B.A. (Prog.) Semester-V with Mathematics as Major

Category-II

DISCIPLINE SPECIFIC CORE COURSE (DSC-5): LINEAR PROGRAMMING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Linear Programming	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:

- The solution of linear programming problem using simplex method.
- The solution of transportation and assignment problems.
- Game theory which makes possible the analysis of the decision-making process of two interdependent subjects.

Learning Outcomes: This course will enable the students to:

- Learn about the simplex method used to find optimal solutions of linear optimization problems subject to certain constraints.
- Write the dual of a linear programming problem.
- Solve the transportation and assignment problems.
- Learn about solution of rectangular games using graphical method and dominance.
- Formulate game to a pair of associated prima-dual linear programming problems.

SYLLABUS OF DSC-5

UNIT-I: Linear Programming Problem, Simplex Method, and Duality (18 hours)

Standard form of the LPP, graphical method of solution, basic feasible solutions, and convexity; Introduction to the simplex method**:** Optimality criterion and unboundedness, Simplex tableau and examples, Artificial variables; Introduction to duality, Formulation of the dual problem with examples.

UNIT-II: Transportation and Assignment Problems (15 hours)

Definition of transportation problem, finding initial basic feasible solution using Northwest-corner method, Least-cost method, and Vogel approximation method; Algorithm for solving transportation problem; Hungarian method of solving assignment problem.

UNIT-III: Two-Person Zero-Sum Games (12 hours)

Introduction to game theory, rectangular games, Mixed strategies, Dominance principle; Formulation of game to primal and dual linear programming problems.

Essential Readings

3. Thie, Paul R., & Keough, G. E. (2014). An Introduction to Linear Programming and Game Theory. (3rd ed.). Wiley India Pvt. Ltd.
4. Taha, Hamdy A. (2017). Operations Research: An Introduction (10th ed.). Pearson.

Suggestive Readings

- Hadley, G. (1997). Linear Programming. Narosa Publishing House. New Delhi.
- Hillier, F. S., & Lieberman, G. J. (2021). Introduction to Operations Research (11th ed.).McGraw-Hill Education (India) Pvt. Ltd.

DISCIPLINE SPECIFIC CORE COURSE – 5 (Discipline A-5): ELEMENTS OF REAL ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Real Analysis	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:

- The real line with algebraic, order and completeness properties.
- Convergence and divergence of sequences and series of real numbers with applications.

Learning Outcomes: This course will enable the students to:

- Understand the basic properties of the set of real numbers, including completeness and Archimedean with some consequences.
- Recognize bounded, convergent, monotonic and Cauchy sequences
- Learn to apply various tests such as limit comparison, ratio, root, and alternating series tests for convergence and absolute convergence of infinite series of real numbers.

SYLLABUS OF DISCIPLINE A-5

UNIT-I: Basic Properties of the Set of Real Numbers (12 hours)

Field and order properties of $\mathbb{R}$, basic properties and inequalities of the absolute value of a real number, bounded above and bounded below sets, Suprema and infima, The completeness axiom and the Archimedean property of $\mathbb{R}$.

UNIT-II: Real Sequences (18 hours)

Convergence of a real sequence, Algebra of limits, The squeeze principle and applications, Monotone sequences, Monotone convergence theorem and applications, Cauchy sequences, Cauchy criterion for convergence and applications.

UNIT-III: Infinite Series of Real Numbers (15 hours)

Convergence and divergence of infinite series of real numbers, Necessary condition for convergence, Cauchy criterion for convergence of series, Tests for convergence of positive term series, Applications of the integral test, Comparison tests, D'Alembert's ratio test, Cauchy's *n*th root test, Raabe's test; Alternating series, Leibniz alternating series test, Absolute and conditional convergence.

Essential Reading

1. Denlinger, Charles G. (2011). Elements of Real Analysis. Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

Suggestive Readings

- Bartle, Robert G., & Sherbert, Donald R. (2011). Introduction to Real Analysis (4th ed.). John Wiley & Sons. Wiley India Edition 2015.
- Bilodeau, Gerald G., Thie, Paul R., & Keough, G. E. (2010). An Introduction to Analysis (2nd ed.). Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

DSE Courses of B.A. (Prog.) Semester-V
Category-II

DISCIPLINE SPECIFIC ELECTIVE COURSE – 1(i): COMBINATORICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Combinatorics	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to:

- Introduce various techniques of permutations, combinations, and inclusion-exclusion.
- Learn basic models of generating functions and recurrence relations in their application to the theory of integer partitions.

Learning Outcomes: After completing the course, student will:

- Enhance the mathematical logical skills by learning different enumeration techniques.
- Be able to apply these techniques in solving problems in other areas of mathematics.
- Be trained to provide reasoning and arguments to justify conclusions.

SYLLABUS OF DSE-1(i)

UNIT – I: Basics of Combinatorics **(15 hours)**

Basic counting principles, Permutations and Combinations (with and without repetitions), Binomial coefficients, Multinomial coefficients, Counting subsets of size k; Set-partitions, The inclusion-exclusion principle and applications.

UNIT – II: Generating Functions and Recurrence Relations **(18 hours)**

Generating functions: Generating function models, Calculating coefficients of generating functions, Polynomial expansions, Binomial identity, Exponential generating functions. Recurrence relations: Recurrence relation models, Divide-and-conquer relations, Solution of linear recurrence relations, Solutions by generating functions.

UNIT – III: Partition **(12 hours)**

Partition theory of integers: Ordered partition, Unordered partition, Ferrers diagram, Conjugate of partition, Self-conjugate partition, Durfee square, Euler's pentagonal theorem.

Essential Readings

1. Sane, Sharad S. (2013). Combinatorial Techniques. Hindustan Book Agency (India).
2. Tucker, Alan (2012). Applied Combinatorics (6th ed.). John Wiley & Sons, Inc.

Suggestive Readings

- Brualdi, Richard A. (2009). Introductory Combinatorics (5th ed.). Pearson Education.
- Cameron, Peter J. (1994). Combinatorics: Topics, Techniques, Algorithms. Cambridge University Press.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 1(ii): ELEMENTS OF NUMBER THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Number Theory	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:

- The Euclidean algorithm and linear Diophantine equations, the Fundamental theorem of arithmetic and some of the open problems of number theory viz. the Goldbach conjecture.
- The modular arithmetic, linear congruence equations, system of linear congruence equations, arithmetic functions, and multiplicative functions, e.g., Euler's Phi-function.
- Introduction of the simple encryption and decryption techniques, and the numbers of specific forms viz. Mersenne numbers, Fermat numbers etc.

Learning Outcomes: This course will enable the students to:

- Get familiar with the basic number-theoretic techniques.
- Comprehend some of the open problems in number theory.
- Learn the properties and use of number-theoretic functions and special types of numbers.
- Acquire knowledge about public-key cryptosystems, particularly RSA.

SYLLABUS OF DSE-1(ii)

UNIT – I: Divisibility and Prime Numbers (12 hours)

Revisiting: The division algorithm, divisibility and the greatest common divisor. Euclid's lemma; The Euclidean algorithm, Linear Diophantine equations; The Fundamental theorem of Arithmetic, The sieve of Eratosthenes, Euclid theorem and the Goldbach conjecture; The Fibonacci sequence and its nature.

UNIT – II: Theory of Congruences and Number-Theoretic Functions (21 hours)

Congruence relation and its basic properties, Linear congruences and the Chinese remainder theorem, System of linear congruences in two variables; Fermat's little theorem and its generalization, Wilson's theorem and its converse; Number-theoretic functions for sum and the number of divisors of a positive integer, Multiplicative functions, The greatest integer function; Euler's Phi-function and its properties.

UNIT – III: Public Key Encryption and Numbers of Special Form (12 hours)

Basics of cryptography, Hill's cipher, Public-key cryptosystems and RSA encryption and decryption technique; Introduction to perfect numbers, Mersenne numbers and Fermat numbers.

Essential Reading

1. Burton, David M. (2011). Elementary Number Theory (7th ed.). McGraw-Hill Education Pvt. Ltd. Indian Reprint 2017.

Suggestive Readings

- Jones, G. A., & Jones, J. Mary. (2005). Elementary Number Theory. Springer Undergraduate Mathematics Series (SUMS). Indian Reprint.
- Robbins, Neville (2007). Beginning Number Theory (2nd ed.). Narosa Publishing House Pvt. Ltd. Delhi.
- Rosen, Kenneth H. (2011). Elementary Number Theory and its Applications (6th ed.). Pearson Education. Indian Reprint 2015.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 1(iii): MATHEMATICAL PYTHON

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Mathematical Python	4	3	0	1	Class XII pass with Mathematics	Basic knowledge of Python

Learning Objectives: The Learning Objectives of this course are as follows:

- To be able to model and solve mathematical problems using Python Programs.
- To experience utility of open-source resources for numerical and symbolic mathematical software systems.

Learning Outcomes: This course will enable the students to use Python:

- For numerical and symbolic computation in mathematical problems from calculus, algebra, and geometry.
- To tabulate and plot diverse graphs of functions and understand tracing of shapes, geometries, and fractals.
- To prepare smart documents with LaTeX interface.

SYLLABUS OF DSE - 1(iii)

Theory

UNIT – I: Drawing Shapes, Graphing and Visualization (15 hours)

Drawing diverse shapes using code and Turtle; Using matplotlib and NumPy for data organization, Structuring and plotting lines, bars, markers, contours and fields, managing subplots and axes; Pyplot and subplots, Animations of decay, Bayes update, Random walk.

UNIT – II: Numerical and Symbolic Solutions of Mathematical Problems (18 hours)

NumPy for scalars and linear algebra on *n*-dimensional arrays; Computing eigenspace, Solving dynamical systems on coupled ordinary differential equations, Functional programming fundamentals using NumPy; Symbolic computation and SymPy: Differentiation and integration of functions, Limits, Solution of ordinary differential equations, Computation of eigenvalues, Solution of expressions at multiple points (lambdify), Simplification of expressions, Factorization, Collecting and canceling terms, Partial fraction decomposition, Trigonometric simplification, Exponential and logarithms, Series expansion and finite differences, Solvers, Recursive equations.

UNIT – III: Document Generation with Python and LaTeX (12 hours)

Pretty printing using SymPy; Pandas API for IO tools: interfacing Python with text/csv, HTML, LaTeX, XML, MSExcel, OpenDocument, and other such formats; Pylatex and writing document files from Python with auto-computed values, Plots and visualizations.

Practical (30 hours): Software labs using IDE such as Spyder and Python Libraries.

- Installation, update, and maintenance of code, troubleshooting.
- Implementation of all methods learned in theory.
- Explore and explain API level integration and working of two problems with standard Python code.

Essential Readings

1. Farrell, Peter (2019). Math Adventures with Python. No Starch Press. ISBN Number: 978-1-59327-867-0.
2. Farrell, Peter and et al. (2020). The Statistics and Calculus with Python Workshop. Packet Publishing Ltd. ISBN: 978-1-80020-976-3.
3. Saha, Amit (2015). Doing Math with Python. No Starch Press. ISBN: 978-1-59327-640-9

Suggestive Readings

- Morley, Sam (2022). Applying Math with Python (2nd ed.). Packet Publishing Ltd. ISBN: 978-1-80461-837-0
- Online resources and documentation on the libraries, such as:
    - https://matplotlib.org
    - https://sympy.org
    - https://pandas.pydata.org
    - https://numpy.org
    - https://pypi.org
    - https://patrickwalls.github.io/mathematicalpython/

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

B.Sc. (Prog.)/ BA (Prog.) Semester-V with Mathematics as non-Major

Category-III

DISCIPLINE SPECIFIC CORE COURSE – 5 (Discipline A-5): ELEMENTS OF REAL ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Real Analysis	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:

- The real line with algebraic, order and completeness properties.
- Convergence and divergence of sequences and series of real numbers with applications.

Learning Outcomes: This course will enable the students to:

- Understand the basic properties of the set of real numbers, including completeness and Archimedean with some consequences.
- Recognize bounded, convergent, monotonic and Cauchy sequences
- Learn to apply various tests such as limit comparison, ratio, root, and alternating series tests for convergence and absolute convergence of infinite series of real numbers.

SYLLABUS OF DISCIPLINE A-5

UNIT-I: Basic Properties of the Set of Real Numbers (12 hours)

Field and order properties of $\mathbb{R}$, basic properties and inequalities of the absolute value of a real number, bounded above and bounded below sets, Suprema and infima, The completeness axiom and the Archimedean property of $\mathbb{R}$.

UNIT-II: Real Sequences (18 hours)

Convergence of a real sequence, Algebra of limits, The squeeze principle and applications, Monotone sequences, Monotone convergence theorem and applications, Cauchy sequences, Cauchy criterion for convergence and applications.

UNIT-III: Infinite Series of Real Numbers (15 hours)

Convergence and divergence of infinite series of real numbers, Necessary condition for convergence, Cauchy criterion for convergence of series, Tests for convergence of positive term series, Applications of the integral test, Comparison tests, D'Alembert's ratio test, Cauchy's *n*th root test, Raabe's test; Alternating series, Leibniz alternating series test, Absolute and conditional convergence.

Essential Reading

1. Denlinger, Charles G. (2011). Elements of Real Analysis. Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

Suggestive Readings

- Bartle, Robert G., & Sherbert, Donald R. (2011). Introduction to Real Analysis (4th ed.). John Wiley & Sons. Wiley India Edition 2015.
- Bilodeau, Gerald G., Thie, Paul R., & Keough, G. E. (2010). An Introduction to Analysis (2nd ed.). Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.