NEP 2020

Syllabus of

Five-Years Integrated Programme

in Mathematics

Bodoland University

Kokrajhar-783370, Assam, India

STRUCTURE OF THE SYLLABUS
FIVE-YEARS INTEGRATED COURSE IN MATHEMATICS
BODOLAND UNIVERSITY

	Class	Paper	Topics	Credit	Marks
1ST YEAR	SEMESTER-I	MATMAJ101-4	Foundation of Mathematics	4	Internal: 30 Theory: 50 Practical:20
		MATMIN101-4	Foundation of Mathematics	4	Internal: 30 Theory:70
		MATIDC101-3	Commercial Arithmetic-I	3	Theory: 40
		MATSEC101-3	HTML and Web Designing	3	Theory: 40 Practical:10
	SEMESTER -II	MATMAJ102-4	Calculus	4	Internal: 30 Theory: 70
		MATMIN102-4	Integral Calculus and Differential Equations	4	Internal: 30 Theory:70
		MATIDC102-3	Commercial Arithmetic-II	3	Theory: 40
		MATSEC102-3	Programming in C	3	Theory: 40 Practical:10
2ND YEAR	SEMESTER -III	MATMAJ201-4	Elements of Real Analysis	4	Internal: 30 Theory:70
		MATMAJ202-4	Differential Equations (ODE)	4	Internal: 30 Theory: 50 Practical:20
		MATMIN201-4	Analytical Geometry	4	Internal: 30 Theory:70
		MATIDC201-3	Logic and Graphical Representation of Data	3	Theory: 50
		MATSEC201-3	SciLab	3	Theory: 40 Practical:10
	SEMESTER -IV	MATMAJ203-4	Group Theory	4	Internal: 30 Theory:70
		MATMAJ204-4	Numerical Methods	4	Internal: 30 Theory: 50 Practical:20
		MATMAJ205-4	Analytical Geometry (2D) and Vector Calculus	4	Internal: 30 Theory:70
		MATMIN202-4	Vector Calculus	4	Internal: 30 Theory:70
3RD YEAR	SEMESTER -V	MATMAJ301-4	Ring Theory	4	Internal: 30 Theory:70
		MATMAJ302-4	Metric Space	4	Internal: 30 Theory:70
		MATMAJ303-4	Multivariate Calculus	4	Internal: 30 Theory: 50 Practical:20
		MATMAJ304-4	Mechanics	4	Internal: 30 Theory:70

		MATMIN301-4	Mechanics	4	Internal: 30 Theory:70
	SEMESTER -VI	MATMAJ305-4	Linear Algebra	4	Internal: 30 Theory:70
		MATMAJ306-4	Linear Programming Problem	4	Internal: 30 Theory:70
		MATMAJ307-4	Complex Analysis	4	Internal: 30 Theory: 50 Practical:20
		MATMAJ308-4	Analytical Geometry (3D) and Differential Geometry	4	Internal: 30 Theory:70
		MATMIN302-4	Differential Calculus	4	Internal: 30 Theory:70

	Class	Paper	Topics	Credit	Marks
4TH YEAR	**SEMESTER-VII**	MATADL 14014	Analysis-I	4	Internal: 30 Theory: 70
		MATADL14024	Functional Analysis	4	Internal: 30 Theory: 70
		MATADL 14034	Partial Differential Equation	4	Internal: 30 Theory: 70
		MATADL14044	Tensor Analysis	4	Internal: 30 Theory: 70
		MATADL14054	Advanced Algebra	4	Internal: 30 Theory: 70
	SEMESTER -VIII	MATADL 14064	Mathematical Methods	4	Internal: 30 Theory: 70
		MATSPL 15074 (A)	Analysis-II	4	Internal: 30 Theory: 70
		MATSPL 15074 (B)	Mathematical Modeling		
		MATSPL 15084 (A)	Graph Theory I	4	Internal: 30 Theory: 70
		MATSPL 15084 (B)	Continuum Mechanics		
		MATSPL 15094 (A)	General Topology	4	Internal: 30 Theory: 70
		MATSPL 15094 (B)	Differential Geometry		
		MATSPL15104	Computer Lab I	4	Internal: 30 Practical: 70

	Class	Paper	Topics		Credit	Marks
5TH YEAR	**SEMESTER -IX**	MATSPL 25014	MATSPL 25014 (A)	Fuzzy Set Theory	4	Internal: 30 Theory: 70
			MATSPL 25014 (B)	Fluid Dynamics I		
			MATSPL 25014 (C)	Advanced Topology I		
		MATSPL 25024	MATSPL 25024 (A)	Graph Theory II	4	Internal: 30 Theory:70
			MATSPL 25024 (B)	Special Theory of Relativity		
			MATSPL 25024 (C)	Category Theory I		
		MATSPL 25034	MATSPL 25034 (A)	Number Theory I	4	Internal: 30 Theory: 70
			MATSPL 25034 (B)	Dynamical Systems I		
		MATSPL 25044	MATSPL 25044 (A)	Advanced Functional Analysis	4	Internal: 30 Theory: 70
			MATSPL 25044 (B)	Numerical Analysis I		
		MATSPL 25054	Computer Lab II		4	Internal: 30 Practical: 70
	SEMESTER -X	MATSPL 25064	MATSPL 25064(A)	Fuzzy Logic and Control System	4	Internal: 30 Theory: 70
			MATSPL 25064(B)	Numerical Analysis II		
			MATSPL 25064(C)	Advanced Topology II		
		MATSPL 25074	MATSPL25074 (A)	Graph Theory III	4	Internal: 30 Theory: 70
			MATSPL25074 (B)	Relativity and Cosmology		
			MATSPL25074 (C)	Category Theory II		
		MATSPL 25084	MATSPL 25084 (A)	Number Theory II	4	Internal: 30 Theory: 70
			MATSPL 25084 (B)	Dynamical Systems II		
		MATSPL 25094	MATSPL 25094 (A)	Analysis III	4	Internal: 30 Theory: 70
			MATSPL 25094 (B)	Biomathematics		
		MATSPL 25104	MATSPL 25104 (A)	Network Theory	4	Internal: 30 Theory: 70
			MATSPL 25104 (B)	Fluid Dynamics II		

Detailed Syllabus

SEMESTER-I

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMAJ101-4	Foundation of Mathematics	Major	3	1	0	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- The types of functions and relations
- The basic tools of the theory of equations, Complex numbers
- The basic number theory
- The system of Linear Equations and their applications
- To apply Mathematica Software in matrix algebra

Course Learning Outcomes:

This course will enable the students to

- Identify different types of functions and relations with their applications
- Determine the number of positive/negative real roots of a real polynomial
- To learn the modular arithmetic and their applications
- To learn the systems of linear equations and their applications.
- To learn the use of Mathematica Software in solving system of linear equations

Syllabus of the Course

Theory:

Unit-1: Basics of Relations and Functions

Relations, Types of relations, Equivalence relations, Equivalence Classes and partitions of a set, Functions, Types of functions, Composition of functions, Inverse of a function, Image and inverse image of subsets under functions.

Contact Hour-11; Marks: 12

Unit-2: 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, De-Moivre's theorem for integer and rational indices and their applications, The nth roots of unity, Cardan's solution of the cubic equations.

Contact Hour-11; Marks: 13

Unit-3: Basic Number Theory

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

Contact Hour-11; Marks: 12

Unit-4: Basics of Linear Algebra:

Systems of linear equations, Row reduction and echelon forms, vector equations, the matrix equation Ax=b, Solution sets of linear systems, Applications of linear systems, the Inverse of a matrix, Algorithm to find the inverse of a matrix, Characterizations of invertible matrices.

Contact Hour-12; Marks: 13

Practical:

Software to be used Wolfram Mathematica:

Construction of matrices, Algebraic operations of Matrices, Elementary operations of matrices, Partitions of matrices, Determinant of a matrix, Rank of a Matrix, Adjoint of a matrix, Inverse of a matrix, and Solutions of a system of linear equations.

Contact Hour- 15; Marks-20

Prescribed Textbooks:

[1] A Foundation Course in Mathematics, A. Kumar, S. Kumaresan, B. K. Sarma, Alpha Science International Ltd. Oxford, U.K. (**For Unit-1**)

[2] Dickson, Leonard Eugene (2009). First Course in the Theory of Equations. John Wiley & Sons, Inc. (**For Unit-2**)

[3] Goodaire, Edgar G., & Parmenter, Michael M. (2006). Discrete Mathematics with Graph Theory (3rd ed.). Pearson Education Pvt. Ltd. Indian Reprint 2018.(**For Unit-3**)

[4] David C. Lay, *Linear Algebra and its Applications*, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.(**For Unit-4**)

Reference Books:

[1] Titu Andreescu and Dorin Andrica, *Complex Numbers from A to Z*, Birkhauser, 2006.

[2] 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.

[3] Burton, David M. (2011). Elementary Number Theory (7th ed.). McGraw-Hill Education Pvt. Ltd. Indian Reprint. Joseph A. Gallian, Contemporary Abstract Algebra (Fourth Edition), Narosa,1999.

SEMESTER-I

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMIN101-4	Foundation of Mathematics	Minor	3	0	1	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- The basic knowledge and background to understand other courses in either mathematics or physics.

- The basic concepts of matrix and compute the eigenvalues and eigenvectors.

Course Learning Outcomes:

This course will enable the students to

- Get the basic idea of Complex Numbers, Matrices and Theory of Equations.
- Utilize the knowledge of Complex Numbers, Matrix and Theory of Equations to understand.
- Learn to solve Complex Numbers, matrices and the Theory of Equations.

Syllabus of the Course:

Theory:

Unit-1: Complex Numbers

Complex numbers as ordered pairs of real numbers, geometrical representation and polar form of complex numbers, modulus, argument and their properties, complex equations of straight line and circle. De Moivre's theorem, expansion of cos*x* and sin*x* in positive integral powers of x, the logarithm of a complex number, exponential and trigonometric functions of a complex variable, Euler's expansion of cosine and sine, hyperbolic functions, inverse functions, Gregory's series.

Contact Hour- 25; Marks-32

Unit-2: Matrices

Basic concepts of matrices, Types of matrices, Transpose, trace and determinant of a matrix, Elementary operations, Row Reduced echelon form, Rank and inverse of a matrix, Normal form of a matrix, Solutions of a system of linear equations, Symmetric, skew-symmetric and orthogonal matrices, Eigenvalues, eigenvectors, Diagonalization of matrices, Cayley-Hamilton theorem.

Contact Hour- 12; Marks-22

Unit-3: Theory of Equations

Relation between the roots and coefficients of a general polynomial equation in one variable, transformation of equations, Descartes' rule of signs, Solutions of reciprocal and binomial equations, and solution of cubic equation by Cardon's method.

Contact Hour- 8; Marks-16

Prescribed Textbooks:

[1] Higher Trigonometry - Das and Mukherjee: Dhur and Sons (**For Unit-1**)

[2] Seymour Lipschutz; Marc Lipson: Schaum's Outline of Linear Algebra, McGraw-Hill Education, Schaum's Outlines, 4, 2008. (**For Unit-2**)

[3] Higher Algebra (Classical) - S.K. Mappa, Asoke Prakasan. (**For Unit-3**)

Reference Books:

[1] Titu Andreescu and Dorin Andrica, *Complex Numbers from A to Z*, Birkhauser, 2006.

[2] Herstein I. N. & Winter D. J. - Matrix theory and linear algebra Macmillan Pub Co, 1988

[3] 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.

[4] Dickson, Leonard Eugene (2009). First Course in the Theory of Equations. John Wiley & Sons, Inc.

SEMESTER-I

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATIDC101-3	Commercial Arithmetic-I	IDC	2	0	1	3

Course Learning Objectives:

The primary objective of this course is to introduce:

- The concept of interest levied on borrowed capital from financial institutions or banks

Course Learning Outcomes:

This course will enable the students to

- Evaluate the legal, social and economic environment of business
- Apply decision support tools to business decision making
- Will be able to apply knowledge of business concepts and functions in an integrated manner

SylCus of the Course:

Theory:

Unit-1: Commercial Arithmetic

Interest: Concept of Present value and Future value, Simple interest, Compound interest, Nominal and Effective rate of interest, Examples and Problems of Annuity: Ordinary Annuity, Sinking Fund, Annuity due, Present value and Future value of Annuity, Equated Monthly Instalments (EMI) by Interest of Reducing Balance and Flat Interest methods, Examples and Problems.

Contact Hours- 15; Marks-20

Unit-2: **Measures of Central Tendency and Dispersion**

Frequency distribution: Raw data, attributes and variables, Classification of data, frequency distribution, cumulative frequency distribution, Histogram and give curves. Requisites of ideal measures of central tendency, Arithmetic Mean, Median and Mode for ungrouped and grouped data. Combined mean, Merits and demerits of measures of central tendency, Geometric mean: Definition, merits and demerits, Harmonic mean: Definition, merits and demerits, Choice of A.M., G.M. and H.M. Concept of dispersion, Measures of dispersion: Range, Variance, Standard deviation (SD) for grouped and ungrouped data, Combined SD, Measures of relative dispersion: Coefficient of range, Coefficient of variation, Examples and problems.

Contact Hours- 15; Marks-30

Reference Books:

[1] M. K. Bhowal, Fundamentals of Business Mathematics, Asian Books Pvt. Ltd., New Delhi, 2007

[2] M. G. Das and J. K. Das, Business Mathematics and Statistics, McGraw Hill, New Delhi, 2017

[3] K. Selvakumar, Mathematics for Commerce, Motion Press, Chennai, 2014.

SEMESTER-I

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATSEC101-3	HTML and Web Designing	SEC	2	1	0	3

Course Learning Objectives:

The primary objective of this course is to introduce:

- To provide an understanding of the basic structure and syntax of HTML.
- To develop skills in creating and formatting basic web pages using HTML.
- To equip students with the ability to design and develop a simple website.
- To develop skills in creating visually appealing and effective presentations using PowerPoint and deliver a professional-level presentation.

Course Learning Outcomes:

This course will enable the students to

- Able to create and publish a basic website using HTML.
- Able to use common web design principles and techniques.
- Differentiate between effective and ineffective visual communication.
- Create visually appealing and effective presentations using PowerPoint.

Syllabus of the Course:

Theory + Practical:

Unit-1

Definition of HTML, Overview of markup languages, HTML structure, Syntax of HTML, Basic HTML tags, Advanced HTML tags, Formatting and Styling with CSS, Building a Simple Website.

Contact Hours-20; Marks-20

Unit-2

Introduction to Web Designing, Design Tools, Web Design Principles, Responsive Design, Web hosting and domain registration, Uploading web files to the server, Testing and maintaining the website. Introduction to PowerPoint, Features of PowerPoint, Creating a new presentation, Understanding effective visual communication, Visual hierarchy and alignment, Planning and designing a presentation.

Contact Hours-25; Marks-20

Practical: **Marks:10**

Building of HTML web pages (basic and advanced), Table properties, web designing, Styling of web pages with CSS, Formating of web pages, Power point preparation and presentation, Preparation of slides by applying features.

Prescribed Textbooks:

[1] *HTML and CSS: Design and Build Websites,* Jon Duckett, John Wiley & Sons, 2011. **(For Unit-1)**

[2] *Web Design with HTML, CSS, JavaScript and jQuery Set*, Jon Duckett, Wiley, 2014. **(For Unit-2)**

Reference Books:

[1] Elizabeth Castro and Bruce Hyslop, *HTML and CSS: Visual QuickStart Guide*, Peachpit Press, 2013.

[2] Jennifer Niederst Robbins, *Learning Web Design: A Beginner's Guide to HTML, CSS, JavaScript, and Web Graphics*, O'Reilly Media, 2018.

[3] Jason Beaird, *The Principles of Beautiful Web Design*, SitePoint, 2010.

[4] Garr Reynolds, *Presentation Zen: Simple Ideas on Presentation Design and Delivery*, New Riders, 2008.

[5] Nancy Duarte, *Slide:ology: The Art and Science of Creating Great Presentations*, O'Reilly Media, 2008.

SEMESTER-II

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMAJ102-4	Calculus	Major	3	0	1	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- Differential calculus and integral calculus to study the physical phenomena-the differential equation. To apply Mathematica Software in matrix algebra.

Course Learning Outcomes:

This course will enable the students to

- To learn the technique of finding nth derivative of some standard functions
- Identify and apply the intermediate value theorem.
- Learn the centre of curvature, asymptotes of the given curve.
- Learn to evaluate integrals, find arc -lengths , areas and volume .

Syllabus of the Course:

Theory:

Unit-1

Limits, Continuity, Differentiability and properties. Properties of continuous functions. $n^{(th)}$ Derivatives of Standard functions e^{ax+b}, $(ax + b)^n$, log(ax +b), sin(ax+b), cos(ax+b) $e^{ax}\sin(bx+c)$, $e^{ax}\cos(bx+c)$, derivatives hyperbolic functions, Leibnitz theorem and its application.

Contact Hour-11; Marks-17

Unit-2

Intermediate value theorem, Rolle's Theorem, Lagrange's Mean Value theorem, Cauchy's Mean value theorem and examples. Taylor's theorem, Maclaurin's series, Indeterminate forms hyperbolic function and evaluation of limits using L'Hospital's rule.

Contact Hour-11; Marks-18

Unit-3

Polar coordinates, angle between the radius vector and tangent. Angle of intersection of two curves (polar forms), length of perpendicular from pole to the tangent, pedal equations. Derivative of an arc in Cartesian, parametric and polar forms, curvature of plane curve-radius of curvature formula in Cartesian, parametric and polar and pedal forms- center of curvature, asymptotes.

Contact Hour-13; Marks-20

Unit-4

Recapitulation of definite integrals and its properties. Reduction formulae- $\int sin^n x dx$. $\int cos^n x dx$ $\int sin^n x\, cos^n x dx$. $\int_0^{\frac{\pi}{2}} sin^n x dx$. $\int_0^{\frac{\pi}{2}} cos^n x dx$. $\int_0^{\frac{\pi}{2}} sin^n x\, cos^n x dx$. Problems, computation of length of an arc, Area of plane curves, surface area and volume of revolution in Cartesian and polar forms.

Contact Hour-10; Marks-15

Prescribed Textbook:

[1] Shanti Narayan, Differential Calculus - S. Chand & Company, New Delhi. (**Unit-1 & 2**)

[2] B. C.Das and B.N Mukherjee, Calculus , U.N. DHUR & SONS PRIVATELTD (**Unit-1 & 2**)

[3] B. C.Das and B.N Mukherjee, Integral Calculus, U.N. DHUR & SONS PRIVATELTD (**Unit-3 & 4**)

[4] Shanti Narayan and PK Mittal, Integral Calculus, S. Chand and Co. Pvt. Ltd., (**Unit-3 & 4**)

Reference Books:

[1] Debasish Sengupta, Applications of Calculus, Books and Allied (P) Ltd.,2019.

[2] Lipman Bers, Calculus Holt, Rinehart &Winston.

[3] S Narayanan & T. K. Manicavachogam Pillay, Calculus S. Viswanathan Pvt.Ltd., vol. I &II.

[4] Schaum's Outline of Calculus - Frank Ayres and Elliott Mendelson, 5th ed.USA: Mc. Graw.

[5] M. J. Strauss, G.L. Bradley and K. J. Smith, *Calculus,* 3rd Ed., Dorling Kindersley (India) P. L td. (Pearson Education), Delhi, 2007.

[6] H. Anton, I. Bivens and S. Davis, *Calculus,* 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.

SEMESTER-II

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMIN102-4	Integral Calculus and Differential Equations	Minor	3	0	1	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- Methods of integration and reduction formulae.
- Various methods to solve differential equations and introduce partial differential equations.

Course Learning Outcomes:

This course will enable the students to

- Get the basic idea of integration and reduction formulae.
- Utilize the knowledge of integration by parts for definite integral.
- Learn various methods for solving differential equations and partial differential equations.

Syllabus of the Course:

Unit-1 Integration and reduction formulae

A review of familiar integration formula, Integration by parts, Repeated integration by parts, Integration by parts for definite integrals, Integration by substitution, Reduction formulae to obtain the iterative formulae for the integrals of the form: $\int sin^n x\, dx$, $\int cos^n x\, dx$, $\int tan^n x\, dx$, $\int sec^n x\, dx$ and $\int sin^n x\, cos^m x\, dx$.

Contact Hour-15; Marks-22

Unit-2 First-order differential equations

First-order exact differential equations. Integrating factors, Rules to find an integrating factor. First-order higher-degree equations solvable for x, y, p. Methods for solving higher-order differential equations. The basic theory of linear differential equations, Wronskian and its properties.

Contact Hour-12; Marks-18

Unit-3 Higher Order Linear Differential Equations and Formation of Partial Differential Equations

Linear homogeneous equations with constant coefficients, Linear non-homogeneous equations, The method of variation of parameters, and The Cauchy-Euler equation; Order and degree of partial differential equations, Concept of linear and non-linear partial differential equations, Formation of first order partial differential equations.

Contact Hour-18; Marks-30

Prescribed Textbook:

[1] Anton, Howard, Bivens, Irl, & Davis, Stephen (2013), Calculus (10th ed.), John Wiley & Sons, Singapore Pvt. Ltd., Indian Reprint (2016) by Wiley Indian Pvt. Ltd. Delhi. (**Unit-1**)

[2] Ross, Shepley L(1984), Differential Equations(3rd ed.), John Wiley & Sons, Inc. (**Unit-2 & Unit-3**)

[3] I, Sneddon, Elements of Partial Differential Equations, McGraw-Hill, International Edition, 1967. (**Unit-3**)

Reference Books:

[1] M. J. Strauss, G. L. Bradley and K. J. Smith, Calculus (3rd ed.), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.

[2] Prasad, Gorakh (2016), Differential Calculus (19th ed.), Pothishala Pvt. Ltd., Allahabad.

[3] Kreyszig, Erwin (2011), Advanced Engineering Mathematics (10th ed.), John Wiley & Sons, Inc. Wiley India Edition 2015.

[4] Ordinary differential equations by M. D. Raisinghania.

SEMESTER-II

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATIDC102-3	Commercial Arithmetic-II	IDC	2	0	1	3

Course Learning Objectives:

The primary objective of this course is to introduce:

- To understand ratio and proportion, profit and loss, and cost & expenditures.
- To understand the key concept of still water, upstream, downstream and stream in real-time under different circumstances.

Course Learning Outcomes:

This course will enable the students to

- Integrate the concept of basic mathematics for business.
- To learn different techniques of simplification of the real number system.
- To enable students to answer competitive examinations.
- To apply knowledge of business concepts and functions in an integrated manner

Syllabus of the Course:

Unit-1

Techniques of solving problems involving numbers system and decimal fraction to calculate the share of profit, simplification of an equation involving cost and expenditure, Average, Profit and loss.

Contact Hours- 15; Marks-25

Unit-2

Percentage, Ratio and proportion, Partnership, Time and Work, Situation in Boats and Stream, Simple problems on the train and other moving objects, different types of problems the in Calendar, number of days and dates to calculate the period of payments and share and problem related to clock.

Contact Hours- 15; Marks-25

Reference Books:

[1] R.S Agarwal, Quantitative, S Chand & Company Pvt, Ltd,2014
[2] K Selvakumar, Mathematics for Commerce, Notion Press Chinnai,2014
[3] M.K. Bhowal, Fundamental of Mathematics, Asian Books Pvt.Ltd New Delhi, 2009
[4] Martin Anthony and Norman Biggs, Mathematics for Economics and Finance: Methods and Modelling, Cambridge University, Cambridge,1996

SEMESTER-II

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATSEC102-3	Programming in C	SEC	2	1	0	3

Course Learning Objectives:

The primary objective of this course is to introduce:

- C programming in the context of mathematics.
- Transmit a starting orientation using available mathematical libraries, and their applications

Course Learning Outcomes:

This course will enable the students to

- Understand and learn data-types, Library functions of C
- Used the programming concepts of C to mathematical investigation and problem solving.
- Learn about applications in factorization of an integer, Cartesian geometry and uses understanding in various applications in algebra
- In practical students learn about the roots of a quadratic equation, solution of sin(x), cos(x) with the help of functions

Syllabus of the Course:

Theory:

Unit-1

Algorithm and Flowchart, Variables, constants, Keywords, variable declaration, basic data types, operators and expression (arithmetic, relational, logical, assignment, conditional, increment and decrement), hierarchy of operations(s), library functions, structure of a C program, input/output functions and statements.

Contact Hours-15; Marks-20

Unit-2

Control Statements: if-else statement (including nested if-else statement), switch statement. Loop control Structures (for and nested for and while). Break, continue, exit function. Arrays and subscripted variables: One and Two-dimensional array declaration, accessing values in an array, initializing values in an array, sorting of numbers in an array, addition and multiplication of matrices with the help of array, Functions: function declaration, actual and formal arguments, function prototype, calling a function by value, recursive function.

Contact Hours-15; Marks-20

Programs for practical

To find sum, average, greatest or smallest of the digits of any given positive integers, factorial of a given positive integer, Fibonacci numbers, square root of a number, cube root of a number, sum of different algebraic and trigonometric series, root of quadratic equation, a given number to be prime or not, reversing digits of an integer. Sorting of numbers in an array, to find addition, subtraction and multiplication of matrices. To find sin(x), cos(x) with the help of functions.

Contact Hours-15; Marks-10

Prescribed Textbooks:

T. Jeyapoovan, A First Course in Programming with C T. Jeyapoovan, Vikash Publishing House Pvt. Ltd

Reference Books:

[1] E. Balaguruswamy, Programming with C, Schaum Series.

[2] Y. Kanetkar, *Let us C*, B.P. Publication Elizabeth Castro and Bruce Hyslop, *HTML and CSS: Visual QuickStart Guide*, Peachpit Press, 2013.

SEMESTER-III

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMAJ201-4	Elements of Real Analysis	Major	3	0	1	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- The Algebraic and Order Properties of Real Numbers
- The boundedness of the Real numbers
- Sequences and their convergences
- Series and their convergences

Course Learning Outcomes:

This course will enable the students to

- To learn in-depth about the suprema and infima of real numbers and their applications

- To learn about the convergence and the divergence of real sequences and their series.

Syllabus of the Course:

Unit-1 Basics of Real Analysis

The Algebraic and Order Properties of $\mathbb{R}$, Inequalities including Bernoulli's Inequality, Absolute value and the real line, Neighbourhood of a point, Bounded above and bounded below sets, Suprema and infima, The completeness property of $\mathbb{R}$ and $\mathbb{Q}$, Applications of the supremum property, Archimedean Property of $\mathbb{R}$, Density of rational numbers in $\mathbb{R}$, Intervals, (up to Nested Interval Property), Countable and uncountable sets, Countability of $\mathbb{Z}$, $\mathbb{R}$, $\mathbb{N} \times \mathbb{N}$, $\mathbb{Q}$, [0, 1] and related theorems.

Contact Hour-20; Marks-22

Unit-2 Sequences of Real Numbers

Sequences, The limit of a sequence with examples and related theorems, Bounded sequence, Limit Theorems, Squeeze theorem, Monotone Sequences, and Monotone Convergence Theorem; Euler's Number, Subsequences, Divergence Criteria, Bolzano Weierstrass Theorem for Sequences, Monotone Subsequence Theorem, Cauchy sequence, and Cauchy's Convergence Criterion with applications.

Contact Hour-20; Marks-25

Unit-3 Infinite Series of Real Numbers

Basic concepts and examples, General Term Test, Grouping, Cauchy Criterion for convergence of series, Linearity of sums of series, Nonnegative series, The Integral Test, p-series, Comparison Test, Limit Comparison Test, Ratio Test, Root Test, Alternating series Test, Absolute and Conditional convergence.

Contact Hour-20; Marks-23

Prescribed Textbooks:

[1] Bartle, Robert G., & Sherbert, Donald R. (2015). *Introduction to Real Analysis* (4^{th} ed.). Wiley India Edition. New Delhi (**For Units-1 & 2**).

[2] Denlinger, Charles G. (2011). *Elements of Real Analysis*. Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015(**For Units 3**).

Reference Books:

[1] Ross, Kenneth A. (2013). *Elementary Analysis*: *The Theory of Calculus* (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian Reprint.

[2] Thomson, Brian S., Bruckner, Andrew. M., & Bruckner, Judith B. (2001). *Elementary Real Analysis.* Prentice Hall.

SEMESTER-III

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMAJ202-4	Differential Equations (ODE)	Major	3	1	0	4

Course Learning Objectives:

The primary objective of this course is to introduce:

The primary objective of this course is to introduce the students to the exciting world of ordinary differential equations, mathematical modeling and their applications.

Course Learning Outcomes:

This course will enable the students to

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

Syllabus of the Course:

Theory:

Unit-1 First-Order Differential Equations

Basic concepts and origin of ordinary differential equations, explicit, implicit, singular, general and particular solutions of a differential equation; initial value problems, and existence of solutions; Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors and transformations.

Contact Hour-12; Marks-14

Unit-2 Formulation and Analysis of Mathematical Models

Introduction to compartmental model, exponential decay model, lake pollution model (case study of Lake Burley Griffin), drug assimilation into the blood (case of a single cold pill, case of a course of cold pills), exponential growth of population, density- dependent growth model, limited growth with harvesting, predatory-prey model and its analysis, epidemic model of influenza and its analysis, battle model and its analysis, Equilibrium points, Interpretation of phase plane.

Contact Hour-15; Marks-16

Unit-3 Second and Higher-Order Differential Equations

General solution of homogeneous equation of second order, principle of super position for a homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, method of undetermined coefficients, method of variation of parameters, Cauchy-Euler equation.

Contact Hour-18; Marks-20

Practical: **Contact Hours: 30: Marks: 20**

Practical / Lab work to be performed in a computer Lab.
List of Practicals using Mathematica/MATLAB/Scilab/Python etc.

1. Solutions of following differential equations.

   a) $\frac{dy}{dx} + 2\left(\frac{y}{x}\right) = \sin x$

   b) $\frac{dy}{dx} = \mathrm{y}\ \tan \mathrm{x} - 2\sin x$

   c) $x^2 \frac{d^2y}{dx^2} + 2x\frac{dy}{dx} = \log x$

   d) $\frac{d^2y}{dx^2} + 3\frac{dy}{dx} + 2y = x + \cos x$

e) $x^3\frac{d^3y}{dx^3} + 3x^2\frac{d^2y}{dx^2} + x\frac{dy}{dx} + 8y = 0$

f) $x^3\frac{d^3y}{dx^3} - x^2\frac{d^2y}{dx^2} + 2x\frac{dy}{dx} - 2y = x^3 + 3x$

2. Plotting of family of solutions of following differential equations.

   a) $\frac{dy}{dx} = 0.2,\ y(0) = 1$

   b) $2\frac{d^2y}{dx^2} - 5\frac{dy}{dx} + 2y = 0, y(0) = 0, y'(0) = 1,$

   c) $\frac{d^3y}{dx^3} - e^x = 0; y(0) = 3, y'(0) = 1, y''(0) = 5$

3. Growth and decay model (exponential case only).
4. Lake pollution model (with constant/seasonal flow and pollution concentration).
5. Density-dependent growth model.
6. Limited growth of population (with and without harvesting).
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).
9. Battle model (basic battle model, jungle warfare, long range weapons).

Prescribed Textbooks:

[1] Barnes, Belinda &Fulford, Glenn R. (2015). Mathematical Modelling with Case Studies, Using Maple and MATLAB (3rd ed.). CRC Press, Taylor & Francis Group. (**Unit-2**)

[2] Edwards, C. Henry, Penney, David E., & Calvis, David T. (2015). Differential Equation and Boundary Value Problems: Computing and Modeling (5th ed.). Pearson Education.(**Unit-3**)

[3] Ross, Shepley L. (2004). Differential Equations (3rded.). John Wiley & Sons. India (**Units-1 & 3**)

Reference Books:

[1] Martha L Abell, James P Braselton, Differential Equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.

[2] M. D. Raisinghania, Ordinary and Partial Differential Equations, S Chand, 2018

SEMESTER-III

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMIN201-4	Analytical Geometry	Minor	3	0	1	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- The systems of polar co-ordinate systems, transformation of coordinate axes, pair of straight lines.
- The basic concepts of parabola, ellipse and hyperbola
- Concepts of tangents and normals, condition of tangency, pole and polar o the conic section.
- Rectangular coordinates in 3-dimensional space, Planes in 3-dimensional space.
- Equation of a sphere, plane section of sphere, tangents and tangent plane to a sphere

Course 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 the Course:

Unit-1 Transformation of coordinates

Polar coordinate system, transformation of Cartesian coordinates to polar coordinates, transformation of coordinate axes, pair of straight lines.

Contact Hour-10; Marks-15

Unit-2 General second degree equations

Classification of quadratic equation representing lines, parabola, ellipse and hyperbola, tangents and normals to the conics, parametric forms of tangents and normal, condition of tangency, pole and polar, centre of a conic, equation of pair of tangents, reduction to standard forms.

Contact Hour-25; Marks-27

Unit-3 Sphere, Cone and Cylinder

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.

Contact Hours-25; Marks-28

Prescribed Textbook:

[1] P. R. Vittal: *Analytical Geometry-2D & 3D*, Pearson Education, 2013.

[2] 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.

[3] J. G. Chakravorty and P. R. Ghosh: *Analytical Geometry and Vector Analysis,* U. N. Dhur & Sons Pvt. Ltd, 1973.

Reference Books:

[1] S.L. Loney: *The Elements of Coordinate Geometry*, McMillan and Company, London, 2018.

[2] Shanti Narayan and P. K. Mittal: *Analytical Solid Geometry*, S. Chand & Company, 2007.

[3] Jyoti Das: *Analytical Geometry*, Academic Publisher, 2011.

[4] Henry B. Fine and H. D. Thompson: *Coordinate Geometry,* the Macmillan Company, 1909.

[5] George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry*, Pearson Education, 2010.

[6] Robert J. T. Bell: *An Elementary Treatise on Coordinate Geometry of three dimensions,*

Macmillan India Ltd., 1923.
[7] P. K. Jain: *A Textbook of Analytical Geometry*, New Age Publication, 2014.

SEMESTER-III

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATIDC201-3	Logic and Graphical Representation of Data	IDC	2	0	1	3

Course Learning Objectives:

The primary objective of this course is to introduce:

- Logical calculus
- Graphical representation of data

Course Learning Outcomes:

This course will enable the students to:

- Understand about logics in mathematics
- Understand to analyze data graphically

Syllabus of the Course:

Unit-1 Logic

Propositions, truth values and truth tables, negation, conjunction and disjunction, implications, bi-conditional propositions, converse, contrapositive and inverse propositions, propositional equivalence: logical equivalences, predicates and quantifiers, tautology and contradiction, Analysis of arguments. Examples and exercises on these topics.

Contact Hours- 15; Marks-25

Unit-2 Graphical Representation of Data

Bar charts with spreadsheets, histograms and pie charts with spreadsheets, line plots, line plots and graphs in spreadsheets, identifying trends from graphs, linear interpolation and line of the best fit, scatter plots in spreadsheets, locating the center, mode, median and mean and their calculations with spreadsheets, percentiles, percentiles in spreadsheets, percent rank, variance and standard deviation.

Contact Hours- 15; Marks-25

Prescribed Textbooks:

[1] Steve Warner, *Pure Mathematics of Beginners*, Get 800 LLC, 2018. (**For Unit-1**)
[2] Shobha Bagai, Amber Habib and Geetha Venkataraman, *A Bridge to Mathematics*, Saga Publications India Pvt Ltd. 2017. **(For Unit-2**)

Reference Books:

[1] David M. Burton, *Elementary Number Theory*, McGraw Hill Education, 2017.
[2] Ajit Kumar, S. Kumaresen and Bhaba Kumar Sarma, *A Foundation Course in Mathematics*, Narosa Publications, 2018.
[3] Paul R. Halmos, *Naïve Set Theory*, Springer, 1998.

SEMESTER-III

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATSEC201-3	**SciLab**	SEC	2	1	0	3

Course Learning Objectives:

The primary objective of this course is to introduce:

- To give working knowledge of Scilab typesetting language.
- To create or import graphics into Scilab.

Course Learning Outcomes:

This course will enable the students to

- Get the basic idea of Scilab and how to install it.
- Learn to write equations, matrix and tables.
- Implement simple mathematical equations in numerical computing environment.
- Draw 2D and 3D graphs and export it.

Syllabus of the Course:

Theory + Practical

Unit-1 Overview of Scilab

Introduction to Scilab and its features, Installing Scilab on different platforms, Different data types in Scilab, Basic arithmetic and logical operators in Scilab, Expressions and their evaluation in Scilab, Variables and arrays, Initialising variables in Scilab, Multidimensional arrays.

Contact Hours-20; Marks-20

Unit-2 Applications of Scilab

Basic plot commands in Scilab, plotting 2D and 3D graphs in Scilab, Formatting and customizing plots, Saving and exporting graphs, Matrices and vectors in Scilab, Numerical integration and differentiation in Scilab.

Contact Hours-25; Marks-20

Practical: **Contact Hours: 15; Marks: 10**

Practical along with theories of Units-I & II

Prescribed Textbooks:

[1] Sandeep Nagar, *Introduction to Scilab: For Engineers and Scientists*, Apress (2017).

Reference Books:

[1] Er. Hema Ramachandran, Dr. Achuthsankar S. Nair, *Computer SCILAB-A free software to MATLAB*, S Chand (2011).

[2] Anil Kumar Verma, *SCILAB: A Beginner's Approach*, Cengage Learning India Pvt. Ltd (2018).

SEMESTER-IV

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMAJ203-4	Group Theory	Major	3	0	1	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- Groups, Cyclic groups, permutation groups, normal subgroups, Lagrange's Theorem on the order of a finite group
- Homomorphism and isomorphism of groups

Course Learning Outcomes:

This course will enable the students to

- Understand groups and classify them as abelian, cyclic and permutation groups
- Explain the significance of the notion of cosets, normal subgroups and homomorphism of groups.

Syllabus of the Course:

Unit-1 Introduction to Groups

Definition and examples of groups, Elementary properties of groups, Order of a group and order of an element of a group; Subgroups and its examples, Subgroup tests; Center of a group and centralizer of an element of a group, Symmetries of a square and Dihedral groups.

Contact Hour-12; Marks-18

Unit-2 Cyclic Groups and Permutation Groups

Cyclic groups and their properties, Generators of a cyclic group; Classifications of subgroups of cyclic groups; Permutation groups, Cyclic decomposition of permutations and its properties, Even and odd permutations and the alternating group, Klein's group, Order of a permutation.

Contact Hour-11; Marks-17

Unit-3 Cosets, Lagrange's Theorem and Normal Subgroups

Costs and their properties, Lagrange's theorem and consequences; Stabilizer and orbit of a point, Orbit-Stabilizer Theorem, Definition and examples of normal subgroups, Quotient groups, Cauchy's Theorem for Abelian group.

Contact Hour-11; Marks-18

Unit-4 Isomorphism and Homomorphism of Groups

Group homomorphism, Isomorphism, and their properties, First, Second and Third Theorems of Isomorphism, Cayley's Theorem and application, Automorphisms and Inner automorphisms.

Contact Hour-11; Marks-17

Prescribed Textbooks:

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

Reference Books:

[1] I.N. Herstein, *Topics in Algebra*, Wiley Eastern Limited, India, 1975.

[2] Dummit, David S. & Foote, Richard M. (2016). Abstract Algebra (3rd ed.). Student Edition. Wiley India.

SEMESTER-IV

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMAJ204-4	Numerical Methods	Major	3	1	0	4

Course Learning Objectives:

The primary 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.

Course Learning Outcomes:

This course will enable the students to

- Learn some numerical methods to find the zeroes of nonlinear functions of a single variable and solution of a system of linear equations, up to a certain given level of precision.
- Know about methods to solve system of linear equations, such as Gaussian Elimination and Gauss Jordan methods, LU decomposition method, Gauss Jacobi method, Gauss Seidel method.
- Compute the values for a tabulated function at points not in the table using interpolation techniques.
- Know about applications of numerical differentiation and integration to convert differential equations into difference equations for numerical solutions.

Syllabus of the Course:

Theory:

Unit- Methods for Solving Algebraic and Transcendental Equations

Rate and order of convergence; Bisection method, Method of false position, Secant method and Newton's method, Rate of convergence of these methods.

Contact Hour-12; Marks-12

Unit-2 Methods for solving systems of linear equations and interpolation

Gaussian Elimination and Gauss Jordan methods, LU decomposition method, Iterative methods: Gauss Jacobi method, Gauss Seidel method; Errors: Round off, Truncation, Absolute, Relative and Percentage, Lagrange and Newton interpolation: linear and higher order, Finite difference operators.

Contact Hour-15; Marks-18

Unit-3 Numerical Differentiation and Integration

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, Euler's method to solve ODE's, Modified Euler method, Runge−Kutta Method (fourth-order).

Contact Hour-18; Marks-20

Practical: **Contact Hours: 30 hours; Marks: 20**

Practical / Lab work to be performed in a computer Lab.
Use of computer algebra system (CAS) software: Mathematica/MATLAB/Scilab/Python etc., for developing the following Numerical programs:
List of Practicals:

(i) Bisection Method.
(ii) Secant Method.
(iii) Newton-Raphson Method.
(iv) Gauss Elimination method.
(v) L U decomposition Method.
(vi) Gauss-Jacobi Method.
(vii) Gauss−Seidel method.
(viii) Lagrange interpolation.
(ix) Newton interpolation.
(x) Trapezoidal rule.
(xi) Simpson's rule.
(xii) Euler's method.
(xiii) Runge−Kutta Method (fourth-order).

Text Books:

[1] Bradie, Brian. (2006). A Friendly Introduction to Numerical Analysis. Pearson Education India. Dorling Kindersley (India) Pvt. Ltd. Third impression 2011. **(For all Units)**
[2] M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering Computation, New age International Publisher, India, 5th edition, 2007. (**Unit-2**)

Reference Books:

[1] C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education, India, 2008.
[2] B.S. Grewal, Numerical Methods in Engineering and Science.

SEMESTER-IV

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMAJ205-4	Analytical Geometry (2D) and Vector Calculus	Major	3	0	1	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- 2D analytical geometry
- Vector calculus

Course Learning Outcomes:

This course will enable the students to:

- Understanding of mathematical concepts with geometrical/graphical interpretations. After studying this course student will be able to visualize mathematical concepts geometrically. Further, the course will enable students to know about the practical applicability of the concept of vectors to explain and analyze physical situations. Students will acquire basic knowledge and background to understand other courses either in mathematics or physics from this course.

Syllabus of the Course:

Unit- 1 Transformation of coordinates

Polar coordinate system, transformation of Cartesian coordinates to polar coordinates, transformation of coordinate axes, pair of straight lines.

Contact Hour-20; Marks-17

Unit-2 General second-degree equations

Classification of quadratic equation representing lines, parabola, ellipse and hyperbola, tangents and normals to the conics, parametric forms of tangents and normal, condition of tangency, pole and polar, centre of a conic, equation of pair of tangents, reduction to standard forms.

Contact Hour-20; Marks-25

Unit-3 Vector Calculus

Scalar triple product, vector triple product, Definition of vector field, Gradient, Divergence and Curl, Line integrals, Green's theorem and its application to find area, Definition of surface, Stokes' theorem and the divergence theorem.

Contact Hour-20; Marks-28

Prescribed Textbooks:

[1] J. G. Chakravorty and P. R. Ghosh: *Analytical Geometry and Vector Analysis*, U. N. Dhur & Sons Pvt. Ltd, 1973.

[2] 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.

[3] Spiegel, M. R., Schwam Series.

[4] Richard E. Johnson, *Vector Algebra,* Krishna Prakashan Media (P) Ltd.

Reference Books:

[1] S.L. Loney: *The Elements of Coordinate Geometry*, McMillan and Company, London, 2018.

[2] Shanti Narayan and P. K. Mittal: *Analytical Solid Geometry*, S. Chand & company, 2007.

[3] Jyoti Das: *Analytical Geometry*, Academic Publisher, 2011.

[4] Henry B. Fine and H. D. Thompson: *Coordinate Geometry*, The Macmillan company, 1909.

[5] George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry*, Pearson

Education, 2010.
[6] Robert J. T. Bell: *An Elementary Treatise on Coordinate Geometry of three dimensions,* Macmillan India Ltd., 1923.
[7] P. K. Jain: *A Textbook of Analytical Geometry*, New Age Publication, 2014.
[8] P. R. Vittal: *Analytical Geometry-2D & 3D,* Pearson Education, 2013.

SEMESTER-IV

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMIN202-4	Vector Calculus	Minor	3	0	1	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- To have knowledge of different types of vector product.
- To have knowledge of Vector differentiation and about gradient. Divergent and curl

Course Learning Outcomes:

This course will enable the students to

- Understand the scalar and vector triple products.
- Understand the calculus of vector functions and their uses to develop the basic principles of planetary motion.

Syllabus of the Course:

Unit-1 Vector triple product

Vector and Scalar Triple Product, Geometric Interpretation, Distributive Law for Vector Product, Properties of vector and scalar triple product, Scalar triple product in terms of three non-coplanar vectors.

Contact Hour-10; Marks-15

Unit-2 Derivative of a vector

Vector function, Limit, continuity and derivative of a vector function, Derivatives of higher order, Derivative of sum and products, Derivative of scalar and vector product of two vectors and related theorems. Derivative of scalar and vector product of three vectors, Scalar point functions, scalar fields, Vector point functions, Vector fields, Partial derivatives, Level surfaces, Directional Derivative, normal derivative, The del operator ∇ and ∇^2, Gradient, Divergence and Curl and corresponding Vector Identities.

Contact Hour-35; Marks-35

Unit- 3 Line Integrals

Line integrals, Applications of line integrals, Fundamental theorem for line integrals, Conservative vector fields, Green's theorem, Area as a line integral.

Contact Hour-15; Marks-20

Prescribed Textbook:

[1] A.R. Vasistha, Vector Algebra by Krishna Prakashan Media(P) Ltd.
[2] Ghose and Maity, Vector Analysis, New Central Book Agency.
[3] Strauss, Monty J., Bradley, Gerald L., & Smith, Karl J. (2007). Calculus (3rd ed.).

Reference Books:

[1] Shantinarayan and J.N. Kapoor, Vector Calculus Shantinarayan and J.N. Kapoor
[2] Spiegel, Vector Calculus (Schaum's series)
[3] H.K. Das, Mathematical Physics, S. Chand & Company Ltd.

SEMESTER-V

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMAJ301-4	Ring Theory	Major	3	0	1	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- Rings and ideals.
- Homomorphism and isomorphism of rings
- Polynomials in terms of rings and fields and their factorizations
- Preliminary ideas on extension fields

Course Learning Outcomes:

This course will enable the students to

- Understand rings and their relations to a group.
- Interpret the number systems from a different perspective in an abstract way.
- Understand the notion of homomorphism of rings
- Understand zeros and factorization of polynomials in a ring and the difference between equality of polynomials in a ring and equality of functions.
- Understand some preliminary ideas to extend a field.

Syllabus of the Course:

Unit- 1 Introduction to Ring:

Definition and examples of rings, properties of rings, subrings, integral domains and fields, characteristics of a ring. Ideal, ideal generated by a subset of a ring, factor rings, operations on ideals, prime and maximal ideals.

Contact Hour-15; Marks-15

Unit-2 Ring Homomorphism:

Ring homomorphisms, properties of ring homomorphisms, Isomorphism theorems I, II and III, Field of Quotients.

Contact Hour-10; Marks-15

Unit-3 Polynomial Rings:

Notation and Terminology, Division algorithm and congruences, Zero of a polynomial, Principal Ideal Domain (PID), Factorization of polynomials, Reducibility and Irreducibility Tests of a polynomial, Content of polynomial, Primitive polynomials, Eisenstein's Criterion, Cyclotomic Polynomials, Maximality Test of a polynomial.

Contact Hour-20; Marks-20

Unit-4 Divisibility in Integral Domain:
Associate, Irreducible and Prime elements, Unique Factorization Domain (UFD), Ascending Chain Condition, Euclidean Domain (ED), Relation among PID, ED and UFD.

Contact Hour-15; Marks-20

Prescribed Textbooks:

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

Reference Books:

[1] I.N. Herstein, *Topics in Algebra*, Wiley Eastern Limited, India, 1975.
[2] John B. Fraleigh, *A First Course in Abstract Algebra*, 7th Ed., Pearson, 2002.

SEMESTER-V

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMAJ302-4	Metric Space	Major	3	0	1	4

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

- The usual idea of distance into an abstract form on any set of objects, maintaining its inherent characteristics, and the resulting consequences.
- The two important topological properties, namely connectedness and compactness of metric spaces.

Course Learning Outcomes:
This course will enable the students to

- Learn various natural and abstract formulations of distance on the sets of usual or unusual entities. Become aware of one such formulation leading to metric spaces.
- Analyse how a theory advances from a particular frame to a general frame.
- Appreciate the mathematical understanding of various geometrical concepts, viz. balls or connected sets etc. in an abstract setting.

Syllabus of the Course:
Unit- 1 Introduction to Metric Spaces
Definitions and examples, sequences in metric spaces and examples with their convergence, Cauchy sequences, Subsequences, Complete metric spaces, Completion of a metric space.

Contact Hour-15; Marks-17

Unit-2 Topology of a Metric Space
Open and closed balls, Neighborhood, Open set, Interior of a set, Limit point of a set, Derived set, Closed set, Closure of a set, Diameter of a set, Cantor's theorem, Subspaces.

Contact Hour-15; Marks-18

Unit-3 Continuity and Uniform Continuity in Metric Spaces

Continuous mappings, Sequential criterion and other characterizations of continuity, Extension Theorems, Uniform continuity and its characterizations, Urysohn's lemma, Homeomorphism, Isometry and equivalent metrics.

Contact Hour-15; Marks-18

Unit-4 Connectedness and Compactness

Connectedness, Connected subsets of $\mathbb{R}$, Connectedness and continuous mappings, Compactness and boundedness, Characterizations of compactness, and Continuous functions on compact spaces.

Contact Hour-15; Marks-17

Prescribed Textbooks:

[1] Shirali, Satish & Vasudeva, H. L. (2009). Metric Spaces. Springer. Indian Reprint 2019.

Reference Books:

[1] Kumaresan, S. (2014). Topology of Metric Spaces (2nd ed.). Narosa Publishing House. New Delhi.
[2] Rudin, Walter. Principles of Mathematical Analysis (3rd ed.).
[3] Simmons, George F. (2004). Introduction to Topology and Modern Analysis. McGraw-Hill Education. New Delhi.

SEMESTER-V

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMAJ303-4	Multivariate Calculus	Major	3	1	0	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- To understand the extension of the studies of single variable differential and integral calculus to functions of two or more independent variables.
- Also, the emphasis will be on the use of Computer Algebra Systems by which these concepts may be analyzed and visualized to have a better understanding.
- This course will facilitate to become aware of applications of multivariable calculus tools in physics, economics, optimization, and understanding the architecture of curves and surfaces in plane and space etc.

Course 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.

Syllabus of the Course:

Unit- 1 Calculus of Functions of Several Variables

Functions of several variables, Level curves and surfaces, Limits and continuity, Partial differentiation, Higher order partial derivative, Tangent planes, Total differential and differentiability, Chain rule, Directional derivatives.

Contact Hour-15; Marks-15

Unit-2 Extrema of Functions up to three variables

First and second partial derivative tests for relative extrema of functions of two variables, and absolute extrema of continuous functions, Method of Lagrange multipliers, Constrained optimization problems.

Contact Hour-10; Marks-10

Unit-3 Double and Triple Integrals

Double integration over rectangular and nonrectangular regions, Double integrals in polar coordinates, Triple integral 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.

Contact Hour-20; Marks-25

Practical: **Contact Hours: 30; Marks: 20**

Practical / Lab work to be performed in Computer Lab.

List of practicals to be done using **Mathematica** / MATLAB / Maple/Maxima/Scilab, etc.

i. Let $f(x)$be any function and L be any real number. For given a and $\varepsilon > 0$, find a $\delta > 0$ such that for all x satisfying $0 < |x - a| < \delta$, the inequality $0 < |f(x) - L| < \varepsilon$ holds.

ii. For example

$f(x) = x + 1\ , L = 5\ , a = 4, \varepsilon = 0.01$

$f(x) = \sqrt{x+1}\ , L = 1\ , a = 4, \varepsilon = 0.1$

$f(x) = x^2\ , L = 4\ , a = -2, \varepsilon = 0.5$

$f(x) = \frac{1}{x}\ , L = -1\ , a = -1, \varepsilon = 0.1$

iii. Discuss the limit of the following functions when $x \to 0$:

$$\pm\frac{1}{x}\ , \sin\frac{1}{x}\ , \cos\frac{1}{x}\ , x\sin\frac{1}{x}\ , x\cos\frac{1}{x}\ , x^2\sin\frac{1}{x}, \frac{1}{x^n}(n \in \mathbb{N}), \frac{1}{x}\sin\frac{1}{x}$$

iv. Discuss the limit of the following functions when $x \to \infty$:

$e^{\pm\frac{1}{x}}$, $\sin\frac{1}{x}\ , \frac{1}{x}, e^{\pm x}, \frac{x}{1+x}\ , x^2\ \sin\frac{1}{x}$ etc.

v. Discuss the continuity of the functions at x = 0 in the Practical 2.

vi. Draw the following surfaces and find level curves at the given heights:

$f(x,y) = 10 - x^2 - y^2\ , z = 1\ , z = 6, z = 9$

$f(x,y) = x^2 + y^2\ , z = 1\ , z = 6, z = 9$

$f(x,y) = x^3 - y\ , z = 1\ , z = 6$

$f(x,y) = x^2 + \frac{y^2}{4}\ , z = 1\ , z = 5, z = 8$

$f(x,y) = 4x^2 + y^2\ , z = 0\ , z = 6, z = 9$

vii. Draw the following surfaces and discuss whether limit exits or not as (x, y) approaches to the given points. Find the limit, if it exists:

$f(x,y) = \frac{x+y}{x-y}$, $(x,y) \to (0,0) and\ (x,y) \to (1,3)$

$f(x,y) = \frac{x+y}{\sqrt{x^2+y^2}}$, $(x,y) \to (0,0) and\ (x,y) \to (2,1)$

$f(x,y) = \frac{x+y^2}{x^2+y^2}$, $(x,y) \to (0,0)$

$f(x,y) = \frac{x^2-y^2}{x^2+y^2}$, $(x,y) \to (0,0) and\ (x,y) \to (2,1)$

$f(x,y) = (x+y)e^{xy}$, $(x,y) \to (0,0)\ and\ \ (x,y) \to (1,0)$

viii. Draw the tangent plane to the following surfaces at the given point:

$f(x,y) = \sqrt{x^2+y^2}\ at\ (3,1,\sqrt{10})$

$f(x,y) = 10 - x^2 - y^2\ at\ (2,2,2)$

$x^2 + y^2 + z^2 = 9\ \ at(2,0,0)$

$z = \tan^{-1} x\ \ at\ \left(1,\sqrt{3},\frac{\pi}{3}\right)\ and\ \left(2,2,\frac{\pi}{4}\right)$

$z = \log|x+y^2|\ \ at\ (-3,-2,0)$

ix. Find critical points and identify relative maxima, relative minima or saddle points to the following surfaces, if it exists:

$z = x^2 + y^2$ (ii) $z = 1 - x^2 - y^2$ (iii)$z = \ y^2 - x^2$ (iv) z= x^2y^4

x. Draw the following regions D and check whether these regions are of Type I or Type II:

$D = \{(x,y) : 0 \le x \le 2,\ 0 \le y \le e^x)$

$D = \{(x,y) : \log y \le x \le 2,\ 0 \le y \le e^2)$

$D = \{(x,y) : 0 \le x \le 1,\ x^3 \le y \le 1$ (iv) $D = \{(x,y) : 0 \le x \le \frac{\pi}{4}, \sin x \le y \le \cos x$

The region $D\ bounded\ by\ y = x^2 - 2\ \ and\ the\ line\ \ y = x.$

Prescribed Textbook:

[1] Strauss, Monty J., Bradley, Gerald L., & Smith, Karl J. (2007). Calculus (3rd ed.). Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). Delhi. Indian Reprint 2011. Department of Mathematics, University of Delhi 27.

Reference Books:

[1] Marsden, J. E., Tromba, A., & Weinstein, A. (2004). Basic Multivariable Calculus. Springer (SIE). First Indian Reprint.

[2] James Stewart "Multivariate Calculus: Concepts and Contexts" 3rd edition

[3] Thomas' Calculus by Joel Hass, Christopher Heil, Maurice D. Weir, Pearson India Service Ltd. ,14 edition.

[4] Calculus (10th edition) by H. Anton, I. Bivens and S. Davis; Wiley India Pvt. Ltd.

SEMESTER-V

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMAJ304-4	Mechanics	Major	3	0	1	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- The knowledge of forces which will help students in their daily life.
- Velocity and acceleration parameters which give the knowledge about how the vehicles move.

Course Learning Outcomes:

This course will enable the students to

- Understand and learn the concepts in statics such as moments, couple, equilibrium in both two and three dimension
- Know the theory behind centre of gravity of arc, plane area etc.
- Learn about conservation of mechanical energy and work-energy equation.
- Learn about Translation and rotational motion of rigid body.

Syllabus of the Course:

Unit- 1

Composition and resolution of forces, Parallelogram of forces, Triangle of forces, Converse of triangle of forces, Lami's Theorem, Parallel forces, Varignon's theorem, Moment of a force about a point and a line, Couple and Resultant of couples.

Contact Hour-15; Marks-17

Unit-2

Reduction of a system of coplanar forces, Conditions of equilibrium of a system of coplanar forces. Centre of Gravity of an arc, plane area, surface of revolution, solid of revolution.

Contact Hour-15; Marks-18

Unit-3

Motion in a straight line, Motion in a plane, radial and transverse velocities and acceleration, angular velocity and acceleration, tangential and normal acceleration, relative motion, motion in a straight line with constant and variable accelerations.

Contact Hour-15; Marks-18

Unit-4

simple harmonic motion, Hooke's law, motion under inverse square law, Projectile, projection to pass through a given point, range on an inclined plane, envelop of the paths, Work, Energy, principle of energy, impulse, conservation of linear momentum.

Contact Hour-15; Marks-17

Prescribed Textbooks:

[1] B. C. Das and B.N Mukherjee, Statics, U.N. Dhur & Sons Privateltd
[2] M. Ray, G.C Sharma, A Text Book on Dynamics, S. Chand & Company Ldt.

Reference Books:

[1] A. R. Vashistha, & K.K Gupta, Statics, Krishna Prakashan
[2] A. R. Vashistha, & K.K Gupta, Dynamics Part-1 and Part-2, Krishna Prakashan
[3] L Loney the Element of Statics and Dynamics Part-1 & Part-2, Radha Publishing House, Calcutta.

SEMESTER-V

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMIN301-4	Mechanics	Minor	3	0	1	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- The knowledge of forces which will help students in their daily life.
- Velocity and acceleration parameters which give the knowledge about how the vehicles move.

Course Learning Outcomes:

This course will enable the students to

- Understand and learn the concepts in statics such as moments, couple, equilibrium in both two and three dimensions
- Know the theory behind centre of gravity of arc, plane area etc.
- Learn about conservation of mechanical energy and work-energy equation.
- Learn about Translation and rotational motion of rigid body.

Syllabus of the Course:

Unit- 1 (Statics)

Composition and resolution of forces, Parallelogram of forces, Triangle of forces, Converse of triangle of forces, Lami's Theorem, Parallel forces, Varignon's theorem, Moment of a force about a point and a line, Couple and Resultant of couples, Reduction of a system of coplanar forces, Conditions of equilibrium of a system of coplanar forces.

Contact Hour-30; Marks-40.

Unit-2 (Dynamics)

Motion in a straight line, Motion in a plane, radial and transverse velocities and acceleration, angular velocity and acceleration, tangential and normal acceleration, relative motion, motion in a straight line with constant acceleration, simple harmonic motion, Hooke's law, motion under inverse square law.

Contact Hour-30; Marks-30

Prescribed Textbooks:

[1] B. C. Das and B.N Mukherjee, STATICS, U.N. DHUR & SONS PRIVATELTD
[2] M. Ray, G.C Sharma, A Text Book on DYNAMICS, S. CHAND & COMPANY LDT.

Reference Books:

[1] A. R. Vashistha, & K.K Gupta, Statics, Krishna Prakashan
[2] A. R. Vashistha, & K.K Gupta, Dynamics Part-1 and Part-2, Krishna Prakashan
[3] L Loney the Element of Statics and Dynamics Part-1 & Part-2, Radha Publishing House, Calcutta.

SEMESTER-VI

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMAJ305-4	Linear Algebra	Major	3	0	1	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- Vector spaces and their geometrical interpretation and dual spaces of a vector space
- Linear transformations and their matrix representations
- Eigenvalues and eigenvectors of a linear operator and their applications to determine the diagonalizability of a linear operator.
- Cayley-Hamilton Theorem and its applications
- Inner product and norms of vectors
- Orthonormal bases and their applications
- Algebra of linear operators

Course Learning Outcomes:

This course will enable the students to

- Understand the interpretation of vector spaces geometrically and in an abstract way.
- Understand subspaces generated by subsets and their significance in building a vector space.
- Learn the meaning of linear operators and their corresponding matrix representations with algebraic operations and their properties such as normality, unitary etc.
- Understand the significance of eigenvalues and eigenvectors in the diagonalization process of linear operators and their corresponding matrices

Syllabus of the Course:

Unit- 1 Introduction to Vector Space

Introduction, Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, bases and dimension, dimension of subspaces, dimension of sum, intersection and union of subspaces, quotient spaces.

Contact Hour-22; Marks-25

Unit-2 Linear Transformations and their Matrices

Linear transformations, null space, range, rank and nullity of a linear transformation, dimension theorem, Coordinate vector, matrix representation of a linear transformation, algebra of linear transformations. Composition of linear transformations and matrix multiplications,

Invertibility and isomorphisms and their related theorems, change of coordinate matrix, Dual spaces, Dual bases and annihilator.

Contact Hour-23; Marks-30

Unit-3 Diagonalization

Eigenvalues and eigenvectors, Characteristic polynomials, Eigenspace, Diagonalization and Diagonalizability Test, Invariant subspaces, T-cyclic subspace, Cayley-Hamilton Theorem and Minimal Polynomials.

Contact Hour-15; Marks-15

Prescribed Textbooks:

[1] Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, *Linear Algebra*, 4th Ed., Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.

Reference Books:

[1] I.N. Herstein, *Topics in Algebra*, Wiley Eastern Limited, India, 1975.
[2] S. Lang, *Introduction to Linear Algebra*, 2nd Ed., Springer, 2005.
[3] Surjeet Singh and Qasi Zameeruddin, Modern Algebra, Vikas Publishing House (Second Edition), New Delhi, 1975.

SEMESTER-VI

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMAJ306-4	Linear Programming Problem	Major	3	0	1	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- To develop a clear understanding of the concepts and principles of linear programming problem (LPP).
- To learn how to formulate LPPs and solve them using different techniques.
- To understand the interpretation of the solution and sensitivity analysis of LPP.
- To develop skills in the application of LPP in real-world situations.
- To enhance problem-solving abilities and analytical skills of students.

Course Learning Outcomes:

This course will enable the students to

- Develop mathematical models to represent real-world problems as LPPs.
- Use different methods to solve LPPs, including graphical method, simplex method, and duality theory.
- Interpret the solution of an LPP and perform sensitivity analysis.
- Apply LPPs to real-world situations, including resource allocation, production planning, and transportation problems.

- Enhance their problem-solving abilities and analytical skills, which are important for both academic and professional success.

Syllabus of the Course:

Unit- 1

Convex sets and their properties, Convex functions, Convex polygon, Introduction to optimization problems, Introduction to LPP, Assumptions and limitations of LPP, Graphical method of solutions of LPP, Basic feasible solution and its determination, Simplex method for LPP, Duality in LPP.

Contact Hour-20; Marks-25

Unit-2

Introduction to transportation problem, Balanced and unbalanced transportation problem, North-west corner rule, Least cost method, Vogel's approximation method, Introduction to assignment problem, Hungarian method, Variations of assignment problem.

Contact Hour-22; Marks-25

Unit-3

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

Contact Hour-18; Marks-20

Prescribed Textbooks:

[1] Mokhtar S. Bazaraa, John J. Jarvis, and Hanif D. Sherali, *Linear Programming and Network Flows*, 4th Edition Wiley, 2010.

[2] David G. Luenberger and Yinyu Ye,*Linear and Nonlinear Programming*, 4th Edition Springer, 2015.

[3] Taha Hamdy, *Operations Research: An Introduction*, 10th Edition Pearson Education India, 2017.

[4] Frederick S. Hillier and Gerald J. Lieberman, *Introduction to Operations Research*, 10th Edition McGraw-Hill Education, 2014.

Reference Books:

[1] G. Hadley, *Linear Programming*, Narosa Publishing House, New Delhi, 2002.

[2] Kanti Swarup, Operations Research, Sultan Chand & Sons, New Delhi.

SEMESTER-VI

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMAJ307-4	Complex Analysis	Major	3	1	0	4

Course Learning Objectives:

The primary objective of this course is to introduce:

This course aims to introduce the basic ideas of analysis for complex functions in complex variables with visualization through relevant practicals. Emphasis has been laid on Cauchy's theorems, series expansions and calculation of residues.

Course Learning Outcomes:

This course will enable the students to

- Learn the significance of differentiability of complex functions leading to the understanding of Cauchy−Riemann equations.
- Learn some elementary functions and valuate the contour integrals.
- Understand the role of Cauchy−Goursat theorem and the Cauchy integral formula.
- Expand some simple functions as their Taylor and Laurent series, classify the nature of singularities, find residues and apply Cauchy Residue theorem to evaluate integrals.

Syllabus of the Course:

Theory:

Unit- 1

Functions of complex variable, mappings, mappings by the exponential functions, limits, theorems on limits, limits involving point at infinity, continuity, derivatives, differentiations formulas, Cauchy−Riemann equations, Sufficient conditions for differentiability, polar coordinates, Analytic functions, Harmonic functions, uniquely determined analytic functions, reflection principle, branches and derivatives of logarithms.

Contact Hour-20; Marks-20

Unit-2

Integrals: Contours, contour integrals, upper bounds for moduli of contour integrals, Cauchy−Goursat theorem, Cauchy integral formula, An extension of Cauchy integral formula, Consequences of Cauchy integral formula, Liouville's theorem and the fundamental theorem of algebra, maximum modulus principle.

Contact Hour-15; Marks-15

Unit-3

Convergence of sequences and series, Taylor series, Laurent series, absolute and uniform convergence of power series, continuity of sums of power series, integration and differentiation of power series, uniqueness of series representations, multiplication and division of power series, residues and poles, singular points, Cauchy's residue theorem, residue at infinity, types of isolated singular points, residues at poles, zeros of analytic functions, zeros and poles.

Contact Hour-10; Marks-15

Practical: **Contact Hours: 30 Hours, Marks: 20**

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

i. Make a geometric plot to show that the n^{th} roots of unity are equally spaced points that lie on the unit circle $C_1(0) = \{z: |z| = 1\}$ and form the vertices of a regular polygon with n sides, for $n = 4, 5, 6, 7, 8$.

ii. Find all the solutions of the equation $z^3 = 8i$ and represent these geometrically.

iii. Write parametric equations and make a parametric plot for an ellipse centered at the origin with horizontal major axis of 4 units and vertical minor axis of 2 units.

Show the effect of rotation of this ellipse by an angle of $\frac{\pi}{6}$ radians and shifting of the centre from (0,0) to (2,1), by making a parametric plot.

iv. Show that the image of the open disk $\mathrm{D}_1(-1-i) = \{z: |z+1+i| < 1\}$ under the linear transformation $w = f(z) = (3-4i)z + 6 + 2i$ is the open disk:

$$\mathrm{D}_5(-1+3i) = \{w : |w+1-3i| < 5\}$$

v. Show that the image of the right half plane $\mathrm{Re}\, z = x > 1$ under the linear transformation $w = (-1+i)z - 2 + 3i$ is the half plane $v > u + 7$, where $u = \mathrm{Re}(w)$, etc. Plot the map.

vi. Show that the image of the right half plane $A = \left\{z : \mathrm{Re}\, z \geq \frac{1}{2}\right\}$ under the mapping $w = f(z) = \frac{1}{z}$ is the closed disk $\overline{\mathrm{D}_1(1)} = \{w: |w-1| \leq 1\}$ in the w- plane.

vii. Make a plot of the vertical lines $x = a$, for $a = -1, -\frac{1}{2}, \frac{1}{2}, 1$ and the horizontal lines $y = b$, for $b = -1, -\frac{1}{2}, \frac{1}{2}, 1$. Find the plot of this grid under the mapping $w = f(z) = \frac{1}{z}$.

viii. Find a parametrization of the polygonal path $\mathrm{C} = \mathrm{C}_1 + \mathrm{C}_2 + \mathrm{C}_3$ from $-1+i$ to $3-i$, where C_1 is the line from: $-1+i$ to -1, C_2 is the line from: -1 to $1+i$ and C_3 is the line from $1+i$ to $3-i$. Make a plot of this path.

Prescribed Textbooks:

[1] Brown, James Ward, & Churchill, Ruel V. (2014). *Complex Variables and Applications* (9th ed.). McGraw-Hill Education. New York.

Reference Books:

[1] Bak, Joseph & Newman, Donald J. (2010). *Complex Analysis* (3rd ed.). Undergraduate Texts in Mathematics, Springer. New York.

[2] Zills, Dennis G., & Shanahan, Patrick D. (2003). *A First Course in Complex Analysis with Applications*. Jones & Bartlett Publishers, Inc.

[3] Mathews, John H., & Howell, Rusell W. (2012). *Complex Analysis for Mathematics and Engineering* (6th ed.). Jones & Bartlett Learning. Narosa, Delhi. Indian Edition.

SEMESTER-VI

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMAJ308-4	Analytical Geometry (3D) and Differential Geometry	Major	3	0	1	4

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

- Different three dimensional shapes and their equations
- Different types of rectangular and non-rectangular coordinate systems.

Course Learning Outcomes:
This course will enable the students-

1. To develop mathematical skills in geometry from basic level to depth of knowledge.
2. To learn and visualize the fundamental ideas about coordinate geometry and learn to describe some of the surfaces by using analytical geometry.
3. To know about different types of coordinate systems apart from the rectangular coordinate system and to transform the coordinates in one system to another.

Syllabus of the Course:

Unit-1 Sphere, Cone and Cylinder

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.

Contact Hour-22; Marks-25

Unit-2 Central Conicoids and Paraboloids

Plane sections of a Conicoid, Confocal Conicoids, Reduction of General Equation of Second Degree, Generating lines, Paraboloids.

Contact Hour-16; Marks-20

Unit-3 Curvilinear Coordinates

Orthogonal curvilinear coordinates, Unit vectors in curvilinear systems, Special orthogonal coordinate systems, Cylindrical coordinates, Spherical coordinates, Parabolic cylindrical coordinates, Paraboloidal coordinates. Elliptic cylindrical coordinates. Prolate spheroidal coordinates. Oblate spheroidal coordinates. Ellipsoidal coordinates. Bipolar coordinates.

Contact Hour-22; Marks-25

Prescribed Textbooks:

[1] Robert J.T Bell, Elementary Treatise on Coordinate Geometry of three dimensions, Macmillan India Ltd.
[2] P.R. Vittal, Analytical Geometry 2d & 3D, Pearson
[3] S.L. Loney, The Elements of Coordinate Geometry, McMillan and Company, London.

Reference Books:

[1] Shanti Narayan and P. K. Mittal: Analytical Solid Geometry, S. Chand & company, 2007.
[2] Jyoti Das: Analytical Geometry, Academic Publisher, 2011.
[3] Henry B. Fine and H. D. Thompson: Coordinate Geometry, The Macmillan company, 1909.
[4] P. K. Jain: A Textbook of Analytical Geometry, New Age Publication, 2014.

SEMESTER-VI

Paper Code	Paper Title	Paper Type	Credit Distribution of the Course			Contact Hour Per Week
			Theory	Practical	Tutorial	
MATMIN302-4	Differential Calculus	Minor	3	0	1	4

Course Learning Objectives:

The primary objective of this course is to introduce:

- Limit, continuity and differentiability of a function
- Mean Value Theorems and their geometrical interpretation with applications
- Differential calculus to study the physical phenomena-the differential equation
- Arc length, curvatures and asymptotes

Course Learning Outcomes:

This course will enable the students to

- To learn the technique of finding nth derivative of some standard functions
- Identify and apply the intermediate value theorem.
- Learn the centre of curvature, asymptotes of the given curve.
- Learn to evaluate integrals, find arc -lengths, areas and volume.

Syllabus of the Course:

Theory:

Unit-1

Limits, Continuity, Differentiability and properties. Properties of continuous functions. $n^{(th)}$ Derivatives of Standard functions e^{ax+b}, $(ax + b)^n$, $\log(ax +b)$, $\sin(ax+b)$, $\cos(ax+b)$ $e^{ax}\sin(bx+c)$, $e^{ax}\cos(bx+c)$, Leibnitz theorem and its application.

Contact Hour-17; Marks-20

Unit-2

Intermediate value theorem, Rolle's Theorem, Lagrange's Mean Value theorem, Cauchy's Mean value theorem and examples. Taylor's theorem, Maclaurin's series, evaluation of limits using L'Hospital's rule.

Contact Hour-18; Marks-20

Unit-3

Polar coordinates, angle between the radius vector and tangent. Angle of intersection of two curves (polar forms), length of perpendicular from pole to the tangent, pedal equations. Derivative of an arc in Cartesian, parametric and polar forms, curvature of plane curve-radius of curvature formula in Cartesian, parametric and polar and pedal forms- center of curvature, asymptotes.

Contact Hour-25; Marks-30

Prescribed Textbook:

[1] Shanti Narayan, Differential Calculus - S. Chand & Company, New Delhi.

[2] B. C.Das and B.N Mukherjee, Calculus , U,N, DHUR & SONS PRIVATELTD

[3] B. C.Das and B.N Mukherjee, Integral Calculus, U,N, DHUR & SONS
[4] Shanti Narayan and PK Mittal, Integral Calculus, S. Chand and Co. Pvt. Ltd.

Reference Books:

[1] Debasish Sengupta, Applications of Calculus, Books and Allied (P) Ltd.,2019.
[2] Lipman Bers, Calculus Holt, Rinehart &Winston.
[3] S Narayanan & T. K. Manicavachogam Pillay, Calculus S. Viswanathan Pvt.Ltd., vol. I &II.
[4] Schaum's Outline of Calculus - Frank Ayres and Elliott Mendelson, 5th ed.USA: Mc. Graw.
[5] M. J. Strauss, G.L. Bradley and K. J. Smith, *Calculus,* 3rd Ed., Dorling Kindersley (India) P. L td. (Pearson Education), Delhi, 2007.
[6] H. Anton, I. Bivens and S. Davis, *Calculus,* 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.

SEMESTER - VII
Detailed Syllabus

Paper Code: MATADL 14014
Paper Title: Analysis-I
Theory Marks: 70
Internal Marks: 30

Course Outcome: Comparison of Infinite sets in terms of cardinality, various properties of sequences and series of real-valued functions, properties of continuous real-valued functions on an arbitrary set through the notions compactness and connectedness respectively.

Unit-I: **Marks: 15**
Elements of set theory, finite and infinite sets, cardinal numbers, countable and uncountable sets, Axiom of choice, Real number system.

Unit-II: **Marks: 20**
Sequences and series of real-valued functions, point wise and uniform convergence, Cauchy criterion for uniform convergence, relation of uniform convergence with continuity, differentiation and integration, Weierstrass approximation theorem.

Unit-III: **Marks: 20**
Compactness, Sequential compactness in Metric spaces, Heine Borel Theorem, Bolzano-Weierstrass Property, Totally bounded metric spaces, finite intersection property. Continuous functions on compact metric spaces, Baire's Category Theorem for complete metric space. Arzela Ascoli Theorem.

Unit-IV: **Marks: 15**
Connectedness in Metric spaces, intermediate value theorem, Continuous functions on connected metric spaces, Generalised Intermediate-Value Theorem, Components of a Metric Space.

Text Books:

[1] N. L. Carothers. Real Analysis, Cambridge University Press, UK, 2000.
[2] S. C. Malik and Savita Arora, Mathematical Analisis, New Age International Publishers, New Delhi, 2011

Reference Books:

[1] Apostol, T. M. Mathematical Analysis, Narosa Publishing House, 1985.
[2] Simmons, G. F. Introduction to Topology and Modern Analysis, Tata McGraw Hill Book Co. Ltd.,1963.

SEMESTER - VII

Paper Code: MATADL 14024
Paper Title: Functional Analysis
Theory Marks: 70
Internal Marks: 30

Course Outcome: This study can help the students to learn about basic concepts of functional analysis and can understand about Normed linear space, Banach spaces, lp spaces, Lp spaces, inner product space.

Unit-I: **Marks: 20**

Normed linear space, Banach spaces, lp spaces, Lp spaces, Quotient space, Function spaces of normed linear spaces, Convergence and completeness. Riesz lemma, basic properties of finite dimensional normed linear spaces and compactness, Bounded linear functional on Banach spaces.

Unit-II: **Marks: 20**

Equivalent norms, Continuous linear transformations between normed linear spaces, Hahn-Banach theorem and its consequences, Normed linear spaces of bounded linear transformations, Dual spaces, Conjugate of an operator, Uniform boundedness theorem and some of its consequences, Closed range theorem.

Unit-III: **Marks: 15**

Inner product spaces: inner product; Gram-Schmidt orthogonalization process, linear functionals and adjoints, self-adjoint, normal and unitary operators, orthogonal projections, spectral theorem for normal operators on a finite dimensional vector space. Bilinear forms: bilinear, positive and quadratic forms.

Unit-IV: **Marks: 15**

Hilbert spaces, polarization identity and parallelogram law; orthogonality. Orthonormal systems. Fourier expansion and relation to orthonormal basis, Bessel's inequality. Parsevai's identity. Structure of Hilbert spaces. Projection theorem. Riesz representation theorem. Adjoint of an operator on a Hilbert space. Reflexitivity of Hilbert spaces.

Text Books:

[1] Kreyszig E., Introductory Functional Analysis with Applications (John Wiley and Sons, New York, 1978).
[2] Lipschutz S., Lipson M., Schaum's Outline of Linear algebra, Mc Graw Hill, Third edition

Reference Books:

[1] Limaye, B. V. Functional Analysis (Wiley Eastern Ltd., New Delhi, 1989).
[2] Rudin, W. Functional Analysis (McGraw Hill, 2000).
[3] Halmos, P. R., Linear Algebra Problem Book, The Mathematical Association of America (MAA), USA, 1995.
[4] Halmos, P. R., Finite dimensional vector spaces, Springer Verlag, New York, 1987.
[5] Simmons, G. F. Introduction to Topology and Modern Analysis (Tata McGraw Hill Book Co. Ltd.,1963)

SEMESTER - VII

Paper Code: MATADL 14034
Paper Title: Partial Differential Equation
Theory Marks: 70
Internal Marks: 30

Course Learning Objectives:

1. Comprehend the fundamental concepts and origins of partial differential equations, focusing on both first-order and second-order equations.
2. Develop skills to solve various types of partial differential equations, including linear and nonlinear equations using different methods and techniques.
3. Apply analytical methods such as the method of characteristics, separation of variables, and integral transforms to find solutions to partial differential equations.
4. Formulate and solve boundary value problems and initial value problems associated with Laplace's equation, wave equation, and diffusion equation.
5. Relate the theoretical concepts of partial differential equations to practical applications in physics, engineering, and other scientific fields.

Course Learning Outcomes:

1. Demonstrate the ability to solve first-order partial differential equations using techniques such as Cauchy's method of characteristics and Jacobi's method.
2. Effectively solve second-order partial differential equations with constant and variable coefficients, and apply separation of variables and integral transforms.
3. Analyze and solve Laplace's equation for different boundary conditions, and utilize the theory of Green's function to address boundary value problems.
4. Formulate and solve wave equations in one, two, and three dimensions, and understand the application of the calculus of variations in solving related problems.
5. Apply analytical techniques to solve diffusion equations, including the use of separation of variables, integral transforms, and Green's functions to find solutions.

Unit-I: Partial Differential Equation of the first order **Marks: 15**

Partial Differential Equations – Origins of First Order Differential Equations – Cauchy's Problem for first order equations – Linear Equations of the first order – Nonlinear partial

differential equations of the first order – Cauchy's method of characteristics – Compatible system of First order Equations – Solutions satisfying Given Condition, Jacobi's method

Unit-II: Partial Differential Equations of the Second order **Marks: 15**

The Origin of Second Order Equations – Linear partial Differential Equations with constant coefficients – Equations with variable coefficients – Separation of variables – The method of Integral Transforms – Non – linear equations of the second order.

Unit-III: Laplace's Equation **Marks: 15**

Elementary solutions of Laplace equation – Families of Equipotential Surfaces – Boundary value problems – Separation of variables – Surface Boundary Value Problems – Separation of Variables – Problems with Axial Symmetry – The Theory of Green's Function for Laplace Equation.

Unit-IV: The wave equation **Marks: 15**

The Occurrence of the wave equation in Physics – Elementary Solutions of the One – dimensional Wave equations – Vibrating membrane, Application of the calculus of variations – Three-dimensional problem – General solutions of the Wave equation.

Unit-V: The Diffusion Equation **Marks: 10**

Elementary Solutions of the Diffusion Equation – Separation of variables – The use of Integral Transforms – The use of Green's functions

Text Book:

[1] Ian Sneddon – Elements of Partial Differential Equations – McGraw Hill International Book Company, New Delhi, 1983

Reference Books:

[2] M.D. Raisinghania Advanced Differential Equations S. Chand and Company Ltd., New Delhi, 2001

[3] K. Sankara Rao, Introduction to Partial Differential Equations, Second edition – Prentice – Hall of India, New Delhi 2006

[4] J.N. Sharma & K. Singh Partial Differential Equations for Engineers & Scientists, Narosa Publishing House, 2001

SEMESTER - VII

Paper Code: MATADL 14044
Paper Title: Tensor Analysis
Theory Marks: 70
Internal Marks: 30

Course Outcome:

By the end of this course, students will:

- Understand coordinate transformations, covariant and contravariant vectors, and tensor algebra.
- Work with symmetric, skew-symmetric, and mixed tensors.
- Use Christoffel symbols, solve geodesic equations, and perform covariant differentiation.

- Calculate vector divergence, curl, and the Laplacian operator.
- Learn about metric tensors, Riemannian spaces, and curvature tensors.
- Apply the Bianchi Identity and understand flat spacetime properties.
- Explore vector parallelism, tensor differentiation, and the Weyl tensor.

Unit-I: **Marks: 20**

Curvilinear coordinates; Transformation of coordinates; Summation Convention; Dummy Suffix; Real Suffix; Covariant and Contravariant vectors; Tensors of Second Order; Mixed Tensors; Kronecker Delta; Algebra of Tensors; Symmetric and Skew-Symmetric tensors; Outer multiplication, Contraction and Inner Multiplication, Quotient Law of Tensors, Reciprocal Symmetric Tensor; Relative Tensor; Fundamental Tensor; Group property of tensors; Tensor Field.

Unit-II: **Marks: 20**

Christoffel's symbols; Transformation of Christoffel's symbols; Differential equation of a Geodesic; Covariant differentiation of vectors; Covariant differentiation of tensors; Intrinsic derivative of a tensor; Laws of covariant differentiation of tensors; Divergence of a vector; Curl of a vector; Laplacian operator; Parallel displacement of a vector.

Unit-III: **Marks: 15**

The metric tensor; Riemannian metric; Riemannian space; Geodesic coordinates; Natural coordinates; Riemannian Christoffel's tensor; Curvature of a curve; First curvature; Covariant curvature tensor; Properties of covariant curvature tensor; Bianchi Identity; Flat space time.

Unit-IV: **Marks: 15**

Parallelism of vector of constant magnitude; Parallelism for vector of variable magnitude along a curve; Tensor differentiation; Laws of tensor differentiation; Weyl tensor.

Reference Books:

[1] Tensor Calculus and Riemannian Geometry: D. C. Agarwal.

[2] An Introduction to Riemannian Geometry and Tensor Calculus: Cambridge University Press: C. E. Weatherburn (1950).

[3] Tensor Analysis: De Gruyter: Heinz Schade**,** Klaus Neemann**,** Andrea Dziubek**,** Edmond Rusjan (2018).

SEMESTER - VII

Paper Code: MATADL 14054
Paper Title: Advanced Algebra
Theory Marks: 70
Internal Marks: 30

Course Outcome: This course will state about Properties of external direct products, Group actions, stabilizers, Sylow 's theorems, Extension fields and splitting fields.

Unit-I: **Marks: 15**

Properties of external direct products, the group of units modulo n as an external direct product, internal direct products, Fundamental Theorem of finite abelian groups.

Unit-II: **Marks: 20**

Group actions, stabilizers and kernels, permutation representation associated with a given group action, Applications of group actions: Generalized Cayley s theorem, Index theorem.

Unit-III: **Marks: 20**

Groups acting on themselves by conjugation, class equation and consequences, conjugacy in Sn, p-groups, Sylow ‘s theorems and consequences, Applications of Sylow’s Theorems, Cauchy's theorem, Simplicity of An for n=5, nonsimplicity tests.

Unit-IV: **Marks: 15**

Extension fields, splitting fields, zeros of an irreducible polynomial, perfect field, algebraic extension, finite fields, Construction of fields, Prime field.

Reference Books:

[1] Modern Algebra by Surjeet Singh and Qasi Zameeruddin, Vikas Publishing House (Second Edition), New Delhi, 1975.

[2] A First Course in Abstract Algebra by John B. Fraleigh, Published by Pearson Education (Singapore) Pte. Ltd.

[3] Topics in Algebra, Second edition (Wiley Eastern Ltd.) by I.N. Herstein.

[4] Joseph A. Gallian, Contemporary Abstract Algebra (Fourth Ed.), Narosa,1999.

[5] P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, Basic Abstract Algebra (Second Ed.), Cambridge Univ. Press (Indian Ed.1995).

SEMESTER - VIII

Paper Code: MATADL 14064
Paper Title: Mathematical Methods
Theory Marks: 70
Internal Marks: 30

Course Learning Objectives:

1. Develop a comprehensive understanding of linear integral equations of the first and second kinds, including Fredholm and Volterra types, and learn methods to solve these equations using separable kernels.
2. Gain proficiency in the use of Laplace transforms, including their basic properties, convolution theorem, and inverse transforms, and apply these techniques to solve ordinary and partial differential equations in initial and boundary value problems.
3. Learn the properties of Fourier transforms, including Fourier sine and cosine transforms, and apply these techniques to solve ordinary and partial differential equations, as well as to evaluate definite integrals.
4. Understand the principles of calculus of variations, including the variation of a functional and the Euler-Lagrange equation, and apply these concepts to find necessary and sufficient conditions for extrema.
5. Develop methods to solve boundary value problems in ordinary and partial differential equations using variational methods and integral transforms.

Course Learning Outcomes:

1. Demonstrate the ability to solve linear integral equations of the Fredholm and Volterra types using methods involving separable kernels, and understand characteristic numbers, eigenfunctions, and the resolvent kernel.
2. Effectively use Laplace transforms and their properties to solve ordinary and partial differential equations, particularly in the context of initial and boundary value problems.
3. Apply Fourier transforms, including Fourier sine and cosine transforms, to solve ordinary and partial differential equations, and evaluate definite integrals using these techniques.
4. Utilize the principles of calculus of variations to derive and solve the Euler-Lagrange equation, and determine the necessary and sufficient conditions for extrema in various functional forms.
5. Solve boundary value problems in ordinary and partial differential equations using variational methods and integral transform techniques, demonstrating a comprehensive understanding of the mathematical methods involved.

Unit-I: **Marks: 20**

Linear Integral Equations: Linear integral equation of the first and second kind of Fredholm and Volterra type, Solutions with separable kernels. Characteristic numbers and eigen functions, Resolvent kernel.

Unit-II: **Marks: 20**

Laplace Transform: Basic properties of Laplace transform convolution theorem and properties of convolution, Inverse Laplace transform, Application of Laplace transform to the solution of ordinary and partial differential equations of initial and boundary value problems.

Unit-III: **Marks: 20**

Fourier Transform: Fourier integral transform properties of Fourier transform; Fourier sine and cosine transform application of Fourier transform to ordinary and partial differential equations initial and boundary value problems evaluation of the definite integral.

Unit-IV: **Marks: 10**

Calculus of Variations: Variation of a functional, Euler-Lagrange equation, Necessary and sufficient conditions for extrema. Variational methods for boundary value problems in ordinary and partial differential equations.

Reference Books:

[1] M. D. Raisinghania, Advanced Differential equations.
[2] M. R. Spiegel Willard, Theory and Problems of Laplace Transform.
[3] A. S. Gupta.**,** Calculus of variation with Applications.
[4] P. Jones, Python: The Fundamentals of Python Programming, CreateSpace Independent Pub.
[5] S. Linge, H.P. Langtangen, Programming for computations, Springer.

SEMESTER - VIII

Paper Code: MATSPL 15074 (A)
Paper Title: Analysis-II
Theory Marks: 70
Internal Marks: 30

Course Outcome: Study about the properties of Riemann integral in more general framework by defining the integral as the limit of a sequence of simpler functions. Study about the convergence structure in LP Space.

Unit-I: **Marks: 15**
Lebesgue outer measure, Borel sets and their measurability, Characterisation of Measurable sets and non-measurable sets.

Unit-II: **Marks: 15**
Measurable functions, Littlewood's principles, Simple and step functions,Lebesgue integral of bounded functions, Bounded convergence theorem.

Unit-III: **Marks: 20**
Integral of non-negative functions, Fatou's Lemma, Monotone convergence theorem, Comparison with Riemann integral, Lebesgue general integral, Lebesgue Dominated convergence theorem, countability additivity and continuity of integration, uniform integrability: Vitali convergence theorem, Convergence in measure, integration of convex functions.

Unit-IV: **Marks: 20**
L^P Space: Completeness and approximation, duality and weak convergence.

Textbooks:

[1] Royden,H. L., Fitzpatrick, P. M. , Real Analysis, 4th Edition, PHI Learning Private Limited, New Delhi, 2011
[2] Barra, G. de, Measure Theory and Integration; Wiley-Eastern, 1981.

Reference Books:

[1] Jain, P. K. and Gupta, V. P., Lebesgue Measure and Integration, New Age International(P) Limited, New Delhi, 1986.
[2] Halmos, P. R., Measure Theory; Springer-Verlag, 1974.

SEMESTER - VIII

Paper Code: MATSPL 15074 (B)
Paper Title: Mathematical Modelling
External Marks: 70
Internal Marks: 30

Course Learning Objectives:

1. Develop a comprehensive understanding of the definition, importance, and classification of mathematical modelling, and learn the process of creating elementary mathematical models.
2. Learn to model single-species population dynamics using exponential and logistic growth models, including harvesting models and determining their critical values.
3. Gain proficiency in modelling with ordinary differential equations, including concepts of stability, steady states, and applications in various fields such as economics, ecology, and epidemiology.
4. Learn to construct and analyze mathematical models using difference equations, including applications in economics, finance, and population dynamics, and understand the basic theory of linear difference equations with constant coefficients.
5. Understand the derivation and application of partial differential equations in various situations, including solving the one-dimensional heat equation and wave equation.

Course Learning Outcomes:

1. Demonstrate the ability to define, classify, and construct elementary mathematical models, and understand the role of mathematics in solving real-world problems.
2. Effectively model single-species population dynamics using exponential and logistic growth models, analyze harvesting models, and determine critical values.
3. Apply ordinary differential equations to model growth and decay processes, analyze the stability of solutions, and use these models in practical applications such as economics, ecology, and epidemiology, including understanding basic reproduction numbers.
4. Construct and analyze mathematical models using difference equations, solve linear difference equations with constant coefficients, and apply these models to problems in economics, finance, and population dynamics.
5. Derive and solve partial differential equations arising from various situations, specifically solving the one-dimensional heat equation and wave equation, and apply these solutions to practical modelling scenarios.

Unit-I: **Marks: 20**

Introduction to Mathematical Modelling: Definition and Importance of Mathematical Modelling, Need, Classification, Modelling Process, Elementary Mathematical Models; Role of mathematics in Problem Solving.

Single Species Population Models: The Exponential Growth Model and the Logistic Growth Model, Harvesting Model and its Critical Value.

Unit-II: **Marks: 20**

Modelling with Ordinary Differential Equations: Overview of Basic Concepts in ODE and Stability of Solutions, Steady State and their Local and Global Stability, Linear and Non-linear Growth and Decay Models. Compartment models. Some Applications in Economics, Ecology, Modelling in Epidemiology (SIS, SIR, SIRS Models) and Basic Reproduction Number.

Unit-III: **Marks: 20**

Mathematical Models through Difference Equations, Some Simple Models, Basic theory of Linear Difference Equations with Constant Coefficients, Mathematical Modelling through Difference Equations in Economics and Finance, Mathematical Modelling through Difference Equations in Population Dynamics.

Unit-IV: **Marks: 10**

Mathematical Modelling through Partial Differential Equations, Situations Giving Rise to of Partial Differential Equation Models. The One-Dimensional Heat Equation: Derivation and Solution. Wave Equation: Derivation and Solution.

Reference Books:

[1] D. N. P. Murthy, N. W. Page and E. Y. Rodin, Mathematical Modelling, Pergamon Press.
[2] J. N. Kapoor, Mathematical Modelling, Wiley Estern Ltd.
[3] J.N. Kapur, Mathematical Models in Biology and Medicine, East-West Press.
[4] F. Charlton, Ordinary Differential and Differential equation, Van Nostarnd.
[5] Fred Brauer and Carlos Castillo-Chavez, Mathematical Models in Population Biology and Epidemiology, Springer.
[6] Frank R. Giordano, William Price Fox, Maurice D. Weir, A First Course in Mathematical Modelling, 4th Ed., Charlie Van Wagner.

SEMESTER - VIII

Paper Code: MATSPL 15084 (A)
Paper Title: Graph Theory I
External Marks: 70
Internal Mark: 30

Course Outcome: This course is an introduction to the theory of graphs intended for students of mathematics and other sciences. The course introduces in an elementary way some basic knowledge and primary methods in Graph Theory.

Unit-I: **Marks: 30**

The Basic: Graphs, Graph isomorphism, Regular and complete graph, Bipartite graph, Intersection Graph, line graph, block graph, Walk, trail, path, cycle, digraph, weighted graph and Adjacency matrix of a labeled graph, Degree partition.

Unit-II: **Marks: 20**

Tree: Basic properties of trees, Distance in trees, Spanning tree, Shortest path. Connectivity: Cut vertex, cut edge, blocks, Point-connectivity (connectivity) and line connectivity

Unit-III: **Marks:20**

Traversability: Euler tour, Eulerian graph, The Chinese postman problem, Hamilton cycle, Hamiltonian graph, Travelling salesman problem. Covering: Point cover, Edge cover, Independent sets, König theorems.

Books:

[1] Graph Theory, F. Harary, Narosha Publishing Co (Reprint 1998).
[2] Introduction to Graph Theory, D. B. West, Prentice-Hall, (2001).
[3] Basic Graph Theory, K. R. Parthasarathy, Tata McGraw Hill, (1994)
[4] Graph Theory with Applications, J. A. Bondy & U. S. R. Murty, North-Holland (1976).

SEMESTER - VIII

Paper Code: MATSPL 15084 (B)
Paper Title: Continuum Mechanics
External Marks: 70
Internal Marks: 30

Course Learning Objectives:

1. Understand the basic principles and assumptions of continuum mechanics, including the continuum hypothesis, mass, density, and various types of forces and stresses.
2. Develop the ability to analyze and compute stress and strain in materials, including the use of stress and strain tensors, principal stresses and strains, and stress invariants.
3. Gain insight into the kinematics of deformation, including the description of motion using Lagrangian and Eulerian frameworks, and the calculation of deformation gradients and strain tensors.
4. Learn the principles of fluid mechanics, including the conservation laws of mass, momentum, and energy, and apply these principles to the study of both viscous and inviscid fluids.
5. Utilize mathematical tools such as tensors, differential equations, and compatibility conditions to solve complex problems in continuum mechanics, including those involving stress, strain, and fluid flow.

Course Learning Outcomes:

1. Demonstrate an understanding of the continuum hypothesis and calculate mass, density, body forces, and surface forces in a given material.
2. Calculate stress components using Cauchy's law and stress tensor, and interpret normal and shear stresses, principal stress, stress invariants, and stress deviators.
3. Accurately describe the deformation of materials using Lagrangian and Eulerian descriptions, material and spatial coordinates, and calculate displacement and deformation gradients.
4. Analyze steady, uniform, linear, and irrotational motion, and understand the concepts of path lines, streamlines, and vortex lines, applying Reynolds transport theorem to fluid motion problems.
5. Apply the conservation principles of mass, linear momentum, angular momentum, and energy to solve problems involving both incompressible and compressible fluids, and calculate fluid pressure and viscous stress tensors.

Unit-I: **Marks: 20**

Continuum hypothesis, mass and density, body force and surface force, stress components, Cauchy's law, state of stress at a point, stress tensor, normal and shear stresses, principal stress, stress invariants, stress deviator, boundary condition for stress tensor.

Unit-II: **Marks: 20**

Continuum configuration, Lagrangian and Eulerian description, material and spatial coordinates, deformation, displacement and deformation gradients, stretch and rotation tensor, strain tensor, strain-displacement relations, infinitesimal strain tensor, interpretation of linear strain tensor, compatibility conditions, principal strains, strain deviator.

Unit-III: **Marks: 15**

Material and local time derivatives, velocity and acceleration, steady, uniform and linear motion, irrotational motion and potential flow, path lines, streamlines and vortex lines, Reynolds transport theorem, circulation and vorticity,

Unit-IV: **Marks: 15**

Conservation of mass, continuity equation, linear momentum principle, equation of motion, angular momentum principle, general solution of the equation of equilibrium, energy equation. Viscous and inviscid fluids, viscous stress tensor, fluid pressure, incompressible and compressible fluids.

Reference Books:

[1] Continuum Mechanics by D. S. Chandra Sekharaiah and Lokenath Debnath, Prism Books Pvt. Ltd., Bangalore.

[2] Mathematical Theory of Continuum Mechanics by Rabindranath Chatterjee, Narosa Publishing House.

[3] Schaum's Outline of Theory and Problems of Continuum Mechanics by George E. Mase., Schaum's Outline Series, McGraw-Hill.

SEMESTER - VIII

Paper Code: MATSPL 15094 (A)
Paper Title: General Topology
Theory Marks: 70
Internal Marks: 30

Course Outcome: Able to study about the properties of Metric spaces mainly related to continuous functions, in more general framework known as topological spaces.

Unit-I: **Marks: 15**

Topological spaces, base and sub-base, subspaces. Closure, interior and boundary of a subset: their properties. Neighbourhood structures. Characterisation of topology in terms of closure and interior operator. Continuity, open and closed functions, homeomorphisms, strong and weak topologies. Quotient and product spaces (finite product).

Unit-II: **Marks: 20**

Countability axioms, separability, Lindelof spaces. Separation axioms (T0, T1, T2, T3, T4), regularity, complete regularity, normality, Urysohn's Lemma (Statement only) and its applications.

Unit-III: **Marks: 20**

Compactness, local compactness, compactification, The Stone-Cech compactification. Alexandroff one point compactification, Connectedness, components, local and path connectedness.

Unit-IV: **Marks: 15**

Tychonoff product (Product topology on arbitrary product), Separation axioms and product spaces, Compactness and product spaces, Connectedness and product spaces.

Textbooks:

[1] Willard, S. General Topology, Addision-Wesley, Reading, 1970
[2] Munkres, J. R.**,** Topology: A first course (2/e), Prentice-Hall, 2000

Reference Books:

[1] Joshi, K. D.**,** Topology, Wiley-Eastern, 1988
[2] Dugundji, J., Topology, Allyn and Bacon, 1966
[3] Steen, L., Seebach, J., Counter Examples in Topology, Holt, Reinhart and Winston, New York, 1970

SEMESTER - VIII

Paper Code: MATSPL 15094 (B)
Paper Title: Differential Geometry
External Marks: 70
Internal Marks: 30

Course Learning Objectives:

1. Gain a comprehensive understanding of space curves, including their fundamental properties such as curvature, torsion, and their related intrinsic equations.
2. Learn about the intrinsic properties of surfaces, including metrics, direction coefficients, and the intrinsic nature of various surfaces like surfaces of revolution and helicoids.
3. Develop a deep understanding of geodesics on surfaces, including their canonical equations, normal properties, and theorems related to geodesic parallels and curvatures.
4. Examine non-intrinsic properties of surfaces such as the second fundamental form, principal curvatures, lines of curvature, and the characteristics of developable and minimal surfaces.
5. Apply fundamental equations of surface theory to analyze and understand the existence and properties of compact and complete surfaces, and explore specific concepts like Hilbert's lemma and umbilic points.

Course Learning Outcomes:

1. Demonstrate the ability to model space curves, calculate arc lengths, tangents, normals, binormals, and understand curvature, torsion, and the contact between curves and surfaces.
2. Characterize surfaces through their intrinsic properties, including isometric correspondence, metric properties, and the behavior of curves on these surfaces.
3. Solve problems involving geodesics on surfaces, including using canonical equations and understanding geodesic curvature, Gaussian curvature, and applying the Gauss-Bonnet Theorem.
4. Analyze and determine non-intrinsic properties of surfaces, such as principal curvatures and lines of curvature, and understand the properties of developable and minimal surfaces.
5. Apply the principles of surface theory to solve problems involving compact surfaces, surfaces of constant curvature, and complete surfaces, leveraging the fundamental existence theorems and specific geometric lemmas.

Unit-I: **Marks:20**

SPACE CURVES: Definition of a space curve - Arc length - tangent - normal and binormal - curvature and torsion - contact between curves and surfaces - tangent surface - involutes and evolutes - Intrinsic equations - Fundamental Existence Theorem for space curves - Helics.

Unit-II: **Marks: 20**

INTRINSIC PROPERTIES OF A SURFACE: Definition of a surface - curves on a surface - Surface of revolution - Helicoids - Metric - Direction coefficients - families of curves - Isometric correspondence - Intrinsic properties.

Unit-III: **Marks: 10**

GEODESICS: Geodesics - Canonical geodesic equations - Normal property of geodesics - Existence Theorems - Geodesic parallels - Geodesics curvature - Gauss - Bonnet Theorem - Gaussian curvature - surface of constant curvature.

Unit-IV: **Marks: 10**

NON-INTRINSIC PROPERTIES OF A SURFACE: The second fundamental form - Principal curvature - Lines of curvature - Developable - Developable associated with space curves and with curves on surface - Minimal surfaces - Ruled surfaces.

Unit-V: **Marks: 10**

DIFFERENTIAL GEOMETRY OF SURFACES: Fundamental Equations of Surface Theory - Fundamental Existence Theorem for surfaces - Compact surfaces whose points are umblics - Hilbert's lemma - Compact surface of constant curvature - Complete surfaces.

Reference Books

[1] T. J. Willmore, An Introduction to Differential Geometry, Oxford University Press, (17th Impression) New Delhi 2002. (Indian Print)

[2] Struik, D.T. Lectures on Classical Differential Geometry, Addison - Wesley, Mass. 1950.

[3] Kobayashi. S. and Nomizu. K. Foundations of Differential Geometry, Interscience Publishers, 1963.

[4] Wilhelm Klingenberg: A course in Differential Geometry, Graduate Texts in Mathematics, Springer-Verlag 1978.

[5] 4. J.A. Thorpe Elementary topics in Differential Geometry, Under - graduate Texts in Mathematics, Springer - Verlag 1979.

SEMESTER - VIII

Paper Code: MATSPL 15104
Paper Title: Computer Lab I
Practical Marks: 70
Internal Marks: 30

Course Outcome:
By the end of this course, students will:

- **Understand numerical computation fundamentals, error analysis, and floating-point arithmetic.**
- **Solve equations and perform optimization using methods like Bisection, Newton-Raphson, and Gradient Descent.**
- **Master numerical linear algebra, including matrix operations and eigenvalue computation.**
- **Solve differential equations numerically with methods such as Euler and Runge-Kutta, and apply these techniques to real-world problems.**

Unit-I: Introduction to Numerical Computation

- Overview of Numerical Computation
- Sources of Error: Round-off Error, Truncation Error
- Floating-Point Arithmetic
- Error Analysis and Stability
- Taylor Series Approximation
- Introduction to MATLAB/Python for Numerical Computation

Unit-II: Solving Equations and Optimization

- Root Finding: Bisection Method, Newton-Raphson Method, Secant Method
- Systems of Linear Equations: Gaussian Elimination, LU Decomposition
- Interpolation and Approximation: Lagrange Interpolation, Polynomial Approximation
- Numerical Differentiation and Integration
- Optimization Techniques: Gradient Descent, Newton's Method

Unit-III: Numerical Linear Algebra

- Matrix Operations: Addition, Multiplication, Inversion
- Eigenvalue and Eigenvector Computation: Power Method, QR Algorithm
- Least Squares Approximation
- Applications in Image Processing, Graph Theory, Signal Processing, and Data Analysis

Unit-IV: Numerical Solution of Differential Equations

- Ordinary Differential Equations (ODEs): Euler Method, Runge-Kutta Methods
- Stability and Convergence Analysis
- Boundary Value Problems: Shooting Method, Finite Difference Method
- Applications in Computational Biology, Fluid Dynamics

Textbook:

[1] P. Jones, Python: The Fundamentals of Python Programming, CreateSpaceIndependent Pub.
[2] S. Linge, H. P. Langtangen, Programming for computations, Springer.
[3] E. V. Krishnamurthy and S. K. Sen: Computer Based Numerical Algorithms, East-West press Pvt. Ltd. 1976.
[4] R. Johansson, Numerical Python, A Press.
[5] Numerical Methods for Engineers by Steven C. Chapra and Raymond P. Canale

References:

[1] Numerical Recipes: The Art of Scientific Computing by William H. Press et al.
[2] Introduction to Scientific Computing: A Matrix-Vector Approach Using MATLAB by Charles F. Van Loan

SEMESTER - IX

Paper Code: MATSPL 25014 (A)
Paper Title: Fuzzy Set Theory
Theory Marks: 70
Internal Marks: 30

Curse Outcomes: This course will help the students to learn about the fuzzy set theory and recent practical development of fuzzy set theory in the present environment.

Unit-I: **Marks: 30**

Fuzzy sets - basic definitions, α-level sets, convex fuzzy sets, basic operations on fuzzy sets, types of fuzzy sets, Cartesian products, algebraic products, bounded sum and difference, t-norms and t-conforms. Fuzzy sets in contrast of probability theory.

Unit-II: **Marks: 20**

The extension principle - the Zadeh's extension principle, image and inverse image of fuzzy Sets, fuzzy numbers, elements of fuzzy arithmetic.

Unit-III: **Marks: 20**

Fuzzy relations and fuzzy graphs, composition of fuzzy relations, min-max composition and its properties, fuzzy equivalence relations, fuzzy relation equations, fuzzy graphs.

Reference Books:

[1] Zimmermann, H. J., Fuzzy set theory and its Applications, Allied publishers Ltd., New Delhi, 1991.
[2] Klir, G. J. and Yuan, B., Fuzzy Sets and Fuzzy Logic: Theory and Applications, Prentice Hall of India, New Delhi, 1997.

SEMESTER - IX

Paper Code: MATSPL 25014 (B)
Paper Title: Fluid Dynamics I
Theory Marks: 70
Internal Marks: 30

Course Learning Objectives:

1. Comprehend the fundamental properties and dynamics of real and ideal fluids, including velocity, acceleration, and continuity equations.
2. Learn to derive and apply Bernoulli's theorem in various fluid flow scenarios, understanding its implications for fluid motion and energy conservation.
3. Develop skills to analyze two-dimensional fluid motion using complex velocity potentials, conformal mapping, and specific flow patterns around objects.
4. Gain insights into the stress components in real fluids, the relationship between stress and velocity gradients, and perform stress analysis in fluid motion.
5. Study vortex motion, including circular and rectilinear vortices, and understand the concepts of boundary layer theory, including boundary layer thickness and associated properties.

Course Learning Outcomes:

1. Demonstrate the ability to model and analyze fluid flow, using concepts such as velocity potential, streamlines, path lines, and streak lines, and apply Lagrange's and Euler's equations of motion.
2. Solve problems involving two-dimensional fluid motion using complex velocity potentials, sources, sinks, doublets, and conformal mapping techniques.
3. Conduct stress analysis in fluid motion, relating stress components to velocity gradients and understanding the rate of strain quadric of fluid elements.
4. Analyze elementary properties of vortex motion, apply Kirchhoff's vortex theorem, and solve problems involving motions due to circular and rectilinear vortices.
5. Apply boundary layer theory concepts to practical problems, calculate boundary layer thickness, displacement, momentum, and energy thickness, and understand their implications for fluid flow near boundaries.

Unit-I: **Marks: 20**

Real fluids and Ideal fluids; Velocity and Acceleration of a fluid particle; Equation of continuity; Boundary Surface; Stream lines, Path lines and streak lines; Velocity potential; Equation of motion: Langrange's and Euler's equations of motion; Bernoulli's Theorem.

Unit-II: **Marks: 20**

Motion in two-dimensions; Complex velocity potential; Sources, sinks, doublets and their images; Conformal mapping; Milne-Thomson circle theorem; Two-dimensional irrotational motion produced by motion of circular, co-axial and elliptic cylinders in an infinite mass of liquid; Theorem of Blasius; Stoke's stream function.

Unit-III: **Marks: 15**

Stress components in a real fluid; Relations between rectangular components of stress. Connection between stresses and gradients of velocity, Stress analysis in fluid motion, Rate of strain quadric of fluid element, Transformation of rate of strain components.

Unit-IV: **Marks: 15**

Vortex motion and its elementary properties; Motions due to circular and rectilinear vertices; Kirchhoff vortex theorem. Boundary layer theory: Boundary layer concept, boundary layer thickness, displacement, momentum, and energy thickness.

Reference Books:

[1] Fluid Dynamics - William F. Hughes, John A. Brighton, Schaum's Outline Series, McGraw-Hill.
[2] Boundary-Layer Theory - Hermann Schlichting, Klaus Gersten, Springer.
[3] Chorlton, Text Book of Fluid Dynamics, CBS Publishers, Delhi,1985.
[4] G. K. Batchelor, An Introduction to Fluid Mechanics, Foundation Books, New Delhi, 1994.
[5] H. Schlichting, Boundary Layer Theory, McGraw Hill Book Company, New York, 1971.
[6] M. D. Raisinghania, Fluid Mechanics (With Hydrodynamics) S. Chand and Company Ltd., New Delhi.
[7] R. K. Rathy, An Introduction to Fluid Dynamics, Oxford and IBH Publishing Company, New Delhi, 1976.

SEMESTER - IX

Paper Code: MATSPL 25014 (C)
Paper Title: Advanced Topology I
Theory Marks: 70
Internal Marks: 30

Course Outcome: Study about the properties of Metric spaces related to convergence structure in topological spaces. Metrization based on paracompactness. The role of fundamental group in the study of topological spaces.

Unit-I: **Marks: 20**

Nets and filters, convergenge in terms of nets and filters, ultrafilters and compactness. Theories of metrization, Urysohn's Lemma, Tietze Extension theorem, Urysohn metrization Theorem.

Unit-II: **Marks: 15**

Paracompactness, characterisation in regular spaces, metrization based on paracompactness, Nagata-Smirnov theorem, Stone’s theorem, Smirnov’s metrization theorem.

Unit-III: **Marks: 20**

Topological groups, subgroups, quotient groups, homogeneous spaces, product groups.

Unit-IV: **Marks: 15**

Homotopy and the fundamental group, computation of the fundamental group of the circle.

Text Books:

[1] Willard, S. General Topology, Addision-Wesley, Reading, 1970
[2] Munkres, J. R.**,** Topology: A first course (2/e), Prentice-Hall, 2000

Reference Books:

[1] Joshi, K. D., Topology, Wiley-Eastern, 1988.

[2] Kelley, J. L., Topology, Van Nostrand, 1955.

SEMESTER - IX

Paper Code: MATSPL 25024 (A)
Paper Title: Graph Theory II
Theory Marks: 70
Internal Marks: 30

Course Outcome: This course is about to the topics of graph theory like Factoriztion, planarity, colourability matching and domination. The course introduces basic graph algorithms with applications.

Unit-I: **Marks:15**
Factorization: factors, 1-factorization, 2-factorization, Tutte's 1-factor theorem. Planarity: Graph embeddings; Planar graph, Euler's formula, Parameters of planarity.

Unit-II: **Marks: 20**
Colourability: Vertex and edge colouring, Chromatic number and edge chromatic number, Bounds for chromatic number, Brooks' theorem; Vizing's theorem, The four colour theorem, The five colour conjecture, Uniquely colourable graph.

Unit-III: **Marks: 25**
Matching: Basic concepts of matching, maximum, maximal and perfect matching, Augmented path, Berge's theorem, Matching in bipartite graph, König's theorem for maximum matching. Domination: Dominating set and dominating number, Closed and open neighbourhood, Total dominating set and total domination number.

Unit-IV: **Marks:10**
Basic Graph Algorithms: Traversal algorithm like breadth first search, depth first search, Designing and analyzing of algorithms, Topological sort.

Books:

[1] Introduction to Graph Theory, D. B. West, Prentice-Hall, (2001).
[2] Basic Graph Theory, K. R. Parthasarathy, Tata McGraw Hill, (1994)
[3] Graph Theory, F. Harary, Narosha Publishing Co (Reprint 1998).
[4] Algorithm Design: J. Kleinberg and E. Tardos (2006) Pearson Education.
[5] Introduction to Algorithms: H. Cormen, C.E. Leiserson and R.L. Rivest (2009) MIT Press.

SEMESTER - IX

Paper Code: MATSPL 25024 (B)
Paper Title: Special Theory of Relativity
Theory Marks: 70
Internal Marks: 30

Course Learning Objectives:

1. Develop an understanding of inertial and non-inertial frames, the geometry of Newtonian mechanics, and the transformations between these frames, particularly Galilean transformations.
2. Comprehend the fundamental postulates of the special theory of relativity, including Lorentz transformations and their implications for physical phenomena such as length contraction, time dilation, and simultaneity.
3. Study the variation of mass with velocity, the equivalence of mass and energy, and the transformations of mass, force, acceleration, density, momentum, and energy in relativistic contexts, including the formulation of relativistic Lagrangian and Hamiltonian mechanics.
4. Gain insights into Minkowski space and its role in representing relativistic concepts geometrically, including four-vectors, four-velocity, four-force, and four-momentum, and the covariant four-dimensional formulation of the laws of mechanics.
5. Learn the fundamentals of electrodynamics within the framework of special relativity, including the transformation of differential operators, Maxwell's equations, electromagnetic waves, and the transformation properties of electric and magnetic fields.

Course Learning Outcomes:

1. Demonstrate the ability to apply Galilean and Lorentz transformations to solve problems in Newtonian mechanics and special relativity, including calculating length contraction, time dilation, and relativistic velocity addition.
2. Solve problems involving the variation of mass with velocity, the equivalence of mass and energy, and transform physical quantities such as mass, force, acceleration, density, momentum, and energy using relativistic principles.
3. Use Minkowski space to represent and analyze relativistic phenomena, including constructing and interpreting four-vectors, and solving relativistic equations of motion using covariant four-dimensional formulations.
4. Apply the principles of electrodynamics within the context of special relativity to transform differential operators, solve Maxwell's equations, analyze electromagnetic waves, and understand the transformations of electric and magnetic field components.
5. Integrate concepts from special relativity and electrodynamics to solve complex problems, demonstrating a thorough understanding of the interplay between relativistic mechanics and electromagnetic theory.

Unit-I: **Marks: 20**

Inertial and non-inertial frames, Geometry of Newtonian mechanics, Galilean Transformations, Fundamental postulates of the special theory of relativity, Lorentz transformation, Lorentz transformation as a group. Length contraction, Time dilation and Simultaneity. Relativistic addition law of velocities.

Unit-II: **Marks: 15**

Relativistic mechanics, Variation of mass with velocity, Equivalence of mass and energy. Transformation of mass, force acceleration, density, momentum and energy. Relativistic Lagrangian and Hamiltonian.

Unit-III: **Marks: 15**

Minkowski's space, Geometrical representation of simultaneity, contraction and time dilation, Space-like and time- like intervals, Position four vectors, four-velocity, four forces and four momentums, Relativistic equations of motion. Covariant four-dimensional formulations of laws of mechanics.

Unit-IV: **Marks: 20**

Electrodynamics: Fundamental of electrodynamics, Transformation of differential operators, D'Alembert operator, Maxwell's equations and electromagnetic waves, Electromagnetic potentials and force Lorentz condition, Transformations of charge and current density, transformation equations of electric field strength and magnetic field induction components.

Reference Books:

[1] Introduction to Special Relativity, Wiley Eastern Ltd. (1990) Robert.

[2] The Mathematical Theory of Relativity, Cambridge University Press 1965 A. S. Eddington.

[3] Relativity, Thermodynamics and Cosmology - R.C. Tolman (Oxford Press)

SEMESTER - IX

Paper Code: MATSPL 25024 (C)
Paper Title: Category Theory I
Theory Marks: 70
Internal Marks: 30

Course Outcome: Study about the fundamental structure and basic properties of Category Theory as Categories are algebraic structures with many complementary natures, e.g., geometric, logical, computational, combinatorial, just as groups are many-faceted algebraic structures.

Unit-I: **Marks:15**

Definition and examples ofcategories, The concept of functor and the category Cat. Natural Transformations, isomorphism, epimorphism, monomorphism, Mobics, Epis and Zeros Foundations, Large Categories, Hom-sets. Free Categories, Constructions of new categories from old categories, The Dual Category, The Arrow Category, The Slice and Co- Slice Category.

Unit-II: **Marks: 20**

Epis and mono, Initial and Terminal objects, Generalized elements, Sections and Retractions, Categories of categories, properties of functors, natural transformation and natural isomorphism, isomorphisms and equivalences of categories, functor categories.

Unit-III: **Marks: 20**

Groups in categories. The category of groups, Groups as categories, Congruence on a category, quotient category and its univalent mapping property, finitely presented categories.

Unit-IV: **Marks:15**

Equalizers and coequalizers, intersections and factorizations, products and coproducts, sources and sinks, limits and colimits, pullback and pushout, inverse and direct limits, complete categories, limits in factor categories.

Text Books:

[1] Awodey, S.: Category Theory, (Oxford Logic Guides, 49, Oxford University Press.)

Reference Books:

[1] Herrlich, Horst; Strecker, George E. (2007), Category Theory (3rd ed.), HeldermannVerlag Berlin

SEMESTER - IX

Paper Code: MATSPL 25034 (A)
Paper Title: Number Theory I
Theory Marks: 70
Internal Marks: 30

Course Outcome: Basic study of arithmetic number theory including divisibility, congruences, linear Diophantine equation.

Unit-I: **Marks: 15**

Divisibility, greatest common divisor, least common multiple, Euclidean Algorithm. Chinese Remainder Theorem. Prime numbers, factorization in prime numbers, fundamental theorem of arithmetic.

Unit-II: **Marks: 15**

Divisor functions, perfect numbers, Mersenne numbers, Fermat numbers.

Unit-III: **Marks: 20**

Greatest integer function (Gauss function), Mobius function, Euler function.Congruencesand its elementary properties, congruences in one unknown, complete residuesystem, reduced residue system.

Unit-IV: **Marks: 20**

Diophantine equations, linear Diophantine equations, Pythagoras equation, sum of twosquares.Quadratic residues and congruences of second degree in one unknown, Legendre symbol, Jacobi symbol, congruences of second degree with prime modulus and with composite modulus.

Text Books:

[1] Hardy, G.H. and Wright, E. M. An Introduction to the Theory of Numbers, 4th Edition (Oxford University Press, 1960).
[2] Andrews, G.E. Number Theory (Hindustan Publishing Corporation, New Delhi, 1992).

Reference Books:

[1] Burton, D. M. Elementary Number Theory, 6th Edition (Tata McGraw-Hill, NewDelhi,2007).
[2] Niven, I. and Zuckerman, H. An Introduction to the Theory of Numbers, 5th Edition (WileyEastern, New Delhi, 2000).

SEMESTER - IX

Paper Code: MATSPL 25034 (B)
Paper Title: Dynamical Systems I
Theory Marks: 70
Internal Marks: 30

Unit-I: **Marks: 20**

Dynamical systems, discrete and continuous dynamical systems, Examples of dynamical systems. Iteration, Orbits, Types of Orbits, Other Orbits, The Doubling Function.

Unit-II: **Marks: 25**

Graphical Analysis, Orbit Analysis, The Phase Portrait, Examples, Solutions Fixed and Periodic Points, A Fixed-Point Theorem, Attraction and Repulsion. Stability of fixed points and equilibrium points.

Unit-III: **Marks: 25**

Bifurcations: Dynamics of the Quadratic Maps, Saddle Node Bifurcation, Period Doubling Bifurcations, The Quadratic Family

Reference Books:

[1] Differential Equation, Dynamical System and Linear Algebra: Morris W. Hirsch, StephenSmale, Academic Press.
[2] An introduction to Dynamical systems: D. K. Arrowsmith
[3] A First Course in Chaotic Dynamical Systems: Robert L. Devaney

SEMESTER - IX

Paper Code: MATSPL 25044 (A)
Paper Title: Advanced Functional Analysis
Theory Marks: 70
Internal Marks: 30

Course Outcome: This course is about the basic of Topological vector spaces, Banach and C* algebras. The course deals with various properties of different types of linear operators. This course also included fixed point theory

Unit-I: **Marks: 20**

Topological Vector Spaces: Introduction, Separation properties, Linear mappings, Finite-dimensional spaces, Metrization, Boundedness and continuity, Seminorms and local convexity, Quotient space, completeness, convexity, Weak topologies, Compact convex sets.

Unit-II: **Marks: 20**

Preliminaries on Banach Algebras and C* Algebras, Commutative Banach Algebras and Commutative C* Algebras, Representation of C* Algebras.

Unit-III: **Marks:20**

Spectral Theory of linear operators in normed space, Spectral Properties of Bounded Linear Operators, Further Properties of Resolvent, Spectrum and Banach Algebras. Spectral Properties of Bounded Self-Adjoint Linear Operators, Positive Operators, Square Roots of a Positive Operator, Projection Operators, Spectral Family of a Bounded Self-Adjoint Linear, Spectral Representation of Bounded Self-Adjoint Linear Operators.

Unit-IV: **Marks: 10**

Fixed Point Theorems and Some Applications to Analysis.

Books:

[1] Kreyszig E., Introductory Functional Analysis with Applications (John Wiley and Sons, New York, 1978).
[2] Rudin, W. Functional Analysis (McGraw Hill, 2000).
[3] Simmons, G. F. Introduction to Topology and Modern Analysis (Tata McGraw Hill Book Co. Ltd.,1963).
[4] Gerard J. Murphy, C* - Algebras and Operator Theory, Academic Press, Inc, 1990.
[5] Ronald G. Douglas, Banach Algebra Techniques in Operator Theory, Second Edition, Springer-Verlag, New York, Inc, 1998.
[6] Limaye, B. V. Functional Analysis (Wiley Eastern Ltd., New Delhi, 1989).

SEMESTER - IX

Paper Code: MATSPL 25044 (B)
Paper Title: Numerical Analysis I
Theory Marks: 70
Internal Marks: 30

Course Outcome:

By the end of this course, students will:

- Solve linear equations using LU and Cholesky decompositions, and iterative methods.
- Analyze eigenvalues and eigenvectors with methods like the power method and QR algorithm.
- Solve non-linear equations using Newton-Raphson and Steffensen's iteration.
- Perform numerical integration with Gauss-Legendre, Euler-Maclaurin, and Romberg techniques.

Unit-I: **Marks: 20**

Direct method for solving of linear equations (Crout's method, LU decomposition, Cholesky decomposition), Iterative methods (Relaxation method)., Escalator method Steepest descent and conjugate gradient method.

Unit-II: **Marks: 20**

Algebraic Eigen value problem: Properties of Eigen values and Eigen vectors, Power method, Inverse power method, Jacobi's method, Given's method. Orthogonal factorization, QR algorithm for Eigen value problem Eigen values of complex matrix and complex Eigen vectors.

Unit-III: **Marks: 15**

System of non-linear method equations: Solution of Non-linear Equations: Single Equation: Modified Newton-Raphson method (for real roots-simple or repeated). Aitken's Δ^2-method and Steffensen's iteration. Bairstow's method of quadratic factors, Graeffe's root squaring method. Non-Linear Systems of Equations: Newton's method, Quasi-Newton's method.

Unit-IV: **Marks: 15**

Numerical Integration: Gauss- Legendre and Gauss-Chebyshev Quadrature's, Euler-Maclaurin summation formula, Romberg integration.

Reference Books:

[1] An introduction to Numerical Analysis: Kendal E. Atkinson, Johan Wiley and sons, Inc.
[2] Numerical Methods in engineering & Science: Dr. B. S. Grewal
[3] Introduction to Numerical analysis: C. E. Froberg, Addison Wesley publishing Company, sixth edition, 1981.
[4] Introductory Methods of Numerical Analysis: S. S. Sastri, Prentice Hall of India, New Delhi, 1997.

SEMESTER - IX

Paper Code: MATSPL 25054
Paper Title: Computer Lab II
Practical Marks: 70
Internal Marks: 30

Course Outcome:

By the end of this course, students will:

- Master advanced numerical computation techniques, including error analysis, high-performance, and parallel computing.
- Solve complex nonlinear equations and perform constrained and global optimization.
- Apply advanced numerical linear algebra techniques, including SVD and sparse matrix computations.
- dyUtilize sophisticated methods for solving PDEs, including spectral and finite element methods, in various scientific and engineering applications.

Unit-I: Introduction to Numerical Computation

- Review of Numerical Computation Fundamentals
- Advanced Error Analysis
- Introduction to High-Performance Computing
- Parallel and Distributed Computing
- GPU Computing

Unit-II: Solving Nonlinear Equations and Optimization

- Multivariate Root Finding Methods
- Nonlinear Optimization Techniques
- Constrained Optimization
- Global Optimization Methods

Unit-III: Numerical Linear Algebra II

- Singular Value Decomposition (SVD)
- Iterative Methods for Linear Systems
- Sparse Matrix Computations
- Applications in Machine Learning and Big Data Analytics

Unit-IV: Advanced Topics in Computational Mathematics

- Numerical Methods for Partial Differential Equations (PDEs)
- Spectral Methods
- Finite Element Methods for PDEs
- Applications in Computational Fluid Dynamics, Solid Mechanics, and Electromagnetics.

Textbook:

[1] P. Jones, Python: The Fundamentals of Python Programming, CreateSpace Independent Pub.
[2] S. Linge, H. P. Langtangen, Programming for computations, Springer.
[3] E. V. Krishnamurthy and S. K. Sen: Computer Based Numerical Algorithms, East-West press Pvt. Ltd. 1976.
[4] R. Johansson, Numerical Python, A Press.
[5] Numerical Methods for Engineers by Steven C. Chapra and Raymond P. Canale

References:

[1] Numerical Recipes: The Art of Scientific Computing by William H. Press et al.
[2] Introduction to Scientific Computing: A Matrix-Vector Approach Using MATLAB by Charles F. Van Loan.

SEMESTER - X

Paper Code: MATSPL 25064 (A)
Paper Title: Fuzzy Logic and Control System
Theory Marks: 70
Internal Marks: 30

Course outcomes: This course will be beneficial for the students to learn about the application of fuzzy logic and its application. Also, this course will give the idea about multi criteria decision making.

Unit-I: **Marks: 15**
Fuzzy logic, fuzzy propositions, fuzzy quantifiers, linguistic variables, inference from conditional fuzzy propositions, compositional rule of inference.

Unit-II: **Marks: 20**
Approximate reasoning - an overview of fuzzy expert systems, fuzzy implications and their selection, multi-conditional approximate reasoning, role of fuzzy relation equation.

Unit-III: **Marks: 15**
An introduction to fuzzy control - fuzzy controllers, fuzzy rule base, fuzzy inference engine, fuzzification, defuzzification and the various defuzzification methods.

Unit-IV: **Marks: 20**
Decision making in fuzzy environment - individual decision making, multi-person decision making, multi-criteria decision making, multistage decision making, fuzzy ranking methods, fuzzy linear programming, fuzzy logic as a tool in soft computing.

Reference Books:

[1] Zimmermann, H. J., Fuzzy set theory and its Applications, Allied publishers Ltd., New Delhi, 1991.
[2] Klir, G. J. and Yuan, B., Fuzzy Sets and Fuzzy Logic: Theory and Applications, Prentice Hall of India, New Delhi, 1997.

SEMESTER - X

Paper Code: MATSPL 25064 (B)
Paper Title: Numerical Analysis II
Theory Marks: 70
Internal Marks: 30

Course Outcome:
By the end of this course, students will:

- Solve ordinary differential equations using methods like Modified Euler's and Adams-Bashforth.
- Address boundary-value problems with numerical techniques and the finite-difference method.

- Develop finite-difference approximations and solve elliptic equations for partial differential equations.
- Use relaxation methods and appropriate techniques for parabolic and hyperbolic equations.
- Apply different types of approximations, including least square polynomial and Chebyshev polynomials.

Unit-I: **Marks: 15**

Numerical Solution of Ordinary Differential equations: Modified Euler's method, Predictor-corrector method, Milne's method, Adams-Bash forth method, Boundary-value problems, Finite-difference method.

Unit-II: **Marks: 20**

Numerical Solution of Partial Differential equations: Finite-Difference approximations to partial derivatives, Elliptic equations, Solution of Laplace equation, Solution of Poisson's equation.

Unit-III: **Marks: 20**

Solution of Elliptic Equations by Relaxation Method, Parabolic Equations, Hyperbolic Equations.

Unit-IV: **Marks: 15**

Approximations: Different types of approximation, least square polynomial approximation, polynomial approximation by use of orthogonal polynomials, approximation with Chebyshev polynomials.

Reference Books:

[1] Numerical Methods in Engineering & Science: Dr. B. S. Grewal
[2] An introduction to Numerical Analysis: Kendal E. Atkinson, Johan Wiley and sons, Inc.
[3] Introduction to Numerical analysis: C. E. Froberg, Addision Wesley publishing Company, sixth edition, 1981.
[4] Introductory Methods of Numerical Analysis: S. S. Sastri, Prentice Hall of India, New Delhi, 1997.

SEMESTER - X

Paper Code: MATSPL 25064 (C)
Paper Title: Advanced Topology II
Theory Marks: 70
Internal Marks: 30

Course Outcome: Study about the notion related to the uniform structure in topological spaces. Introduction to the notion of Function space and Proximity structure.

Unit-I: **Marks: 20**

Uniformities, uniform continuity, product uniformities, metrisation, completeness and Compactness, completion.

Unit-II: **Marks: 20**
Uniform structures in Topological groups, complete groups, completion of topological groups.

Unit-III: **Marks: 15**
Function spaces, pointwise convergence, uniform convergence, compact-open topology, k-spaces, equicontinuity, Ascoli theorem.

Unit-IV: **Marks: 15**
Proximity Structure: Smirnov Compactification.

Text Books:

[1] Willard, S. General Topology, Addision-Wesley, Reading, 1970
[2] Munkres, J. R.**,** Topology: A first course (2/e), Prentice-Hall, 2000

Reference Books:

[1] Joshi, K. D. Topology, Wiley-Eastern, 1988.
[2] Kelley, J. L. Topology, Van-Nostrand, 1955.
[3] Bourbaki, N. Elements of Mathematics: General Topology, Vols. I & II,Springer-Verlag, 1988.

SEMESTER - X

Paper Code: MATSPL 25074 (A)
Paper Title: Graph Theory III
Theory Marks: 70
Internal Marks: 30

Course Outcome: This course is an introduction to the generalizations of graphs. The course introduces in an elementary way some basic knowledge of hypergraph and semigraph. This course also included some important algorithms.

Unit-I: **Marks: 20**
Hypergraph: Introduction to Hypergraph, Degree and rank, Incidence matrix, Cycles in hypergraph, conformal hypergraphs, Representative graph of a hypergraph, Dual of hypergraph.

Unit-II: **Marks: 25**
Semigraph: Introduction to Semigraph, Degrees in semigraph; Subsemigraph and partial subsemigraph, Path and cycle, Complete Semigraph, Strongly Complete Semigraph, Edge bipartite, Edge regular, Edge Complete Semigraph, Dendroids (Semitree).

Unit-III: **Marks: 25**
Graph Algorithms: Interval scheduling, Minimum spanning tree, Kruskal's algorithm, Prim's algorithm, Single-source Shortest path, The Bellman-Ford algorithm, Dijkstra's algorithm, Strongly connected components.

Books:

[1] Introduction to Graph Theory, D. B. West, Prentice-Hall, (2001).
[2] Graphs and Hypergraphs, C. Berge, North-Holland, London (1973).
[3] Hypergraphs, C. Berge, North-Holland, London (1973).
[4] Semigraph and Their Application, E. Sampathkumarachar, Academy of DiscreteMathematics and Applications, Lecture Notes, Series No. 1 (2019).
[5] Algorithm Design: J. Kleinberg and E. Tardos (2006) Pearson Education.
[6] Introduction to Algorithms: H. Cormen, C.E. Leiserson and R.L. Rivest (2009) MIT Press

SEMESTER - X

Paper Code: MATSPL 25074 (B)
Paper Title: Relativity and Cosmology
Theory Marks: 70
Internal Marks: 30

Course Learning Objectives:

1. Develop a comprehensive understanding of the foundational principles of general relativity, including the principles of equivalence, covariance, and geodesic principle.
2. Learn to derive and understand Einstein's field equations, including the Newtonian approximation, and analyze solutions such as the Schwarzschild external solution and its isotropic form.
3. Study and interpret various relativistic phenomena, such as redshift, the advance of perihelion of a planet, bending of light rays in a gravitational field, and the energy-momentum tensor of a perfect fluid.
4. Gain insights into static and non-static cosmological models, including the derivation and properties of the Einstein and De-Sitter models, and understand Hubble's law, cosmological principles, and the Robertson-Walker metric.
5. Understand the fundamental equations of dynamical cosmology, explore Friedmann models, and analyze concepts such as critical density, closed and open universes, the age of the universe, and steady state cosmology.

Course Learning Outcomes:

1. Demonstrate the ability to apply the principles of equivalence, covariance, and geodesic principle to solve problems in general relativity and understand their implications for the motion of objects in a gravitational field.
2. Successfully derive Einstein's field equations using variational principles and solve them for specific cases like the Schwarzschild external solution, understanding their physical significance in various relativistic scenarios.
3. Analyze and interpret the effects of general relativity on planetary orbits, the advance of perihelion, bending of light, and gravitational redshift, and understand their observational consequences.
4. Construct static and non-static cosmological models, derive and compare the properties of the Einstein and De-Sitter models with observations of the actual universe, and understand the implications of Hubble's law and the Robertson-Walker metric.
5. Apply the fundamental equations of dynamical cosmology to solve problems related to Friedmann models, calculate critical density, and determine the age and structure of the

universe, understanding concepts like particle and event horizons and the steady state cosmological principle.

Unit-I: **Marks: 20**

General Relativity, Principles of equivalence, Principle of covariance, Geodesic principle, Newtonian approximation of equation of motion, Einstein's field equations, Schwarzschild external solution and its isotropic form, Redshift, Tests of general theory of relativity, Planetary orbits and analogues of Kepler's Laws in general relativity.

Unit-II: **Marks: 20**

Advance of perihelion of a planet, Bending of light rays in a gravitational field, Gravitational redshift of spectral lines, Energy-momentum tensor of a perfect fluid, Schwarzschild internal solution, Boundary conditions, Action Principle, Derivation of Einstein field equations from variational principle, Mach's principle

Unit-III: **Marks: 15**

Static cosmological models of Einstein and De-Sitter, their derivation, properties and comparison with the actual universe. Non-static cosmological models, Derivation of Robertson-Walker metric, Hubble's law, Cosmological principles, Weyl's postulate.

Unit-IV: **Marks: 15**

Friedmann models, Fundamental equations of dynamical cosmology, Critical density, Closed and open universes, Age of the universe, Matter dominated era of the universe, Einstein-de Sitter model, Particle and event horizons, Perfect cosmological principle, Steady state cosmology.

Reference Books:

[1] Introduction to General Relativity - Ronald Ader, Maurice Bazin, Menahem Schiffer, 2 Edition, McGraw Hill Company.
[2] General Relativity and Cosmology - J. V. Narlikar, Macmillan Company of India, 1978.
[3] Gravitation and Cosmology: Principles and Applications of General Theory of Relativity - Steven Weinberg, John Wiley Publication.
[4] Introduction to General Relativity, McGraw Hill Inc., 1975.
[5] B. Schutz, Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity, John Wiley & Sons, Inc., 1972.
[6] R. K. Sachs and H. Wu., General Relativity for Mathematician, Springer Verlag, 1977.

SEMESTER - X

Paper Code: MATSPL 25074 (C)
Paper Title: Category Theory II
Theory Marks: 70
Internal Marks: 30

Course Outcome: Study about Convergence structure in Category Theory. Axiomatization of short exact sequences in additive categories.

Unit-I: **Marks: 15**

Exponential in a category, Heyting algebra, ccc category, λ –calculus.

Unit-II: **Marks: 20**

Set-valued functor categories, The Yoneda embedding, The Yoneda Lemma, Applications of the Yoneda lemma, Limits, Colimits and Exponentials in Categories of diagrams. Hom (X, G^P) and Hom (X x P, Q).

Unit-III: **Marks: 20**

Adjunction between categories, left and right adjoints, Hom-Set definition of adjoints. Examples of Adjoints, Uniqueness up to isomorphism. Order Adjoints and interior operation in Topology as an order adjoint. Preservation of Limits (Co limits) by Right (Left) Adjoints. UMP of the Yoneda Embedding and Kan Extensions. Statement only of the Adjoint Functor Theorem.

Unit-IV: **Marks: 15**

Normal and exact categories, additive categories, abelian categories.

Text Books:

[1] Awodey, S.: Category Theory, (Oxford Logic Guides, 49, Oxford University Press.)

Reference Books:

[1] Herrlich, Horst; Strecker, George E. (2007), Category Theory (3rd ed.), Heldermann Verlag Berlin

SEMESTER - X

Paper Code: MATSPL 25084 (A)
Paper Title: Number Theory II
Theory Marks: 70
Internal Marks: 30

Course Outcome: Introduction to the arithmetic functions and their properties. Study on congruence theory, distribution of prime numbers and partition theory.

Unit-I: **Marks: 20**

Arithmetical functions and Dirichlet multiplication, averages of arithmetical functions. Elementary theorems on the distribution of primes, the prime number theorem, Chebyshev's functions and their relations. Dirichlet's theorem for primes.

Unit-II: **Marks: 15**

Quadratic residues and quadratic reciprocity law, applications of the reciprocity law, Gauss sums.

Unit-III: **Marks: 20**

Dirichlet series, Euler products, Riemann zeta function and Dirichlet *L*-functions.

Unit-IV: **Marks: 15**

Introduction to partitions, geometric representation, generating functions, Euler's Pentagonal number. theorem, Jacobi triple product identity, Jacobi's identity, recursion formula for *p(n)*. Ramanujan's partition identities.

Text Books:

[1] Apostol, T. M. Introduction to Analytic Number Theory, Springer International Student Edition (Narosa Publishing House, New Delhi, 1993).
[2] Hardy, G.H. and Wright, E. M. An Introduction to the Theory of Numbers, 4th Edition (Oxford University Press, 1960).

Reference Books:

[1] Berndt, B.C., Number Theory in the spirit of Ramanujan.
[2] Niven, I. and Zuckerman, H. An Introduction to the Theory of Numbers, 5th Edition (WileyEastern, New Delhi, 2000).
[3] Andrews, G.E. Number Theory (Hindustan Publishing Corporation, New Delhi, 1992).

SEMESTER - X

Paper Code: MATSPL 25084 (B)
Paper Title: Dynamical Systems II
Theory Marks: 70
Internal Marks: 30

Course Outcome:

By the end of this course, students will:

- Differentiate between discrete and continuous dynamical systems and analyze iterations and orbits.
- Conduct graphical and orbit analysis, including phase portraits and stability evaluation.
- Identify and analyze fixed points, periodic points, and their stability.
- Study dynamics and bifurcations, including saddle node and period doubling bifurcations.

Unit-I: **Marks: 20**

Transition of Chaos, Symbolic Dynamics, Chaos, Sharkovskii's Theorem, The role of critical orbits, Newtons Method, Complex Functions, The Julia Set, The Mandelbrot Set.

Unit-II: **Marks: 20**

The Poincaré Map: Introduction to the Poincaré map and its significance in dynamical systems, Construction, and properties of the Poincaré map, Applications in periodic orbits, stability analysis, and chaos theory.

Gortman-Hartman Theorem: Statement and proof of the Gortman-Hartman theorem, Implications for stability analysis of dynamical systems, Applications in nonlinear dynamics and control theory.

Phase Plane: Classification of linear systems, Lyapunov stability, Structural stability, Examples and applications, Problems.

Unit-IV: **Marks: 20**

Nonlinear Oscillators: Introduction to nonlinear oscillators, The Duffing oscillator: Lindstedt's method, elliptic functions, and problem-solving, The van der Pol oscillator: Method of averaging, Hopf bifurcations, homoclinic bifurcations, relaxation oscillations, and problem-solving**.**

Unit-V: **Marks: 10**

Fractals: Definition of fractals and fractal geometry, Historical background and key contributors, Self-similarity and fractal dimension, the cantor set revisited, Sierpinski triangle, Koch Snowflake, Topological dimension, Fractal dimension.

Reference Books:

[1] Differential Equation, Dynamical System and Linear Algebra: Morris W. Hirsch, Stephen Smale, Academic Press.
[2] An introduction to Dynamical systems: D. K. Arrowsmith
[3] A First Course in Chaotic Dynamical Systems: Robert L. Devaney
[4] Chaos and Fractals: New Frontiers of Science: Heinz-Otto Peitgen, Hartmut Jürgens, and Dietmar Saupe.
[5] Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering: Steven H. Strogatz
[6] Dynamical Systems: Stability, Symbolic Dynamics, and Chaos: Clark Robinson
[7] An Introduction to Dynamical Systems and Chaos: G.C. Layek
[8] Nonlinear Dynamics and Chaos: Geometric Methods for Engineers and Scientists by J. M. T. Thompson and H. B. Stewart
[9] Dynamical Systems and Chaos by Mauricio Matos Peixoto and David A. Rand

SEMESTER - X

Paper Code: MATSPL 25094 (A)
Paper Title: Analysis III
Theory Marks: 70
Internal Marks: 30

Course Outcome: Study about Lebesgue measure over general measure spaces, productivity on $\mathbb{R}^n$, with the topological properties.

Unit-I: **Marks: 15**

General Measure Theory: Measure space, completion of a measure space, signed measure, Hahn and Jordan decomposition theorem for finite signed measure, extension of a premeasure to a measure, Carathéodory-Hahn theorem, Randon-Nikodym theorem for finite and σ -finite signed measures and its consequences, computation of the Randon-Nikodym derivative, Nikodym metric space, Vitali-Hahn-Saks Theorem.

Unit-II: **Marks: 15**

General L^P Space: Completeness, duality and weak convergence.

Unit-III: **Marks: 20**

Product measures: Fubini and Tonelli theorem, Lebesgue measure on Euclidean space $\mathbb{R}^n$ Lebesgue-Stieltjes measures and Lebesgue-Stieltjes integral, Hausdorff measure and its dimension.

Unit-IV: **Marks: 20**

Measure and Topology: Construction of Radon measure, Riesz-Markov theorem, Riesz representation theorem for the dual of C(X), regularity of Baire measures, Borel measure on compact groups, Von Neumann's theorem, Bogoliubov-Krilov theorem.

Text Books:

1. Royden,H. L., Fitzpatrick, P. M., Real Analysis, 4thEdition, PHI Learning Private Limited, New Delhi, 2011

Reference Books:

1. Munroe, M. E.: Introductions to measure and integration, Addison Wesley, 1953.
2. Berberian, S. K.: Measure and integration, Chelsa Pub. Co. N.Y. 1965.
3. Ruddin, W.: Real and Complex Analysis, Tata McGraw Hill, New Delhi, 1974

SEMESTER - X

Paper Code: MATSPL 25094 (B)
Paper Title: Biomathematics
Theory Marks: 70
Internal Marks: 30

Course Learning Objectives:

1. Comprehend continuous population models for single species, including exponential and logistic growth models, and their qualitative analysis.
2. Learn to perform stability and equilibrium analysis of various population growth models, including those with delays.
3. Understand and model interactions between species using continuous models, focusing on competition, mutualism, and predator-prey dynamics.
4. Gain insights into the impact of harvesting on natural populations, including models with delayed recruitment and age distribution.
5. Utilize mathematical techniques such as differential equations and qualitative analysis to study and solve population dynamics problems.

Course Learning Outcomes:

1. Demonstrate the ability to model single-species population growth using exponential, Malthusian, and logistic growth models, and perform qualitative analysis of these models.
2. Analyze continuous single-species population models with delays, understand the general delay model, and perform stability and equilibrium analysis.
3. Apply continuous models to study interactions between species, including competition, mutualism, and predator-prey dynamics using Lotka-Volterra models.
4. Evaluate the effects of different harvesting strategies on population dynamics, including constant effort and constant yield harvesting, and analyze models with age distribution.
5. Analyze predator-prey interactions using Lotka-Volterra models, understand the role of density dependence, and study classic laboratory experiments and natural system predation.

Unit-I: **Marks: 20**

Continuous population Model for single species, Exponential population growth model, continuous population growth model: Malthus model for population growth, General population growth model, Qualitative Analysis: Equilibrium points, Stability Analysis,

Logistic population growth model and their qualitative analysis, logistic growth model for non-isolated population.

Unit-II: **Marks: 20**

Insect Out-break model: Spruce Budworm, Continuous Single species population model with Delays: Introduction, General Delay model and Qualitative Analysis, Logistic model with time delay effects, Definition of stability, equilibrium points & stability Analysis.

Unit-III: **Marks: 10**

Continuous Models for Interacting Population: Interaction between species: two species models, community matrix approach, Qualitative behaviour of community matrix, Competition: Lotka-Volterra models, Competition Models, Principle of competitive exclusion, Models for Mutualism.

Unit-IV: **Marks: 10**

Harvesting a single Natural population: Harvesting in Delayed recruitment models: Constant effort Harvesting, constant yield harvesting, population model with Age Distribution, Simple Discrete population model.

Unit-V: **Marks: 10**

Predator: Prey interaction: Lotka-Volterra models, dynamic of simple Lotka-Volterra models, Role of density dependent in the Prey, Classic laboratory experiment on predator, predation in natural system. Some predator- prey models.

Reference Books:

[1] J. N. Kapur, Mathematical Modelling, New Age International Publishers.
[2] J.D. Murray Mathematical Biology (An Introduction, Vol. I & II), Springer- Verlag.
[3] J.N. Kapur, Mathematical Model in Biology and Medicines.
[4] S. I. Rubinow, Introduction to Mathematical Biology, John Wiley andSons, 1975.
[5] MA Khanday, Introduction to Modeling and Biomathematics, Dilpreet Publishers New Delhi, 2016.
[6] Jaffrey R. Chasnov, Mathematical Biology, Hong Kong Press.

SEMESTER - X

Paper Code: MATSPL 25104 (A)
Paper Title: Network Theory
Theory Marks: 70
Internal Marks: 30

Course Outcome: This course is about the networks involving graphs. The course deal with various types of complex and random networks. This course also included the basic of Graph neural networks.

Unit-I: **Marks: 15**

Overview of graph network, Network Flow: Max-flow Min-cut and the Ford-Fulkerson algorithm.

Unit-II: **Marks: 20**

Complex Networks: Introduction to complex networks, Network traversal, Construction of Euler tour, Finding a Hamilton cycle, Trees in transportation networks, Routing in communication networks.

Unit-III: **Marks: 10**

Random networks, Computer networks; Social networks analysis; Structural balance; Affiliation networks; Equivalence; Structural equivalence.

Unit-IV: **Marks: 25**

Representation Learning, Graph representation learning, Introduction to Graph Neural network (GNN), Convolutional neural network (CNN), General Framework of GNN and CNN, Types of GNN: Recurrent Graph Neural Network (RECGNN or RGNN), Graph Attention Network (GAN), Applications of GNN.

Books:

[1] Introduction to Graph Theory, D. B. West, Prentice-Hall, (2001).
[2] Graph Theory and Complex Networks: An Introduction, Maarten van Steen, (2010).
[3] Networks, Crowds, and Markets: Reasoning about a Highly Connected World, David Easley and Jon Kleinberg. Cambridge University Press, (2010).
[4] Introduction to Graph Neural Networks, Zhiyuan Liu and Zhou Jie, Springer Nature, (2022).
[5] Graph Neural Networks: Foundations, Frontiers, and Applications, Jian Pei (Editor), Liang Zhao (Editor), Lingfei Wu (Editor), Peng Cui (Editor), Springer, (2022).
[6] Graph Representation Learning, William L. Hamilton, McGill University, (2020).

SEMESTER - X

Paper Code: MATSPL 25104 (B)
Paper Title: Fluid Dynamics II
Theory Marks: 70
Internal Marks: 30

Course Learning Objectives:

1. Gain a comprehensive understanding of wave dynamics, including the behaviour of waves at the interface of two liquids, energy transmission in waves, and the significance of group velocity.
2. Develop a thorough understanding of the Navier-Stokes equations for viscous fluid motion, and study various types of steady laminar flows, including flows between parallel plates and through tubes.
3. Learn the principles of dynamical similarity and dimensional analysis, including the Buckingham Pi-theorem, and understand the significance of Reynolds number and magnetic Reynolds number.
4. Explore the theory of very slow motions, including Stokes and Oseen's equations, and apply these to analyze flow past a sphere and lubrication theory.
5. Gain insights into the theory of laminar boundary layers, including the two-dimensional boundary layer equations for flow over a plane wall, and apply Blasius-Topfer solutions to solve boundary layer problems.

Course Learning Outcomes:

1. Demonstrate the ability to analyze energy in stationary and progressive waves, calculate group velocity, and understand its dynamical significance in simple harmonic surface waves.
2. Apply the Navier-Stokes equations to solve problems involving steady laminar flow between parallel plates, through circular and non-circular tubes, and understand various flow scenarios such as Plane Couette and Poiseuille flow.
3. Utilize principles of dimensional analysis and the Buckingham Pi-theorem to solve fluid dynamics problems, and explain the significance of Reynolds number and its applications in different fluid flow conditions.
4. Solve problems involving very slow motions using Stokes and Oseen's equations, analyze flow past a sphere, and apply lubrication theory to practical fluid dynamics problems.
5. Apply the theory of laminar boundary layers to two-dimensional flow over a plane wall, use Blasius-Topfer solutions to find solutions to boundary layer equations, and understand the implications for practical fluid dynamics scenarios.

Unit-I: **Marks: 20**

Waves, Waves at the interface of two liquids, and with upper surface free, Energy of Stationary Waves and Progressive Waves, Group Velocity, Rate of Transmission of energy in simple harmonic surface waves, Dynamical significance of group velocity.

Unit-II: **Marks: 20**

Navier-Stoke's equations of motion of a viscous fluid, Equation of state for perfect fluid, Steady laminar flow between two parallel plates, Plane Coutte flow, Plane Poiseuille flow, The Hagen-Poiseuille flow, Laminar steady flow between two coaxial circular cylinders. Laminar steady flow of incompressible viscous fluid in tubes of cross-section other than circular.

Unit-III: **Marks: 15**

Dynamical similarity; Dimensional Analysis, Buckingham Pi-theorem; Reynold's number; Significance of Reynold's number, Maxwell's electromagnetic field equation; Magnetic Reynold's number.

Unit-IV: **Marks: 15**

Theory of very slow motions, Stokes equation, Oseen's equations, flow past a sphere, Lubrication theory. Theory of laminar boundary layers, Two-dimensional boundary layer equations for flow over a plane wall, Blasious-Topfer solutions.

Reference Books:

[1] Chorlton, Text Book of Fluid Dynamics, CBS Publishers, Delhi,1985.
[2] G. K. Batchelor, An Introduction to Fluid Mechanics, Foundation Books, New Delhi, 1994.
[3] H. Schlichting, Boundary Layer Theory, McGraw Hill Book Company, New York, 1971.
[4] M. D. Raisinghania, Fluid Mechanics (With Hydrodynamics) S. Chand and Company Ltd., New Delhi.
[5] R. K. Rathy, An Introduction to Fluid Dynamics, Oxford and IBH Publishing Company, New Delhi, 1976.