
	a	Based on Unit I	
	b	Based on Unit I	
	c	Based on Unit I	
	d	Based on Unit I	
Q. 2	Answer ***any two*** of the following		**16**
	a	Based on Unit II	
	b	Based on Unit II	
	c	Based on Unit II	
	d	Based on Unit II	
Q. 3	Answer ***any two*** of the following		**16**
	a	Based on Unit III	
	b	Based on Unit III	
	c	Based on Unit III	
	d	Based on Unit III	
Q. 4	Answer ***any two*** of the following		**12**
	a	Based on Unit I	
	b	Based on Unit II	
	c	Based on Unit III	
	d	Based on Unit IV	

** (4 questions of 8 marks each / 8 questions of 4 marks can be asked with 50% options)

Marks Distribution and Passing Criterion for Each Semester

Theory					Practical		
Course Code	Internal	Min marks for passing	Theory Examination	Min marks for passing	Course Code	Practical Examination	Min marks for passing
BNBUSMT3T1	**40**	**16**	**60**	**24**	BNBUSMT3P3	**150**	**60**
BNBUSMT3T2	**40**	**16**	**60**	**24**	-	**-**	**-**
BNBUSMT3T3	**40**	**16**	**60**	**24**	-	**-**	**-**

Theory					Practical		
Course Code	Internal	Min marks for passing	Theory Examination	Min marks for passing	Course Code	Practical Examination	Min marks for passing
BNBUSMT4T1	**40**	**16**	**60**	**24**	BNBUSMT4P4	**150**	**60**
BNBUSMT4T2	**40**	**16**	**60**	**24**	**-**	**-**	**-**
BNBUSMT4T3A / BNBUSMT4T3B	**40**	**16**	**60**	**24**			

List of paper Setters

Aided Staff

1. **Mrs. Minal T Wankhede**
2. **Mrs. AkankshaShinde**
3. **Mrs. UmalaxmiPatne**

Unaided Staff

1. **Ms. Priyanka G Rajput**

List of Moderators

1. **Mrs. Minal T Wankhede**
2. **Mrs. VeenaShindeDeore (External)**
3. **Mrs. Santosh Tikre (External)**
4. **Mr. Prakash Sansare (External)**

List of Examiners

Aided Staff

1. **Mrs. Minal T Wankhede**
2. **Mrs. AkankshaShinde**
3. **Mrs. UmalaxmiPatne**

Unaided Staff

2. **Ms. Priyanka G Rajput**

~ * ~ * ~ * ~ * ~ * ~