Semester-I

DEPARTMENT OF MATHEMATICS

B.SC. (H) MATHEMATICS

Category-I

DISCIPLINE SPECIFIC CORE COURSE – 1: 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		
Algebra	4	3	1	0	Class XII pass with Mathematics	Nil

Learning Objectives

The primary objective of this course is to introduce:

- The basic tools of theory of equations, number theory, and group theory.
- Symmetry group of a plane figure, basic concepts of cyclic groups.
- Classification of subgroups of cyclic groups.

Learning Outcomes:

This course will enable the students to:

- Determine number of positive/negative real roots of a real polynomial.

- Solve cubic and quartic polynomial equations with special condition on roots and in general.
- Employ De-Moivre's theorem in a number of applications to solve numerical problems.
- Use modular arithmetic and basic properties of congruences.
- Recognize the algebraic structure, namely groups, and classify subgroups of cyclic groups.

SYLLABUS OF DSC-1

Theory

Unit – 1 **(24 hours)**

Theory of Equations and Complex Numbers

General properties of polynomials and equations, Fundamental theorem of algebra, Relations between the roots and the coefficients, Upper bounds for the real roots; Theorems on imaginary, integral and rational roots; Newton's method for integral roots, Descartes' rule of signs; De-Moivre's theorem for integer and rational indices and their applications, The nth roots of unity, Cardan's solution of the cubic, Descartes' solution of the quartic equation.

Unit – 2 **(16 hours)**

Basic Number Theory

Division algorithm in $\mathbb{Z}$, Divisibility and the Euclidean algorithm, Fundamental theorem of arithmetic, Modular arithmetic and basic properties of congruences.

Unit – 3 **(20 hours)**

Basics of Group Theory

Groups, Basic properties, Symmetries of a square, Dihedral group, Order of a group, Order of an element, Subgroups, Center of a group, Centralizer of an element, Cyclic groups and properties, Generators of a cyclic group, Classification of subgroups of cyclic groups.

Practical component (if any) - NIL

Essential Readings

1. Andreescu, Titu & Andrica, D. (2014). Complex numbers from A to...Z. (2nd ed.). Birkhäuser.
2. Dickson, Leonard Eugene (2009). First Course in the Theory of Equations. John Wiley & Sons, Inc. The Project Gutenberg eBook: http://www.gutenberg.org/ebooks/29785
3. Gallian, Joseph. A. (2017). Contemporary Abstract Algebra (9th ed.). Cengage Learning India Private Limited, Delhi. Indian Reprint 2021.
4. Goodaire, Edgar G., & Parmenter, Michael M. (2006). Discrete Mathematics with Graph Theory (3rd ed.). Pearson Education Pvt. Ltd. Indian Reprint 2018.

Suggestive Readings

- Burnside, W.S., & Panton, A.W. (1979), The Theory of Equations, Vol. 1. Eleventh

Edition, (Fourth Indian Reprint. S. Chand & Co. New Delhi), Dover Publications, Inc.
- Burton, David M. (2011). Elementary Number Theory (7th ed.). McGraw-Hill Education Pvt. Ltd. Indian Reprint.
- Rotman, Joseph J. (1995). An Introduction to The Theory of Groups (4th ed.). Springer-Verlag, New York.

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

DISCIPLINE SPECIFIC CORE COURSE – 2: ELEMENTARY 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		
Elementary Real Analysis	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives

The course will develop a deep and rigorous understanding of:
- Real line $\mathbb{R}$ with algebraic.
- Order and completeness properties to prove the results about convergence and divergence of sequences and series of real numbers.

Learning Outcomes

This course will enable the students to:
- Understand the fundamental properties of the real numbers, including completeness and Archimedean, and density property of rational numbers in $\mathbb{R}$.
- Learn to define sequences in terms of functions from $\mathbb{N}$ to a subset of $\mathbb{R}$ and find the limit.
- Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate the limit superior and limit inferior of a bounded sequence.
- Apply limit comparison, ratio, root, and alternating series tests for convergence and absolute convergence of infinite series of real numbers.

SYLLABUS OF DSC - 2

Theory

Unit – 1 **(16 hours)**

Real Number System

Algebraic and order properties of $\mathbb{R}$, Absolute value of a real number, Bounded above and bounded below sets, Supremum and infimum of a non-empty subset of $\mathbb{R}$, The completeness property of $\mathbb{R}$, Archimedean property, Density of rational numbers in $\mathbb{R}$.

Unit – 2 **(24 hours)**

Sequences

Sequences and their limits, Convergent sequence, Limit theorems, Monotone sequences, Monotone convergence theorem, Subsequences, Bolzano-Weierstrass theorem for sequences, Limit superior and limit inferior for bounded sequence, Cauchy sequence, Cauchy's convergence criterion.

Unit – 3 **(20 hours)**

Infinite Series

Convergence and divergence of infinite series of real numbers, Necessary condition for convergence, Cauchy criterion for convergence, Tests for convergence of positive term series, Integral test, Basic comparison test, Limit comparison test, D'Alembert's ratio test, Cauchy's nth root test, Raabe's test, Alternating series, Leibniz test, Absolute and conditional convergence.

Practical component (if any) – NIL

Essential Readings

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

Suggestive Readings

- Aliprantis C. D., & Burkinshaw, O. (1998). Principles of Real Analysis (3rd ed.). Academic Press.
- Ross, Kenneth A. (2013). Elementary Analysis: The Theory of Calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian reprint.
- Thomson, B. S., Bruckner, A. M., & Bruckner, J. B. (2001). Elementary Real Analysis. Prentice Hall.

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

DISCIPLINE SPECIFIC CORE COURSE – 3: PROBABILITY AND STATISTICS

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		
Probability and Statistics	4	3	0	1	Class XII pass with Mathematics	NIL

Learning Objectives

The Learning Objectives of this course are as follows:

- To make the students familiar with the basic statistical concepts and tools which are needed to study situations involving uncertainty or randomness.
- To render the students to several examples and exercises that blend their everyday experiences with their scientific interests to form the basis of data science.

Learning Outcomes

This course will enable the students to:

- Understand some basic concepts and terminology - population, sample, descriptive and inferential statistics including stem-and-leaf plots, dotplots, histograms and boxplots.
- Learn about probability density functions and various univariate distributions such as binomial, hypergeometric, negative binomial, Poisson, normal, exponential and lognormal.
- Understand the remarkable fact that the empirical frequencies of so many natural populati ons, exhibit bell-shaped (i.e., normal) curves, using the Central Limit Theorem.
- Measure the scale of association between two variables, and to establish a formulation helping to predict one variable in terms of the other, i.e., correlation and linear regression.

SYLLABUS OF DSC – 3

Theory

Unit – 1 **(15 hours)**

Descriptive Statistics, Probability, and Discrete Probability Distributions

Descriptive statistics: Populations, Samples, Stem-and-leaf displays, Dotplots, Histograms, Qualitative data, Measures of location, Measures of variability, Boxplots; Sample spaces and events, Probability axioms and properties, Conditional probability, Bayes' theorem and independent events; Discrete random variables and probability

distributions, Expected values; Probability distributions: Binomial, geometric, hypergeometric, negative binomial, Poisson, and Poisson distribution as a limit.

Unit – 2 **(15 hours)**

Continuous Probability Distributions

Continuous random variables, Probability density functions, Uniform distribution, Cumulative distribution functions and expected values, The normal, exponential and lognormal distributions.

Unit – 3 **(15 hours)**

Central Limit Theorem and Regression Analysis

Sampling distribution and standard error of the sample mean, Central Limit Theorem and applications; Scatterplot of bivariate data, Regression line using principle of least squares, Estimation using the regression lines; Sample correlation coefficient and properties.

Practical (30 hours)

Software labs using Microsoft Excel or any other spreadsheet.

1) Presentation and analysis of data (univariate and bivariate) by frequeny tables, descriptive statistics, stem-and-leaf plots, dotplots, histograms, boxplots, comparative boxplots, and probability plots ([1] Section 4.6).
2) Fitting of binomial, Poisson and normal distributions.
3) Illustrating the Central Limit Theorem through Excel.
4) Fitting of regression line using the principle of least squares.
5) Computation of sample correlation coefficient.

Essential Reading

1. Devore, Jay L. (2016). Probability and Statistics for Engineering and the Sciences (9th ed.). Cengage Learning India Private Limited. Delhi. Indian Reprint 2020.

Suggestive Reading

- Mood, A. M., Graybill, F. A., & Boes, D. C. (1974). Introduction to the Theory of Statistics (3rd ed.). Tata McGraw-Hill Pub. Co. Ltd. Reprinted 2017.

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

GENERIC ELECTIVES: FUNDAMENTALS OF 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		
Fundamentals of Calculus	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives

The Learning Objectives of this course is as follows:

- Understand the quantitative change in the behaviour of the variables and apply them on the problems related to the environment.

Learning Outcomes

Upon completion of this course, students will be able to:

- Understand continuity and differentiability in terms of limits.
- Describe asymptotic behavior in terms of limits involving infinity.
- Understand the importance of mean value theorems and its applications.
- Learn about Maclaurin's series expansion of elementary functions.
- Use derivatives to explore the behavior of a given function, locating and classifying its extrema, and graphing the polynomial and rational functions.

SYLLABUS OF GE

Theory

Unit – 1 **(20 hours)**

Continuity and Differentiability of Functions

Limits and continuity, Types of discontinuities; Differentiability of functions; Successive differentiation: Calculation of the nth derivatives, Leibnitz theorem; Partial differentiation, Euler's theorem on homogeneous functions.

Unit – 2 **(20 hours)**

Mean Value Theorems and its Applications

Rolle's theorem, Mean value theorems and applications to monotonic functions and inequalities; Expansion of functions: Taylor's theorem, Taylor's series, Maclaurin's series expansion of $e^x, \sin x, \cos x, \log(1+x)$ and $(1+x)^m$; Indeterminate forms.

Unit – 3 **(20 hours)**

Tracing of Curves

Concavity and inflexion points, Asymptotes (parallel to axes and oblique), Relative extrema, Tracing graphs of polynomial functions, rational functions, and polar equations.

Practical component (if any) – NIL

Essential Readings

- Anton, Howard, Bivens, Irl, & Davis, Stephen (2013). Calculus (10th ed.). Wiley India Pvt. Ltd. New Delhi. International Student Version. Indian Reprint 2016.
- Prasad, Gorakh (2016). Differential Calculus (19th ed.). Pothishala Pvt. Ltd. Allahabad.

Suggestive Reading

- Thomas Jr., George B., Weir, Maurice D., & Hass, Joel (2014). Thomas' Calculus (13th ed.). Pearson Education, Delhi. Indian Reprint 2017.

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

GENERIC ELECTIVES: THEORY OF EQUATIONS AND SYMMETRIES

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		
Theory of Equations and Symmetries	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives

The goal of this course is to acquaint students with certain ideas about:

- Integral roots, rational roots, an upper bound on number of positive or negative roots of a polynomial.
- Finding roots of cubic and quartic equations in special cases using elementary symmetric functions.
- Using Cardon's and Descartes' methods, respectively.

Learning outcomes

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

- Understand the nature of the roots of polynomial equations and their symmetries.
- Solve cubic and quartic polynomial equations with special condition on roots and in general.
- Find symmetric functions in terms of the elementary symmetric polynomials.

SYLLABUS OF GE

Theory

Unit - 1 **(24 hours)**

Polynomial Equations and Properties

General properties of polynomials and equations; Fundamental theorem of algebra and its consequences; Theorems on imaginary, integral and rational roots; Descartes' rule of signs for positive and negative roots; Relations between the roots and coefficients of equations, Applications to solution of equations when an additional relation among the roots is given; De Moivre's theorem for rational indices, the nth roots of unity and symmetries of the solutions.

Unit - 2 **(16 hours)**

Cubic and Biquadratic (Quartic) Equations

Transformation of equations (multiplication, reciprocal, increase/diminish in the roots by a given quantity), Removal of terms; Cardon's method of solving cubic and Descartes' method of solving biquadratic equations.

Unit - 3 **(20 hours)**

Symmetric Functions

Elementary symmetric functions and symmetric functions of the roots of an equation; Newton's theorem on sums of the like powers of the roots; Computation of symmetric functions such as $\sum\alpha^2\beta$, $\sum\alpha^2\beta^2$, $\sum\alpha^2\beta\gamma$, $\sum\frac{1}{\alpha^2\beta\gamma}$, $\sum\alpha^{-3}$, $\sum(\beta+\gamma-\alpha)^2$, $\sum\frac{\alpha^2+\beta\gamma}{\beta+\gamma}$,... of polynomial equations; Transformation of equations by symmetric functions and in general.

Practical component (if any) –

NILEssential Readings

- Burnside, W.S., & Panton, A.W. (1979). The Theory of Equations (11th ed.). Vol. 1.Dover Publications, Inc. (4th Indian reprint. S. Chand & Co. New Delhi).
- Dickson, Leonard Eugene (2009). First Course in the Theory of Equations. John Wiley &Sons, Inc. The Project Gutenberg eBook: http://www.gutenberg.org/ebooks/29785

Suggestive Reading

- Prasad, Chandrika (2017). Text Book of Algebra and Theory of Equations. Pothishala PvtLtd.

Semester-II

DEPARTMENTOFMATHEMATICS

Category-I

B.Sc.(Hons.) Mathematics

DISCIPLINESPECIFICCORECOURSE–4:LINEARALGEBRA

CREDITDISTRIBUTION,ELIGIBILITYANDPRE-REQUISITESOFTHECOURSE

Course title &Code	Credits	Creditdistributionofthe course			Eligibility criteria	Pre-requisite ofthecourse (if any)
		Lecture	Tutorial	Practical/ Practice		
Linear Algebra	4	3	1	0	ClassXII passwith Mathematics	DSC-I: Algebra

LearningObjectives: Theobjectiveofthecourseisto introduce:

- Theconceptofvectorsin R^n,and theirlinearindependenceand dependence.
- Rankandnullityoflineartransformationsthroughmatrices.
- Variousapplicationsof vectorsin computergraphicsand movementsinplane.

1

LearningOutcomes: Thiscoursewillenablethe studentsto:

- Visualizethe spaceR^nin termsof vectorsand theirinterrelation with matrices.
- Familiarizewithbasicconceptsinvectorspaces,linearindependenceandspan of vectors over a field.
- Learnabouttheconceptofbasisanddimensionof a vector space.
- Basicconceptsoflineartransformations,dimensiontheorem,matrixrepresentation of a linear transformation with application to computer graphics.

SYLLABUSOFDSC-4

UNIT – I: Matrices and System of Linear Equations (18hours)

Fundamental operationswith vectors in Euclidean spaceR^n, Linear combinations of vectors, Dot product and their properties, Cauchy-Schwarz inequality, Triangle inequality, Solving linearsystemsusingGaussianelimination,Gauss-Jordanrowreduction,Reducedrowechelon 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 (12hours)

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

UNIT–III:Linear Transformations (15hours)

Lineartransformations,Nullspace,Range,Rankandnullityofalineartransformation,Matrix representationofalineartransformation,Algebraoflineartransformations,Invertibilityand isomorphisms; Application**:** Computer Graphics-Fundamental movements in a plane, homogenous coordinates, composition of movements.

Essential Readings

1. Andrilli,S.,&Hecker,D.(2016).*ElementaryLinearAlgebr*a(5thed.).ElsevierIndia.
2. Friedberg,StephenH.,Insel,ArnoldJ.,&Spence,LawrenceE.(2003).*LinearAlgebra* (4thed.).Prentice-Hallof IndiaPvt.Ltd.New Delhi.

SuggestiveReadings

- Lay,DavidC.,Lay,StevenR.,&McDonald,JudiJ.(2016).*LinearAlgebraandits Applications* (5th ed.). Pearson Education.
- Kolman,Bernard,&Hill,DavidR.(2001).*IntroductoryLinearAlgebrawithApplications* (7thed.).PearsonEducation,Delhi.First IndianReprint 2003.
- Hoffman,Kenneth,&Kunze,RayAlden(1978).*LinearAlgebra*(2nded.).PrenticeHall of India Pvt. Limited. Delhi. Pearson Education India Reprint, 2015.

DISCIPLINESPECIFICCORECOURSE–5:CALCULUS

CREDITDISTRIBUTION,ELIGIBILITYANDPRE-REQUISITESOFTHECOURSE

Course title & Code	Credits	Creditdistributionofthe course			Eligibility criteria	Pre-requisite of thecourse (ifany)
		Lecture	Tutorial	Practical/ Practice		
Calculus	4	3	1	0	ClassXIIpass with Mathematics	DSC-2: Elementary RealAnalysis

LearningObjectives: Theprimaryobjectiveofthiscourseis:

- Tointroducethebasictoolsofcalculus,also known as‘scienceof variation’.
- Toprovideawayof viewingand analyzingthereal-world.

LearningOutcomes: Thiscoursewillenablethe studentstounderstand:

- Thenotionoflimits, continuityanduniformcontinuityof functions.
- Geometricalpropertiesof continuousfunctionson closedandbounded intervals.
- Applicationsofderivative,relativeextremaandmeanvalue theorems.
- Higherorderderivatives,Taylor’stheorem,indeterminate forms andtracingofcurves.

SYLLABUSOFDSC-5

UNIT–I:LimitsandContinuity **(15hours)**

Limitsoffunctions(ε-δandsequentialapproach),Algebraoflimits,Squeezetheorem,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 **(15hours)**

Differentiability of a real-valued function, Algebra of differentiable functions, Chain rule, Relativeextrema,Interiorextremumtheorem,Rolle’stheorem,Mean-valuetheoremandits applications, Intermediate value theorem for derivatives.

UNIT–III: **(15hours)**

SuccessiveDifferentiation,Taylor’sTheoremandTracingofPlaneCurves

Higher order derivatives and calculation of the *n*th derivative, Leibnitz’s theorem; Taylor’s theorem,Taylor’sseries expansionsofe^x,sin *x*, cos *x*.Indeterminate forms,L’Hôpital’srule; Concavity and inflexion points; Singular points, Asymptotes, Tracing graphs of rational functions and polar equations.

Essential Readings

1. Anton,Howard,Bivens,Irl,&Davis,Stephen(2013).*Calculus*(10thed.).JohnWiley& Sons Singapore Pvt. Ltd. Reprint (2016) by Wiley India Pvt. Ltd. Delhi.
2. Bartle,RobertG.,&Sherbert,DonaldR.(2011).*IntroductiontoRealAnalysis*(4thed.). John Wiley & Sons. Wiley India edition reprint.

3. Prasad,Gorakh(2016).*DifferentialCalculus*(19thed.).PothishalaPvt.Ltd.Allahabad.
4. Ross,KennethA.(2013).*ElementaryAnalysis*:*TheTheoryofCalculus*(2nded.). Undergraduate Texts in Mathematics, Springer. Indian reprint.

SuggestiveReadings

- Apostol, T. M. (2007). *Calculus*: *One-Variable Calculus with an Introduction to Linear Algebra* (2nd ed.). Vol. 1. Wiley India Pvt. Ltd.
- Ghorpade, Sudhir R. & Limaye, B. V. (2006). *A Course in Calculus and Real Analysis*.Undergraduate Texts in Mathematics, Springer (SIE). Indian reprint.

DISCIPLINESPECIFICCORECOURSE– 6:ORDINARYDIFFERENTIALEQUATIONS

CREDITDISTRIBUTION,ELIGIBILITYANDPRE-REQUISITESOFTHECOURSE

Coursetitle & Code	Credits	Creditdistributionofthe course			Eligibility criteria	Pre-requisite of thecourse (ifany)
		Lecture	Tutorial	Practical/ Practice		
Ordinary Differential Equations	4	3	0	1	ClassXII passwith Mathematics	NIL

LearningObjectives: The mainobjectiveofthiscourse istointroducethe students:

- Theexcitingworld ofdifferential equations.
- Theirapplicationsandmathematical modeling.

LearningOutcomes: Thecoursewillenablethe studentsto:

- Learnthebasicsofdifferentialequationsandcompartmental models.
- Formulatedifferentialequationsforvariousmathematicalmodels.
- Solvefirstordernon-lineardifferentialequations,lineardifferentialequationsof higher order and system of linear differential equations using various techniques.
- Applythesetechniquestosolveandanalyzevariousmathematicalmodels.

SYLLABUSOFDSC-6

UNIT – I: First-Order Differential Equations (12hours)

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:SecondandHigher-OrderDifferentialEquations (18hours)

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'sequation,Systemoflineardifferentialequations,Applicationofsecondorder differential equation: Simple pendulum problem.

UNIT – III: Formulation and Analysis of Mathematical Models (15 hours)
Introduction to compartmental models, Lake pollution model; Density-dependent growth model,Interactingpopulationmodels,Epidemicmodelofinfluenzaanditsanalysis,Predator- prey model and its analysis, Equilibrium points, Interpretation of phase plane

Practical(30hours)-Practical /Labworktobeperformedin aComputerLab:

Modelingofthefollowing problemsusing SageMath/Mathematica/MATLAB/Maple/Maxima /Scilabetc.

1. Solutionsoffirst, secondandthirdorderdifferential equations.
2. Plottingoffamilyofsolutionsofdifferentialequationsoffirst,secondandthirdorder.
3. Solutionofdifferential equationsusingmethodof variationof parameters.
4. Growthanddecaymodel(exponentialcaseonly).
5. Lakepollutionmodel(withconstant/seasonalflowandpollutionconcentration).
6. Density-dependentgrowth model.
7. Predatory-preymodel(basicVolterramodel,withdensitydependence,effectof DDT, two prey one predator).
8. Epidemicmodelofinfluenza(basicepidemicmodel,contagiousforlife,diseasewith carriers).

Essential Readings

1. Barnes,Belinda&Fulford,GlennR.(2015).*MathematicalModelingwithCaseStudies*, Using Maple and MATLAB (3rd ed.). CRC Press. Taylor & Francis Group.
2. Edwards, C. Henry, Penney, David E., & Calvis, David T. (2015). *Differential Equations andBoundaryValueProblems*:*ComputingandModeling*(5thed.).PearsonEducation.
3. Ross,ShepleyL.(2014).*DifferentialEquations*(3rd ed.).WileyIndiaPvt.Ltd.

SuggestiveReading

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

Note:Examinationschemeandmodeshallbeasprescribedbytheexamination Branch, University of Delhi, from time to time.

GENERICELECTIVES(GE-2(i)):ANALYTICGEOMETRY

CREDITDISTRIBUTION,ELIGIBILITYANDPRE-REQUISITESOFTHECOURSE

Course title &Code	Credits	Creditdistributionofthe course			Eligibility criteria	Pre-requisite of thecourse
		Lecture	Tutorial	Practical/ Practice		

e						
Analytic Geometry	**4**	**3**	**1**	**0**	**ClassXII passwith Mathematics**	**NIL**

LearningObjectives: Thecourseaims at:

- Identifyingandsketchingcurves,studyingthreedimensionalobjects,theirgeometric properties and applications.
- Use of vector approach to three-dimensional geometry makes the study simple and elegant.

LearningOutcomes: Thiscoursewillenablethe studentsto:

- Learnconceptsintwo-dimensional geometry.
- Identifyandsketchconicsnamely,ellipse,parabolaandhyperbola.
- Learnaboutthree-dimensionalobjectssuchasstraightlinesandplanesusing vectors, spheres, cones and cylinders.

SYLLABUSOFGE-2(i)

UNIT–I:ConicSections (15hours)

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 (18hours)

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 betweenalineandaplane,distancebetweenparallelplanes;Shortestdistancebetweentwo skew lines.

UNIT – III: Sphere, Cone and Cylinder **(12hours)**

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.

RecommendedReadings:

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

SuggestiveReadings:

- Bell,RobertJ.T.(1972).*AnElementaryTreatiseonCoordinateGeometryofThree Dimensions*. Macmillan & Co. Ltd. London.
- George B. Thomas, Jr., & Ross L. Finney (2012). *Calculus and Analytic Geometry* (9th ed.). Pearson Indian Education Services Pvt Ltd. India.

GENERICELECTIVES(GE-2(ii)):INTRODUCTIONTOLINEAR ALGEBRA

CREDITDISTRIBUTION,ELIGIBILITYANDPRE-REQUISITESOFTHECOURSE

Coursetitle & Code	Credits	Creditdistributionofthe course			Eligibility criteria	Pre-requisite of thecourse
		Lecture	Tutorial	Practical/ Practice		
Introduction toLinear Algebra	4	3	1	0	ClassXII passwith Mathematic s	NIL

LearningObjectives: Theobjectiveofthecourse is:

- Tointroducetheconcept of vectorsinR^n.
- Understandthenatureofsolution ofsystemof linearequations.
- Toviewthe$m\times n$matricesasalinearfunctionfromR^ntoR^mandviceversa.
- To introduce the concepts of linear independence and dependence, rank and linear transformations has been explained through matrices.

LearningOutcomes: Thiscoursewillenablethe studentsto:

- VisualizethespaceR^nintermsofvectorsandtheinterrelationofvectorswith matrices.
- Understand importantusesof eigenvaluesandeigenvectorsin thediagonalization of matrices.
- Familiarize with concepts of bases, dimension and minimal spanning sets in vectorspaces.
- Learnaboutlineartransformation anditscorresponding matrix.

SYLLABUSOFGE-2(ii)

UNIT –I:VectorsandMatrices **(18 hours)**

FundamentaloperationsandpropertiesofvectorsinR^n,Linearcombinationsofvectors,Dot productandtheirproperties,Cauchy-Schwarzandtriangleinequality,Orthogonalandparallel

vectors;Solvingsystemoflinearequationsusing Gaussianelimination,andGauss-Jordanrow 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:VectorSpaces (12hours)

Definition, examples and some elementary properties of vector spaces; Subspaces, Span, Linearindependenceanddependence;Basisanddimensionofavectorspace;Diagonalization and bases.

UNIT–III:Linear Transformations (15hours)

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.

Essential Reading

1. Andrilli,S.,&Hecker,D.(2016).*ElementaryLinearAlgebr*a(5thed.).ElsevierIndia.

SuggestiveReading

- Kolman,Bernard,&Hill,DavidR.(2001).*IntroductoryLinearAlgebrawithApplications* (7thed.).PearsonEducation,Delhi.First IndianReprint 2003.

Semester-III

DEPARTMENTOFMATHEMATICS

B.Sc.(Hons) MATHEMATICS

Category-I

DISCIPLINESPECIFICCORECOURSE-7:GROUPTHEORY

CREDITDISTRIBUTION,ELIGIBILITYANDPRE-REQUISITESOFTHECOURSE

Course title &Code	Credits	Creditdistributionofthe course			Eligibility criteria	Pre-requisite ofthecourse (if any)
		Lecture	Tutorial	Practical/ Practice		
Group Theory	4	3	1	0	Class XII pass with Mathematics	Algebra

Learning Objectives

Theprimaryobjectiveofthiscourseisto introduce:

- Symmetricgroups,normalsubgroups,factorgroups,anddirectproductsof groups.
- Thenotionsofgrouphomomorphismtostudytheisomorphismtheoremswithapplications.
- Classificationofgroupswithsmallorderaccordingtoisomorphisms.

Learning Outcomes

Thiscoursewillenablethestudents to:

- Analyse the structure of 'small' finite groups, and examine examples arising as groups of permutations of a set, symmetries of regular polygons.
- Understandthesignificanceofthenotionofcosets,Lagrange'stheoremandits consequences.
- Know about group homomorphisms and isomorphisms and to relate groups using these mappings.
- Expressafiniteabeliangroupasthedirectproductofcyclicgroupsofprimepowerorders.
- Learnaboutexternaldirectproductsanditsapplicationstodatasecurityandelectriccircuits.

SYLLABUSOFDSC-7

Unit–1 **(18 hours)**

PermutationGroups,Lagrange'sTheoremandNormalSubgroups

Permutationgroupsandgroupofsymmetries,Cyclenotationforpermutationsandproperties, Evenandoddpermutations,Alternatinggroups;Cosetsanditsproperties,Lagrange'stheorem and consequences including Fermat's Little theorem, Number of elements in product of two finite subgroups; Normal subgroups, Factor groups, Cauchy's theorem for finite Abelian groups.

Unit–2 **(15 hours)**

GroupHomomorphismsand Automorphisms

Group homomorphisms, isomorphisms and properties, Cayley's theorem; First, Second and

Thirdisomorphismtheoremsforgroups;Automorphism,Innerautomorphism,Automorphis

groups,Automorphismgroupsofcyclicgroups,Applicationsoffactorgroupstoautomorphism groups.

Unit–3 **(12 hours)**

Direct Products of Groups and Fundamental Theorem of Finite Abelian Groups
Externaldirectproductsofgroupsanditsproperties,Thegroupofunitsmodulo*n*asan externaldirectproduct,Applicationstodatasecurityandelectriccircuits;Internaldirect products; Fundamental theorem of finite abelian groups and its isomorphism classes.

Essential Reading

1. Gallian, Joseph. A. (2017). Contemporary Abstract Algebra (9th ed.). Cengage Learning India Private Limited, Delhi. Indian Reprint 2021.

SuggestiveReadings

- Artin,Michael.(1991).Algebra(2nded.).PearsonEducation.IndianReprint2015.
- Dummit,DavidS.,&Foote,RichardM.(2016).AbstractAlgebra(3rded.).Student Edition. Wiley India.
- Herstein,I.N. (1975).TopicsinAlgebra(2nd ed.). Wiley India,Reprint 2022.
- Rotman, Joseph J. (1995). An Introduction to The Theory of Groups (4th ed.). Springer-Verlag, New York.

Note:Examinationschemeandmodeshallbeasprescribedbytheexamination Branch, University of Delhi, from time to time.

DISCIPLINESPECIFICCORECOURSE-8: RIEMANN INTEGRATION

CREDITDISTRIBUTION,ELIGIBILITYANDPRE-REQUISITESOFTHECOURSE

Course title &Code	Credits	Creditdistributionofthe course			Eligibility criteria	Pre-requisite ofthecourse (if any)
		Lecture	Tutorial	Practical/ Practice		
Riemann Integration	4	3	1	0	Class XII pass with Mathematics	ElementaryReal Analysis, and Calculus

Learning Objectives

Theprimaryobjectiveof thiscourseis to:

- Understandtheintegrationofboundedfunctionsonaclosedandboundedintervaland its extension to the cases where either the interval of integration is infinite, or the integrand has infinite limits at a finite number of points on the interval of integration.
- LearnsomeofthepropertiesofRiemannintegrablefunctions,itsgeneralizationand the applications of the fundamental theorems of integration.
- Getanexposuretotheutilityofintegrationforpracticalpurposes.

Learning Outcomes

Thiscoursewillenablethestudents to:

- Learn about some of the classes and properties of Riemann integrable functions, and the applications of the Riemann sums to the volume and surface of a solid of revolution.
- Getinsightofintegrationbysubstitutionandintegrationbyparts.
- Knowaboutconvergence ofimproperintegralsincluding,betaandgamma functions.

SYLLABUSOFDSC-8

Unit–1 (18 hours)

TheRiemann Integral

Definition of upper and lower Darboux sums, Darboux integral, Inequalities for upper and lower Darboux sums, Necessary and sufficient conditions for the Darboux integrability; Riemann's definition of integrability by Riemann sum and the equivalence of Riemann's and Darboux's definitions of integrability; Definition and examples of the Riemann-Stieltjes integral.

Unit–2 (15 hours)

PropertiesofTheRiemannIntegralandFundamental Theorems

Riemannintegrabilityofmonotonefunctionsandcontinuousfunctions,PropertiesofRiemann integrable functions; Definitions of piecewise continuous and piecewise monotone functions and their Riemann integrability; Intermediate value theorem for integrals, Fundamental Theorems of Calculus (I and II).

Unit–3 (12 hours)

ApplicationsofIntegralsandImproper Integrals

Methodsofintegration:integrationbysubstitutionandintegrationbyparts;Volumebyslicing and cylindrical shells, Length of a curve in the plane and the area of surfaces of revolution. ImproperintegralsofType-I,Type-IIandmixedtype,Convergenceofimproperintegrals, The beta and gamma functions and their properties.

Essential Readings

1. Ross,KennethA.(2013).ElementaryAnalysis:TheTheoryofCalculus(2nded.). Undergraduate Texts in Mathematics, Springer.
2. Anton, Howard, Bivens Irl and Davis Stephens (2012). Calculus (10th edn.). John Wiley & Sons, Inc.
3. Denlinger,CharlesG.(2011).ElementsofRealAnalysis,Jones&BartlettIndiaPvt.Ltd., Indian Reprint.
4. Ghorpade,SudhirR.and Limaye,B.V.(2006).ACourseinCalculusandRealAnalysis. Undergraduate Texts in Mathematics, Springer (SIE). Indian Reprint.

SuggestiveReadings

- Bartle, Robert G., & Sherbert, Donald R. (2015). Introduction to Real Analysis (4th ed.). Wiley, Indian Edition.
- KumarAjitandKumaresanS.(2014).ABasicCourseinRealAnalysis.CRCPress, Taylor & Francis Group, Special Indian Edition.

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

DISCIPLINESPECIFICCORECOURSE–9: DISCRETE MATHEMATICS

CREDIT DISTRIBUTION,ELIGIBILITY ANDPRE-REQUISITESOFTHE COURSE

Coursetitle & Code	**Credits**	**Creditdistributionofthe course**			**Eligibility criteria**	**Pre-requisite ofthecourse** (if any)
		Lecture	**Tutorial**	**Practical/ Practice**		
Discrete Mathematics	4	3	0	1	Class XII pass with Mathematics	Algebra and LinearAlgebra

Learning Objectives

Theprimaryobjectiveof thecourseis to:

- Makestudentsembarkuponajourneyofenlightenment,startingfromtheabstractconcepts in mathematics to practical applications of those concepts in real life.
- Makethestudents familiarwith thenotion ofpartially ordered set and alevel up with the study of lattice, Boolean algebra and related concepts.
- Culminatethejourneyoflearningwithpracticalapplicationsusingtheknowledgeattained from the abstract concepts learnt in the course.

Learning Outcomes

Thiscoursewillenablethestudents to:

- Understandthenotionofpartiallyorderedset,lattice,Booleanalgebrawithapplications.
- Handlethepracticalaspectofminimizationofswitchingcircuitstoagreatextentwiththe methods discussed in this course.
- Applytheknowledgeof Booleanalgebrastologic,settheoryandprobabilitytheory.

SYLLABUSOFDSC-9

Unit–1 **(15 hours)**

CardinalityandPartiallyOrderedSets

The cardinality of a set; Definitions, examples and basic properties of partially ordered sets, Order-isomorphisms, Covering relations, Hasse diagrams, Dual of an ordered set, Duality principle, Bottom andtop elements, Maximal and minimalelements, Zorn's lemma, Building new ordered sets, Maps between ordered sets.

Unit–2 **(15 hours)**

Lattices

Lattices as ordered sets, Lattices as algebraic structures, Sublattices, Products, Lattice isomorphism; Definitions, examples and properties of modular and distributive lattices; The M_3– N_5theorem with applications, Complemented lattice, Relatively complemented lattice, Sectionally complemented lattice.

Unit–3 **(15 hours)**

BooleanAlgebrasandApplications

Boolean algebras, De Morgan's laws, Boolean homomorphism, Representation theorem, Boolean polynomials, Boolean polynomial functions, Equivalence of Boolean polynomials, Disjunctivenormalformandconjunctivenormalform ofBooleanpolynomials;Minimalforms

of Boolean polynomials, Quine-McCluskey method, Karnaugh diagrams, Switching circuits andapplications,ApplicationsofBooleanalgebras tologic,settheoryandprobabilitytheory.

Practical(30hours):

Practical/Lab work to be performed in a computer Lab using any of the Computer Algebra System Software such as Mathematica/MATLAB /Maple/Maxima/Scilab/SageMath etc., for the following problems based on:

1) Expressingrelationsasorderedpairsandcreatingrelations.
2) Findingwhether ornot,agivenrelationis:
   i. Reflexiveii.Antisymmetriciii.Transitiveiv.Partialorder
3) Findingthefollowingforagivenpartiallyorderedset
   i. Coveringrelations.
   ii. ThecorrespondingHassediagramrepresentation.
   iii. Minimalandmaximalelements.
4) FindingthefollowingforasubsetSofagivenpartiallyorderedset*P*
   i. Whetheragivenelementin*P*isanupper bound(lowerbound)of *S*or not.
   ii. Setofallupperbounds(lowerbounds)of*S*.
   iii. Theleastupperbound(greatestlowerbound)of*S*,ifitexists.
5) Creatinglatticesanddeterminingwhetherornot,agivenpartiallyorderedsetisa lattice.
6) FindingthefollowingforagivenBooleanpolynomialfunction:
   i. RepresentationofBooleanpolynomialfunctionandfindingitsvaluewhentheBoolean variables in it take particular values over the Boolean algebra {0,1}.
   ii. Display in table form of all possible values of Boolean polynomial function over the Boolean algebra {0,1}.
7) Findingthe following:
   i. DualofagivenBoolean polynomial/expression.
   ii. Whetherornottwogiven Booleanpolynomialsareequivalent.
   iii. Disjunctivenormalform(Conjunctivenormalform)fromagivenBooleanexpression.
   iv. Disjunctivenormalform(Conjunctivenormalform)whenthegivenBoolean polynomial function is expressed by a table of values.
8) Representingagivencircuitdiagram(expressedusinggates)intheformofBoolean expression.
9) MinimizingagivenBooleanexpressiontofindminimalexpressions.

EssentialReadings

1. Davey,B.A.,&Priestley,H.A.(2002).IntroductiontoLatticesandOrder(2nded.). Cambridge University press, Cambridge.
2. Goodaire,EdgarG.,&Parmenter,MichaelM.(2006).DiscreteMathematicswithGraph Theory (3rd ed.). Pearson Education Pvt. Ltd. Indian Reprint.
3. Lidl, Rudolf & Pilz, Gunter. (2004). Applied Abstract Algebra (2nd ed.), Undergraduate Texts in Mathematics. Springer (SIE). Indian Reprint.

SuggestedReadings

- Donnellan,Thomas.(1999).LatticeTheory(1sted.).KhoslaPub.House. IndianReprint.
- Rosen,KennethH.(2019).DiscreteMathematicsanditsApplications(8thed.),Indian adaptation by Kamala Krithivasan. McGraw-Hill Education. Indian Reprint 2021.

B.Sc.(Hons)Mathematics,Semester-III,DSE-Courses

DISCIPLINESPECIFICELECTIVECOURSE-1(i):GRAPHTHEORY

CREDIT DISTRIBUTION,ELIGIBILITY ANDPRE-REQUISITESOFTHE COURSE

Course title &Code	Credits	Creditdistributionofthe course			Eligibility criteria	Pre-requisite ofthecourse (if any)
		Lecture	Tutorial	Practical/ Practice		
Graph Theory	4	3	1	0	Class XII pass with Mathematics	Nil

Learning Objectives

Theprimaryobjectiveofthiscourseisto introduce:

- Problem-solvingtechniquesusingvariousconceptsofgraphtheory.
- Variouspropertieslikeplanarityandchromaticityof graphs.
- Severalapplicationsoftheseconceptsinsolvingpracticalproblems.

Learning Outcomes

Thiscoursewillenablethestudents to:

- Learnmodellingofreal-worldproblemsbygraphs.
- Knowcharacteristicsofdifferent classesofgraphs.
- Learnrepresentationofgraphsintermsof matrices.
- Learnalgorithmstooptimizea solution.
- Understandsomepropertiesofgraphsandtheirapplicationsindifferentpractical situations.

SYLLABUSOFDSE-1(i)

Unit–1 **(12 hours)**

Graphs,PathsandCircuits

Definition, Examples and basic properties of graphs, Subgraphs, Pseudographs, Complete graphs, Bipartite graphs, Isomorphism of graphs, Paths and circuits, Connected graphs, Euleriancircuits,Hamiltoniancycles,Adjacencymatrix,Weightedgraph,Travellingsalesman problem, Shortest path, Dijkstra's algorithm.

Unit–2 **(15 hours)**

ApplicationsofPathsandCircuits,Trees

Applications of Path and Circuits: The Chinese Postman Problem, Digraphs, Bellman-Ford Algorithm, Tournaments, Scheduling Problem, Trees, Properties of Trees, Spanning Trees, Minimum Spanning Tree Algorithms.

Unit–3 **(18 hours)**

ConnectivityandGraphColoring,PlanarGraphs

Cut-vertices, Blocks and their Characterization, Connectivity and edge-connectivity, Planar graphs, Euler's formula, Kuratowski theorem, Graph coloring and applications, Matchings, Hall's theorem, Independent sets and covers.

Essential Readings

1. Goodaire, Edgar G., & Parmenter, Michael M. (2006). DiscreteMathematics with Graph Theory (3rd ed.). Pearson Education Pvt. Ltd. Indian Reprint.
2. Chartrand,Gary,&Zhang,Ping(2012).AFirstCourseinGraphTheory.Dover Publications.

SuggestiveReadings

- Bondy, J. A., and Murty, U.S.R. (2008). Graph Theory. Graduate Texts in Mathematics, Springer.
- Diestel,Reinhard(2017).GraphTheory(5thed.).GraduateTextsinMathematics,Springer.
- West, Douglas B. (2001).Introduction to Graph Theory(2nd ed.). Prentice Hall. Indian Reprint.

Note:Examinationschemeandmodeshallbeasprescribedbytheexamination Branch, University of Delhi, from time to time.

DISCIPLINESPECIFICELECTIVECOURSE–1(ii): MATHEMATICAL PYTHON

CREDIT DISTRIBUTION,ELIGIBILITY ANDPRE-REQUISITESOFTHE COURSE

Coursetitle & Code	**Credits**	**Creditdistributionofthe course**			**Eligibility criteria**	**Pre-requisite ofthecourse** (if any)
		Lecture	**Tutorial**	**Practical/ Practice**		
Mathematical Python	4	3	0	1	Class XII pass with Mathematics	Basic knowledge of Python

Learning Objectives

TheLearningObjectivesofthiscourseareasfollows:

- TobeabletomodelandsolvemathematicalproblemsusingPython Programs.
- To experience utility of open-source resources for numerical and symbolic mathematical software systems.

Learning Outcomes

ThiscoursewillenablethestudentstousePython:

- Fornumericalandsymboliccomputationinmathematicalproblemsfromcalculus,algebra, and geometry.
- Totabulateandplotdiversegraphsoffunctionsandunderstandtracingofshapes,geometries, and fractals.
- TopreparesmartdocumentswithLaTeX interface.

SYLLABUSOFDSE-1(ii)

Theory

Unit–1 (15 hours)

DrawingShapes,GraphingandVisualization

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–2 (18 hours)

NumericalandSymbolicSolutionsofMathematical Problems

NumPyforscalarsandlinearalgebraon*n*-dimensionalarrays;Computingeigenspace,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–3 (12 hours)

DocumentGenerationwithPythonandLaTeX

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

Practical(30hours): Softwarelabsusing IDEsuchasSpyderandPythonLibraries.

- Installation,update,andmaintenanceofcode, troubleshooting.
- Implementationofallmethodslearnedin theory.
- ExploreandexplainAPIlevelintegrationandworkingoftwoproblemswithstandard Python code.

Essential Readings

1. Farrell,Peter(2019).MathAdventureswithPython.NoStarchPress.ISBNNumber:978- 1-59327-867-0.
2. Farrell,Peterandetal.(2020).TheStatisticsandCalculuswithPythonWorkshop.Packet Publishing Ltd.ISBN: 978-1-80020-976-3.
3. Saha,Amit(2015).DoingMathwithPython.NoStarchPress.ISBN:978-1-59327-640-9

SuggestedReadings

- Morley,Sam(2022).ApplyingMathwithPython(2nded.).PacketPublishingLtd.ISBN: 978-1-80461-837-0
- Onlineresourcesanddocumentationonthelibraries,suchas:
  - 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 modes shall be as prescribed by the Examination Branch, University of Delhi, from time to time.**

DISCIPLINESPECIFICELECTIVECOURSE-1(iii):NUMBERTHEORY

CREDITDISTRIBUTION,ELIGIBILITYANDPRE-REQUISITESOFTHECOURSE

Course title &Code	Credits	Creditdistributionofthe course			Eligibility criteria	Pre-requisite ofthecourse (if any)
		Lecture	Tutorial	Practical/ Practice		
Number Theory	4	3	1	0	Class XII pass with Mathematics	Algebra

Learning Objectives

Theprimaryobjectiveofthiscourseisto introduce:

- Thenumbertheoretictechniquesofcomputationswiththeflavourof abstraction.
- TheEuclidean algorithm,linearDiophantineequations,congruence equations, arithmeticfunctionsandtheirapplications,Fermat'slittle,Euler'sandWilson's theorems.
- Primitiveroots,quadraticresiduesandnonresidues,theLegendresymbolandthelawof Quadratic Reciprocity.
- Introductiontocryptography,public-keycryptosystemsand applications.

Learning Outcomes

Thiscoursewillenablethestudents to:

- Usemodulararithmeticin solvinglinearandsystem oflinearcongruenceequations.
- Workwiththenumbertheoreticfunctions,theirpropertiesandtheiruse.
- Learntheformsofpositiveintegersthatpossessprimiterootsandthe Quadratic Reciprocity Law which deals with the solvability of quadratic congruences.
- Understandthepublic-keycryptosystems,inparticular,RSA.

SYLLABUSOFDSE-1(iii)

Unit–1 **(12 hours)**

LinearDiophantineequationandTheoryof Congruences

The Euclidean Algorithm and linear Diophantine equation; Least non-negative residues and complete set of residues modulo *n*; Linear congruences, The Chinese remainder theorem and system of linear congruences in two variables; Fermat's little theorem, Wilson's theorem and its converse, Application to solve quadratic congruence equation modulo odd prime *p*.

Unit–2 **(21 hours)**

Number-TheoreticFunctionsandPrimitiveRoots

Number-theoretic functions for the sum and number of divisors, Multiplicative function, Möbius inversion formula and its properties; Greatest integer function with an application to

the calendar; Euler's Phi-function, Euler's theorem and some properties of the Phi-function; Theorderofan integer modulo n and primitiveroots forprimes, Primitiveroots ofcomposite numbers n: when n is of the form 2^k, and when n is a product of two coprime numbers.

Unit–3 **(12 hours)**

QuadraticReciprocityLawandPublicKey Cryptosystems

The quadratic residue and nonresidue of an odd prime and Euler's criterion, The Legendre symbol and its properties, Quadratic Reciprocity law and its application; Introduction to cryptography, Hill's cipher, Public-key cryptography and RSA.

EssentialReading

1. Burton,DavidM.(2011).Elementary NumberTheory(7th ed.).McGraw-HillEducation Pvt. Ltd. Indian Reprint 2017.

SuggestiveReadings

- Andrews,GeorgeE.(1994).NumberTheory.Doverpublications,Inc.New York.
- 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:Examinationschemeandmodeshallbeasprescribedbythe Examination Branch, University of Delhi, from time to time.

GENERICELECTIVES-GE-3(i):DIFFERENTIALEQUATIONS

CREDITDISTRIBUTION,ELIGIBILITYANDPRE-REQUISITESOFTHECOURSE

Course title &Code	Credits	Creditdistributionofthe course			Eligibility criteria	Pre-requisite ofthecourse (if any)
		Lecture	Tutorial	Practical/ Practice		
Differential Equations	4	3	1	0	Class XII pass with Mathematics	Nil

LearningObjectives

Theprimaryobjectiveofthiscourseisto introduce:

- Ordinaryandpartialdifferential equations.
- Basictheoryofhigherorderlineardifferentialequations,Wronskiananditsproperties.
- Varioustechniquestofindthesolutionsofabovedifferentialequationswhichprovidea basis to model complex real-world situations.

LearningOutcomes

Thiscoursewillenablethestudents to:

- Solve the exact, linear,Bernoulli equations, find orthogonal trajectories and solve rateproblems.
- Applythemethodofundeterminedcoefficientsandvariationofparameterstosolvelinear differential equations.
- SolveCauchy-EulerequationsandSystemoflineardifferential equations.
- Formulateandsolvevarioustypesoffirstandsecondorderpartialdifferentialequations.

SYLLABUSOFGE-3(i)

Unit–1 (15 hours)

OrdinaryDifferentialEquations

First order ordinary differential equations: Basic concepts and ideas, First order Exact differentialequations,Integratingfactorsandrulestofindintegratingfactors,Linearequations and Bernoulli equations, Initial value problems, Applications of first order differential equations: Orthogonal trajectories and Rate problems; Basic theory of higher order linear differential equations, Wronskian and its properties.

Unit–2 (12 hours)

ExplicitMethodsofSolvingHigher-OrderLinearDifferential Equations

Linearhomogeneousequationswithconstantcoefficients,Linearnon-homogeneousequations, Methodofundeterminedcoefficients,Methodofvariationofparameters,Two-pointboundary value problems, Cauchy-Euler equations, System of linear differential equations.

Unit–3 **(18 hours)**

FirstandSecondOrderPartialDifferential Equations

Classification and Construction of first-order partial differential equations, Method of characteristics and general solutions of first-order partial differential equations, Canonical forms and method of separation of variables for first order partial differential equations; Classification and reduction to canonical forms of second-order linear partial differential equations and their general solutions.

EssentialReadings

1. Myint-U,TynandDebnath,Lokenath(2007).LinearPartialDifferentialEquationsfor Scientist and Engineers (4th ed.). Birkhäuser. Indian Reprint.
2. Ross,ShepleyL.(1984).DifferentialEquations(3rded.).JohnWiley&Sons.

SuggestiveReadings

- Edwards,C.Henry,Penney,DavidE.,&Calvis,DavidT.(2015).DifferentialEquations and Boundary Value Problems: Computing and Modeling (5th ed.). Pearson Education.
- Kreyszig,Erwin.(2011). AdvancedEngineering Mathematics(10thed.).Wiley India.
- SneddonI. N.(2006).ElementsofPartialDifferentialEquations.DoverPublications.

GENERICELECTIVES-GE-3(ii):LATTICESANDNUMBERTHEORY

CREDITDISTRIBUTION,ELIGIBILITYANDPRE-REQUISITESOFTHECOURSE

Course title &Code	Credits	Creditdistributionofthe course			Eligibility criteria	Pre-requisite ofthecourse (if any)
		Lecture	Tutorial	Practical/ Practice		
Lattices and Number Theory	4	3	1	0	ClassXII passwith Mathematics	Nil

Learning Objectives

Theprimaryobjectiveofthiscourseisto introduce:

- Theconceptsoforderedsets,lattices,sublatticesandhomomorphismsbetweenlattices.
- DistributivelatticesalongwithBooleanalgebra andtheirapplicationsinthereal-world.
- Divisibilitytheoryofcongruencesalongwithsome applications.
- Thenumber-theoreticfunctionsandquadraticreciprocitylaw.

Learning Outcomes

Thiscoursewillenablethestudents to:

- Understandthenotionoforderedsets.Learnaboutlattices,distributivelattices,sublattices and homomorphisms between lattices.
- BecomefamiliarwithBooleanalgebra,Booleanpolynomials,switchingcircuitsandtheir applications.
- Learn the concept of Karnaugh diagrams and Quinn–McCluskey method which gives an

aid to apply truth tables in real-world problems.

- Learn about some fascinating properties of prime numbers, and some of the open problems in number theory, viz., Goldbach conjecture etc.
- Know about modular arithmetic and number-theoretic functions like Euler's Phi-function.
- Find quadratic residues and nonresidues modulo primes using Gauss's Quadratic Reciprocity Law.

SYLLABUS OF GE-3(ii)

Unit – 1 **(21 hours)**

Partially Ordered Sets and Lattices

Definitions, Examples and basic properties of partially ordered sets, Order isomorphism, Hasse Diagram, Maximal and minimal elements, Dual of an ordered set, Duality principle; Statements of Well Ordering Principle and Zorn's Lemma; Lattices as ordered sets, Lattices as algebraic structures, Sublattices, Products and homomorphisms, Distributive lattices, Boolean algebras, Boolean polynomials, Minimal forms of Boolean polynomials, Quinn-McCluskey method, Karnaugh diagrams, Switching circuits and applications.

Unit – 2 **(12 hours)**

Divisibility and Theory of Congruences

The division algorithm: GCD, The Euclidean algorithm, Diophantine equation $ax + by = c$ Primes: The Fundamental Theorem of Arithmetic, Infinitude of primes, Twin primes and Goldbach conjecture.

The theory of congruences: Basic properties and applications, Linear congruences and the Chinese Remainder Theorem, Fermat's Little Theorem and Wilson's Theorem.

Unit – 3 **(12 hours)**

Number-Theoretic Functions, Primitive roots and Quadratic Reciprocity Law

Number-Theoretic Functions: Sum and number of divisors, Euler's Phi-function and Euler's generalization of Fermat's Little Theorem.

Primitive roots: The order of an integer modulo n, and primitive roots of an integer.

Quadratic Reciprocity Law: Quadratic residue and nonresidue, Euler's Criterion, The Legendre symbol and its properties and Quadratic Reciprocity Law.

Essential Readings

1. Davey, B A., & Priestley, H. A. (2002). Introduction to Lattices and Order (2nd ed.), Cambridge University Press, Cambridge.
2. Lidl, Rudolf & Pilz, Günter. (1998). Applied Abstract Algebra (2nd ed.), Undergraduate Texts in Mathematics, Springer (SIE), Indian Reprint 2004.
3. Burton, David M. (2012). Elementary Number Theory (7th ed.), Mc-Graw Hill Education Pvt. Ltd. Indian Reprint.

Suggestive Readings

- Rosen, Kenneth H. (2019). Discrete Mathematics and its Applications (8th ed.), Indian adaptation by Kamala Krithivasan. McGraw-Hill Education. Indian Reprint 2021.
- Goodaire, Edgar G., & Parmenter, Michael M. (2006). Discrete Mathematics with Graph Theory (3rd ed.). Pearson Education Pvt. Ltd. Indian Reprint 2018.
- Jones, G. A., & Jones, J. Mary. (2005). Elementary Number Theory. Springer Undergraduate Mathematics Series (SUMS). Indian Reprint.

Semester-IV

DEPARTMENT OF MATHEMATICS

Category-I

B.Sc. (Hons.) Mathematics

DISCIPLINE SPECIFIC CORE COURSE – 10: SEQUENCES AND SERIES OF FUNCTIONS

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		
Sequences and Series of Functions	4	3	1	0	Class XII pass with Mathematics	DSC-2: Real Analysis DSC-5: Calculus DSC-8: Riemann Integration

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

- The sequences and series of real-valued functions as a generalization to the sequences and series of real numbers.
- The situations under which the process of convergence of a sequence and series of real-valued functions may commute with the processes of calculus while taking differentiation, or integration.
- An important class of series functions (i.e., power series), and the elementary functions-exponential, logarithmic and trigonometric.

Learning Outcomes: This course will enable the students to:

- Learn about Cauchy criterion for uniform convergence and Weierstrass *M*-test for uniform convergence of series of real-valued functions.
- Know about the constraints for the inter-changeability of differentiation, and integration with infinite sum of a series of functions.
- Handle the convergence of power series and properties of the limit function, including differentiation and integration of power series.
- Appreciate utility of polynomials in the space of continuous functions.

SYLLABUS OF DSC-10

UNIT – I: Sequences of Functions (18 hours) Pointwise and uniform convergence of sequence of functions, The uniform norm, Cauchy criterion for uniform convergence, Continuity of the limit function of a sequence of functions, Interchange of the limit and derivative, and the interchange of the limit and integral of a sequence of functions, Bounded convergence theorem.

UNIT – II: Series of Functions (12 hours)

Pointwise and uniform convergence of series of functions, Theorems on the continuity, differentiability and integrability of the sum function of a series of functions, Cauchy criterion and the Weierstrass *M*-test for uniform convergence.

UNIT – III: Power Series (15 hours)

Definition of a power series, Radius of convergence, Absolute convergence (Cauchy-Hadamard theorem), Differentiation and integration of power series, Abel's theorem, Weierstrass's approximation theorem; The exponential, logarithmic and trigonometric functions: Definitions and their basic properties.

Essential Readings

1. Bartle, Robert G., & Sherbert, Donald R. (2011). Introduction to Real Analysis (4th ed.).Wiley India Edition. Indian Reprint.
2. Ross, Kenneth A. (2013). Elementary Analysis: The Theory of Calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian Reprint.

Suggestive Readings

- Bilodeau, Gerald G., Thie, Paul R., & Keough, G. E. (2010). An Introduction to Analysis (2nded.). Jones and Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.
- Denlinger, Charles G. (2011). Elements of Real Analysis. Jones and Bartlett India Pvt. Ltd.Student Edition. Reprinted 2015.

DISCIPLINE SPECIFIC CORE COURSE – 11: MULTIVARIATE 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		
Multivariate Calculus	**4**	**3**	**1**	**0**	**Class XII pass with Mathematics**	**DSC-2: Real Analysis DSC-5: Calculus DSC-8: Riemann Integration**

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

- The extension of the studies of single variable differential and integral calculus to functions of two or more independent variables.
- The geometry and visualisation of curves and surfaces in two dimensions (plane) and three dimensions (space).
- The techniques of integration to functions of two and three independent variables.
- The applications of multivariate calculus tools to physics, economics, optimization etc.

Learning Outcomes: This course will enable the students to:

- Learn the conceptual variations when advancing in calculus from one variable to multivariable discussion.
- Understand the maximization and minimization of multivariable functions subject to the given constraints on variables.
- Learn about inter-relationship amongst the line integral, double, and triple integral formulations.
- Familiarize with Green's, Stokes' and Gauss divergence theorems, and learn applications.

SYLLABUS OF DSC-11

UNIT – I: Calculus of Functions of Several Variables (18 hours)
Basic concepts, Limits and continuity, Partial derivatives, Tangent planes, Total differential, Differentiability, Chain rules, Directional derivatives and the gradient, Extrema of functions of two variables, Method of Lagrange multipliers with one constraint.

UNIT – II: Double and Triple Integrals (15 hours)
Double integration over rectangular and nonrectangular regions, Double integrals in polar co-ordinates, Triple integrals over a parallelopiped and solid regions, Volume by triple integrals, Triple integration in cylindrical and spherical coordinates, Change of variables in double and triple integrals.

UNIT – III: Green's, Stokes' and Gauss Divergence Theorem (12 hours) Vector field, Divergence and curl, Line integrals and applications to mass and work, Fundamental theorem for line integrals, Conservative vector fields, Green's theorem, Area asa line integral, Surface integrals, Stokes' theorem, Gauss divergence theorem.

Essential Reading

1. Strauss, Monty J., Bradley, Gerald L., & Smith, Karl J. (2007). Calculus (3rd ed.). Dorling Kindersley (India) Pvt. Ltd. Pearson Education. Indian Reprint.

Suggestive Reading

- Marsden, J. E., Tromba, A., & Weinstein, A. (2004). Basic Multivariable Calculus. Springer(SIE). Indian Reprint.

DISCIPLINE SPECIFIC CORE COURSE – 12: NUMERICAL 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		
Numerical Analysis	**4**	**3**	**0**	**1**	**Class XII pass with Mathematics**	**DSC-2: Real Analysis DSC-5: Calculus**

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

- Various computational techniques to find approximate value for possible root(s) of algebraic and non-algebraic equations.
- Methods to solve system of linear equations and ordinary differential equations.
- The use of computer algebra system (CAS) by which the numerical problems can be solved both numerically and analytically, and to enhance the problem-solving skills.

Learning Outcomes: This course will enable the students to:

- Learn some numerical methods to find the zeroes of nonlinear functions of a single variable, up to a certain given level of precision.
- Learn Gauss−Jacobi, Gauss−Seidel methods to solve system of linear equations.
- Get aware of using interpolation techniques, for example in finding values of a tabulated function at points which are not part of the table.
- Learn finding numerical solutions of difference equations which are obtained converting differential equations using techniques from calculus.

SYLLABUS OF DSC-12

UNIT – I: Methods for Solving Algebraic and Transcendental Equations (12 hours) Rate and order of convergence; Bisection method, Method of false position, Fixed point iteration method, Newton's method, and Secant method, their order of convergence and convergence analysis.

UNIT – II: Techniques to Solve Linear Systems and Interpolation (15 hours) LU decomposition and its applications; Iterative methods: Gauss−Jacobi, Gauss−Seidel methods; Lagrange and Newton interpolation, Piecewise linear interpolation.

UNIT – III: Numerical Differentiation and Integration (18 hours) First and higher order approximation for the first derivative, Approximation for the second derivative; Numerical integration by closed Newton−Cotes formulae: Trapezoidal rule, Simpson's rule and its error analysis; Euler's method to solve ODE's, Modified Euler method,Runge−Kutta Method (fourth-order).

Essential Reading

1. Bradie, Brian. (2006). A Friendly Introduction to Numerical Analysis. Pearson EducationIndia. Dorling Kindersley (India) Pvt. Ltd. Third impression 2011.

Suggestive Readings

- Gerald, Curtis F., & Wheatley, Patrick O. (2007). Applied Numerical Analysis (7th ed.).Pearson Education. India.
- Jain, M. K., Iyengar, S. R. K., & Jain, R. K. (2012). Numerical Methods for Scientific andEngineering Computation. (6th ed.). New Age International Publisher, India, 2016.

Note: Non programmable scientific calculator may be allowed in the University examination.

Practical (30 hours)- Practical / Lab work to be performed in Computer Lab: Use of computer algebra system (CAS) software: Python/SageMath/Mathematica/MATLAB/Maple/Maxima/ Scilab etc., for developing the following numerical programs:

1. Bisection method.

2. Newton-Raphson method.
3. Secant method.
4. LU decomposition method.
5. Gauss−Jacobi method.
6. Gauss−Seidel method.
7. Lagrange interpolation.
8. Newton interpolation.
9. Trapezoidal rule.
10. Simpson's rule.
11. Euler’s method.
12. Runge−Kutta Method (fourth-order).

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

B.Sc. (Hons) Mathematics, Semester-IV, DSE-Courses

DISCIPLINE SPECIFIC ELECTIVE COURSE – 2(i): BIOMATHEMATICS

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		
Biomathematics	**4**	**3**	**1**	**0**	**Class XII pass with Mathematics**	**DSC-6: Ordinary Differential Equations**

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

- Develop and analyse the models of the biological phenomenon with emphasis on population growth and predator-prey models.
- Interpret first-order autonomous systems of nonlinear differential equations using the Poincaré phase plane.
- Apply the basic concepts of probability to understand molecular evolution and genetics.

Learning Outcomes: This course will enable the students to:

- To learn and appreciate study of long-term behavior arising naturally in study of mathematical models and their impact on society at large.
- To understand spread of epidemic technically through various models and impact of recurrence phenomena.
- Learn what properties like Chaos and bifurcation means through various examples and their impact in Bio-Sciences.

SYLLABUS OF DSE-2(i)

UNIT – I: Mathematical Modeling for Biological Processes (15 hours)

Formulation a model through data, A continuous population growth model, Long-term behavior and equilibrium states, The Verhulst model for discrete population growth, Administration of drugs, Differential equation of chemical process and predator-prey model (Function response: Types I, II and III).

UNIT – II: Epidemic Model: Formulation and Analysis (15 hours) Introduction to infectious disease, The SIS, SIR and SEIR models of the spread of an epidemic, Analyzing equilibrium states, Phase plane analysis, Stability of equilibrium points, Classifying the equilibrium state; Local stability, Limit cycles, Poincaré-Bendixson theorem.

UNIT – III: Bifurcation, Chaos and Modeling Molecular Evolution (15 hours)

Bifurcation, Bifurcation of a limit cycle, Discrete bifurcation and period-doubling, Chaos,

Stability of limit cycles, Introduction of the Poincaré plane; Modeling molecular evolution: Matrix models of base substitutions for DNA sequences, Jukes-Cantor and Kimura models, Phylogenetic distances.

Essential Readings

1. Robeva, Raina S., et al. (2008). An Invitation to Biomathematics. Academic press.
2. Jones, D. S., Plank, M. J., & Sleeman, B. D. (2009). Differential Equations andMathematical Biology (2nd ed.). CRC Press, Taylor & Francis Group.
3. Allman, Elizabeth S., & Rhodes, John A. (2004). Mathematical Models in Biology: AnIntroduction. Cambridge University Press.

Suggestive Readings

- Linda J. S. Allen (2007). An Introduction to Mathematical Biology. Pearson Education.
- Murray, J. D. (2002). Mathematical Biology: An Introduction (3rd ed.). Springer.
- Shonkwiler, Ronald W., & Herod, James. (2009). Mathematical Biology: An Introductionwith Maple and MATLAB (2nd ed.). Springer.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 2(ii): MATHEMATICAL MODELING

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 Modeling	**4**	**3**	**0**	**1**	**Class XII pass with Mathematics**	**DSC-6: Ordinary Differential Equations**

Learning Objectives: Primary objective of this course is to introduce:

- Mathematical modeling as the representation of a system by a set of mathematical relations or equations.
- Mathematical epidemiological models susceptible-infectious-recovered (SIR) and its variant SEIR (S-Exposed-IR) for the spread of diseases.
- Monte Carlo simulation techniques, and simplex method for solving linear programming problems.

Learning Outcomes: This course will enable the students to:

- Understand the methodology of solving SIR models for disease spread.
- Learn significance of dieting model that provides important insights and guides to a biomedical issue that is of interest to the general public.
- Understand nonlinear systems and phenomena with stability analysis ranges from phase plane analysis to ecological and mechanical systems.

- Use Monte Carlo simulation technique to approximate area under a given curve, and volume under a given surface.

SYLLABUS OF DSE-2(ii)

UNIT – I: Mathematical Epidemiological and Dieting Models (15 hours) Modeling concepts and examples, Scaling of variables, and approximations of functions; SIR and SEIR models for disease spread: Methodology, Standard and solvable SIR models, Basic reproduction number; Dieting model with analysis and approximate solutions.

UNIT – II: Modeling with Nonlinear Systems and Phenomena (15 hours) Stability and the phase plane, Almost linear systems; Ecological models: Predators and competitors, Critical points, Oscillating populations, Survival of single species, Peaceful coexistence of two species, Interaction of logistic populations, Wildlife conservation preserve; Nonlinear mechanical systems: Hard and soft spring oscillations, Damped nonlinear vibrations.

UNIT – III: Simulation and Optimization Modeling (15 hours) Monte Carlo simulating deterministic, and probabilistic behavior, Generating random numbers; Linear programming model: Geometric and algebraic solutions, Simplex method and its tableau format, Sensitivity analysis.

Essential Readings

1. Mickens, Ronald E. (2022). Mathematical Modelling with Differential Equations.CRC Press, Taylor & Francis Group.
2. Edwards, C. Henry, Penney, David E., & Calvis, David T. (2023). Differential Equationsand Boundary Value Problems: Computing and Modeling (6th ed.). Pearson.
3. Giordano, Frank R., Fox, William P., & Horton, Steven B. (2014). A First Course inMathematical Modeling (5th ed.). Brooks/Cole, Cengage Learning India Pvt. Ltd.

Suggestive Readings

- Barnes, Belinda & Fulford, Glenn R. (2015). Mathematical Modeling with Case Studies,Using Maple and MATLAB (3rd ed.). CRC Press. Taylor & Francis Group.
- Ross, Shepley L. (2014). Differential Equations (3rd ed.). Wiley India Pvt. Ltd.
- Simmons, George F. (2017). Differential Equations with Applications and Historical Notes(3rd ed.). CRC Press. Taylor & Francis Group.

Practical (30 hours)- Practical work to be performed in Computer Lab: Modeling of the following problems using: R/Python/SageMath/Mathematica/MATLAB/Maxima/Scilab etc.

1. a) Simulation of SIR model and its variants using some initial parameter values, and finding basic reproduction number for analysis.
   b) Analysis of the dieting process, which includes both body-mass loss and gain.
2. Nonlinear Systems and Phenomena.
   a) Plot phase plane portraits and solutions of first-order equations.
   b) Obtain interesting and complicated phase portraits for almost linear systems.

c) Discuss large wildlife conservation preserve model and obtain (i) The period of oscillation of the rabbit and fox populations, (ii) The maximum and minimum numbers of rabbits and foxes.

d) Discuss the Rayleigh and van der Pol models.

3. (i) Random number generation and then use it for the following:
   a) Simulate area under a given curve.
   b) Simulate volume under a given surface.

(ii) [2] Chapter 7 (Projects 7.4 and 7.5).

DISCIPLINE SPECIFIC ELECTIVE COURSE – 2(iii): MECHANICS

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		
Mechanics	**4**	**3**	**1**	**0**	**Class XII pass with Mathematics**	**DSC-5: Calculus DSC-6: Ordinary Differential Equations**

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

- Starting Newtonian laws, learning various technical notions which explains various states of motion under given forces.
- Deals with the kinematics and kinetics of the rectilinear and planar motions of a particle including constrained oscillatory motions of particles, projectiles, and planetary orbits.
- Understand hydrostatic pressure and thrust on plane surfaces.

Learning Outcomes: This course will enable the students to:

- Understand necessary conditions for the equilibrium of particles acted upon by various forces and learn the principle of virtual work for a system of coplanar forces.
- Apply the concepts of center of gravity, laws of static and kinetic friction.
- Learn that a particle moving under a central force describes a plane curve and know the Kepler's laws of the planetary motions.
- Evaluate the hydrostatic pressure at any given depth in a heavy homogeneous liquid at rest under gravity.

SYLLABUS OF DSE-2(iii)

UNIT – I: Statics **(15 hours)**

Fundamental laws of Newtonian mechanics, Law of parallelogram of forces, Equilibrium of a particle, Lamy's theorem, Equilibrium of a system of particles, External and internal forces, Couples, Reduction of a plane force system, Work, Principle of virtual work, Potential energy and conservative field, Mass centers, Centers of gravity, Friction.

UNIT – II: Dynamics **(18 hours)**

Kinemetics of a particle, Motion of a particle, Motion of a system, Principle of linear momentum, Motion of mass center, Principle of angular momentum, Motion relative to mass center, Principle of energy, D'Alembert's principle; Moving frames of reference, Frames of reference with uniform translational velocity, Frames of reference with constant angular velocity; Applications in plane dynamics- Motion of a projectile, Harmonic oscillators, Generalmotion under central forces, Planetary orbits.

UNIT – III: Hydrostatics **(12 hours)**

Shearing stress, Pressure, Perfect fluid, Pressure at a point in a fluid, Transmissibility of liquid pressure, Compression, Specific gravity, Pressure of heavy fluid- Pressure at all points in a horizontal plane, Surface of equal density; Thrust on plane surfaces.

Essential Readings

1. Synge, J. L., & Griffith, B. A. (2017). Principles of Mechanics (3rd ed.). McGraw-HillEducation. Indian Reprint.
2. Ramsey, A. S. (2017). Hydrostatics. Cambridge University Press. Indian Reprint.

Suggestive Readings

- Roberts, A. P. (2003). Statics and Dynamics with Background Mathematics. CambridgeUniversity Press.
- Ramsey, A. S. (1985). Statics (2nd ed.). Cambridge University Press.

GENERIC ELECTIVES (GE-4(i)): 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 GE-4(i)

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, Thecompleteness 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.

GENERIC ELECTIVES (GE-4(ii)): 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 GE-4(ii)

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

1. Thie, Paul R., & Keough, G. E. (2014). An Introduction to Linear Programming and Game Theory. (3rd ed.). Wiley India Pvt. Ltd.
2. 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.