

**Parvatibai Chowgule College of Arts & Science
(Autonomous)
Margao – Goa**

**MINUTES OF MEETING OF THE BOARD OF STUDIES IN MATHEMATICS
HELD ON 20TH April, 2023 at
Parvatibai Chowgule College of Arts & Science
(Autonomous)
Margao – Goa**

Vide Chowgule College notice F.133(C)/94 dated 15th April, 2023 a meeting of this BOS was convened on 20th April 2023, at 9:30 am through online Google Meet, Parvatibai Chowgule College of Arts & Science, Margao – Goa. Since the number of members present represented the Quorum, the BOS began its proceedings.

Members present:

1. Mr. Anand Masur
2. Ms. Danielle Monteiro
3. Dr. Chitra Mekoth
4. Mr. Rovon Vaz
5. Dr. Milind Kulkarni
6. Mr. Meetal Raikar

Member Absent with Intimation

1. Dr. Stephen Dais Barreto
2. Dr. Rajeev Sapre

Proceedings

The Chairperson welcomed the members of the Board of Studies (BOS). The Chairperson introduced and explained the agenda for the meeting and read out the minutes of the previous B.O.S meet. The meeting continued taking up the following agenda.

Agenda Items:

1. To appraise the New Course structure as per the new UGC guidelines for UG programs based on NEP 2020
2. To approve the list of Courses under the Nomenclatures: Core (Major and Minor), Skilled Enhancement Course (SEC), and Multidisciplinary Course (MDC).
3. To approve the syllabi of semester I and II courses under the New Course Structure
4. A.O.B

PART A: The BOS passed the resolutions as follows:

1. The New Course structure was appraised.
2. The Coordinate Geometry course was shifted from Semester 5 to Semester 4 and Graph Theory was taken to Semester 5.
3. The Reference book of Linear Algebra by Krishnamurty was suggested for Mathematics for Sciences Course.
4. Applications of Derivatives was added to unit 4 of Basic Calculus course in semester I
5. The list of courses under the nomenclatures Core (Major and Minor), Skilled Enhancement Course (SEC), and Multidisciplinary Course (MDC) for the four-year BA/BSc Honors program were approved.
6. The semester I and II courses' syllabus under the new structure was approved.

PART B: Important Points/ recommendations of BOS that require consideration/approval of the Academic Council:

1. The New Course structure was appraised.
2. The list of courses under the nomenclatures Core (Major and Minor), Skilled Enhancement Course (SEC), and Multidisciplinary Course (MDC) for the four-year BA/BSc Honors program were approved.
3. The semester I and II courses' syllabus under the new structure was approved.

The following members of the Board of Studies in Mathematics were present for the meeting.

1. Mr. Anand Masur
2. Ms. Danielle Monteiro
3. Dr. Chitra Mekoth
4. Mr. Rován Vaz
5. Dr. Milind Kulkarni
6. Mr. Meetal Raikar

Member Absent with Intimation

1. Dr. Stephen Dais Barreto
2. Dr. Rajeev Sapre



Dr. Chitra Mekoth
Member Secretary
Board of Studies



Ms. Danielle Monteiro
Chairperson
Board of Studies

Date: 24th April, 2023

PART C: The remarks of the Dean of the Faculty: -

- a. The minutes are in order.
- b. The minutes may be placed before the Academic Council with remarks, if any.
- c. Important points of the minutes which need clear policy decisions of the Academic Council to be recorded.

Date: 25/4/2023

Signature of the Dean:
(Faculty of Science)



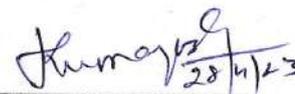
Dr. Meghana Devli

PART D: The remarks of the Members Secretary of the Academic Council:-

- a. The minutes are in order.
- b. The minutes may be placed before the Academic Council with remarks, if any.
- c. Important points of the minutes which need clear policy decisions of the Academic Council to be recorded.

Date: 28/4/23

Signature of the Member Secretary
Academic Council



Mr. V. C. Kumaresh

Annexure A

**BA/ BSc. MATHEMATICS 3 YEARS AND 4 YEARS HONOURS LIST OF COURSES 2022-23 UNDER NEP 2020
COURSE STRUCTURE**

SEMESTER	COURSE CODE	TITLE OF THE COURSE	NOMENCLATURE/TYPE OF COURSE	CREDITS
1	UG-MAT-101	Basic Algebra	DSC	4
	UG-MAT-102	Basic Calculus	DSC	4
	UG-MAT-MDC1	Statistics I	MDC	3
	UG-MAT-SEC1	Differential Equations I	SEC	3
2	UG-MAT-103	Basic Real Analysis	DSC	4
	UG-MAT-104	Mathematics for Sciences	DSC	4
	UG-MAT-MDC2	Mathematics for Competitive Exams	MDC	3
	UG-MAT-SEC2	Operations Research I	SEC	3
3	UG-MAT-201	Mathematical Analysis I	DSC	4
	UG-MAT-202	Algebra I	DSC	4
	UG-MAT-203	Combinatorics	DSC	4
	UG-MAT-MDC3	Statistics II	MDC	3
	UG-MAT-SEC3	Numerical Methods	SEC	3
4	UG-MAT-204	Mathematical Analysis II	DSC	4
	UG-MAT-205	Linear Algebra	DSC	4
	UG-MAT-206	Number Theory I	DSC	4
	UG-MAT-207	Coordinate Geometry	DSC	4
	UG-MAT-VOC1	Pedagogy of Mathematics	VOC	4
5	UG-MAT-301	Functions of Several Variables	DSC	4
	UG-MAT-302	Graph Theory	DSC	4
	UG-MAT-303	Advanced Analysis	DSC	4
	UG-MAT-304	Operations Research II	DSC	4
	UG-MAT-VOC2	Probability	VOC	4
6	UG-MAT-305	Vector Analysis	DSC	4
	UG-MAT-306	Complex Analysis	DSC	4
	UG-MAT-307	Metric Spaces	DSC	4
	UG-MAT-308	Differential Equations II	DSC	4
7	UG-MAT-401	Algebra II	DSC	4
	UG-MAT-402	Advanced Analysis II	DSC	4
	UG-MAT-403	Topology	DSC	4
	UG-MAT-404	Functional Analysis	DSC	4
	UG-MAT-405	Computational Linear Algebra	DSC	4
8	UG-MAT-406	Measure Theory	DSC	4
	UG-MAT-407	Partial Differential Equations	DSC	4
	UG-MAT-408	Rings and Modules	DSC	4
	UG-MAT-409	Number Theory II	DSC	4
	UG-MAT-410	Cryptography	DSC	4

Annexure B

DEPARTMENT OF MATHEMATICS
 SYLLABUS FOR THREE/FOUR YEAR UNDERGRADUATE DEGREE HONOURS
 PROGRAMME IN MATHEMATICS
 (Implemented from the Academic Year 2023-2024 onwards)

COURSE STRUCTURE

SEMESTER	MAJOR CORE	MINOR/ VOCATIONA L	MULTIDISCI PLINARY COURSE (MDC)	VALUE ADDED COURSES (VAC)	ABILITY ENHANCE MENT COURSE (AEC)	SKILL ENHANCEM ENT COURSE (SEC)
I	UG-MAT-101: Basic Algebra	UG-MAT- 102: Basic Calculus	UG-MAT- MDC1: Statistics I			UG-MAT- SEC1: Differential Equations I
II	UG-MAT-103: Basic Real Analysis	UG-MAT- 104: Mathematics for Sciences	UG-MAT- MDC2: Mathematics for Competitive Exams			UG-MAT- SEC2: Operations Research I
III	UG-MAT-201: Mathematical Analysis I	UG-MAT- 203: Combinatorics	UG-MAT- MDC3: Statistics II			UG-MAT- SEC3: Numerical Methods
	UG-MAT-202: Algebra I					
IV	UG-MAT-204: Mathematical Analysis II	UG-MAT- VOC1: Pedagogy of Mathematics				
	UG-MAT-205: Linear Algebra					
	UG-MAT-206: Number Theory I					
	UG-MAT-207: Coordinate Geometry					
V	UG-MAT-301: Functions of Several Variables	UG-MAT- VOC2: Probability				
	UG-MAT-302: Graph Theory					
	UG-MAT-303: Advanced Analysis					

	UG-MAT-304: Operations Research II					
VI	UG-MAT-305: Functions of Several Variables					
	UG-MAT-306: Complex Analysis					
	UG-MAT-307: Metric Spaces					
	UG-MAT-308: Differential Equations II					
VII	UG-MAT-401: Algebra II					
	UG-MAT-402: Advanced Analysis II					
	UG-MAT-403: Topology					
	UG-MAT-404: Functional Analysis					
	UG-MAT-405: Computational Linear Algebra					
VIII	UG-MAT-406: Measure Theory					
	UG-MAT-407: Partial Differential Equations					
	UG-MAT-408: Rings and Modules					
	UG-MAT-409: Number Theory II					
	UG-MAT-410: Cryptography					

SEMESTER I

DISCIPLINE-SPECIFIC CORE COURSE

Course Title: BASIC ALGEBRA

Course Code: UG-MAT-101

Marks: 100

Credits: 4

Duration: 60 hours

Course Objectives: To introduce the basic Algebra concepts used in other branches of mathematics.

Course learning outcome: Upon completion of the course the student will be able to:

- C01. Apply various concepts of logic to produce clear and valid arguments.
- C02. Define and interpret the various concepts of sets, and relations.
- C03. Apply the concept of Boolean Algebra to the study of logic gates.
- C04. Compute and use determinants and matrices
- C05. Solve systems of linear equations using Gaussian Elimination

Course Content

Unit 1: Logic

(15 lectures)

Statements in logic, symbolic representation, connectives, truth-tables. The logic of compound statements: Logical form and logical equivalence, conditional statements, duality law, normal forms, rules of inference, valid and invalid arguments. Quantified statements: Predicates and quantified statements, universal quantifiers, existential quantifiers, and statements with multiple quantifiers. Methods of Proof.

Unit 2: Sets and Relations

(8 lectures)

The notion of Sets- Subsets - Power sets - Equality of sets - Finite and Infinite sets - Set operations - De-Morgan's laws – The cartesian product of sets, Relations - Types of relations - Binary relation - Equivalence relations, Partial Orderings, Equivalence classes, and partitions.

Unit 3: Boolean Algebra

(12 lectures)

Boolean Functions, Study of logic gates: AND, OR, NOT, XOR, XNOR, NAND, and NOR gates, Minimization of Circuits.

Unit 4: Matrices and determinants

(25 lectures)

Matrices, Algebra of Matrices, Determinants of a square matrix, Inverse of a square matrix- Elementary Row, Column operations- Elementary matrices- the inverse of a matrix using elementary operations- Rank of a Matrix- Normal Form- Row-Echelon form of a matrix, Row rank and column rank of a matrix, Concept of Linear Independence, Linear Equations: the system of homogeneous equations, Consistency and solution of a system of linear equations using Gaussian Elimination.

List of books recommended for reference

1. Rosen, K.H. (2012), *Discrete Mathematics and its Applications* (7th Ed.), Mc Graw Hill
2. R.D. Bhatt, *Algebraic Structures*, Vipul Prakashan
3. C.L.Liu, *Discrete Mathematical Structures*,
4. Shanti Narayan and P.K.Mittal, *A textbook of Matrices*, S. Chand and Company
5. K.B.Datta, *Matrix and Linear Algebra*, PHI
6. S. Lang, *Introduction to Linear Algebra*, Second Ed., Springer-Verlag

Course Title: BASIC CALCULUS

Course Code: UG-MAT-102

Marks: 100

Credits: 4

Duration: 60 hours

Course Objectives: To introduce the number system with its geometrical properties and axioms of real numbers

Course learning outcome: Upon completion of the course, the student will be able to

- C01. Construct real numbers
- C02. Use properties of real numbers in the analysis
- C03. Draw and recognize graphs of some important functions
- C04. Understand the concepts of limit and continuity
- C05. Analyse if the functions are differentiable

Course Content

Unit 1: Number System:-

(20 lectures)

Simple Algebraic development from Natural numbers to Real numbers. The geometry of Real numbers:- Representation of real numbers on a line, Trichotomy Law, Order on R, Archimedes property, Hausdorff property, distance concept: absolute value (all inequalities ex. Triangle inequality). Subsets of R: bounded-unbounded sets, bounded sets, lub. glb. Completeness axiom, intervals, open-closed intervals, open/closed nbd. of a point, limit points, dense set (Q and Q' only), the concept of infinity-

Unit 2: Functions:-

(10 lectures)

Examples of functions with graphs ($\log x$, a^x , x^n , trigonometric functions, step function, absolute value function, polynomial/rational functions, signum function.) Inverse function:- How /why to restrict domain/ co-domain (range), graphs of inverses of above functions, Compositions, addition, the product of functions.

Unit 3: Limits and Continuity:-

(15 lectures)

Limit of a function (Limit at ∞ and $\lim \rightarrow \infty$), Algebra of limits, continuous functions(ϵ - δ definition), types of discontinuity,

Unit 4: Differentiable functions :-**(15 lectures)**

Definition, properties, theorems, increasing/decreasing functions, Taylor's theorem, Newton's Method, L'Hospital's rules, maxima-minima, MVTs. Applications of differentiable functions

List of books recommended for reference

- 1) Apostol Tom, *Calculus Vol. I*. Second Edition. Wiley Students Edition, India, 2012.
- 2) G.B Thomas, *Thomas' Calculus*, Pearson Publication.
- 3) Malik S.C. and Arora Sarita. *Mathematical Analysis*, Second edition. Wiley Eastern Ltd, 1994.
- 4) Narayan Shanti. *Differential Calculus*. S. Chand and Company Pvt. Ltd. 1988.
- 5) Goldberg Richard R., *Methods of Real Analysis*. Oxford and IBH Publishing Co. Pvt. Ltd. Indian Edition, 1970.
- 6) Bhat R.D. *A Textbook of Mathematical Analysis II*. Vipul Prakashan, First Edition.

MULTIDISCIPLINARY COURSES (MDC)**Course Title:** Statistics I**Course Code:** UG-MAT-MDC1**Marks:** 75**Credits:** 3

Duration: 45 hours

Course Objectives: To develop the student's ability to use and interpret properly some of the basic statistical concepts.**Course learning outcome:** Upon completion of the course, the student will be able to

- CO1 Understand the importance of statistics
- CO2 Calculate and interpret the measures of central tendency and dispersion.
- CO3 Solve and Interpret correlation and regression problems
- CO4 Use Excel to find measures of central tendency and dispersion and coefficient of correlation

Course Content**Unit 1: Introduction to Statistics****(12 lectures)**

Definition, importance, and scope of statistics, limitations of statistics. Data collection, primary and secondary data, data collection methods, classification and tabulation of data, construction of frequency distribution tables, cumulative frequency distribution table. Graphical representation of data: Histogram, frequency polygon, ogives. Diagrammatic representation of data: bar diagrams, pie diagrams.

Unit 2: Univariate Statistics**(18 lectures)**

Measures of central tendency: Arithmetic mean, median, mode. Quartiles, deciles, percentiles. Locating mode, median, quartiles, deciles, and percentiles using graphs. Measures of dispersion: Range, Mean deviation, Standard Deviation, Coefficient of Variation. Skewness and Kurtosis.

Unit 3: Correlation and Regression**(10 lectures)**

Introduction to correlation, types of correlation, scatter diagram, Karl Pearson's correlation coefficient, Spearman's Rank correlation coefficient. Linear and non-linear regression, Lines of regression, coefficients of regression.

Unit 4: Excel**(5 lectures)**

Introduction to Excel, Simple arithmetic and statistical calculations, plotting graphs and diagrams.

List of books recommended for reference

1. S.C. Gupta, *Fundamentals of Statistics*, Himalayan Publishing House
2. B.L. Agarwal, *Basic Statistics*, New Age International

SKILL ENHANCEMENT COURSE (SEC)**Course Title:** Differential Equations I**Course Code:** UG-MAT-SEC1**Marks:** 75**Credits:** 3**Duration:** 45 hours**Course Objectives:** To introduce some methods of solving ODE of first and higher order, applications of the same in different fields.**Course learning Outcomes:** Upon completion of the course, the student will be able to

- C01. Understand the genesis of ordinary differential equations.
- C02. Learn various techniques for getting exact solutions of solvable first order differential equations and linear differential equations of higher order.
- C03. Grasp the concept of a general solution of a linear differential equation of an arbitrary order and also learn a few methods to obtain the general solution of such equations.
- C04. Formulate mathematical models in the form of ordinary differential equations to obtain possible solutions to the day-to-day problems arising in different disciplines.

Course Content**Unit 1:****(15 lectures)**

Introduction. Some simple situations where we come across ODE, the Geometrical Meaning of ODE, and Solutions of an ODE. Picard's Existence and Uniqueness theorem. First order ODE. Variable separable, Homogeneous, Non- Homogeneous, Exact differential equations, integrating factor, linear differential equations, Bernoulli equations.

Unit 2:**(15 lectures)**

Second-order differential equations, Homogeneous and non-homogeneous differential equations, complementary function, particular integral, Wronskian, Solution space, General solution, complex solutions. Some methods of solving second-order differential equations (undetermined

coefficients, variation of parameters, using one solution to find another). Finding particular integral by operator method.

Unit 3:

(15 lectures)

Linear differential equations of higher order, simple examples of non-homogenous differential equations. Some application of differential equations, LR / LCR circuits, SHM (simple-damped-forced), Equation of Catenaries, Planetary Motions – Kepler's Laws.

List of books recommended for reference

1. Simmons G.F., *Differential Equations with Historical Notes*, Tata McGraw Hill
2. Boyce W.E. & DiPrima R.C., *Elementary Differential Equations and Boundary Valued Problems*, John Wiley Pvt Ltd.
3. Braun C, *Differential Equations and Their Applications: An Introduction to Applied Mathematics* (Texts in Applied Mathematics), springer.
4. Coddington E., *Theory of Ordinary Differential Equations*, Tata McGraw Hill
5. Rainville E.D., *Elementary Differential Equations*, Pearson

SEMESTER II

Course Title: BASIC REAL ANALYSIS

Course Code: UG-MAT-103

Marks: 100

Credits: 4

Duration: 60 hours

Course Objectives: To introduce the number system with its geometrical properties and axioms of real numbers

Course learning outcome: Upon completion of the course, the student will be able to

- C01. Construct real numbers
- C02. Use properties of real numbers in analysis
- C03. Draw and recognize graphs of some important functions
- C04. Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and calculate the limit superior, limit inferior, and the limit of a bounded sequence.
- C05. Apply the ratio, root, alternating series and limit comparison tests for convergence and absolute convergence of an infinite series of real numbers.

Course Content

Unit 1: Number System (20 lectures)

Simple Algebraic development from Natural numbers to Real numbers. Representation of real numbers on a line, Tricotomy Law, Order on \mathbb{R} , Archimedes property, Hausdorff property, distance concept: absolute value (all inequalities ex. Triangle inequality). \mathbb{R} : bounded-unbounded sets, bounded sets, lub. glb. Completeness axiom, intervals, open-closed intervals, open/closed nbd. of a point, limit points, dense set (\mathbb{Q} and \mathbb{Q}' only), concept of infinity

Unit 2: Functions (7 lectures)

Examples with graphs ($\log x$, a^x , x^n , trigonometric functions, step function, absolute value function, polynomial / rational functions, signum function.) Inverse function:- How /why to restrict domain/ co-domain (range), graphs of inverses of above functions, Compositions, addition, product of functions.

Unit 3: Sequences (17 lectures)

Definition, examples, convergence/ divergence of sequence, types of sequences, Cauchy sequences, Sub sequences, absolute convergence, all theorems, Bolzano Weierstrass theorem.

Unit 4: Series (17 lectures)

Definition, Examples, alternate series, Convergence, Cauchy criteria, absolute convergence, rearrangement of series, All theorems for testing the convergence (absolute and non-absolute)

List of books recommended for reference

- 1) R.G. Bartle and D. Sherbert, *Introduction to Real Analysis*, Wiley
- 2) Robert Sticartz, *The Way of Analysis*, Jones and Bartlett Publishers
- 3) T. Apostol, *Calculus (volume I)*, Wiley Eastern Ltd.
- 4) S.C. Malik, Savita Arora, *Mathematical Analysis*, New Age International Publishers

Course Title: MATHEMATICS FOR SCIENCES

Course Code: UG-MAT-102

Marks: 100

Credits: 4

Duration: 60 hours

Course Objectives: To build the foundation in Numerical Methods and Linear algebra

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

CO1: Apply interpolation methods to solve problems numerically

CO2: Numerically determine the roots of equations

CO3: Understand the properties of vector spaces

CO4: Relate matrices and linear transformations

CO5: Compute eigen values and eigen vectors

Course Content

Unit 1: Interpolation and Extrapolation (15 lectures)

Operators- Δ , and E (Definitions and some relations among them), finite difference tables. Newton Gregory Forward and backward interpolation formulae for equal intervals. For unequal intervals- Lagrange's Formula and Newton's divided difference formula (No proof) and examples

Unit 2: Numerical Integration and Differentiation (10 lectures)

Trapezoidal rule, Simpson's $1/3^{\text{rd}}$ and $3/8^{\text{th}}$ rules (with proof), and problems. Weddle's rule (no proof, only problems), Numerical differentiation, and examples

Unit 3: Numerical Solutions of Equations (10 Lectures)

To find a real root of an algebraic or transcendental equation using the Bisection method, regular falsi method, Newton Raphson method with geometrical significance and problems and method of iteration. Gauss-Seidel method to solve simultaneous equations.

Unit 4: Linear Algebra (25 lectures)

Vector space [Definition and examples], subspaces, Linear span, linear dependence, independence, and their properties. Basis, dimension of a vector space. Linear transformation, Kernel, and Range of a Linear Transformation. Matrix representation of linear transformation, Rank Nullity theorem. Eigen values and Eigen vectors of a linear transformation and matrices. Diagonalization

List of books recommended for reference

1. Chatterji P.N, *Numerical Analysis*, Rajhans Prakashan Mandir
2. Sastry S.S, *Introductory Methods of Numerical Analysis*, Prentice Hall India
3. Krishnamurty, *An Introduction to Linear Algebra*, Affiliated East-West Press

MULTIDISCIPLINARY COURSES (MDC)

Course Title: Mathematics for competitive examination

Course Code: UG-MAT-MDC2

Marks: 75

Credits: 3

Duration: 45 hours

Course Objectives: To make students aware of different types of questions asked in such examinations, logical thinking, and data interpretation.

Course learning outcome: Upon completion of the course, the student will be able to

- CO1 Solve with speed and accuracy the MCQ-type questions asked at various examinations
- CO2 Think logically to solve problems.
- CO3 Improve their thinking ability.

Course Content

1. Numerals (integers, rationales, real numbers) Place values, face values, Prime numbers, Composite numbers, co-prime numbers, and Binary Numbers.
2. Divisibility test for 2,3,4, 5, 6, 8, 9, etc. Division algorithm, Progressions, ratio, proportions (direct, indirect), Percentages, LCM, HCF.
3. Averages, Square root, cube root, square, cube, surds and indices, logarithms. Linear – Quadratic equations, Simultaneous Equations, and Some special cases of higher degree polynomial equations.
4. Time and work, Time and distance, speed and velocity, Trains and boats, stream problems, pipes & containers.
5. Problems on Age, Averages, simple & compound interest, profit & loss, Partnership, stock & shares, True discount, and Banker's discount.
6. Calendar, clock, race, games, logical problems, Logical gates.
7. Area, volumes, surface area, three-dimensional perspectives, Height & distance.
8. Permutation & combinations, Probability, the odd man out, series.
9. Data interpretation, Tables, bar graphs, pie charts, line graphs, curves.

Note: Most classes will be allotted to solving problems

List of books recommended for reference

- 1) R.S. Agarwal, *Quantitative Aptitude for Competitive Exams*, S.Chand
- 2) Arun Sharma, *Quantitative Aptitude for CAT*, McGraw Hill

SKILL ENHANCEMENT COURSE (SEC)

Course Title: Operations Research I

Course Code: UG-MAT-SEC2

Marks: 75

Credits: 3

Duration: 45 hours

Course Objectives: This course aims to teach linear programming

Course learning Outcomes: Upon completion of the course, the students will be able to

- C01. Analyse and solve linear programming models of real-life situations.
- C02. Provide graphical solutions of linear programming problems with two variables, and illustrate the concept of convex set and extreme points.
- C03. Know about the relationships between the primal and dual problems
- C04. Analyse the optimal solution for various parametric and structural changes
- C05. Solve the transportation, assignment problems.

Course Content

Unit 1. Linear Programming Problem and Simplex Method (18 Hours)

Definition of standard form, formulation of LPP, convex set and their properties, extreme points. Graphical solution of LPP (Only two variables). Simplex method, Cases pertaining to the existence of multiple solutions, unbounded and no feasible solution. Big M method and two-phase Simplex method.

Unit 2. Duality and post optimal analysis: (17 Hours)

General Primal-Dual Pair, Formulating Dual problem, Primal-dual pair in matrix Form, Duality theorems, Duality and simplex Method. Change in Objective function/ constraint/activity coefficients, Structural changes.

Unit 3. Transportation and Assignment Problems: (10 Hours)

Mathematical formulation of Transportation Problem, condition for the existence of feasible solution, Initial basic feasible solution by (i) NWC method (ii) Matrix-minima and (iii) VAM, Modi's method to find an optimal solution, balanced and unbalanced transportation problems. Mathematical formulation of Assignment problem, Hungarian methods to solve assignment problems, balanced & unbalanced assignments problems

List of books recommended for reference

1. Kanti Swarup, Gupta P.K, Man Mohan, *Operations research*, S Chand
2. N.Paul Loomba, *Linear Programming: An Introductory Analysis*, McGraw Hill
3. Taha H, *Operation Research*, Pearson