Appendix-56
Resolution No. 38 {38-1 [38-1-4(1)]}

INDEX

DEPARTMENT OF MATHEMATICS

SEMESTER-II

B.Sc. (Hons.) Mathematics
Category-I

DISCIPLINE SPECIFIC CORE COURSE – 4: LINEAR ALGEBRA

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 Algebra	4	3	1	0	XII pass with Mathematics	DSC-1

Learning Objectives: The objective of the course is to introduce:

- The concept of vectors in $\mathbb{R}^n$, and their linear independence and dependence.
- Rank and nullity of linear transformations through matrices.
- Various applications of vectors in computer graphics and movements in plane.

Learning Outcomes: This course will enable the students to:

- Visualize the space $\mathbb{R}^n$ in terms of vectors and their interrelation with matrices.
- Familiarize with basic concepts in vector spaces, linear independence and span of vectors over a field.
- Learn about the concept of basis and dimension of a vector space.
- Basic concepts of linear transformations, dimension theorem, matrix representation of a linear transformation with application to computer graphics.

SYLLABUS OF DSC-4

UNIT – I: Matrices and System of Linear Equations (6 Weeks)

Fundamental operations with vectors in Euclidean space $\mathbb{R}^n$, Linear combinations of vectors, Dot product and their properties, Cauchy-Schwarz inequality, Triangle inequality, Solving linear systems using Gaussian elimination, Gauss-Jordan row reduction, Reduced row echelon form, Equivalent systems, Rank and row space, Eigenvalues, Eigenvectors, Eigenspace, Diagonalization, Characteristic polynomial of a matrix, Cayley-Hamilton theorem.

UNIT – II: Introduction to Vector Spaces (4 Weeks)

Vector spaces, Subspaces, Algebra of subspaces, Linear combination of vectors, Linear span, Linear independence, Bases and dimension, Dimension of subspaces.

UNIT – III: Linear Transformations (5 Weeks)

Linear transformations, Null space, Range, Rank and nullity of a linear transformation, Matrix representation of a linear transformation, Algebra of linear transformations, Invertibility and isomorphisms; Application**:** Computer Graphics-Fundamental movements in a plane, homogenous coordinates, composition of movements.

Recommended Readings:

1. Andrilli, S., & Hecker, D. (2016). *Elementary Linear Algebra* (5th ed.). Elsevier India.

2. Friedberg, Stephen H., Insel, Arnold J., & Spence, Lawrence E. (2003). *Linear Algebra* (4th ed.). Prentice-Hall of India Pvt. Ltd. New Delhi.

Suggestive Readings:

i. Lay, David C., Lay, Steven R., & McDonald, Judi J. (2016). *Linear Algebra and its Applications* (5th ed.). Pearson Education.
ii. Kolman, Bernard, & Hill, David R. (2001). *Introductory Linear Algebra with Applications* (7th ed.). Pearson Education, Delhi. First Indian Reprint 2003.
iii. Hoffman, Kenneth, & Kunze, Ray Alden (1978). *Linear Algebra* (2nd ed.). Prentice Hall of India Pvt. Limited. Delhi. Pearson Education India Reprint, 2015.

DISCIPLINE SPECIFIC CORE COURSE – 5: CALCULUS

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		
Calculus	**4**	**3**	**1**	**0**	**XII pass with Mathematics**	**DSC-2**

Learning Objectives: The primary objective of this course is to introduce the basic tools of calculus, also known as 'science of variation', which provides a way of viewing and analyzing the real-world.

Learning Outcomes: This course will enable the students to understand:

- The notion of limits, continuity and uniform continuity of functions.
- Geometrical properties of continuous functions on closed and bounded intervals.
- Applications of derivative, relative extrema and mean value theorems.
- Higher order derivatives, Taylor's theorem, indeterminate forms and tracing of curves.

SYLLABUS OF DSC-5

UNIT – I: Limits and Continuity **(5 Weeks)**

Limits of functions ($\varepsilon-\delta$ and sequential approach), Algebra of limits, Squeeze theorem, One-sided limits, Infinite limits and limits at infinity; Continuous functions and its properties on closed and bounded intervals; Uniform continuity.

UNIT – II: Differentiability and Mean Value Theorems **(5 Weeks)**

Differentiability of a real-valued function, Algebra of differentiable functions, Chain rule, Relative extrema, Interior extremum theorem, Rolle's theorem, Mean-value theorem and its applications, Intermediate value theorem for derivatives.

UNIT – III: Successive Differentiation, Taylor's Theorem and Tracing of Plane Curves (5 Weeks) Higher order derivatives and calculation of the n^{th} derivative, Leibnitz's theorem; Taylor's theorem, Taylor's series expansions of $e^x, \sin x, \text{and } \cos x$; Indeterminate forms, L'Hôpital's rule; Concavity and inflexion points; Singular points, Asymptotes, Tracing graphs of rational functions and polar equations.

Recommended Readings:

1. Anton, Howard, Bivens, Irl, & Davis, Stephen (2013). *Calculus* (10th ed.). John Wiley & Sons Singapore Pvt. Ltd. Reprint (2016) by Wiley India Pvt. Ltd. Delhi.
2. Bartle, Robert G., & Sherbert, Donald R. (2011). *Introduction to Real Analysis* (4th ed.). John Wiley & Sons. Wiley India Edition 2015.
3. Prasad, Gorakh (2016). *Differential Calculus* (19th ed.). Pothishala Pvt. Ltd. Allahabad.
4. Ross, Kenneth A. (2013). *Elementary Analysis*: *The Theory of Calculus* (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian reprint.

Suggestive Readings:

i. Apostol, T. M. (2007). *Calculus*: *One-Variable Calculus with an Introduction to Linear Algebra* (2nd ed.). Vol. 1. Wiley India Pvt. Ltd.

ii. Ghorpade, Sudhir R. & Limaye, B. V. (2006). *A Course in Calculus and Real Analysis*. Undergraduate Texts in Mathematics, Springer (SIE). Indian reprint.

DISCIPLINE SPECIFIC CORE COURSE – 6: ORDINARY DIFFERENTIAL EQUATIONS

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		
Ordinary Differential Equations	**4**	**3**	**0**	**1 (2 Hours)**	**XII pass with Mathematics**	**NIL**

Learning Objectives: The main objective of this course is to introduce the students to the exciting world of differential equations, their applications and mathematical modeling.

Learning Outcomes: The course will enable the students to:

- Learn basics of differential equations and compartmental models.
- Formulate differential equations for various mathematical models.
- Solve first order non-linear differential equations, linear differential equations of higher order and system of linear differential equations using various techniques.
- Apply these techniques to solve and analyze various mathematical models.

SYLLABUS OF DSC-6

UNIT – I: First-Order Differential Equations **(4 Weeks)**

Concept of implicit, general and singular solutions for the first order ordinary differential equation; Bernoulli's equation, Exact equations, Integrating factors, Initial value problems, Reducible second order differential equations; Applications of first order differential equations to Newton's law of cooling, exponential growth and decay problems.

UNIT – II: Second and Higher-Order Differential Equations (6 Weeks)

General solution of homogenous equation of second order, Principle of superposition for a homogenous equation, Wronskian and its properties, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Method of variation of parameters, Method of undetermined coefficients, Two-point boundary value problems, Cauchy- Euler's equation, System of linear differential equations, Application of second order differential equation: Simple pendulum problem.

UNIT – III: Formulation and Analysis of Mathematical Models (5Weeks)

Introduction to compartmental models, Lake pollution model; Density-dependent growth model, Interacting population models, Epidemic model of influenza and its analysis, Predator-prey model and its analysis, Equilibrium points, Interpretation of phase plane

Practical component- Practical / Lab work to be performed in a Computer Lab:

Modeling of the following problems using SageMath/Mathematica/MATLAB/Maple/Maxima /Scilab etc.

1. Solutions of first, second and third order differential equations.
2. Plotting of family of solutions of differential equations of first, second and third order.
3. Solution of differential equations using method of variation of parameters.
4. Growth and decay model (exponential case only).
5. Lake pollution model (with constant/seasonal flow and pollution concentration).
6. Density-dependent growth model.
7. Predatory-prey model (basic Volterra model, with density dependence, effect of DDT, two prey one predator).
8. Epidemic model of influenza (basic epidemic model, contagious for life, disease with carriers).

Recommended Readings:

1. Barnes, Belinda & Fulford, Glenn R. (2015). *Mathematical Modeling with Case Studies*, Using Maple and MATLAB (3rd ed.). CRC Press. Taylor & Francis Group.
2. Edwards, C. Henry, Penney, David E., & Calvis, David T. (2015). *Differential Equations and Boundary Value Problems*: *Computing and Modeling* (5th ed.). Pearson Education.
3. Ross, Shepley L. (2014). *Differential Equations* (3rd ed.). Wiley India Pvt. Ltd.

Suggestive Reading:

i. Simmons, George F. (2017). *Differential Equations with Applications and Historical Notes* (3rd ed.). CRC Press. Taylor & Francis Group.

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

BSc. (Prog.) with Mathematics as Major

Category II

DISCIPLINE SPECIFIC CORE COURSE (DSC-2): ANALYTIC GEOMETRY

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		
Analytic Geometry	4	3	1	0	XII pass with Mathematics	NIL

Learning Objectives: The course aims at identifying and sketching curves, studying three dimensional objects, their geometric properties and applications. Use of vector approach to three-dimensional geometry makes the study simple and elegant.

Learning Outcomes: This course will enable the students to:

- Learn concepts in two-dimensional geometry.
- Identify and sketch conics namely, ellipse, parabola and hyperbola.
- Learn about three-dimensional objects such as straight lines and planes using vectors, spheres, cones and cylinders.

SYLLABUS OF DSC-2

UNIT – I: Conic Sections **(5 Weeks)**

Techniques for sketching parabola, ellipse and hyperbola; Reflection properties of parabola, ellipse, hyperbola, and their applications to signals; Classification of quadratic equation representing lines, parabola, ellipse and hyperbola; Rotation of axes; Second degree equations.

UNIT – II: Vectors, Lines and Planes **(6 Weeks)**

Rectangular coordinates in 3-dimensional space, vectors viewed geometrically, vectors in coordinate systems and vectors determined by length and angle; Dot product; Projections; Cross product, scalar triple product, vector triple product and their geometrical properties; Parametric equations of lines, direction cosines and direction ratios of a line, vector and symmetric equations of lines, angle between two lines; Planes in 3-dimensional space, coplanarity of two lines, angle between two planes, distance of a point from a plane, angle between a line and a plane, distance between parallel planes; Shortest distance between two skew lines.

UNIT – III: Sphere, Cone and Cylinder **(4 Weeks)**

Equation of a sphere, plane section of sphere, tangents and tangent plane to a sphere; Equation of a cone, enveloping cone of a sphere, Reciprocal cones and right circular cone; Equation of a cylinder, enveloping cylinder and right circular cylinder.

Recommended Readings:

1. Anton, Howard, Bivens, Irl, & Davis, Stephen (2013). *Calculus* (10th ed.). John Wiley & Sons Singapore Pte. Ltd. Indian reprint (2016) by Wiley India Pvt. Ltd. Delhi.
2. Narayan, Shanti & Mittal, P. K. (2007). *Analytical Solid Geometry*. S. Chand & Company Pvt Ltd. India.

Suggestive Readings:

i. Bell, Robert J.T. (1972). *An Elementary Treatise on Coordinate Geometry of Three Dimensions*. Macmillan & Co. Ltd. London.

ii. George B. Thomas, Jr., & Ross L. Finney (2012). *Calculus and Analytic Geometry* (9th ed.). Pearson Indian Education Services Pvt Ltd. India.

DISCIPLINE SPECIFIC CORE COURSE – 2 (Discipline A-2): Elementary Linear Algebra

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		
Elementary Linear Algebra	**4**	**3**	**1**	**0**	**XII pass with Mathematics**	**NIL**

Learning Objectives: The objective of the course is to introduce the concept of vectors in $\mathbb{R}^n$, understanding the nature of solution of system of linear equations, and to view the $m \times n$ matrices as a linear function from $\mathbb{R}^n$ to $\mathbb{R}^m$ and vice versa. The concepts of linear independence and dependence, rank and linear transformations has been explained through matrices.

Learning Outcomes: This course will enable the students to:

- Visualize the space $\mathbb{R}^n$ in terms of vectors and the interrelation of vectors with matrices.
- Familiarize with concepts of bases, dimension and minimal spanning sets in vector spaces.
- Learn about linear transformation and its corresponding matrix.

SYLLABUS OF DSC-2

UNIT – I: Euclidean Space $\mathbb{R}^n$ and Matrices **(6 Weeks)**

Fundamental operations with vectors in Euclidean space $\mathbb{R}^n$, Linear combinations of vectors, Dot product and their properties, Cauchy-Schwarz inequality, Triangle inequality, Solving system of linear equations using Gaussian elimination, Application: Curve Fitting, Gauss-Jordan row reduction, Reduced row echelon form, Application: Solving several

systems simultaneously, Equivalent systems, Rank and row space of a matrix, Eigenvalues, Eigenvectors, Eigenspace, Diagonalization, Characteristic polynomial of a matrix.

UNIT – II: Introduction to Vector Spaces (4 Weeks)

Definition, Examples and some elementary properties of vector spaces, Subspaces, Span, Linear independence and linear dependence of vectors, Basis and dimension of a vector space, Maximal linearly independent sets, Minimal spanning sets.

UNIT – II: Linear Transformations (5 Weeks)

Linear transformations**:** Definition, Examples and elementary properties, The matrix of a linear transformation, Kernel and range of a linear transformation, The dimension theorem, one-to-one and onto linear transformations, Invertible linear transformations, Isomorphic vector spaces.

Recommended Reading:

1. Andrilli, S., & Hecker, D. (2016). *Elementary Linear Algebr*a (5th ed.). Elsevier India.

Suggestive Readings:

i. Lay, David C., Lay, Steven R., & McDonald, Judi J. (2016). *Linear Algebra and its Applications* (5th ed.). Pearson Education.
ii. Kolman, Bernard, & Hill, David R. (2001). *Introductory Linear Algebra with Applications* (7th ed.). Pearson Education, Delhi. First Indian Reprint 2003.

BSc. (P)/B.A. (P) with Mathematics as Non Major
Category-III

DISCIPLINE SPECIFIC CORE COURSE – 2 (Discipline A-2): Elementary Linear Algebra

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		
Elementary Linear Algebra	4	3	1	0	XII pass with Mathematics	NIL

Learning Objectives: The objective of the course is to introduce the concept of vectors in $\mathbb{R}^n$, understanding the nature of solution of system of linear equations, and to view the $m \times n$ matrices as a linear function from $\mathbb{R}^n$ to $\mathbb{R}^m$ and vice versa. The concepts of linear independence and dependence, rank and linear transformations has been explained through matrices.

Learning Outcomes: This course will enable the students to:

- Visualize the space $\mathbb{R}^n$ in terms of vectors and the interrelation of vectors with matrices.
- Familiarize with concepts of bases, dimension and minimal spanning sets in vector spaces.
- Learn about linear transformation and its corresponding matrix.

SYLLABUS OF DSC-2

UNIT – I: Euclidean Space $\mathbb{R}^n$ and Matrices **(6 Weeks)**

Fundamental operations with vectors in Euclidean space $\mathbb{R}^n$, Linear combinations of vectors, Dot product and their properties, Cauchy-Schwarz inequality, Triangle inequality, Solving system of linear equations using Gaussian elimination, Application: Curve Fitting, Gauss-Jordan row reduction, Reduced row echelon form, Application: Solving several systems simultaneously, Equivalent systems, Rank and row space of a matrix, Eigenvalues, Eigenvectors, Eigenspace, Diagonalization, Characteristic polynomial of a matrix.

UNIT – II: Introduction to Vector Spaces **(4 Weeks)**

Definition, Examples and some elementary properties of vector spaces, Subspaces, Span, Linear independence and linear dependence of vectors, Basis and dimension of a vector space, Maximal linearly independent sets, Minimal spanning sets.

UNIT – III: Linear Transformations **(5 Weeks)**

Linear transformations**:** Definition, Examples and elementary properties, The matrix of a linear transformation, Kernel and range of a linear transformation, The dimension theorem,

one-to-one and onto linear transformations, Invertible linear transformations, Isomorphic vector spaces.

Recommended Reading:

1. Andrilli, S., & Hecker, D. (2016). *Elementary Linear Algebr*a (5th ed.). Elsevier India.

Suggestive Readings:

i. Lay, David C., Lay, Steven R., & McDonald, Judi J. (2016). *Linear Algebra and its Applications* (5th ed.). Pearson Education.

ii. Kolman, Bernard, & Hill, David R. (2001). *Introductory Linear Algebra with Applications* (7th ed.). Pearson Education, Delhi. First Indian Reprint 2003.

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES OFFERED BY THE DEPARTMENT OF MATHEMATICS
(Category-IV)

GENERIC ELECTIVES (GE-2(i)): ANALYTIC GEOMETRY

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
		Lecture	Tutorial	Practical/ Practice		
Analytic Geometry	4	3	1	0	Xth pass with Mathematics	NIL

Learning Objectives: The course aims at identifying and sketching curves, studying three dimensional objects, their geometric properties and applications. Use of vector approach to three-dimensional geometry makes the study simple and elegant.

Learning Outcomes: This course will enable the students to:

- Learn concepts in two-dimensional geometry.
- Identify and sketch conics namely, ellipse, parabola and hyperbola.
- Learn about three-dimensional objects such as straight lines and planes using vectors, spheres, cones and cylinders.

SYLLABUS OF GE-2(i)

UNIT – I: Conic Sections **(5 Weeks)**

Techniques for sketching parabola, ellipse and hyperbola; Reflection properties of parabola, ellipse, hyperbola, and their applications to signals; Classification of quadratic equation representing lines, parabola, ellipse and hyperbola; Rotation of axes; Second degree equations.

UNIT – II: Vectors, Lines and Planes **(6 Weeks)**

Rectangular coordinates in 3-dimensional space, vectors viewed geometrically, vectors in coordinate systems and vectors determined by length and angle; Dot product; Projections; Cross product, scalar triple product, vector triple product and their geometrical properties; Parametric equations of lines, direction cosines and direction ratios of a line, vector and symmetric equations of lines, angle between two lines; Planes in 3-dimensional space, coplanarity of two lines, angle between two planes, distance of a point from a plane, angle between a line and a plane, distance between parallel planes; Shortest distance between two skew lines.

UNIT – III: Sphere, Cone and Cylinder **(4 Weeks)**

Equation of a sphere, plane section of sphere, tangents and tangent plane to a sphere; Equation of a cone, enveloping cone of a sphere, Reciprocal cones and right circular cone; Equation of a cylinder, enveloping cylinder and right circular cylinder.

Recommended Readings:

1. Anton, Howard, Bivens, Irl, & Davis, Stephen (2013). *Calculus* (10th ed.). John Wiley & Sons Singapore Pte. Ltd. Indian reprint (2016) by Wiley India Pvt. Ltd. Delhi.
2. Narayan, Shanti & Mittal, P. K. (2007). *Analytical Solid Geometry*. S. Chand & Company Pvt Ltd. India.

Suggestive Readings:

i. Bell, Robert J.T. (1972). *An Elementary Treatise on Coordinate Geometry of Three Dimensions*. Macmillan & Co. Ltd. London.

ii. George B. Thomas, Jr., & Ross L. Finney (2012). *Calculus and Analytic Geometry* (9th ed.). Pearson Indian Education Services Pvt Ltd. India.

GENERIC ELECTIVES (GE-2(ii)): INTRODUCTION TO LINEAR ALGEBRA

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
		Lecture	Tutorial	Practical/ Practice		
Introduction to Linear Algebra	4	3	1	0	Xth pass with Mathematics	NIL

Learning Objectives: The objective of the course is to introduce the concept of vectors in $\mathbb{R}^n$, understanding the nature of solution of system of linear equations, and to view the $m \times n$ matrices as a linear function from $\mathbb{R}^n$ to $\mathbb{R}^m$ and vice versa. The concepts of linear independence and dependence, rank and linear transformations has been explained through matrices.

Learning Outcomes: This course will enable the students to:

- Visualize the space $\mathbb{R}^n$ in terms of vectors and the interrelation of vectors with matrices.
- Understand important uses of eigenvalues and eigenvectors in the diagonalization of matrices.
- Familiarize with concepts of bases, dimension and minimal spanning sets in vector spaces.
- Learn about linear transformation and its corresponding matrix.

SYLLABUS OF GE-2(ii)

UNIT – I: Vectors and Matrices **(6 Weeks)**

Fundamental operations and properties of vectors in $\mathbb{R}^n$, Linear combinations of vectors, Dot product and their properties, Cauchy-Schwarz and triangle inequality, Orthogonal and parallel vectors; Solving system of linear equations using Gaussian elimination, and Gauss-Jordan row reduction, Reduced row echelon form; Equivalent systems, Rank and row space

of a matrix; Eigenvalues, eigenvectors and characteristic polynomial of a square matrix; Diagonalization.

UNIT – II: Vector Spaces (4 Weeks)

Definition, examples and some elementary properties of vector spaces; Subspaces, Span, Linear independence and dependence; Basis and dimension of a vector space; Diagonalization and bases.

UNIT – III: Linear Transformations (5 Weeks)

Definition, examples and elementary properties of linear transformations; The matrix of a linear transformation; Kernel and range of a linear transformation, The dimension theorem, one-to-one and onto linear transformations.

Recommended Reading:

1. Andrilli, S., & Hecker, D. (2016). *Elementary Linear Algebr*a (5th ed.). Elsevier India.

Suggestive Reading:

i. Kolman, Bernard, & Hill, David R. (2001). *Introductory Linear Algebra with Applications* (7th ed.). Pearson Education, Delhi. First Indian Reprint 2003.