ATMANIRBHAR BHARAT
SWAYAMPURNA GOA

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Ref: GU/Acad –PG/BoS -NEP/2023/102/36 dated 15.06.2023

CIRCULAR

In supersession to the above referred Circular, the Syllabus of Semester III to VIII of the **Bachelor of Science in Mathematics** Programme approved by the Standing Committee of the Academic Council in its meeting held on 06^{th}, 07^{th} and 21^{st} March 2024 is enclosed. The syllabus of Semester I and II approved earlier is also attached.

The Dean/ Vice-Deans of the School of Physical and Applied Sciences and Principals of the Affiliated Colleges offering the **Bachelor of Science in Mathematics** programme are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

ASHWIN VYAS LAWANDE Digitally signed by ASHWIN VYAS LAWANDE Date: 2024.05.17 11:07:58 +05'30'

(Ashwin Lawande)
Assistant Registrar – Academic-PG

To,

The Principals of Affiliated Colleges offering the Bachelor of Science in Mathematics Programme.

Copy to:

1. The Director, Directorate of Higher Education, Govt. of Goa
2. The Dean, School of Physical and Applied Sciences, Goa University.
3. The Vice-Deans, School of Physical and Applied Sciences, Goa University.
4. The Chairperson, BOS in Mathematics.
5. The Controller of Examinations, Goa University.
6. The Assistant Registrar, UG Examinations, Goa University.
7. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

Programme Structure for Semester I to VIII Under Graduate Programme - Mathematics										
Semester	Major -Core	Minor	MC	AEC	SEC	I	D	VAC	Total Credits	Exit
I	MAT-100* Foundational Mathematics (3L+1P)	MAT-111 Elementary Mathematics (3L+1T) OR MAT-112 Elementary Statistics (3L+1T)	MAT-131 Mathematical Techniques in Competitive Exams (3L)		MAT-141 Numerical Analysis using Python/SageMath (1L+2P)				20	
II			MAT-132 Discreptive Statistics (3L)		MAT-142 (Statistical Methods Using R/SPSS/PSPP (1L+2P)				20	MAT-161 (4)*
III	MAT-200 #$* Calculus of One Variable (3L+1T) MAT-201 Ordinary Differential Equations (3L+1T)	MAT-211 Matrix Algebra (3L+1P) OR MAT-212 Enumerative Combinatorics (3L+1P)	MAT-231 Basic Financial Mathematics (3L)		MAT-241 Technical Typesetting Using LaTeX (1L + 2P)				20	

		OR MAT-213 Transformation Techniques (3L+1P)								
IV	MAT-202* Analysis (3L+1T) MAT-203#$* Linear Algebra (3L+1T) MAT-204 Basic Number Theory (3L+1T) MAT-205#* Analytical 2D Geometry (2L)	MAT-221 Probability Theory VET (3T+1P) OR MAT-222 Theory of Equations (3L+1P) OR MAT-223 Graph Theory (3L+1P)							20	MAT-162 (4)@
V	MAT-300* Riemann Integration and	MAT-321 Linear Programming				Internship (2)			20	

	Improper Integrals (3L+1T) MAT-301#$* Group Theory I (3L+1T) MAT-302# Metric Spaces (3L+1T) MAT-303* Analytical 3D Geometry (2L)	Problems VET (3L+1P) OR MAT-322 Applied Statistics (3L+1P) OR MAT-323 Bio Mathematics (3L+1P)								
VI	MAT-304 Group Theory II (3L+1T) MAT-305#$* Complex Analysis (3L+1T) MAT-306$ Vector Calculus (3L+1T)	MAT-324 Operations Research VET (3T+1P) OR MAT-325 Econometrics (3L+1P) OR							20	

	MAT-307* Project (3L+1T)	**MAT-326 Mathematical Demography (3L+1P)**								
VII	**MAT-400* Advanced Real Analysis (3L+1T) MAT-401*$ Rings and Fields (3L+1T) MAT-402#$* Advanced Linear Algebra (3L+1T) MAT-403 Advanced Complex Analysis (3L+1T)**	**MAT-411 Difference Equations (3L+1T) OR MAT-412 Measure Theory (3L+1T)**							**20**	
VIII	**MAT-404 Functions of Several Variables (3L+1T)**	**MAT-413 Integral Equations (3L+1T)**							**20**	

	MAT-405*$ **Topology** **(3L+1T)** **MAT-406** **Functional Analysis** **(3L+1T)** **MAT-407#$*** **Advanced Differential Equations** **(3L+1T)**	**OR** **MAT-414** **Partial Differential Equations** **(3L+1T)**								

*- Courses to be taken for Double major programme (60%).

$- Courses to be taken for Double major programme (40%).

#- Courses to be taken for Multidisciplinary/Interdisciplinary programmes.

@- List of Exit Courses will be provided separately.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-100**
Title of the Course : **Foundational Mathematics**
Number of Credits : **4 (3L+1P)**
Effective from AY : **2023-24**

Prerequisites for the Course	Basic 12th standard mathematics.	
Course Objectives	To develop logical reasoning among students in order to be able to organize all aspects of mathematics in such a way that at the base are the most fundamental concepts, assumptions and principles, and the other aspects depend on this base.	
Content		**No. of Hours**
Unit I	**Statements and Logic**: Statements; Statements with quantifiers; Compound statements; Implications; Proofs in Mathematics. **Sets**: Basic Terminologies; Operations on sets; Family of sets; Power sets; Cartesian product of sets.	**03** **06**
Unit II	**Functions**: Basic definitions: One-One, Onto functions and Bijections; Composition of functions; Inverse of a function; Image of subsets under functions; Inverse image of subsets under functions.	**12**
Unit III	**Relations**: Relation on sets; Types of relations; Equivalence relations; Equivalence classes and partitions of sets. **Induction Principles**: The Induction Principle; The Strong Induction Principle; The Well – Ordering Principle; Equivalence of the three principles.	**05** **05**
Unit IV	**System of Linear Equations:** Solutions & Elementary Operations: Linear system of equations and their solutions; Equivalence of two systems; Elementary operations on equations; elementary row operations. Gaussian Elimination: Row reduced echelon forms; Gaussian algorithm; Rank. Homogeneous Equations: Sufficient condition for the existence of a non-trivial solution. **Determinants:** The Laplace Expansion: Determinants and their properties. Determinant & Matrix inverses: Product theorem and other related theorems (Statements of these theorems only. However, the idea of the proof, though not a part of the syllabus, is encouraged); Adjoint formula for A^{-1}; Cramer's rule.	**08** **06**

Practical	**30 hours are to be dedicated for working with exercises and solving problems on the following:** 1. Identifying and using quantifiers, Negating statements with single and multiple quantifiers, Compound statements with quantifiers, Conjunction and disjunction of statements, and Negation of a compound statement. 2. Different forms of implications, Converse of implications, Negating implications, and Contrapositive of implications. 3. Different types of proofs in mathematics. 4. Operations on sets like union, intersection, set difference, and complementation. 5. Identifying one – one and onto functions – I. 6. Identifying one – one and onto functions – II. 7. Finding "natural" bijections between given sets and finding the inverse of a bijective function. 8. Inverse image of subsets under functions. 9. Identifying the type of relation and Obtaining equivalence classes of an equivalence relation. 10. Using induction principles to establish statements. 11. Solving systems of linear equations using elementary operations. 12. Reducing a matrix to row – echelon form using Gaussian algorithm. 13. Solving homogeneous systems of equations. 14. Computing determinants using the properties of determinants. 15. Solving a system of equations using Cramer's rule.	30
Pedagogy	Lectures/Practical/Self study. Lectures should include theory and examples. Practical to be exclusively dedicated for problem solving. The record of practical shall be maintained by students in a separate manual/journal duly certified by the instructor.	
References/Readings	1) Ajit Kumar, S. Kumaresan, and B. K. Sarma: *A Foundation Course in Mathematics*, Narosa Publishers, 2018. (**Principal Text**) 2) W. K. Nicholson: *Linear Algebra with Applications,* 4th Edition, McGraw – Hill Ryerson Limited, 2003. (**Principal Text**) 3) Vipul Kakkar: *Set Theory: Read it, Absorb it and Forget it*, Narosa Publishers, 2018. 4) Paul Halmos: *Set Theory*, Springer – Verlag, 1960. 5) S. Lipschitz: *Schaum's Outlines: Theory and Problems of Linear Algebra*, McGraw Hill, 2009.	

Course Outcomes	The student will be able to, 1. Infer the truth of various sentences and its equivalents and outline various properties of sets. 2. Examine and Identify the types of relations and functions. 3. Make use of the strong and weak induction. 4. Solve systems of linear equations. 5. Discuss the properties of determinants.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-111**
Title of the Course : **Elementary Mathematics**
Number of Credits : **4 (3L+1T)**
Effective from AY : **2023-24**

Prerequisites for the Course	Basic 12th standard mathematics.	
Course Objectives	To help students understand and acquire basic mathematical concepts and computational skills and apply these fundamental concepts in related disciplines.	
Content		**No. of Hours**
Unit I	**Logic and Propositional Calculus:** Propositions and Compound Statements; Basic Logical Operations; Propositions and Truth Tables; Tautologies and Contradictions; Logical Equivalence; Algebra of Propositions; Conditional and Biconditional Statements. **Sets:** Sets and their representation; The empty set; Finite and Infinite Sets; Equal Sets; Subsets; Power Set; Universal Set; Union and Intersection of sets; Venn Diagrams; Operations on Sets; Complement of a set. **Relations and Functions:** Cartesian product of sets; Relation and their types; Functions and their types; Algebra of functions; Composition of functions; Invertible functions; Binary operations.	**05** **04** **06**
Unit II	**Limits:** Geometric meaning of limits; Standard limits. **Continuity:** Geometric meaning of continuity; Continuous functions; Algebra of continuous functions; Examples of continuous functions; Discontinuities; Types of discontinuities. **Differentiability:** First principle of differentiation; Algebra of differentiability namely sum/product/quotient rule; Examples; Result that every differentiable function is continuous; Derivative of the composition; Chain rule; (Statements of these results only. However, the idea of the proof, though not a part of the syllabus, is encouraged) Examples; Optimization problems.	**02** **04** **04**
Unit III	**Complex Numbers:** Algebra of complex numbers; Modulus and Complex conjugate; Argand plane and polar representation. **Vector Algebra:** Types of vectors; Addition of vectors; Multiplication of a vector by a scalar; Dot product and cross product of vectors, and their geometrical interpretation;	**04** **06**

	Concept and computation of gradient, divergence, and curl of a vector field.	
Unit IV	**Ordinary Differential Equations:** Types of differential equations; Order and Degree of a differential equation; Solution of a differential equation; Types of solutions; Formation of a differential equation by eliminating arbitrary constants; Methods of solving first – order and first – degree differential equations.	**10**
Tutorial	**15 hours shall be utilized for solving the following:** 1. Constructing and understanding truth tables. 2. Problems on set theory. 3. Identifying types of relations. 4. Identifying injective/surjective functions. 5. Computing the inverse of a bijective function. 6. Evaluating limits of functions. 7. Testing the continuity/discontinuity of a function and identifying the type of discontinuity. 8. Using the various differentiation rules to find the derivative of a given function. 9. Finding the maximum value of functions. 10. Finding the minimum value of functions. 11. Expressing complex numbers in polar form. 12. Solving problems involving gradient, divergence, and curl. 13. Forming a differential equation. 14. Solving ordinary differential equations – I. 15. Solving ordinary differential equations – II.	**15**
Pedagogy	Lectures/Tutorials/Self-study. Lectures should include theoretical concepts and examples. Tutorial to be exclusively dedicated for problem solving. The record of tutorials may be maintained by students in a separate notebook.	
References/Readings	1) E. Mendelson: *Shaum's Outlines: Beginning Calculus*, 3rd Edition, McGraw Hill Education, 2007. 2) M. R. Spiegel, S. Lipschutz, J. J. Schiller, and D. Spellman: *Shaum's Outlines: Complex Variables*, 2nd Edition, McGraw Hill Education, 2017. 3) M. R. Spiegel, S. Lipschutz, and D. Spellman: *Shaum's Outlines: Vector Analysis*, 2nd Edition, McGraw Hill Education, 2017. 4) R. Bronson: *Shaum's Outlines: Differential Equations*, 3rd Edition, McGraw Hill Education, 2017. 5) S. Lipschutz, and M. L. Lipson: *Shaum's Outlines: Discrete Mathematics*, 3rd Edition, McGraw Hill Education, 2017.	

Course Outcome	The student will be able to, 1. Identify the truth and falsity of a statement. 2. Comprehend the concept of Sets, Relations, and Functions. 3. Evaluate basic limits, Identify discontinuous functions, and Apply the techniques of differentiation. 4. Construct the polar form of complex numbers. 5. Compute the gradient, curl, and divergence. 6. Formulate and Solve differential equations.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-112**
Title of the Course : **Elementary Statistics**
Number of Credits : **4 (3L+1T)**
Effective from AY : **2023-24**

Prerequisites for the Course	NIL	
Course Objectives:	This course is intended to familiarize students with organizing, summarizing, analyzing data, and drawing appropriate conclusions from it. The various tools and techniques are also intended to be used in day-to-day real – world problems.	
Content		**No. of Hours**
Unit I	**Introductory concepts**: Definition and scope of Statistics; Concept of population and sample. **Types of data**: Quantitative; Qualitative; Attributes; Variates. **Tabulation of data:** Class intervals; Frequency tables. **Presentation of data**: Diagrams and graphs: Bar diagrams and their types; Pie charts; Frequency polygon; Histogram; Ogives. Consistency and independence of data with special reference to attributes. **Scales of measurement:** Nominal, Ordinal, Interval, Ratio. **Measures of Central Tendency**: Mathematical and Positional – Mean, Median, Mode, Quartiles, Percentiles. **Measures of Dispersion**: Range, Quartile deviation, Standard deviation, Coefficient of variation.	**15**
Unit II	**Bivariate data**: Definition; Scatter diagram. **Correlation and Regression:** Simple, Partial and Multiple Correlation (3 variables only); Rank correlation; Simple linear regression.	**10**
Unit III	**Probability**: Introduction; Random experiments; Sample space; Events and algebra of events; Definitions of Probability – Classical, Statistical, and Axiomatic; Conditional Probability; Addition and Multiplication theorem of probability; Independent events; Theorem of Total probability; Bayes' theorem and its applications.	**10**
Unit IV	**Statistical Quality Control:** Introduction; Causes of variation in quality; Objective, advantages, and techniques of SQC. **Attribute data:** P chart, U chart, C chart. **Numerical data:** X bar chart, R bar chart, S bar chart.	**10**

	Sampling techniques: Various methods of data collection; Census survey and sample survey. **Sampling Methods:** Simple random sampling; Systematic sampling; Stratified sampling; Clustered sampling. **Non – probability Sampling Methods:** Convenience sampling; Consecutive sampling; Quota sampling; Purposive or Judgmental sampling; Snowball sampling.	
Tutorial	**15 hours are to be dedicated for illustrations with specific examples and numerical exercises. The following topics are to be covered during practical:** 1. Data entry in Excel and basic tools in Excel. 2. Drawing of Frequency tables for raw, grouped, and ungrouped data. 3. Graphical representations using various diagrams. 4. Finding Mean, Median, Mode. 5. Finding Quartiles and Percentiles. 6. Computing measures of dispersion, namely, Range, Quartile deviation, Standard deviation, and Coefficient of variation. 7. Computing and Analyzing the various types of correlation. 8. Finding the Rank correlation. 9. Analysing Multiple correlation. 10. Analysing Regression. 11. Solving problems on the addition and multiplication theorem of probability. 12. Solving problems on conditional probability and total probability. 13. Solving problems on Bayes' theorem. 14. Demonstration of quality control using P chart, U chart, C chart. 15. Demonstration of quality control using X bar chart, R bar chart, S bar chart.	**15**
Pedagogy	Lectures/Tutorials/Self-study. Lectures should include theoretical concepts and examples. Tutorial to be exclusively dedicated for problem solving. In Unit I and II, more focus is to be kept on the applications of measures. The record of tutorials may be maintained by students in a separate notebook. Tutorial to be conducted using case studies/secondary data. The use of simple software like Excel during tutorial, wherever possible, is encouraged.	
References/Readings	**Principal Text**	

	1) S. C. Gupta: *Fundamentals of Statistics,* 7th Edition, Himalaya Publishing House, 2018. **Other Texts** 2) A. M. Goon, M. K. Gupta, and B. Dasgupta: *Fundamentals of Statistics, Vol. I*, 8th Edition, The World Press, Kolkata, 2016. 3) S. C. Gupta, and V. K. Kapoor: *Fundamentals of Mathematical Statistics*, 12th Edition, S. Chand and Sons, Delhi, 2020. 4) S. P. Gupta: *Statistical Methods,* S. Chand & Sons, 2017. 5) S. Bernstein, and R. Bernstein: *Schaum's Outlines: Elements of Statistics I – Descriptive Statistics and Probability*, McGraw Hill, 2020.
Course Outcomes	The student will be able to, 1. Interpret data and graphically represent it. 2. Calculate measures of central tendencies and variations. 3. Analyze correlation and regression. 4. Solve problems in Probability theory. 5. Understand different data sampling techniques. 6. Apply statistical quality control.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-131**
Title of the Course : **Mathematical Techniques in Competitive Exams**
Number of Credits : **3 (3L)**
Effective from AY : **2023-24**

Prerequisites for the Course	NIL	
Course Objectives	To make students competent enough to answer competitive examinations like Banks, Post Office, SSC, LIC, CDS, CSAT, CAT, CMAT, GMAT, MAT, UPSC, CBI, CPO, Civil Services, Hotel Management, Railway, Police, Defence, etc.	
Content		**No. of Hours**
Unit I	**Ratio and Proportion:** Ratio; Comparison of ratios; Proportion. **Mixture or Alligation:** Mixture; Rule of mixture or allegation. **Partnership:** Types of partnerships; Types of partners. **Problems Based on Ages:** Rules for problems based on ages.	**15**
Unit II	**Work and Time:** Basic rules related to work and time. **Work and Wages:** Important points. **Pipes and Cisterns:** Facts related to pipes and cisterns. **Clock and Calendar:** Clock; Calendar; Day Gain/Loss.	**15**
Unit III	**True Discount and Banker's Discount:** True discount; Banker's discount. **Speed, Time and Distance:** Basic formulae related to speed, time and distance. **Problems Based on Trains:** Basic rule related to problems based on trains. **Boats and Streams:** Concepts and formulae on boats and streams.	**15**
Pedagogy	Lectures/Problem Solving/Self study.	
References/Readings	1) R. Verma: *Fast Track Objective Artithmtic*, Arihant Publications Limited, 2017. (**Principal Text**) 2) A. Sharma: *How to Prepare for Quantitative Aptitude for CAT*, 9th Edition, McGraw Hill, 2021. 3) P. K. Mishra, and R. Mishra: *Elementary & Advanced Mathematics For Competitive Exams*, Source Books, 2018. 4) R. S. Aggarwal: *Quantitative Aptitude for Competitive Examinations*, S. Chand Publications, 2017. 5) R. Mathuriya: *Mathematics for all Competitive Exams SSC (Pre./Mains),* Sunita Publications, 2017.	
Course Outcomes	The student will be able to, 1. Apply mathematical techniques in solving problems.	

	2. Identify tricks in solving problems quickly. 3. Employ various strategies to solve problems arising in various competitive exams. 4. Manage time in answering several questions appearing in the exam.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-132**
Title of the Course : **Descriptive Statistics**
Number of Credits : **3 (3L)**
Effective from AY : **2023-24**

Prerequisites for the Course	NIL	
Course Objectives:	To make students aware of various statistical tools and techniques that can be employed in data analysis and simple research.	
Content		**No. of Hours**
Unit I	**Data Visualization** Introduction to Statistics: Definition and scope of Statistics; Concepts of statistical population and sample; Variates and attributes. Types of Data: Quantitative and Qualitative data, Cross-sectional and Time-series data, Discrete and continuous data. Different types of scales: Nominal, Ordinal, Interval and Ratio. Collection and Scrutiny of Data: Primary data, Secondary data – its major sources, Complete enumeration; Construction of tables with one or more factors of classification; Frequency distributions and cumulative frequency distributions and their graphical representations (Histograms, frequency polygon, Ogives).	**15**
Unit II	**Data Summarization** Measures of Central Tendency: Mean, Median, Mode. Measures of Dispersion: Range, Quartile deviation, Mean deviation, Standard deviation, Coefficient of variation, Skewness and Kurtosis.	**15**
Unit III	**Correlation and Regression** Bivariate data: Scatter diagram; Karl Pearson's coefficient of correlation; Spearman's rank correlation coefficient. Bivariate Regression Analysis: Regression lines; Properties of regression coefficients; Residual variance. Principle of least squares and fitting of polynomials and exponential curves.	**15**
Pedagogy	Lectures/Problem Solving/Self study.	
References/Readings	1) S. C. Gupta: *Fundamentals of Statistics,* 7^{th} Edition, Himalaya Publishing House, 2018. (**Principal Text**) 2) A. M. Goon, M. K. Gupta, and B. Dasgupta: *Fundamentals of Statistics, Vol. I*, 8^{th} Edition, The World Press, Kolkata, 2016.	

	3) S. C. Gupta, and V. K. Kapoor: *Fundamentals of Mathematical Statistics*, 12th Edition, S. Chand and Sons, Delhi, 2020. 4) S. P. Gupta: *Statistical Methods,* S. Chand & Sons, 2017. 5) S. Bernstein, and R. Bernstein: *Schaum's Outlines: Elements of Statistics I – Descriptive Statistics and Probability*, McGraw Hill, 2020.
Course Outcomes	The student will be able to, 1. Understand concepts of sample v/s. population and Identify different types of scales. 2. Distinguish between primary and secondary data and Organize the Statistical data. 3. Calculate measures of central tendencies and variations. 4. Interpret correlation and regression.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-141**
Title of the Course : **Numerical Analysis using Python/SageMath**
Number of Credits : **3 (1L+2P)**
Effective from AY : **2023-24**

Prerequisites for the Course	Basic 12th standard mathematics.	
Course Objectives:	To make students aware of numerical methods that can be employed to obtain good approximate numerical solutions to problems that may not be able to be solved in a closed form and to effectively use software in these computations.	
Content		**No. of Hours**
Unit I	**Elementary Error Analysis:** Numbers: Exact and Approximate; Significant digits; Errors: Absolute, Relative and Percentage errors; Examples. **Solution of Algebraic and transcendental Equations:** Bisection Method; Regula – Falsi Method; Secant Method; Newton – Raphson Method; Special Cases of Newton – Raphson Method like finding q^{th} root of a positive real number 'd' and finding reciprocal of a positive real number 'd' without using division; Bairstow's Method; Remarks on convergence. **(PROBLEMS IN THIS UNIT TO BE DONE IN PRACTICAL)**	**05**
Unit II	**Calculus of Finite Differences:** Operators Δ, ∇, & E; Difference Tables; Properties of Δ, ∇, & E; Fundamental Theorem of Difference Calculus; Expression of any value of a function in terms of leading term and leading differences of a difference table. **Interpolation and Extrapolation:** Newton's Forward and Backward Interpolation formulae; Central difference Interpolation formula; Lagrange's Interpolation formula; Newton's Divided Difference formula. **(PROBLEMS IN THIS UNIT TO BE DONE IN PRACTICAL)**	**05**
Unit III	**Numerical Differentiation and Integration:** Differentiation formulae for equidistant arguments; General quadrature formula for equidistant ordinates (Newton – Cotes Formula or Gauss Legendre quadrature formulae); Trapezoidal rule and its Geometrical interpretation; Simpson's one – third rule; Simpson's three – eighth rule; Weddle's rule. **Method of Least Squares:** Fitting of straight line, Fitting of quadratic curve; Fitting of an exponential curve.	**05**

	<u>(PROBLEMS IN THIS UNIT TO BE DONE IN PRACTICAL)</u>	
Practical	**Out of the 60 total hours for practical, around 30 hours may be dedicated for manual problem solving.** **The remaining time of around 30 hours shall be utilized for executing the following computations using Python/SageMath:** 1. Finding roots of equations using Bisection method. 2. Finding roots of equations using Regula – Falsi method. 3. Finding roots of equations using Secant method. 4. Finding roots of equations using Newton – Raphson method and Finding q^{th} roots and reciprocals of equations using Newton – Raphson method. 5. Finding roots of polynomials using Bairstow's method. 6. Interpolating data using Newton – Gregory's Forward Difference Interpolation Formula. 7. Interpolating data using Newton – Gregory's Backward Difference Interpolation Formula. 8. Interpolating data using Central Difference Interpolation Formula. 9. Interpolating data using Newton's Divided Difference Interpolation Formula. 10. Interpolating data using Lagrange Interpolation Formula. 11. Computing the first and second order numerical derivative. 12. Calculating the numerical integral using Trapezoidal rule. 13. Calculating the numerical integral using Simpson's $1/3^{rd}$ and $3/8^{th}$ rule. 14. Fitting a straight line to a given data. 15. Fitting quadratic and exponential curves to a given data.	**60**
Pedagogy	Lectures/Practical/Self study. Visualizations using software, wherever possible, is encouraged.	
References/Readings	1) B. S. Grewal: *Numerical Methods in Engineering and Science with Programs in C & C++*, Khanna Publishers, 2010. (**Principal Text**) 2) A. N. Kamthane, and A. A. Kamthane: *Programming and Problem Solving with Python*, McGraw Hill Education, 2017. 3) P. P. Gupta, G. S. Malik, and J. P. Chauhan: *Calculus of Finite Differences & Numerical Analysis*, Krishna Prakashan Media, 2015. 4) S. S. Sastry: *Introductory Methods* of *Numerical Analysis,* Prentice Hall India Pvt. Ltd., 2012.	

	5) SAGE Documentation.
Course Outcomes	The student will be able to, 1. Find the roots of algebraic and transcendental equations. 2. Apply Interpolation to solve real life problems. 3. Make use of the techniques of numerical differentiation and integration. 4. Determine the best line/quadratic curve/exponential curve to fit the give data. 5. Utilize Python/SageMath software to aid mathematical pursuits.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-142**
Title of the Course : **Statistical Methods Using R/SPSS/PSPP**
Number of Credits : **3 (1L+2P)**
Effective from AY : **2023-24**

Prerequisites for the Course	NIL	
Course Objectives	To make students aware of various statistical methods that can be employed in data analysis, hypothesis testing and research.	
Content		**No. of Hours**
Unit I	**Introduction – Meaning and Scope**: Definition of Statistics; Importance and scope of Statistics; Limitations of Statistics. **Data Summarization:** Measures of Central Tendency: Mean, Median, Mode. Measures of Dispersion: Range, Quartile deviation, Mean deviation, Standard deviation, Coefficient of variation; Skewness and Kurtosis. Graphical representation of various measures of location and dispersion: Bar Graphs, Histograms, Frequency polygons, Ogives, Pie Charts. **Correlation and Regression Analysis**: Introduction; Karl Pearson's coefficient of Correlation; Spearman's Rank correlation; Bivariate Linear Regression Analysis. **(PROBLEMS IN THIS UNIT TO BE DONE IN PRACTICAL)**	**05**
Unit II	**Theory of Probability**: Introduction; Mathematical probability; Statistical probability; Axiomatic probability; Addition theorem of probability; Multiplication theorem of probability; Pair wise and mutual independence; Total probability theorem; Bayes' theorem. **Random Variables**: Random variable; Probability distribution of a Discrete Random Variable; Probability distribution of a Continuous Random Variable; Mathematical Expectations. **Theoretical Distributions**: Binomial distribution; Poisson Distribution; Normal Distribution. **(PROBLEMS IN THIS UNIT TO BE DONE IN PRACTICAL)**	**05**
Unit III	**Testing of Hypothesis**: Interval Estimation; Testing of Hypothesis.	

	Large sample tests: Introduction; Sampling of Attributes; Sampling of Variables. **Parametric tests**: Student's t distribution (Independent and Paired 't' test); One Way and Two Way ANOVA. **Non-Parametric tests**: Chi Square test; Mann-Whitney test; Kruskal Wallis test. **(PROBLEMS IN THIS UNIT TO BE DONE IN PRACTICAL)**	**05**
Practical	**Out of the 60 total hours for practical, 40 hours may be dedicated for manual problem solving.** **The remaining 20 hours shall be utilized for executing the following computations using R/SPSS/PSPP:** 1. Importing data from CSV or Excel file. Data entry in R/SPSS/PSPP. 2. Finding measures of central tendency, namely, mean, median and mode. 3. Finding measures of dispersion, namely, range, quartile deviation, mean deviation and standard deviation. 4. Graphical representations and their interpretations. 5. Analyzing correlation and regression. 6. Testing of hypothesis for single mean and difference of means using independent t- test and paired t-test. 7. Testing of hypothesis for more than two means using ANOVA. 8. Testing of hypothesis regarding independence of attributes using Chi square test. 9. Testing the hypothesis stating that the k independent samples have been drawn from the populations which have identical distributions using Kruskal Wallis test. 10. Working with questionnaires for understanding the collected data and their analysis.	**60**
Pedagogy	Lectures/Practical/Case study.	
References/Readings	1) S. C. Gupta: *Fundamentals of Statistics,* 7th Edition, Himalaya Publishing House, 2018. (**Principal Text**) 2) A. M. Goon, M. K. Gupta, and B. Dasgupta: *Fundamentals of Statistics, Vol. I*, 8th Edition, The World Press, Kolkata, 2016. 3) S. C. Gupta, and V. K. Kapoor: *Fundamentals of Mathematical Statistics*, 12th Edition, S. Chand and Sons, Delhi, 2020. 4) S. P. Gupta: *Statistical Methods,* S. Chand & Sons, 2017. 5) S. Bernstein, and R. Bernstein: *Schaum's Outlines: Elements of Statistics I – Descriptive Statistics and Probability*, McGraw Hill, 2020.	
Course Outcomes	The student will be able to, 1. Calculate measures of central tendencies and variations.	

	2. Interpret correlation and regression. 3. Solve problems in Probability theory. 4. Demonstrate and Infer based on various statistical tests using statistical software.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-200**
Title of the Course : **Calculus of One Variable**
Number of Credits : **3L+1T**
Effective from AY : **2024-25**

Pre-requisites for the course:	Basic 12th standard mathematics and a Foundational Course in Mathematics.	
Course Objectives:	To develop the habit of critical thinking and solving problems involving the fundamental concepts on the Least Upper Bound (LUB) property, continuity and differentiability of functions of a single variable.	
Content		**No. of Hours (L+T)**
Unit I	**Real Number System:** Algebra of real number system; Upper and Lower bounds of subsets of $\mathbb{R}$; Least Upper Bound Property and its Applications; Absolute value and their properties.	**11+3**
Unit II	**Real Sequences:** Sequences and their convergence; Cauchy sequences; Monotonic sequences; Sandwich Lemma; Some important limits; Subsequences.	**4+2**
Unit III	**Continuity:** Continuous functions; Sequential criteria and $\epsilon - \delta$ definition of continuity; Intermediate value theorem; Extreme value theorem; Monotone functions; Limits; Uniform continuity and results in uniform continuity.	**15+5**
Unit IV	**Derivatives and its Applications:** Derivative of a function at a point; Geometric interpretation of a derivative; Algebra of derivatives; Chain rule; Properties of the derivative; Rolle's theorem, Lagrange's Mean Value Theorem, Cauchy's Mean Value theorem, and their geometric significance; Darboux theorem for differentiable functions; *Higher order derivatives' Taylor's theorem; Maclaurin's theorem; Leibnitz rule for higher order derivative of product of functions; Stationary points and their classification; Local maxima and Local minima; Condition for a stationary point to be local maxima and minima; Indeterminate forms of the type* $\frac{0}{0}, \frac{\infty}{\infty}, \infty - \infty, 0.\infty, 0^0, 1^\infty, \infty^0$. *(Only statements and examples on the topics underlined and in italics).*	**15+5**
Pedagogy:	Lectures/Tutorials/Self-study. Lectures should include theory and examples. Tutorial to be exclusively dedicated for problem solving.	

Reference/ Reading:	**PRINCIPAL TEXT:** A. Kumar, and S. Kumaresan: *A Basic Course in Real Analysis*, CRC Press, 2014. **REFERENCES** 1) M. Spivak: *Calculus,* Publish or Perish, Inc., 2008. 2) R. G. Bartle, and D. R. Sherbert: *Introduction to Real Analysis*, 4th Edition, Wiley, 2014. 3) S. Abbott: *Understanding Analysis,* 2nd Edition, Springer Nature, 2016. 4) S. Narayan, and M. D. Raisinghania: *Elements of Real Analysis,* Revised Edition, S. Chand Publications, 2016. 5) S. C. Malik, and S. Arora: *Mathematical Analysis,* 6th Edition, New Age International Publishers, 2022. 6) T. M. Apostol: *Mathematical Analysis*, 2nd Edition, Narosa Publishing House, 2002.
Course Outcomes:	The student will be able to, 1. Explain the algebra and properties of the set of real numbers. 2. Analyze various real sequences, their properties, and examine their convergence. 3. Prove and apply results in limits and continuity and disprove false statements. 4. Prove and apply results in differentiability and disprove false statements.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-201**
Title of the Course : **Ordinary Differential Equations**
Number of Credits : **3L+1T**
Effective from AY : **2024-25**

Pre-requisites for the course:	Basic 12th standard Mathematics	
Course Objectives:	This course helps in understanding basic concepts of Differential Equations. It develops the ability to solve differential equations by analytical and numerical methods	
Content:		**No. of Hours (L+T)**
Unit I	**Differential Equations of First Order**: Some Basic Mathematical Models; Direction Fields; Solutions of Some Differential Equations; Classification of Differential Equations; Linear Equations; Bernoulli Equation; Method of Separation of Variables; First Order Equations; Linear and Nonlinear Equations; Exact Equations and Integrating Factors; Initial Value Problems; The Existence and Uniqueness Theorem for initial value problem. (Proof to be done).	**15+5**
Unit II	**Differential Equations of Second Order**: Homogeneous Equations with Constant Coefficients; Solutions of Linear Homogeneous Equations: The Wronskian; Complex Roots of the Characteristic Equation**;** Euler-Cauchy Equations, Repeated Roots; Reduction of Order; Nonhomogeneous Equations; Method of Undetermined Coefficients**;** Variation of Parameters. **Higher Order Linear Equations:** General Theory of *n*th Order Linear Equations with Constant Coefficients**;** Homogeneous and Non-Homogeneous Equations**;** The Method of Undetermined Coefficients**,** The Method of Variation of Parameters	**14+4**
Unit III	**D-operator Method**; Inverse D – operators; Solution of f(D)y = X where X = exp(kx), cos(kx), sin(kx), polynomials in x and their products; $\{1/(D^2+a^2)\}f(x)$, where f(x)=Sin(ax), Cos(ax).	**10+4**
Unit IV	**Numerical Solutions of First Order Ordinary Differential Equations**: Euler's and Modified Euler's method; Taylor's Method; Runge – Kutta second and fourth order methods. (Formulae and examples only)	**6+2**
Pedagogy:	Lectures/ tutorials/assignments/self-study. Lectures should include theory and examples. Tutorial to be exclusively dedicated for problem solving.	

Reference/ Reading:	**PRINCIPAL TEXTS:** 1) Boyce, W. E. and DiPrima, R. C.: *Elementary Differential Equations and Boundary Value Problems,* 9th Edition, Wiley Publications, 2009. 2) Iyengar, T. K. V., Krishna Gandhi, B., Ranganatham, S. and Prasad, M. V. S. S. N.: *Mathematical Methods,* S. Chand Publications, 2008. **REFERENCES:** 1. Bronson, Richard. *Differential equations*, 4th Edition. The McGraw Hill Companies, (1973) . 2. Daniel A. Murray: *Introductory Course in Differential Equations*, Orient (2003). 3. Earl A. Coddington, An Introduction to Ordinary Differential Equations, Dover Publications (1920). 4. George F. Simmons: *Differential Equations with Applications and Historical Notes,* 2nd Edition, McGraw Hill Education, 2017. 5. Kreyszig, Erwin: *Advanced Engineering Mathematics (Ed.)*, United States of America: Laurie Rosatone John Wiley & Sons. (2011). 6. Raisinghania, M. D.: *Ordinary and Partial Differential Equations*, 20th Edition, S. Chand Publications, 2020. 7. Ross, S. L.: *Differential Equations,* 3rd Edition, Wiley, 2007. 8. Sastry, S. S.: Introductory Methods of Numerical Analysis, Fifth Edition, PHI (2012)
Course Outcomes:	1. Identify the type of a given differential equation. 2. Understand the concept and apply appropriate analytical techniques for finding the solution. 3. Prove various results concerning the methods and existence and uniqueness of solutions of differential equations. 4. Solve ordinary differential equations by using various numerical methods.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-202**
Title of the Course : **Analysis**
Number of Credits : **3L+1T**
Effective from AY : **2024-25**

Pre-requisites for the course:	A course in Calculus of One Variable.	
Course Objectives:	To develop mathematical thinking so as to understand the underlying geometry behind various concepts in analysis and appreciate various concepts in convergence of sequences and series of real numbers, and sequences and series of functions.	
Content		**Hours (L+T)**
Unit I	**Real Sequences:** Real Sequences; Range of a sequence; Convergence of a sequence; Uniqueness of limit of sequence; Bounded sequence; Algebra of sequences; Cauchy sequences; Monotonic sequences and their convergence; Sandwich Lemma; Some important limits; Sequences diverging to $\pm\infty$; Subsequences; Sequences defined recursively.	**12+3**
Unit II	**Series of Real Numbers:** Positive term series; Geometric series; Convergence of series; Cauchy's General principle of Convergence; Absolute convergence; Conditional convergence; Comparison test; Ratio test; Cauchy's root test; Integral test; Cauchy condensation test; Leibinitz test for Alternating series; Abel – Pringsheim theorem; Abel's summation by parts; Dirichlet's test; Dedekind's test; Rearrangements of an infinite series; Riemann's theorem; Cauchy product of two infinite series.	**11+4**
Unit III	**Sequences of Functions:** Examples of sequences of real – valued function; Pointwise convergence of sequences of real valued functions defined on a subset of Uniform convergence; Cauchy's condition for uniform convergence of a sequence of functions; Consequences of uniform convergence – Boundedness, Continuity, Integrability and Differentiability of the limit function.	**11+4**
Unit IV	**Series of Functions:** Convergence and Uniform convergence of series of functions; Cauchy's condition for uniform Convergence of series; Comparison test; Weierstrass' M-test for Uniform convergence; Dirichlet's test and Abel's test for uniform convergence; Power Series – Uniform convergence and term by term integration and differentiation; Examples of non-uniformly convergent series that can be integrated term by term; Abel's limit	**11+4**

	theorem; Taylor series for a smooth function; Binomial series; Weierstrass Approximation Theorem.	
Pedagogy:	Lectures/Tutorials/Self-study. Lectures should include theory and examples. Tutorial to be exclusively dedicated for problem solving.	
Reference/ Reading:	**PRINCIPAL TEXT:** A. Kumar, and S. Kumaresan: *A Basic Course in Real Analysis*, CRC Press, 2014. **REFERENCES:** 1) M. Spivak: *Calculus,* Publish or Perish, Inc., 2008. 2) R. G. Bartle, and D. R. Sherbert: *Introduction to Real Analysis*, 4th Edition, Wiley, 2014. 3) S. Abbott: *Understanding Analysis,* 2nd Edition, Springer Nature, 2016. 4) S. Narayan, and M. D. Raisinghania: *Elements of Real Analysis,* Revised Edition, S. Chand Publications, 2016. 5) S. C. Malik, and S. Arora: *Mathematical Analysis,* 6th Edition, New Age International Publishers, 2022. 6) T. M. Apostol: *Mathematical Analysis*, 2nd Edition, Narosa Publishing House, 2002.	
Course Outcomes:	The student will be able to, 1. Analyze various real sequences, their properties, and examine their convergence. 2. Apply various convergence tests to identify convergent series. 3. Decide on uniform and pointwise convergence of a sequence of functions. 4. Judge the uniform and pointwise convergence of a series of functions.	

Name of the Programme : **B.Sc. (Mathematics)**
Course Code : **MAT-203**
Title of the Course : **Linear Algebra**
Number of Credits : **3L+1T**
Effective from AY : **2024-25**

Pre-requisites for the Course:	Basic knowledge of Matrices and Matrix Operations along with System of Linear Equations	
Course Objectives:	To display familiarity and knowledge of vector spaces, linear transformations and related concepts.	
Units	**Content**	**No. of Hours (L+T)**
Unit I	**Vector spaces:** Vector space; Subspaces; Sum and Direct sum of two subspaces; Quotient space; Linear combinations; Span; Generating sets; Linear dependence and linear independence; Bases; Replacement theorem; Dimension; Dimension of (W1+W2); Dimension of V/W.	**10+3**
Unit II	**Linear Transformation :** Linear transformation; Null space; Range of linear transformation; Nullity; Rank; Dimension theorem (Rank-Nullity theorem); Ordered basis; Coordinate vector; Matrix representation of linear transformation; Space of linear transformations L(V,W); Composition of linear transformations; Review of matrix multiplication and properties; Left-multiplication transformation; Inverse of a linear transformation; Isomorphism of vector spaces; Standard representation of a finite dimensional vector space; Change of coordinate matrix; Similar matrices.	**12+5**
Unit III	**Diagonalization:** Diagonalizable linear operator; Eigen values and Eigen vectors; Characteristic polynomial; Eigen spaces and Diagonalizability; Test for diagonalization; Diagonalization and direct sums.	**13+4**
Unit IV	**Inner Product Spaces:** Inner product; Norm of a vector; Orthogonal and orthonormal vectors; Gram-Schmidt Orthogonalization Process; Orthogonal Complement.	**10+3**
Pedagogy:	Lectures/Tutorials/Self-study. Lectures should include theory and examples. Tutorial to be exclusively dedicated for problem solving.	
Reference/ Reading:	**PRINCIPAL TEXT:** S. Friedberg, A. Insel, L. Spence: Linear Algebra, 4th Edition **REFERENCES:** 1. Gilbert Strang: Linear Algebra and Applications, 4th Edition, Cengage Learning	

	2. Howard Anton and Chris Rorres: Elementary Linear Algebra, 11th Edition, Wiley 2014 3. Keith Nicholson: Linear Algebra with Applications, 3rd Edition, PWS publishing company 4. Kenneth Hoffmann and Ray Kunze: Linear Algebra, 2nd Edition, PHI, 1997 5. S. Kumaresan: Linear Algebra, A Geometric Approach, PHI Learning Private Limited, Pearson. 6. Sheldon Axler: Linear Algebra Done Right, 3rd Edition, Springer 2015.
Course Outcomes:	1. Display familiarity and knowledge of the concepts in the syllabus. 2. Demonstrate proofs to establish truths related to the concepts in the syllabus. 3. Choose the appropriate procedures and modify them, if needed, to solve method-based problems on the concepts in the syllabus. 4. Analyze and solve unseen problems in Linear Algebra and invent mathematically precise arguments to justify their solutions.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-204**
Title of the Course : **Basic Number Theory**
Number of Credits : **3L+1T**
Effective from AY : **2024-25**

Pre-requisites for the course:	Basic 12th standard mathematics.	
Course Objectives:	The course aims at providing students with the basic knowledge and techniques in Number Theory. The course covers various topics which include, Divisibility Theory, Primes, Theory of Congruences, Fermat's Little Theorem, Number Theoretic Functions, Euler's Generalization of Fermat's Theorem and Some non linear Diophantine Equations. Students will acquire the basic knowledge and techniques required for an elementary course in Algebra.	
Content:		**No. of Hours (L+T)**
Unit I	**Divisibility Theory in the Integers:** The Division Algorithm, The Greatest Common Divisor and its properties, The Euclidean Algorithm, The Linear Diophantine Equation ax+by=c **Primes and Their Distribution:** The Fundamental Theorem of Arithmetic, The Sieve of Eratosthenes, The Goldbach Conjecture.	**12+4**
Unit II	**The Theory of Congruences:** Definition and properties of Congruence, Linear Congruences and Chinese Remainder Theorem. **Fermat's Theorem:** Fermat's Little Theorem and Pseudoprimes, Wilson's Theorem	**9+3**
Unit III	**Number-Theoretic Functions:** The sum and Number of Divisors, The Mobius Inversion Formula, The Greatest Integer Function. **Euler's Generalization of Fermat's Theorem:** Euler's Phi Function, Euler's Theorem, Properties of the Phi-Function	**15L+5T**
Unit IV	**Some Nonlinear Diophantine Equation:** The solutions of the Diophantine Equation $x^2 + y^2 = z^2$, Insolvability of the Diophantine Equations and $x^4 + y^4 = z^2$ and $x^4 - y^4 = z^2$. Proof that the area of a Pythagorean triangle can never be equal to a perfect (integral) square.	**9L+3T**
Pedagogy:	Lectures/Tutorials/Self-study. Lectures should include theory and examples. Tutorial to be exclusively dedicated for problem solving.	
Reference/ Reading:	**PRINCIPAL TEXT:** David M. Burton, Elementary Number Theory, Seventh Edition, Mc Graw Hill, 2017	

	REFERENCES: 1. Gareth A. Jones and J. Mary Jones, Elementary Number Theory, First Edition, Springer, 1998 2. Ivan Niven, Herbert S. Zuckerman, Hugh L. Montgomery, An Introduction to the Theory of Numbers, 5th Edition, Wiley, 2008. 3. Joseph H. Silverman, A Friendly Introduction to Number Theory, Third Edition, Pearson, 2009. 4. Thomas Koshy, Elementary Number Theory with Applications, Academic Press, 2001. 5. Tom M. Apostol, Introduction to Analytic Number Theory, Narosa, 1998.
Course Outcomes:	At the end of this course the student will be able to 1. Recollect the important definitions and theorems in the course. 2. Explain the various proofs and concepts in the course. 3. Solve various computational problems in the course. 4. Solve problems using the concepts learnt in the course.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-205**
Title of the Course : **Analytical 2D Geometry**
Number of Credits : **2L**
Effective from AY : **2024-25**

Pre-requisites for the course:	Basic 12th standard Mathematics.	
Course Objectives:	To make students explore the principles of coordinate geometry, focusing on points, lines, circles and conic sections. To delve into geometry and parametric equations, fostering a comprehensive understanding of 2D geometric structures and their Mathematical representations.	
Content:		**No of Hours**
Unit I	**Metric Properties in Plane** Fundamental Notations: Distance Formula; Section Ratio; Slope or Gradient; Locus; Area of Plane figures. Transformations and Invariants: Translation; Rotation; Invariants. **Straight Lines in Plane** Different Forms of a Line: Gradient Form; Point-gradient Form; Symmetric Form; Parametric Form; Two Point Form; Intercept Form; Normal Form; Algebraic Form. A Point in Relation to a Straight Line; Perpendicular Distance of a Point from a Straight Line; Pair of Straight Lines. **Circles in Plane** Different Forms: Centre Radius Form, Diametral Form, Three Point Form; A Point in Relation to a Circle; A line in Relation to a Circle; Tangents and Normals.	**15**
Unit II	**Conics in Plane** Parabola; Ellipse; Hyperbola; Tangents and Normals; Asymptotes. **Metric Classification of Conics:** Classification Scheme **Polar Coordinate System:** Polar Coordinates; Relation Between Cartesian and Polar Coordinates; Distance Between Two Points; Area of a Triangle; Equation of a Straight Line; Equation of a Circle; Equation of a Conic.	**15**
Pedagogy:	Lectures focusing on developing a strong conceptual understanding of 2D geometry through theoretical frameworks. Use of GeoGebra as a visual aid tool to enhance conceptual understanding. Guiding students to virtually manipulate geometric figures using GeoGebra for intuitive learning,	
Reference/ Reading:	**PRINCIPAL TEXT:** Chatterjee, D. (2009). *Analytical Geometry Two and Three Dimensions*. Narosa Publishing House Pvt. Ltd., New Delhi. **REFERENCES:**	

	1. Das, A. N. (2009). *Analytical Geometry of Two and Three Dimensions*. New Central Book Agency (P) Ltd. New Delhi. 2. Jain, P.K., Ahmad, K. (2014). *Textbook of Analytical Geometry* (3^{rd} ed.). New Age International Publishers, New Delhi. 3. Loney, S.L. *The Elements of Coordinate Geometry*. Aitbs Publishers, India.
Course Outcomes:	Students will be able to 1. Define terms and explain concepts related to geometry. 2. Understand metric properties in a plane, and the different forms of lines and circles in a plane. 3. Classify various conics in a plane and establish results concerning them. 4. Develop analytical skills in solving geometric problems.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-211**
Title of the Course : **Matrix Algebra**
Number of Credits : **3L+1P**
Effective from AY : **2024-25**

Prerequisites for the course:	Basic knowledge of Matrices and Matrix Operations	
Course Objectives:	To introduce and familiarize the learner with the System of Equations, Matrices and Matrix Operations, Gauss Elimination method, Diagonalisation and Quadratic forms.	
Content		**No. of Hours**
Unit I	**Vectors in R^n:** Operations with vectors in R^3 and generalization to R^n; Linear combinations; Linear dependence and independence; Basis and Dimension.	**8**
Unit II	**Elementary operations on a matrix:** Types of matrices, Special matrices – Symmetric, Skew – Symmetric matrices, Conjugate of a matrix, Hermitian matrix, Nilpotent and Idempotent matrices; Properties/Results on each of these; Elementary matrices; Effects of multiplying by these on a matrix; Equivalence of matrices: Row/column equivalence; Echelon forms; Normal form.	**12**
Unit III	**Rank of a matrix:** Definition using minors; Finding rank of a matrix using definition (upto 3x3 only); Theorem: Elementary operations do not change the rank of a matrix; Finding the rank using echelon forms; Linear Independence of Row and Column Matrices; Definition of rank of a matrix using independence of Row or column vectors; Equivalence of two definitions of Rank.	**12**
Unit IV	**Application of matrices:** Existence of solutions of a system of linear equations using Rank method and their solution using Gauss Elimination, Gauss – Jacobi and Gauss – Siedel method; Characteristic Values of a Matrix; Caley – Hamilton Theorem; Diagonalisation of a matrix.	**9**
	Quadratic Forms: Quadratic form as a matrix product; Diagonal reduction of a symmetric matrix; Reduction of quadratic form into sum of squares form.	**4**
	List of Practicals*: 1. Linearly Independent sets and Basis 2. Identifying properties of Special Matrices (Symmetric, Skew-symmetric, Hermitian, Nilpotent, Idempotent) 3. Elementary matrices and effect of their multiplication 4. Echelon forms; Normal form. 5. Finding rank of a matrix using definition (upto 3x3 only) 6. Finding the rank using echelon forms	**30**

<table>
<tr><td></td><td>7. Existence of solutions of a system of linear equations using Rank method and their solution using Gauss Elimination
8. Solution of system using Gauss – Jacobi and Gauss – Siedel method
9. Diagonalisation of a matrix
10. Reduction of quadratic form into sum of squares form
11. Counting the number of walks of a given length between a pair of vertices in a Graph using powers of the adjacency matrix.
12. Demonstration of various Matrix operations using SageMath or any other relevant software
* Any 10 of the above practicals to be completed</td><td></td></tr>
<tr><td>Pedagogy:</td><td colspan="2">Lectures/Practical/Self-study/SageMath. Lectures should include theory and examples. Practical to be exclusively dedicated for problem solving.</td></tr>
<tr><td>Reference Reading:</td><td colspan="2"><u>Principal Text</u>
H. Kishan: A Textbook of Matrices, Atlantic Publishers, 2008.
<u>References</u>
1. Gilbert Strang: Linear Algebra and Applications, 4th Edition, Cengage Learning
2. Keith Nicholson: Linear Algebra with Applications, 3rd Edition, PWS publishing company.
3. S. Narayan, and P. K. Mittal: A Textbook of Matrices, S. Chand Publications, 2008.</td></tr>
<tr><td>Course Outcomes:</td><td colspan="2">1. Display familiarity and knowledge of System of Equations, Matrices and Matrix Operations
2. Demonstrate proofs of Matrix Algebra
3. Choose the appropriate procedures and modify them, if needed, to solve method-based problems on the concepts in the syllabus.
4. Analyze and solve unseen problems in Matrix Algebra and invent mathematically precise arguments to justify their solutions.</td></tr>
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Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-212**
Title of the Course : **Enumerative Combinatorics**
Number of Credits : **3L+1P**
Effective from AY : **2024-25**

Pre-requisites for the Course:	Basic 12th standard Mathematics.	
Course Objectives:	To provide a foundation for understanding and applying combinatorial principles in various mathematical and real-world scenarios.	
Content		**No. of Hours**
Unit I	**Basic methods:** Basic Pigeon-hole principle, Generalized Pigeon-hole principle, Methods of mathematical induction: Weak induction and Strong induction. **Elementary Counting Problems:** Permutations, Strings over finite alphabet, Choice problems.	**12**
Unit II	**The Binomial Theorem:** Binomial theorem, Multinomial theorem, Binomial Theorem: When the exponent is not a positive integer **Partitions:** Compositions, Set partitions, Integer partitions.	**10**
Unit III	**Cycles in permutations:** Cycles in permutations, Permutations with restricted cycle structure. **The Sieve:** Enumerating the elements of intersecting sets, Applications of the sieve formula.	**13**
Unit IV	**Generating Functions:** Ordinary generating functions – Recurrence relations and generating functions, Products of generating functions, Compositions of generating functions. Exponential generating functions – Recurrence relations and exponential generating functions, Products of exponential generating functions, Compositions of exponential generating functions.	**10**
Pedagogy	Lectures/ Practicals/self-study/Assignments. Lectures should include theory and examples. Practical to be exclusively dedicated for problem solving.	
Practical	**30 hours are to be dedicated for working with exercises and solving problems based on following topics** 1. Solving problems on Basic Pigeon-hole principle and generalized Pigeon-hole principle	**30**

	2. Establishing different identities using weak and strong induction 3. Solving counting problems using permutations, lists and subsets 4. Problems on Binomial Theorem and related identities 5. Problems on Multinomial Theorem 6. Solving Problems on compositions, set partitions and integer partitions 7. Problems on cycles in permutation 8. Problems on Sieve formula and its applications 9. Solving various recurrences using ordinary generating function 10. Solving various recurrences using exponential generating function	
Reference/ Reading:	**<u>Principal Text:</u>** Miklos Bona, A Walk Through Combinatorics – An Introduction to Enumeration and Graph Theory, World Scientific Publications, Fourth Edition 2017 **<u>References:</u>** 1. Alan Tucker, Applied Combinatorics, John Wiley and sons, New York, Sixth Edition, 2012 2. Chen Chuan-Chong and Koh Khee-Meng, Principles and Techniques in Combinatorics, World Scientific Publishers, 1992 3. Richard A. Brualdi, Introductory Combinatorics, Pearson Publication, Fifth Edition, 2018 4. V. Krishnamurthy, Combinatorics, Theory and Applications East-West Press private limited, 2015	
Course Outcomes:	Upon successful completion of the course, the students will be able to 1. Understand various counting techniques demonstrated in the syllabus. 2. Develop a combinatorial reasoning and create combinatorial proofs of basic combinatorial identities. 3. Apply appropriate combinatorial techniques to break down various complex problems into more manageable parts and facilitate their solution. 4. Analyze and provide an efficient framework for solving various problems with discrete structures.	

Name of the Programme : **B.Sc. (Mathematics)**
Course Code : **MAT-213**
Title of the Course : **Transformation Techniques**
Number of Credits : **3L+1P**
Effective from AY : **2024-25**

Pre-requisites for the Course:	Basic 12^{th} standard mathematics.	
Course Objectives:	To make students aware of the various available transformation techniques like Laplace transforms, Z – transforms, Fourier transforms, and Henkel transforms, and their applications in various branches of mathematics.	
Content:		**No. of Hours**
Unit I	**Laplace Transforms:** Laplace transforms of various functions; General properties of Laplace transforms; Inverse Laplace transforms; Convolution theorem; Application of Laplace transforms to solve differential equations.	**12**
Unit II	**Z – Transforms:** Z – transforms of various functions; General properties of Z – transforms; Inverse Z transforms; Convolution theorem; Application of Z – transforms to solve difference equations.	**12**
Unit III	**Fourier Series:** Fourier series of a function on an interval of length $2l$, $l>0$; Half range Fourier series; Statement of Bessel's inequality and statement of Parseval's identity; Trigonometric Fourier series, Fourier series of odd & even function. Integration & differentiation of Fourier series at a point. Fourier theorem; Statement of Riemann – Lebesgue lemma.	**8**
Unit IV	**Infinite Fourier Transforms:** Dirichlet's conditions; Fourier integral theorem and Fourier integral representation; Fourier transforms; Fourier sine and cosine transforms; General properties of Fourier transforms; Inverse Fourier transforms; Convolution theorem; Application of Fourier transforms to solve boundary value problems.	**8**
	Finite Fourier Transforms: Finite Fourier sine and cosine transforms; Results on finite Fourier transforms; Inverse Fourier transforms; Applications of finite Fourier transforms to solve boundary value problems.	**5**
Practical:	**30 hours are to be dedicated for illustrations with specific examples and computational based exercises. Any 10 of the following topics are to be covered during practical and problems to be solved in:** 1. Finding Laplace transforms of a given function using various properties. 2. Finding inverse Laplace transforms of a given function.	

	3. Applying Laplace transforms to solve ordinary differential equations. 4. Finding Z – transforms of a given function using various properties. 5. Finding inverse Z – transforms of a given function. 6. Applying Z – transforms to solve difference equations. 7. Computing the Fourier series of a function on an interval of length 2*l*, *l*>0. 8. Applications of Parseval's identity. 9. Computing Fourier transforms of a given functions. 10. Computing Fourier sine and cosine transforms. 11. Computing inverse Fourier transforms. 12. Applications of Fourier transforms in solving boundary value problems. 13. Finding finite Fourier transforms – Fourier sine and cosine transforms. 14. Finding inverse finite Fourier transforms – Fourier sine and cosine transforms. 15. Applications of finite Fourier transforms in solving boundary value problems.	**30**
Pedagogy:	Lectures/Practical/Self-study. Lectures should include theory and examples. Practical to be exclusively dedicated for problem solving. The record of practical shall be maintained by students in a separate manual/journal duly certified by the instructor.	
Reference/ Reading:	**PRINCIPAL TEXTS:** 1) M. D. Raisinghania: *Advanced Differential Equations,* 19th Edition, S. Chand Publications, 2018. 2) T. K. V. Iyengar, B. Krishna Gandhi, S. Ranganatham, and M. V. S. S. N. Prasad: *Mathematical Methods,* S. Chand & Company Ltd., 2008. **REFERENCES:** 1) G. F. Simmons: *Differential Equations with Applications and Historical Notes,* 2nd Edition, Tata McGraw – Hill Edition, 2008. 2) J. W. Brown, and R. V. Churchill: *Fourier Series and Boundary Value Problems,* 6th Edition, McGraw Hill Publishers, 2001. 3) S. Elaydi: *An Introduction to Difference Equations*, 3rd Edition, Springer, 2005.	
Course Outcomes:	The student will be able to, 1. Apply Laplace transforms to solve differential equations. 2. Apply Z – transforms to solve difference equations. 3. Construct the Fourier series of given functions. 4. Apply Fourier transforms to solve Boundary Value Problems.	

Name of the Programme : **B.Sc. (Mathematics)**
Course Code : **MAT-221**
Title of the Course : **Probability Theory**
Number of Credits : **3L+1P**
Effective from AY : **2024-25**

Prerequisites for the Course:	Basic 12^{th} standard Mathematics.	
Course Objectives:	To make students aware of various aspects of probability theory and their applications in solving real life problems.	
Content		**No. of Hours**
Unit I	Basics of Probability Theory: Random experiment; Sample space; Events; Types of events; Independence of events; Mathematical/Statistical definitions of probability; Addition and Multiplication theorems; Conditional probability; Baye's theorem	**5**
Unit II	Random Variables and Distribution Functions: Random variables – discrete and continuous; Distribution functions; Probability mass function and probability density function – Joint probability law; Joint probability mass function; Conditional and marginal probability functions; Stochastic independence; Properties of probability density functions.	**10**
Unit III	Mathematical Expectation and Generating Functions: Mathematical expectation of discrete and continuous random variables – Properties, theorems and problems; Covariance; Moments; Moment generating functions; Properties of generating functions; Uniqueness theorem	**15**
Unit IV	Probability Distributions: Discrete probability distributions; Binomial distribution – properties, derivations of mean, variance and moment generating function; Poisson distribution – properties, derivations of mean, variance and moment generating function; Relationship between Binomial and Poisson distributions; Normal distribution – normal curve and properties; Standard normal distribution; Problems on normal distributions and applications.	**15**

Practical	Any 10 of the following practicals 1. Probability problems based on addition and multiplication theorems. 2. Conditional probability and Baye's theorem. 3. Probability mass functions and probability density functions. 4. Joint probability mass functions, and conditional and marginal probability functions. 5. Stochastic independence. 6. Mathematical expectation 7. Covariance and moments. 8. Moments and moment generating functions. 9. Binomial distribution: Mean and Variance 10. Binomial distribution: Moment Generating Function and Application 11. Poisson distribution. 12. Normal distribution	**30**
Pedagogy	Lectures/Practical/Self-study. Lectures should include theory and examples. Practical to be exclusively dedicated for problem solving. The record of practical shall be maintained by students in a separate manual/journal duly certified by the instructor.	
Reference/ Reading:	**PRINCIPAL TEXT:** S. C. Gupta, and V. K. Kapoor: *Fundamentals of Mathematical Statistics,* 12th Edition, Sultan Chand & Sons, 2020. **REFERENCES:** 1. J. Medhi: *Statistical Methods: An Introductory Text,* New Age International Publishers, 2006. 2. R. V. Hogg, J. W. McKean, and A. T. Craig: *Introduction to Mathematical Statistics,* Pearson Education, 2006. 3. S. C. Gupta: *Fundamentals of Statistics*, 7 th Edition, Himalaya Publishing House, 2018. 4. S. P. Gupta: *Statistical Methods*, Sultan Chand & Sons, 2023.	
Course Outcomes:	The student will be able to, 1. Apply the knowledge of probability theory in analyzing real life situations and case studies. 2. Model various probability functions. 3. Illustrate and interpret mathematical expectation. 4. Solve various problems in probability distributions.	

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-222**
Title of the Course : **Theory of Equations**
Number of Credits : **3L+1P**
Effective from AY : **2024-25**

Pre-requisites for the Cousre:	Basic 12^{th} Standard Mathematics	
Course Objectives:	This course is designed to give students of mathematics a good foundation to the preliminaries required for the study of higher Algebra. The course also endeavors to equip students studying related disciplines with computational skills and techniques.	
Content		**No. of Hours**
Unit I	**Complex Numbers:** Square Roots, Complex Numbers, Cube Roots of Unity, Product and Quotient of Complex Numbers, Roots of Unity, Primitive Roots of Unity **Theorems on Roots of Equations:** Quadratic Equations, Polynomials, Remainder Theorem, Synthetic Division, Factored Form of a Polynomial, Multiple Roots, Identical Polynomials, Fundamental Theorem of Algebra, Relations between Roots and Coefficients, Upper Limit to the Real Roots, Integral Roots, Methods for Integral Roots, Rational Roots	**12**
Unit II	**Constructions with Ruler and Compasses:** Impossible Constructions, Graphical Solution of a Quadratic Equation, Analytic Criterion for Constructibility, Cubic Equations with a Constructible Root, Trisection of an Angle, Duplication of a Cube, Regular Polygon of 7 sides, Roots of Unity, Reciprocal Equations, Regular Polygon of n Sides.	**10**
Unit III	**Cubic And Quartic Equations:** Reduced Cubic Equation, Algebraic Solution of a Cubic, Discriminant Number of Real Roots of a Cubic, Irreducible Case, Trigonometric Solution of a Cubic, Ferrari's Solution of the Quartic Equation, Resolvent Cubic, Discriminant, Descartes' Solution of the Quartic Equation, Symmetrical Form of Descartes' Solution **The Graph of an Equation:** The Graph of Use of Graphs, Bend Points, Derivatives, Horizontal Tangents, Multiple Roots, Ordinary and Inflexion Tangents, Real Roots of a Cubic Equation, Continuity, Continuity of Polynomials, Condition for a Root Between a and b, Sign of a Polynomial at Infinity, Rolle's Theorem.	**10**
	Isolation of Real Roots: Descartes' Rule of Signs, Sturm's Method, Sturm's Theorem, Simplifications of Sturm's	**13**

Unit IV	Functions, Sturm's Functions for a Quartic Equation, Sturm's Theorem for Multiple Roots, Budan's Theorem **Solution of Numerical Equations:** Horner's Method, Newton's Method, Algebraic and Graphical Discussion, Systematic Computation, For Functions not Polynomials, Imaginary Roots. **Symmetric Functions:** Sigma Functions, Elementary Symmetric Functions, Fundamental Theorem on Symmetric Functions, Rational Functions Symmetric in all but one of the roots, Sums of like powers of the roots, Waring's Formula for s_k in Terms of the coefficients, Computation of Symmetric Functions	
Practicals	**Any ten** of the following Practicals should be completed: 1. Use De Moivre's Theorem to find n^{th} roots of unity and complex numbers and represent them on the plane. 2. Use the remainder theorem to find the remainder of a polynomial when divided by a linear polynomial, use Synthetic Division to find the remainder and quotient of a polynomial when divided by a linear polynomial. 3. Find a polynomial with given roots. 4. Find an upper limit to the real roots of a polynomial. 5. Find the integral roots and rational roots of a polynomial with integral coefficients using the various methods. 6. Convert a cubic equation to a reduced cubic and solve the equation, Find the number of real roots of a real cubic polynomial without computing the roots. 7. Find the solution of a Quartic Equation using Ferrari's method. 8. Find the solution of a Quartic Equation using Descarte's Method. 9. Find the bend points, sketch the graph and find the number of real roots of a given cubic polynomials. 10. Use Sturm's Method to isolate the real roots of a given polynomial. 11. Use Budan's Theorem to isolate the real roots of a given polynomial. 12. Use Horner's Method to compute the real roots of a given polynomial. 13. Use Newton's Method to compute the real roots of a given polynomial. 14. Express $\sum$ - Functions in terms of s_k. 15. Express Symmetric Functions in terms of s_k.	**30**
Pedagogy	Lectures, Self-Study, Assignments. Lectures should include theory and examples. Practical to be exclusively dedicated for problem solving.	
Reference Reading	**PRINCIPAL TEXT:**	

	Leonard Eugene Dickson, First Course in the Theory of Equations, John Wiley & Sons, Inc, 2009 **REFERENCES:** 1. Hari Kishan, Theory of Equations, Atlantic, 2022 2. William Snow Burnside, Arthur William Panton, The Theory of Equations, Wave books, 2022
Course Outcomes:	At the end of this course the student will be able to 1. Recollect the important definitions and theorems in the Theory of Equations. 2. Explain the various proofs and concepts in the course. 3. Solve problems in using techniques in the course 4. Solve unseen problems using the concepts learnt in the course.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-223**
Title of the Course : **Graph Theory**
Number of Credits : **3L+1P**
Effective from AY : **2024-25**

Pre-requisites for the Course:	Basic 12^{th} Std Mathematics	
Course Objectives:	To introduce Graph theory and motivate its study via useful computational algorithms.	
Content		**No. of Hours**
Unit I	**Fundamental Concepts** **What Is a Graph**: The Definition, Graphs as Models, Matrices and Isomorphism, Decomposition and Special Graphs. **Paths, Cycles, and Trails:** Connection in Graphs, Bipartite Graphs, Eulerian Circuits **Vertex Degrees and Counting:** Counting and Bijections, Extremal Problems, Graphic Sequences.	**17**
Unit II	**Trees and. Distance** **Basic Properties**: Properties of Trees, Distance in Trees and Graphs. **Spanning Trees and Enumeration:** Enumeration of Trees, Spanning Trees in Graphs, Decomposition and Graceful Labeling. **Optimization and Trees:** Minimum Spanning Tree, Shortest Paths, Trees in Computer Science.	**17**
Unit III	**Coloring of Graphs** **Vertex Colorings and Upper Bounds:** Definitions and Examples, Upper Bounds, Brooks' Theorem.	**6**
Unit IV	**Planar Graphs** **Embeddings and Euler's Formula**: Drawings in the Plane, Dual Graphs, Euler's Formula.	**5**
	List of Practicals*: 1. Bellman_Ford/ Floyd-Warshal Algorithm 2. Counting the number of walks of a given length between a pair of vertices using powers of the adjacency matrix (with proof). 3. Dijkstra's algorithm to find the shortest paths between vertices in a weighted graph. 4. Finding Eulerian Circuit using Hierholzer’s Algorithm. 5. Finding Eulerian path or Circuit using Fleury’s Algorithm. 6. Havel’s and Hakimi’s algorithm to check if a given finite sequence of integers is a degree sequence of a graph.	**30**

	7. Huffman Algorithm to find Optimum Binary Tree (Huffman Tree) and derive the optimum binary prefix code for a given set of weights. Application to Huffman compression. 8. Kruskal's/ Prim's algorithm to find the minimum weighted spanning tree in a connected weighted graph. 9. Obtain Prufer Sequence for a given labeled tree and vice-versa. 10. Showing that 2 given graphs are isomorphic/non-isomorphic. 11. Trajan's Algorithm to find bridges in an undirected graph 12. Welsh and Powell Algorithm to obtain a vertex coloring of a graph. * Any 10 of the above practicals to be completed
Principal Text	**Douglas B. West , Graph Theory, 2nd Edition, Pearson Education 2022.**
Pedagogy	Lectures/Practical/Self-study. Lectures should include theory and examples. Practical to be exclusively dedicated for problem solving.
Reference Reading	1. Chartrand and Lesniak, Graphs and Digraphs, 6th edition, Chapman & Hall, 2015 2. Deo and Narsingh, Graph Theory with Applications to Engineering and Computer Science, Prentice Hall India, 1979. 3. G Agnarsson and R. Greenlaw, Graph Theory, 2nd Edition, Pearson Education 2008. 4. R. B. Bapat, Graphs and Matrices, 2nd Edition, Hindustan Book Agency 2014.
Course Outcomes:	1. Display familiarity and knowledge of the concepts in the syllabus. 2. Demonstrate proofs to establish truths related to the concepts in the syllabus. 3. Choose the appropriate procedures and modify them, if needed, to solve method-based problems on the concepts in the syllabus. 4. Analyze and solve unseen problems in Graph Theory and invent mathematically precise arguments to justify their solutions.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-231**
Title of the Course : **Basic Financial Mathematics**
Number of Credits : **3L**
Effective from AY : **2024-2025**

Pre-requisites for the Course:	Basic 12^{th} standard Mathematics.	
Course Objectives:	1. Introduce students to the concepts in financial mathematics 2. Introduce students to financial instruments as they relate to financial mathematics. 3. Develop student abilities to apply financial mathematics in daily life.	
Content		**No. of Hours**
Unit I	1. Tax: Direct, indirect tax, Income tax-assessment of individuals, GST,IGST, SGST, CGST, UTGST 2. Bills: Types of bills, tariff rates, concept of fixed charge, service charge and their applications in various sectors of Indian Economy.	6
Unit II	1. Interest: rate of interest, simple interest, compound interest, accumulation function, future value, current value, present value, net present value, discount factor, discount rate (rate of discount), convertible monthly, nominal rate, effective rate, inflation and real rate of interest, force of interest, equation of value 2. Annuity-immediate, annuity due, perpetuity, payable monthly or payable continuously, level payment annuity, arithmetic increasing/decreasing annuity, geometric increasing/decreasing annuity, term of annuity 3. Loans: principal, interest, term of loan, outstanding balance, final payment (drop payment, balloon payment), amortization, sinking fund 4. Bonds: price, book value, amortization of premium, accumulation of discount, redemption value, par value/face value, yield rate, coupon, coupon rate, term of bond, callable/non- callable .	18
Unit III	1. Intro to equities. Dividend discount models. Stock valuation. Mutual funds. Sinking funds. 2. Term structure. Duration and convexity. Calculating duration and convexity.	15
Unit IV	1. Hedging: Hedging, arbitrage, diversifiable risk, non-diversifiable risk.	6

	2. Investment Strategies : spreads (option, bull, bear, vertical, box, ratio), collar width, collared stock, zero-cost collar, straddle, strangle, written straddle, butterfly	
Pedagogy:	Lectures/group work/student presentations/ computer assignments/tutorials/Spectrum	
Reference/ Reading:	1. Derivatives Markets (3rd Edition) (Pearson Series in Finance) 3rd Edition by Robert L. McDonald (Author) Publisher: Prentice Hall; 3 edition (September 6, 2012) ISBN: 0321543084 2. Financial Mathematics by B.L.Bajpai, New royal Book Company, 2015 3. Financial Mathematics by Leena S. Shimpi, Bimal Jaiswal, New Royal Book Company, 2020 4. Financial Mathematics: A Practical Guide for Actuaries and Other Business Professionals. Chris Ruckman and Joe Francis. Publisher: BPP Professional Education; 2nd edition (October 2005). ISBN: 0975313649 5. Introduction to Mathematics of Finance, Ruth.J.Williams, The American Mathematical Society, 2006 6. Mathematics of Finance-An Intuitive Introduction, Donald G Saari, Springer, 2019	
Course Outcomes:	1. Introduction to the use of mathematical tools for financial calculations. 2. Develop abilities to create, derive, and apply financial mathematical tools. 3. Apply tax rules to file income tax returns. 4. Use appropriate principles to plan in stock market investment.	

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-241**
Title of the Course : **Technical Typesetting Using LaTeX**
Number of Credits : **1L+2P**
Effective from AY : **2024-2025**

Pre-requisites for the Course:	Basic 12th standard mathematics.	
Course Objectives:	To make students competent in using LaTeX for typesetting any technical document and making impressive presentations.	
Content		**No. of Hours**
Unit I	**Basics of LaTeX:** Introduction to TeX and LaTeX; Document classes; Typesetting a simple document; Adding basic information to a document; Adding watermark to a document; Fonts and Sizes; Sectioning command and alignment; list and Enumeration; Quotations; Environments; Footnotes; Typesetting tables with multiple columns and tabular environment ; boxed text,Minipage. **(DEMONSTRATIONS TO BE DONE DURING PRACTICAL)**	**4**
Unit II	**Mathematical Typesetting with LaTeX:** Accents and symbols; Mathematical formula typesetting (elementary and advanced)**:** Subscript/Superscript, Fractions, Roots,Ellipsis,greek letters, Mathematical Symbols, Special characters, Arrays, Delimiters, Multiline formulas, Matrices, Spacing and changing style in math mode; Boxed equations; Creating mathematical environments, \newtheorem command. **Cross Referencing, Index and Bibliography:** Cross referencing figures, tables, sections, equations, etc; Table of contents; Bibliography using NATBIB; Bibliographic styles; BIBTeX and Database creation. **(DEMONSTRATIONS TO BE DONE DURING PRACTICAL)**	**8**
Unit III	**Graphics and Beamer Presentation in LaTeX:** Graphics in LaTeX; Simple pictures using PSTricks; Beamer presentation. **(DEMONSTRATIONS TO BE DONE DURING PRACTICAL)**	**3**
Practical	**60 hours (4 hours each) of practical should be dedicated for the following:** 1. Typing a basic document in LaTeX – trying out the effect of spaces, line breaks, empty lines, writing special characters in text, adjusting fonts, shapes and styles, adding watermark, sectioning and paragraphs.	**60**

	2. Exploring simple documents – customizing margins, page numbers, quotations, horizontal lines, using vspace and hspace and flushleft/flushright commands, enumeration and itemize environments. 3. Understanding the various document classes such as article/report/thesis/book and experimenting with each class to understand the output. 4. Customizing tables, minipage environment. 5. Typesetting accents and Greek symbols, Basic mathematical typesetting. 6. Working with Subscript/Superscript, Fractions, Roots, Ellipsis, Mathematical operators, Special characters, Arrays, Delimiters. 7. Using equation environment, breaking/appropriately writing long equations, typing equations with cases, spaces in math mode, text in math mode. 8. Typing of matrices, infinite series, continued fractions, and boxed equations, and the like. 9. Using the theorem environment to typeset definitions, remarks, lemmas, theorems, corollaries, etc. 10. Cross referencing – using tag commands, hyperref environment, adding hyperlinks to text. 11. Graphics in LaTeX(Inserting images) using additional apps like geogebra, latexdraw etc . 12. Creating bibliographic database and exploring various bibliographic environments to create bibliography. Generating the Table of Contents. 13. Drawing simple pictures using PSTricks. 14. Making presentations using Beamer in LaTeX. 15. Making use of the exam class to prepare question papers in LaTeX.	
Pedagogy:	Lectures/Practical/Self study. Theory to be kept for explaining what exactly will be done and answering common queries/errors. Practical to focus on how exactly it will be done.	
Reference Reading:	**<u>PRINCIPAL TEXT:</u>** L. Lamport : *A Documentation Preparation System LATEX User's Guide and Reference Manual*, Second Edition, Pearson, 2006. **<u>REFERENCES:</u>** 1) E. Krishnan : *LaTeX Tutorials – A Primer,* Indian TeX Users Group, 2003. 2) G. Gratzer: *More Math Into LaTeX*, Springer, 2016. 3) Karl Berry, Stephen Gilmore and Torsten Martinsen LATEX2e: An unofficial reference manual, January 2023 4) S. Kottwitz: *LaTeX – Beginner's Guide,* Packt Publishing, 2011.	

	5) Van M. R. C. Dongen: *LaTeX and Friends*, Springer – Verlag, 2012.
Course Outcomes:	1.To Create and typeset a LaTeX document. 2.To Build documents containing Mathematics. 3.To experiment with pictures and graphics in LaTeX. 4.To Prepare impressive beamer presentations and typeset question papers using the exam class.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-300**
Title of the Course : **Riemann Integration and Improper Integrals**
Number of Credits : **3L+1T**
Effective from AY : **2025-26**

Pre-requisites for the Course:	A course in Analysis.	
Course Objectives:	To be competent in discussing the integrability of real valued functions and to build the skills required in establishing results in integration.	
Content		**No. of Hours (L+T)**
Unit I	**Riemann Integral:** Partition of an interval; properties of partitions – Upper and Lower sums of a bounded real valued function over a closed interval; Upper and Lower integrals; Examples and related results; Darboux condition for integrability; Riemann Integrability – Necessary and sufficient conditions.	**10+3**
Unit II	**Results in Riemann Integration:** Riemann Integrals of Step; monotonic and continuous functions; Integrability of the absolute value; Monotonicity of Riemann integrals; Integrability of composition of a continuous function with an integrable function on a closed and bounded interval. Properties of Riemann integrals: (i) $\int_a^b \alpha f(x)dx = \alpha \int_a^b f(x)dx$. (ii) $\int_a^b (f(x) \pm g(x))dx = \int_a^b f(x)dx \pm \int_a^b g(x)dx$. (iii) $\int_a^c f(x)dx + \int_c^b f(x)dx = \int_a^b f(x)dx, a \leq c \leq b$. (iv) $\lvert \int_a^b f(x)dx \rvert \leq \int_a^b \lvert f(x) \rvert dx$.	**11+4**
Unit III	**Further Results in Riemann Integration:** First and Second Fundamental theorem of Calculus; Integration by parts; Change of variables; Mean Value Theorem for integrals; Riemann's original definition; Sum of an infinite series as a Riemann integral.	**9+3**
Unit IV	**Improper Integrals:** Improper integrals of Type I, II and III – Convergence results and examples; Beta and Gamma functions – properties and examples.	**15+5**
Pedagogy	Lectures/Tutorials/Self-study. Lectures should include theory and examples. Tutorial to be exclusively dedicated for problem solving.	
Reference Reading	<u>**PRINCIPAL TEXT:**</u> A. Kumar, and S. Kumaresan: *A Basic Course in Real Analysis*, CRC Press, 2014.	

	REFERENCES: 1. M. Spivak: *Calculus,* Publish or Perish, Inc., 2008. 2. R. D. Bhat: *Mathematical Analysis II,* Vipul Prakashan, 1997. 3. R. G. Bartle, and D. R. Sherbert: *Introduction to Real Analysis*, 4th Edition, Wiley, 2014. 4. S. Abbott: *Understanding Analysis,* 2nd Edition, Springer Nature, 2016. 5. S. Narayan, and M. D. Raisinghania: *Elements of Real Analysis,* Revised Edition, S. Chand Publications, 2016. 6. S. C. Malik, and S. Arora: *Mathematical Analysis,* 6th Edition, New Age International Publishers, 2022. 7. T. M. Apostol: *Mathematical Analysis*, 2nd Edition, Narosa Publishing House, 2002.
Course Outcomes:	The student will be able to, 1. Apply the theory of Riemann integration in evaluating integrals. 2. Prove various results in Riemann integration. 3. Analyze and compare various number theoretic functions. 4. Examine the convergence of improper integrals.

Name of the Programme **: B.Sc. Mathematics**
Course Code **: MAT-301**
Title of the Course **: Group Theory I**
Number of Credits **: 3L+1T**
Effective from AY **: 2025-26**

Pre-requisites for the course:	An Elementary course in Number theory.	
Course Objectives:	The course is designed keeping in mind that it is the first course in abstract algebra. The course will give the student a gentle introduction to basic group theory. The various topics covered in this course are Binary Structures, Groups and Subgroups, Cyclic Groups, Permutations Groups, The Fundamental Theorem of Finitely Generated Abelian Groups, Homomorphisms and The Fundamental Homomorphism Theorem.	
Content		**No. of Hours (L+T)**
Unit I	**Binary Structures:** Multiplication of Complex Numbers, Euler's Formula, Roots of Unity, Binary Operations, Isomorphic Binary Structures.	**6+2**
Unit II	**Groups and Subgroups:** Groups, Examples of Groups, Subgroups, Cyclic Groups, Generating Sets and Cayley Digraphs	**15+5**
Unit III	**Permutations, Cosets and Direct Products:** Groups of Permutations, Orbits, Cycles, and the Alternating Groups, Cosets and the Theorem of Lagrange, Direct Products and Finitely Generated Abelian Groups (Proof of Fundamental Theorem of Finitely Generated Abelian Groups is not included.), Plane Isometries, Discussion of groups D_3, D_4 and D_5	**12+4**
Unit IV	**Homomorphisms and Factor Groups:** Group Homomorphisms, Properties of Homomorphisms and kernel of a homomorphism, Normal Subgroups and Factor Groups, The Fundamental Homomorphism Theorem, Definitions of automorphisms and inner automorphisms.	**12+4**
Pedagogy:	Lectures, Self-Study, Assignments. Lectures should include theory and examples. Tutorial to be exclusively dedicated for problem solving.	
Reference/ Reading:	**<u>PRINCIPAL TEXT:</u>** John B. Fraleigh, A First Course in Abstract Algebra, Seventh Edition, Pearson, 2013 **<u>REFERENCES:</u>** 1. David S. Dummit and Richard M. Foote, Abstract Algebra, 3rd Edition, Wiley, 2011 2. Joseph A. Gallian, Contemporary Abstract Algebra, Eight Edition, Cengage India Private Ltd, 2019 3. Michael Artin, Algebra, Second Edition, Pearson, 2015	

	4. Vivek Sahai and Vikas Bist, Algebra, 3rd Edition, Narosa, 2015.
Course Outcomes:	At the end of this course the student will be able to 1. Recollect the basic definitions and theorems in Group Theory. 2. Explain the various proofs and concepts in Group Theory. 3. Solve the various computations problems in Group Theory 4. Solve problems using the concepts learnt in the course.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-302**
Title of the Course : **Metric Spaces**
Number of Credits : **3L+1T**
Effective from AY : **2025-26**

Pre-requisites for the Course:	Courses on Foundations of Mathematics and Basic Real Analysis	
Course Objectives:	i) To understand the introductory concepts of metric spaces ii) To apply sequences and their properties in concepts like completeness, continuity and connectedness iii) To analyse continuous functions and their properties. iv) To understand the abstractness of the topic 'connectedness' beyond their geometrical imaginations. v) To acquire knowledge for advanced courses in real analysis, functional analysis, and topology.	
Content		**No. of Hours**
Unit I	**INTRODUCTORY CONCEPTS IN METRIC SPACES** Inequalities (only statements), Definition and examples of metric Spaces, Bounded and unbounded metric spaces, Open and Closed Balls(spheres), Neighbourhoods, Hausdorff Property, Interior Points and Interior of a Set, Open Sets, Closed Sets, Limit Points and Isolated Points, Derived Set, Closure of a Set and its properties, Boundary Points, Distance between Sets, Diameter of a Set, Subspace of Metric Space and its properties.	**16L+6T**
Unit II	**COMPLETENESS IN METRIC SPACES: -** Convergence of a Sequence in a Metric Space, Cauchy Sequence in a Metric Space, Complete Metric Spaces, Cantor's Intersection Theorem	**6L+2T**
Unit III	**CONTINUOUS FUNCTIONS ON METRIC SPACES: -** Definition and Characterizations, Sequential Continuity, Continuity of Functions using Open Sets and Closed Sets, Continuity of Functions using Closure of a Set, fixed point, Contraction mapping, Banach's fixed point theorem.	**11L+4T**
Unit IV	**CONNECTEDNESS IN METRIC SPACES: -** Separated Sets, Disconnected Sets and Connected Sets in a Metric Spaces, Connected Subsets of IR, Continuous Functions and connected sets	**12L+3T**

Pedagogy	Lectures/ tutorials/assignments/self-study. (All concepts have to be taught with plenty of examples and worked out in special case of Euclidean space, Complex plane and other metric spaces mentioned in Unit I.
Reference Reading	**Principal Text:** Pawan K. Jain, Khalil Ahmad; Metric Spaces (Third Edition) (Narosa Publishing House) **References:** 1. E. T. Copson; Metric Spaces (Cambridge University Press) 2. J. N. Sharma; Mathematical Analysis-I (Metric Spaces) (Krishna Prakashan) 3. M. O. Searcoid; Metric spaces: Springer, 2007. 4. S. Kumaresan; Topology of Metric Spaces (Narosa Publishing House). 5. Satish Shirali, H. Vasudeva; Metric Spacesn (Springer)
Course Outcomes:	1. Display familiarity and knowledge of the concepts in the syllabus. 2. Demonstrate proofs to establish truths related to the concepts in the syllabus. 3. Choose the appropriate procedures and modify them, if needed, to solve method-based problems on the concepts in the syllabus. 4. Analyze and solve unseen problems in Metric Spaces and invent mathematically precise arguments to justify their solutions.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-303**
Title of the Course : **Analytical 3D Geometry**
Number of Credits : **2L**
Effective from AY : **2025-26**

Pre-requisites for the Course:	Basic 12th standard Mathematics.	
Course Objectives:	To make students explore the principles of coordinate geometry, focusing on planes, lines, spheres, cones, cylinders and conicoids.	
Content		**No. of Hours**
Unit I	**Coordinates in 3D** Coordinates of a Point in Space and Distance Formula; Direction Cosines of a Line and its Properties; Projection on a Straight Line; Angle between two straight lines; Condition for perpendicularity and parallelism. **Plane** Different Forms: Normal Form; Algebraic Form; Intercept Form; Three-point Form. Distance of a Point from a Plane; Angle Between Two Planes; Pair of Planes. **Transformations** Translation and Rotation. **Straight Line** Equations of Straight Lines; Distance of a Point from a Straight Line; Distance Between Two Straight Lines; Distance Between a Straight Line and a Plane.	**15**
Unit II	**Sphere** Different Forms: Centre-Radius Form; Four Point Form; Diametral Form. Some Positional Studies. **Cone** Equation of a Cone with a guiding curve; Equation of a Right Circular Cone. **Cylinder** Equation of a Cylinder; Equation of a Right Circular Cylinder. **Conicoids** Ellipsoid; Hyperboloid of One Sheet; Hyperboloid of Two Sheets; Elliptic Paraboloid; Hyperbolic Paraboloid.	**15**
Pedagogy:	Lectures focusing on developing a strong conceptual understanding of 3D geometry through theoretical frameworks. Use of GeoGebra as a visual aid tool to enhance conceptual understanding.	

	Guiding students to virtually manipulate geometric figures using GeoGebra for intuitive learning,
Reference/ Reading:	**PRINCIPAL TEXT:** Chatterjee, D. (2009). *Analytical Geometry Two and Three Dimensions*. Narosa Publishing House Pvt. Ltd., New Delhi. **REFERENCES:** 1. Das, A. N. (2009). *Analytical Geometry of Two and Three Dimensions*. New Central Book Agency (P) Ltd. New Delhi. 2. Jain, P. K., Ahmad, K. (2014). *Textbook of Analytical Geometry* (3rd ed.). New Age International Publishers, New Delhi. 3. Narayan, S. and Mittal, P. K. (2007). *Analytical Solid Geometry,* S. Chand & Company.
Course Outcomes:	Students will be able to 1. Define terms and explain concepts related to 3D Geometry. 2. Understand the properties of straight lines, spheres, cones and cylinders. 3. Establish various properties and results on conicoids. 4. Develop analytical skills in solving geometric problems.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-304**
Title of the Course : **Group Theory II**
Number of Credits : **3L+1T**
Effective from AY : **2025-26**

Pre-requisites for the Course:	A First course in Group Theory,	
Course Objectives:	The course is designed to give the student an exposure to advanced topics in group theory which are useful in higher mathematics. The course covers various topics starting with Group Action on a set, Isomorphism Theorems, Series of Groups, Sylow Theorem and their applications, Free Abelian Groups, Free Groups and Group Presentations.	
Content		**No. of Hours (L+T)**
Unit I	**Group Action on a Set:** Factor Group Computations and Simple Groups, Group Action on a Set, Burnside's Formula, Examples Groups Actions	**9+3**
Unit II	**Isomorphism Theorems and Series of Groups:** Review of the First Isomorphism Theorem, Second Isomorphism Theorem, Third Isomorphism Theorem, Subnormal and Normal Series, Butterfly Lemma, Jordan-Holders Theorem, Solvable Groups, Ascending central series of the group.	**12+4**
Unit III	**Sylow Theorem:** p-Groups, Cauchy's Theorem, First Sylow Theorem, Second Sylow Theorem, Third Sylow Theorem, **Applications of the Sylow Theory:** Class Equation of a group, Proof that every group of order prime square is abelian, Groups of orders products of two primes	**12+4**
Unit IV	**Free Abelian Group:** Free abelian groups, basis and rank of a free abelian group, Statement and proof of The Fundamental Theorem of Finitely Generated Abelian Groups **Free Groups and Group Presentations:** Words and reduced words, Free Groups, Homomorphisms of Free Groups, Homomorphisms of Free Groups, Group Presentations, Applications of Group Presentations.	**12+4**
Pedagogy:	Lectures, Self Study, Assignments. Lectures should include theory and examples. Tutorial to be exclusively dedicated for problem solving.	
Reference/ Reading:	**PRINCIPAL TEXT:** John B. Fraleigh, A First Course in Abstract Algebra, Seventh Edition, Pearson, 2013 **REFERENCES:** 1. David S. Dummit and Richard M. Foote, Abstract Algebra, 3rd Edition, Wiley, 2011	

	2. Joseph A. Gallian, Contemporary Abstract Algebra, Eight Edition, Cengage India Private Ltd, 2019 3. Michael Artin, Algebra, Second Edition, Pearson Edition, 2015 4. Vivek Sahai and Vikas Bist, Algebra, 3rd Edition, Narosa, 2015.
Course Outcomes:	At the end of this course the student will be able to 1. Recollect the basic definitions and theorems in Group Theory. 2. Explain the various proofs and concepts in the course. 3. Solve the various computations problems in the course 4. Solve problems using the concepts learnt in the course.

Name of the Programme : B.Sc. Mathematics
Course Code : MAT-305
Title of the Course : Complex Analysis
Number of Credits : 3L+1T
Effective from AY : 2025-26

Pre-requisites for the Course:	A First Course in Real Analysis.	
Course Objectives:	To provide an introduction to the theory of functions of complex variables, analytic functions, contour integrations and to furnish an introduction to their applications.	
Units	Content	**No. of Hours (L+T)**
Unit I	**Complex Numbers:** Sums and products; Algebraic properties; Vectors and moduli; Complex conjugates; Exponential form; Arguments of products and quotients; Roots of complex numbers; Regions in the complex plane.	**5 + 2**
	Analytic Functions: Functions of a complex variable; Limits; Continuity; Derivatives; Differentiation formulas; Cauchy – Riemann equations; Sufficient condition for Differentiability; Polar coordinates; Analytic functions; Harmonic functions; Uniquely determined analytic functions.	**9 + 3**
Unit II	**Elementary Functions:** Exponential function; Logarithmic function; Branches and Derivatives of Logarithms; Identities involving logarithms; Complex exponents; Trigonometric functions; Hyperbolic functions; Inverse Trigonometric and Hyperbolic Functions.	**8 + 2**
Unit III	**Integrals:** Derivatives of functions; Definite integrals of functions; Contours; Contour integrals; Contour integrals of functions with branch cuts; Upper bounds for moduli of contour integrals; Antiderivatives; Cauchy – Goursat theorem (without proof); Simply and Multiply connected domains; Cauchy integral formula; Extension of Cauchy integral formula [statement only]; Some consequences of the extension; Liouville's theorem; Fundamental theorem of Algebra; Maximum modulus principle.	**13 + 4**
Unit IV	**Series:** Convergence of sequences and series; Taylor series; Taylor's theorem [statement only]; Laurent series; Laurent's theorem. [statement only].	**3 + 1**
	Residues and Poles: Isolated singular points; Residues; Cauchy Residue theorem; Residue at infinity; The three types of Isolated singular points; Residues at poles.	**7 + 3**

Pedagogy:	Lectures/Tutorials/Self-study. Lectures should include theory and examples. Tutorial to be exclusively dedicated for problem solving.
Reference/ Reading:	**PRINCIPAL TEXT:** J. Brown and R. Churchill: Complex Variables and Applications, 8th Edition, McGraw Hill Education, 2017. **REFERENCES:** 1. A. R. Shastri: Complex Analysis, Laxmi Publications, 2010. 2. E. B. Saff and A. D. Snider: Fundamentals of Complex Analysis with Applications to Engineering and Science, 3rd Edition, Pearson Education, 2008 3. J. B. Conway: Functions of a Complex Variable, Springer – Verlag, 1973. 4. J. E. Marsden, and M. J. Hoffman: Basic Complex Analysis, 2nd Edition, W. H. Freeman & Co. Ltd., 1987. 5. L.V. Ahlfors: Complex Analysis, McGraw-Hill Book Company, 1979 6. S. Ponnusamy: Foundations of Complex Analysis, 2nd Edition, Narosa Publishing House, 2005.
Course Outcomes:	The student will be able to: 1. Build the theory of limits, continuity, and differentiation to a function of a complex variable. 2. Prove several results and assess suitable techniques of complex integration. 3. Evaluate integrals of a complex valued function over contours. 4. Apply the theory of residues, and theorems of Taylor and Laurent to solve complex integrals.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-306**
Title of the Course : **Vector Calculus**
Number of Credits : **3L+1T**
Effective from AY : **2025-2026**

Pre-requisites for the Course:	Courses in Calculus of One Variable, Real Analysis, and Linear algebra.	
Course Objectives:	This course helps in understanding the basic concepts in multivariable calculus	
Content:		**No.of Hours (L+T)**
Unit I	**The geometry of Euclidean space:** Vectors in two and three dimensional space, geometry theorems by vector methods, equation of line (parametric form), inner product, length and distance, Cauchy-Schwarz inequality, orthogonal projection, triangle inequality, cross product and its elementary properties, equation of plane in vector form, n-dimensional Euclidean space revisit.	**5+2**
Unit II	**Differentiation:** Graph of functions, level sets, curves and surfaces, limit of function and its properties, continuous functions and its properties, continuity of composite functions. Partial derivatives, the linear approximation, differentiability of functions of two and three variables, tangent plane, differentiability-the general case. Basic theorems related to differentiability and continuity. Paths and curves, velocity and tangents to path, chain rule (no proof), special cases of chain rule, gradient and directional derivatives and its elementary properties, Iterated partial derivatives and equality of mixed partial derivatives, implicit differentiation **Vector valued functions:** Differentiation of paths, differentiation rules, arc length function, reparametrization, vector fields and scalar fields, gradient field, divergence and curl, physical interpretations of divergence and curl, Laplacian operator, Basic identities of vector analysis.	**19+6**
Unit III	**Double and triple integrals:** Double integrals and triple integrals as volume, reduction to iterated integrals, Fubini's theorem (no proof), Integrals over general regions, change of order of integrations	**6+2**

	Change of variable formula (no proof) for two and three variables, special cases- polar co-ordinates, cylindrical co-ordinates and spherical co-ordinates.	
Unit IV	**Integration over paths and surfaces:** Path integrals, line integrals, reparametrization of paths and its properties, parametrized surfaces, tangent vector and tangent plane to a parametrized surface, area of parametrized surface, integrals of scalar fields and vector fields over surfaces, reparametrization of surfaces and its properties, physical interpretation of surface and volume integrals. **The integral theorems of vector analysis:** Green's theorem and its applications, Stokes theorem, Conservative fields, physical interpretations of line integrals, Gauss Divergence theorem.	**15+5**
Pedagogy:	Lectures/tutorials/assignments/self-study. Lectures should include theory and examples. Tutorial to be exclusively dedicated for problem solving.	
Reference Reading:	**PRINCIPAL TEXT:** Jerrold E. Marsden and Anthony Tromba: Vector calculus, Sixth edition, W. H. Freeman and Company New York, 2012 **REFERENCES:** 1. Gosh and Maity: *Vector Analysis*, 7th Edition, New Central book agency, 2011. 2. J. N. Sharma, and A. R. Vasishtha: *Vector Calculus*, Krishna Prakashan Media, 2019 3. Md. A. Ashraf and Md. A. K. Hazra : *Vector Analysis with Applications*, 4th Edition, New Age International Publishers, 2018. 4. T. M Apostol: *Calculus Vol II* , Second Edition, John Wiley & Sons, 2005	
Course Outcomes:	1. To build student's knowledge of multivariable calculus and introduce calculus on manifolds. 2. To develop the ability to work with limits and continuity and differentiability of vector valued functions. 3. To be able to calculate line, surface and volume integrals. 4. To apply the concepts in calculus to solve some problems in physics, engineering etc.	

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-321**
Title of the Course : **Linear Programming Problems**
Number of Credits : **3L+1P**
Effective from AY : **2025-26**

Pre-requisites for the Course:	Basic 12th standard Mathematics.	
Course Objectives:	1. To make students familiarize with the mathematical formulation of real-world problems. 2. To acquaint students with the problem-solving techniques theoretically and graphically.	
Content		**No. of Hours**
Unit I	**Convex sets:** convex set, extreme points of convex sets, convex combination, convex polyhedron, simplex. **Linear Programming Problem**: Introduction, formulation of LPP. General LPP, canonical and standard forms of LPP. Basic solution and degenerate solution of a system of equations, basic feasible solution, optimum basic feasible solution, improved basic feasible solution.	**10**
Unit II	**Simplex method**: reduction of a feasible solution to basic feasible solution, extreme point correspondence, fundamental theorem of linear programming, replacement of a basis vector, net evaluation, improved basic feasible solution, unbounded solution, conditions of optimality.	**14**
Unit III	**Duality in Linear Programming**: general primal-dual pair, formulating a dual problem, primal-dual pair in matrix form. Theorems in Duality, Fundamental theorem of duality, existence theorem. **Post optimal analysis**: changes in objective function coefficients $c_j's$ and changes in the $b_i's$ values.	**13**
Unit IV	**Transportation Problem**: LP formulation of the transportation problem, existence of feasible solution, basic feasible solution, duality in transportation problem, the transportation table, loops in transportation table. **Assignment problem**: mathematical formulation of the problem, reduction theorem.	**08**

Practical	**30 Hours to be dedicated for solving problems on:** 1. Graphical solution method to LPP 2. Computational procedure of Simplex Method 3. Two Phase Method 4. Big M method 5. Duality and simplex method 6. Dual Simplex Method 7. Post-Optimal analysis: i. Changes in objective function coefficients ii. changes in the values 7. Finding initial basic feasible solution to transportation problem (balanced and unbalanced): i. North-West corner method ii. Least Cost Method iii. Vogel's Approximation method 8. Optimal solution (degenerate and nondegenerate) to transportation problem (MODI method) 9. Hungarian Assignment Method (balanced and unbalanced)	**30**
Pedagogy	Lectures/Practical/Self study/Assignments/TORA Lectures shall include theory and examples. Practical to be exclusively dedicated to problem solving. The record of practical shall be maintained by students in a separate manual/journal duly certified by the instructor. * Introduction to the use of TORA software to solve the problems is recommended.	
Reference Reading	**Principal Text:** Kanti Swarup, P. K. Gupta and Man Mohan, Operations Research, 5th Edition, Sultan Chand and sons, 2016 **Reference:** 1. G. Hadley, Linear Programming, Narosa, 2002 2. J. K. Sharma, Operations Research: Theory and Applications, Macmillan India Limited 3. P. K. Gupta and D. S. Hira, Operations Research, S. Chand, 2019. 4. S. D. Sharma, Operations Research: Theory, methods and applications, Kedar Nath Ram Nath, 2014	
Course Outcomes	The student will be able to, 1. Construct Linear Programming Problems and Solve them Graphically. 2. Solve Linear Programming Problems by simplex method and Interpret the solution. 3. Determine a minimum transportation cost of a given commodity from a number of sources. 4. Choose the minimum cost or time of completing a number of jobs by a number of persons.	

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-322**
Title of the Course : **Applied Statistics**
Number of Credits : **3L+1P**
Effective from AY : **2025-26**

Pre-requisites for the Course:	Basic 12th standard Mathematics.	
Course Objectives:	To make students aware of various ways of doing data analysis by employing statistical techniques in applied statistics.	
Content		**No. of Hours**
Unit I	Correlation and Regression: Multiple correlation; Multiple regression; Log linear and Log Log models; Partial correlation – computations and their coefficients	**15**
Unit II	Analysis of time series data; Moving Averages; Linear trend and quadratic curves	**6**
Unit III	Parametric tests: Snedecor's F – distribution; F – test; One way and Two way ANOVA with and without repetition, Interactions; Post – hoc analysis. Non – Parametric tests: Chi square test for goodness of fit and independence of attributes; Run's test; median test	**10**
Unit IV	Factor Analysis: Mathematical basis; Exploratory Factor analysis; Important methods of factor analysis – Centroid method, Principal Components method, Maximum Likelihood method; Rotation in factor analysis.	**14**
Practical	30 hours are to be dedicated for illustrations with specific examples on the concepts learnt in unit I to Unit IV using manual computation and/or statistical softwares SPSS/PSPP/R. Any 10 of the following: 1. Partial and Multiple Corelation 2. Multiple Regression 3. Log Log Model 4. Log Linear Model 5. Estimation of Moving Averages 6. Estimation using Linear Trend 7. Estimation using Quadratic curves 8. One way ANOVA 9. Two way ANOVA 10. Non-Parametric (Run's test; median test) 11. Post-hoc Analysis 12. Factor Analysis (Principal Component Analysis) 13. Factor Analysis (Rotation)	**30**

Pedagogy	Lectures/Practical/Self-study. Lectures should include theory and examples. Practical to be exclusively dedicated for problem solving. The record of practical shall be maintained by students in a separate manual/journal duly certified by the instructor.
Reference/ Reading	**PRINCIPAL TEXT:** 1) S. C. Gupta, and V. K. Kapoor: *Fundamentals of Mathematical Statistics,* 12th Edition, Sultan Chand & Sons, 2020. 2) J. F. Hair Jr., W. C. Black, B. J. Babin, and R. E. Anderson: *Multivariate Data Analysis,* 8th Edition, Cengage, 2018. **REFERENCES:** 1. G. B. Singh: *Statistical Probability,* Paradise Publishers, 2012. 2. J. Medhi: *Statistical Methods: An Introductory Text,* New Age International Publishers, 2006. 3. S. C. Gupta, and V. K. Kapoor: *Fundamentals of Applied Statistics,* 11^{th} Edition, Sultan Chand & Sons, 1994.
Course Outcomes:	The student will be able to, 1. Apply the various techniques in applied statistics for doing data analysis. 2. Solve problems in testing hypothesis. 3. Construct multiple regression models for real life problems. 4. Set up suitable models using factor analysis and discriminant analysis.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-323**
Title of the Course : **Bio Mathematics**
Number of Credits : **3L+1P**
Effective from AY : **2025-26**

Pre-requisites for the Cours:	Basic 12th standard Mathematics and any computer programming tool.	
Course Objectives:	1. To enable students to understand how mathematics can be used to describe biological processes. 2. Make students appreciate the power and limitations of mathematics in solving practical real life problems.	
Content		**No. of Hours**
Unit I	Introduction: Scope and Role of mathematics in biomathematics, Population dynamics, Mathematical ecology, Mathematical epidemiology, Mathematical genetics.	**5**
Unit II	Mathematical Biology: Single species continuous population model, Malthus model, Logistic model (Formulation, analytic solution, behaviour of population as t tends to infinity, Carrying capacity), Steady state, equilibrium point, biological interpretation of steady state, stability of steady state, Geometric analyses.	**15**
Unit III	Interacting Population:Prey predator system, Lotka Volterra model, Competition model Harvesting problems of single natural population: constant yield harvesting and constant effort harvesting	**15**
Unit IV	Epidemic Models: Basic terminologies, SI, SIRS models, basic reproduction number	**10**
Practicals	**30 Hours to be dedicated for problem solving in:** 1. Take any modelling equation, find its solution, check the stability of equilibrium point and analyse the solution geometrically (Using any software any six modeling equations)(**Six Practicals**) 7. Take any logistic equation, find its solution, check the stability of equilibrium point and analyse the solution geometrically (Using any software) 8. Take any logistic equation, find its solution, check the stability of equilibrium point and analyse the solution analytically (Using any software) 9. Model a prey predator situation with One prey two predators 10. Model a prey predator situation with two preys and a predator	**30**

	11. Model any Epidemic or disease and analyse the data using the software	
Pedagogy:	Lectures/Tutorials/Self-study/MATLAB/Scilab	
Reference/ Reading:	1. F. Braler, P.V.D.Driessche and J.Wu, Mathematical Epidemiology, Springer 2008. 2. I.D.Murray, Mathematical Biology, Springer, 1993. 3. J.N. Kapur, EWP 1981, Mathematical Models in Biology and Medicine 4. J.N. Kapur, 2022, Mathematical Modelling, New Age International Publishers. 5. Mathematical Models in Biology, SIAM, 1988 6. Y.C. Fung, Biomechanics, Springer-Verlag, 1990	
Course Outcomes:	1. Apply Mathematical techniques to get insight into the problems of biosciences. 2. Solve any modelling equation and check its stability. 3. Model prey-predator situations. 4. Analyze the date modelled by any epidemic or disease.	

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-324**
Title of the Course : **Operations Research**
Number of Credits : **3L+1P**
Effective from AY : **2025-26**

Pre-requisites for the Course:	Basic 12th standard Mathematics.	
Course Objectives:	To apply various optimisation techniques for decision making.	
Content		**No. of Hours**
Unit I	**Network Scheduling by PERT/CPM**: Basic components of network, logical sequencing, rules of network construction, concurrent activities. **Critical path analysis**: forward pass, backward pass, critical path, floats.	**08**
Unit II	**Game Theory**: Introduction, two-person zero-sum games, basic terms, minimax-maximin principle, solving games with saddle points, mixed strategies games	**10**
Unit III	**Queueing Theory**: queueing system, elements of a queueing system, operating characteristics of a queueing system, deterministic queueing system and probability distributions in queueing systems: distribution of arrivals, distribution of inter-arrival times, distribution of departures, distribution of service times. Classification of queueing models, transient and steady states, Poisson queueing systems: (M/M/1):(∞/FIFO), (M/M/1):(N/FIFO), (M/M/C):(∞/FIFO), (M/M/C):(N/FIFO) * Derivation of the formulae to be done in theory and problems to be done in the practical	**14**
Unit IV	**Inventory Control**: Introduction, types of inventories, objectives of scientific inventory control, costs associated with inventories, factors affecting inventory control, the concept of EOQ. Deterministic inventory problems with no shortages: i) the fundamental problem of EOQ, ii) EOQ with several production runs of unequal length iii) EOQ with finite replenishment Deterministic inventory problem with shortages: i) EOQ with instantaneous production and variable order cycle time ii) EOQ with instantaneous production and fixed order cycle One period problem without set-up cost: i) uniform demand (discrete and continuous units) ii) instantaneous demand (discrete and continuous units)	**13**

	* Derivation of the formulae to be done in theory and problems to be done in the practical	
Practical	**30 Hours to be dedicated for problem solving on the following topics:** 1. Critical path method (deterministic and probabilistic time) 2. Graphical solution of $2 \times n$ games 3. Graphical solution of $m \times 2$ games 4. Dominance property 5. (M/M/1):(∞/FIFO), (M/M/1):(N/FIFO) 6. (M/M/C):(∞/FIFO), (M/M/C):(N/FIFO) 7. EOQ without shortages having i. uniform demand and equal production length ii. unequal production length iii. with finite replenishment 8. EOQ with instantaneous production with shortages and i. variable order cycle time ii. fixed order cycle 9. One period problem without set-up cost, uniform demand, discrete and continuous units 10. One period problem without set-up cost, instantaneous demand, discrete and continuous units	**30**
Pedagogy	Lectures/Practical/Self study/Assignment/TORA Lectures shall include theory and examples. Practical to be exclusively dedicated to problem solving. The record of practical shall be maintained by students in a separate manual/journal duly certified by the instructor. * Introduction to the use of TORA software to solve the problems is recommended.	
Reference Reading	**<u>Principal Text:</u>** Kanti Swarup, P. K. Gupta and Man Mohan, Operations Research, Sultan Chand and sons, 2016 **<u>References:</u>** 1. G. Hadley, Linear Programming, Narosa, 2002 2. J. K. Sharma, Operations Research: Theory and Applications, Macmillan India Limited 3. P. K. Gupta and D. S. Hira, Operations Research, S. Chand, 2019. 4. S. D. Sharma, Operations Research: Theory, methods and applications, Kedar Nath Ram Nath, 2014	
Course Outcomes:	The student will be able to, 1. Design a project management technique when the time to finish a project is not certain. 2. Solving games with saddle points and understanding mixed strategies games.	

	3. Construct the most cost – effective services by studying the movement of people, objects, or information through a line. 4. Organize inventory levels to ensure an optimal amount of each product for the smooth functioning of a supply chain.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-326**
Title of the Course : **Mathematical Demography**
Number of Credits : **3L+1P**
Effective from AY : **2025-26**

Pre-requisites for the Course:	Basic 12th standard Mathematics and knowledge of computers	
Course Objectives:	1. To equip the students with a comprehensive understanding of the techniques and tools of demography and to provide analytical skills 2. To impart a thorough knowledge about the past, present and future population scenario of the world and India 3. To make students understand the various demographic events and processes that shape the population size and structure, various factors affecting population and its determinants	
Content		**No. of Hours**
Unit I	Introduction: Definition, Origin and Scope of demography, history of population growth, sources of demographic data: census and sample survey. Population Composition: Based on age, sex, religion and education, Components of population change: Fertility, mortality, migration(factors, causes and consequences)	**10**
Unit II	Demographic theories: Malthus theory, socialistic views of population, demographic transition theory, Social theory of fertility: Freedman Davis-Blake model, Theory of migration.	**8**
Unit III	Techniques of demographic analyses: Measures of age, sex composition of population, age pyramid, measures of population growth-arithmetic, exponential, logistic Mortality rate, morbidity rate, fertility rate(Crude and specific)	**12**
Unit IV	Life Tables: Concept, assumptions, construction of age tables, uses, methods of population estimation and projections (Mathematical and cohort component method)	**15**
Practicals	**30 Hours to be dedicated for problem in:** 1. Extract the migration/ various factors data from census data and analyze using the software. 2. Take population data of any Taluka/city / village of Goa and find mortality change of population change using the software.	**30**

	3. Take population data of any Taluka/city / village of Goa and find morbidity change of population change using the software. 4. Take population data of any Taluka/city / village of Goa and find rate of fertility change using the software. 5. Take population data of any Taluka/city / village of Goa and find migration of males and population change using the software. 6. Take population data of any Taluka/city / village of Goa and find migration of females and population change using the software. 7. Take population data of any Taluka/city / village of Goa and find population ageing using the software. 8. Carry out population analyses of Goa using the software. 9. Carry out population projection of Goa using the software. 10. Construct Life Tables.5	
Pedagogy	Lectures/seminars/fieldwork/tutorials/MortPak/DemProj/Spectrum	
Reference Reading	1. Bougue, Donald J: Principles of demography – New York: John Wiley and Sons, 1969 2. Bhende, Asha A and Tara Kanitkar: Principles of population studies – 5th rev. ed. Delhi: Himalaya, 1997 3. Ghosh B N Population Theories and demographic analysis – New Delhi 4. Pollard J H Demographic Techniques Australia, Pengamon Press 5. Prakasa Rao VLS: Urbanisation in India: Spatial Dimensions – New Delhi: Concept, 1983 6. Ramakumar R; Technical Demography, New Delhi, Wiley Eastern Ltd. 7. Ramakumar. R and Gopal Y S: Technical demography – New Delhi: Wiley Eastern, 1986 8. Spiegelman M, Introduction to Demography, Cambridge, Harvard University Press 9. Srinivasan K, Basic Demographic Techniques and Applications, New Delhi Sage Publications 10. United Nations: Determinants and consequences of population trends – New York, United Nations 11. United Nations, Determinants and consequences of population trends – New York United Nations	
Course Outcomes:	1. Acquire practical knowledge of the important components of formal demography. 2. Forecast various factors affecting population. 3. Projection of population in addition to finding morbidity, migration and fertility changes. 4. Use appropriate software in carrying out population analysis.	

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-325**
Title of the Course : **Econometrics**
Number of Credits : **3L+1P**
Effective from AY : **2025-26**

Pre-requisites for the course:	Basic 12th standard mathematics.	
Course Objectives:	To provide learners with the knowledge and skills of basic applied econometrics to enable them to understand and to conduct basic econometrics analyses.	
Content		**No. of Hours**
Unit I	**The Structure of Economic Data:** Cross-Sectional Data; Time Series Data; Pooled Cross Sections; Panel and Longitudinal Data. **Simple Linear Regression Model**: Two Variable Case Estimation of model by method of ordinary least squares; properties of estimators; goodness of fit; tests of hypotheses; scaling and units of measurement; confidence intervals; Efficiency of OLS: Gauss-Markov theorem; forecasting.	**15**
Unit II	**Multiple Linear Regression Model**: Estimation of parameters; properties of OLS estimators; goodness of fit - R^2 (R square) and adjusted R^2; partial regression coefficients; testing hypotheses – individual and joint; functional forms of regression models; Omitted Variable Bias, Multicollinearity: Nature of the problem and its consequences; econometric solutions.	**10**
Unit III	**Heteroscedasticity and Autocorrelation:** Problems of Heteroscedasticity and Autocorrelation; Identification & Solution, GLS method of estimation; tests for heteroscedasticity and autocorrelation.	**10**
Unit IV	**Qualitative Response Models:** Qualitative (dummy) independent variables; Probit model, Alternative measures of Goodness of Fit (R^2) in Qualitative response models, Logit vs Probit model selection, Limited dependent variable model/ Tobit Model.	**10**
Practical	**Any 10 practicals may be done by using manual computation / SPSS/ R** 1. Structure of Data: Preparing cross sectional and time series data base in SPSS/ EXCEL worksheet. 2. Representation of time series in graph. 3. Fitting of linear regression equation (y= f(x)) 4. Fitting of linear regression equation (x = f(y)) 5. Forecasting using regression equations. 6. Multiple regression equation (2 independent variables) 7. Multiple regression equation (3 independent variables)	**30**

	8. Estimation by log linear model and log log model 9. Computation of partial regression coefficients 10. Problem of multicollinearity: Methods of removing the multicollinearity in regression models. 11. Illustration of autocorrelation: Calculation of Durbin- Watson coefficient. 12. Illustration and computation of heteroskedasticity.
Pedagogy	Lectures/Practical/Self-study. Lectures should include theory and examples. Practical to be exclusively dedicated for problem solving. The record of practical shall be maintained by students in a separate manual/journal duly certified by the instructor. A discussion on Economic Concepts and Database for Econometric Analysis namely National Income Accounting – Base year – Methods of estimation – Types of reporting – BOP and NI – SGDP; Census - types – other data sets from Census –Economic Census, Educational Census, Agricultural census, etc.; NSSO – sample – large and small samples, NFHS, RBI; International data – World bank, IMF, ILO, WTO, UNCTAD, UN, wherever required in the course, must be done.
Reference Reading	**PRINCIPAL TEXT:** Gujarati, D. N. and Porter, D.C., *Essentials of Econometrics*, McGraw Hill, 4th edition, International Edition, 2009. **REFERENCES:** 1) Dougherty Christopher, *Introduction to Econometrics*, Oxford University Press, 3rd edition, Indian edition, 2007. 2) Maddala, G.S., *Introduction to Econometrics*, John Wiley, 2001. 3) Wooldridge, J. M., *Introductory Econometrics: A Modern Approach*, Cengage Learning, 2008.
Course Outcomes:	The student will be able to, 1. Understand economic data. 2. Evaluate economic data. 3. Analyse economic data. 4. Interpret statistical evidence from economic data.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-400**
Title of the Course : **Advanced Real Analysis**
Number of Credits : **3L+1T**
Effective from AY : **2026-27**

Pre-requisites for the course:	A course in Calculus of One Variable, Analysis, and Riemann Integration	
Course Objectives:	To construct solutions/strategies/proofs oneself and effectively communicate the same by understanding the mathematical meaning behind the most fundamental concepts, apply the results to solve problems in analysis at hand, and appreciate the connection between various branches of mathematics.	
Content		**No. of Hours (L+T)**
Unit I	**Real Number System:** Peano's Axioms for Natural Numbers; Finite sets; Cardinality of finite sets; Subset of finite sets. **Theorem:** Proper subset of a finite set has cardinality strictly less that the super set. Integers and Rational numbers (Discussion); Ordered sets and LUB Property; Ordered Field Axioms; Field of Real Numbers and Completeness; Existence of n^{th} roots of nonnegative reals; Proof of existence of decimal representation of reals; Countable sets – definition and equivalent reformulations of countability; Countability of unions and Cartesian products of sets; Uncountable sets; Countability of rationals; Uncountability of reals, Extended Real Number System; Lindelöf Covering Theorem. **Cantor's Set:** Cantor set – Construction and basic properties; Cantor set and ternary expansion. **Perfect sets:** Theorem: Every non – empty perfect set of $\mathbb{R}^n$ is uncountable.	**15+5**
Unit II	**Calculus:** Limit inferior and Limit superior of a sequence; Higher order derivatives; Inflection points; Convex functions and differentiability; Taylor's theorem (with Cauchy and Lagrange form of remainder); Maclaurin's theorem; Leibnitz rule for higher order derivative of product of functions; Stationary points and their classification; Local maxima and Local minima; Indeterminate forms of the type $\frac{0}{0}, \frac{\infty}{\infty}, \infty - \infty, 0.\infty, 0^0, 1^\infty, \infty^0$.	**7+3**
Unit III	**Riemann Steiltjes Integration:** Weights and measures; The Riemann – Steiltjes integral; Space of integrable functions; Integrators of bounded variation.	**11+4**

Unit IV	**Compactness:** Compact sets in Metric Spaces; Properties of Compact Sets; Sequential Compactness; Bolzano – Weierstrass Property; Heine – Borel Theorem; Totally Boundedness; Equivalence of Compactness and Sequential Compactness; Lebesgue Covering Lemma; Compactness and Finite Intersection Property; Continuous functions and Compactness in Metric Spaces; Cantor Intersection Theorem; Compactness in $\mathbb{R}^n$.	**12+3**
Pedagogy	Lectures/Tutorials/Self-study. Lectures should include theory and examples. Tutorial to be exclusively dedicated for problem solving.	
Reference Reading	**<u>PRINCIPAL TEXTS (UNITWISE):</u>** 1. T. Tao: *Analysis I,* 4th Edition, Hindustan Book Agency, 2022. **[For Unit I]** 2. A. Kumar, and S. Kumaresan: *A Basic Course in Real Analysis*, CRC Press, 2014. **[For Unit II]** 3. W. Rudin: *Principles of Mathematical Analysis,* Standard Edition, McGraw Hill Publisher, 2023. **[For Unit III]** 4. P. K. Jain, and K. Ahmad: *Metric Spaces*, 3rd Edition, Narosa Publishing House, 2019. **[For Unit IV]** **<u>REFERENCES:</u>** 1. A. Kumar, S. Kumaresan, and B. K. Sarma: *A Foundation Course in Mathematics,* Narosa Publishing House, 2.18. 2. N. L. Carothers: *Real Analysis*, Cambridge University Press, 2000. 3. S. Narayan, and M. D. Raisinghania: *Elements of Real Analysis,* Revised Edition, S. Chand Publications, 2016. 4. S. C. Malik, and S. Arora: *Mathematical Analysis,* 6th Edition, New Age International Publishers, 2022.	
Course Outcomes:	The student will be able to, 1. Deduce properties of real numbers by applying definitions and axioms. 2. Explain the advance theory of differentiability. 3. Prove theorems in Riemann – Steiltjes integration. 4. Build results in compactness in metric space.	

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-401**
Title of the Course : **Rings and Fields**
Number of Credits : **3L+1T**
Effective from AY : **2026-2027**

Pre-requisites for the Course:	A course in Group Theory.	
Course Objectives:	The 'Rings and Fields' course aims to acquaint students with fundamental concepts within rings and fields. Encompassing diverse subjects like Rings and Fields, Ring of Polynomials, Ideals and Factor Rings, and Factorization in Integral Domains. Students will acquire the necessary knowledge and techniques to advance into topics like Field Extensions and Galois Theory.	
Content:		**No. of Hours**
Unit I	**Basic Topics in Rings:** Rings, Homomorphisms and Isomorphisms, Division Rings, Skew Fields, Integral Domains, Theorems in Integral Domains, Characteristic of a Ring, Fermat's and Euler's Theorems, Application to solution of linear congruences, Field of Quotients of an Integral Domain, Uniqueness of field of Quotients	**15+5**
Unit II	**Ring of Polynomials** Polynomials, The polynomial ring R[x], The Evaluation Homomorphism, Zero of a Polynomial, Factorization of Polynomials over Fields, The Division Algorithm, Factor Theorem, Irreducible Polynomials, Eisenstein's Criterion and consequences	**9+3**
Unit III	**Ideals and Factor Rings:** Ring Homomorphisms, Properties of Homomorphisms, Quotient Rings, Ideals, Fundamental Homomorphism Theorem, Prime and Maximal Ideals Prime Fields	**9+3**
Unit IV	**Factorization in Integral Domains:** Division in Rings, Unique Factorization Domain and Principal Ideal Domain, Every PID is a UFD and consequence to F[x] and integers, If D is a UFD then D[x] is a UFD, Euclidean Domains, Every Euclidean Domain is a PID, Arithmetic in Euclidean Domains, Gaussian Integers, Fermat's $p = a^2 + b^2$ theorem	**12+4**
Pedagogy:	Lectures, Self Study, Assignments. Lectures to be dedicated for theory and problems. Tutorials shall be exclusively for solving exercises.	
Reference/ Reading;	<u>**PRINCIPAL TEXT:**</u> John B. Fraleigh, A First Course in Abstract Algebra, Seventh Edition, Pearson, 2013 <u>**REFERENCES:**</u> 1. David S. Dummit and Richard M. Foote, Abstract Algebra, 3rd Edition, Wiley, 2011 2. Joseph A. Gallian, Contemporary Abstract Algebra, Eight Edition, Cengage India Private Ltd, 2019 3. Michael Artin, Algebra, Second Edition, Pearson Edition, 2015	

	4. Vivek Sahai and Vikas Bist, Algebra, 3rd Edition, Narosa, 2015.
Course Outcomes:	At the end of this course the student will be able to 1. Recollect the basic definitions and theorems in Ring Theory. 2. Explain the various proofs and concepts in the course. 3. Solve the various computations problems in the course 4. Solve problems using the concepts learnt in the course.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-402**
Title of the Course : **Advanced Linear Algebra**
Number of Credits : **3L+1T**
Effective from AY : **2026-2027**

Pre-requisites for the Course:	A First Course in Linear Algebra	
Course Objectives:	To introduce and familiarize the learner with Linear Functionals, Triangulable and Diagonalizable Operators, Annihilating Polynomials, Decompositions of Vector Spaces using Operators and the Jordan Canonical Form.	
Content:		**No. of Hours (L+T)**
Unit I	Linear functional on vector spaces, Hyper plane, Annihilator, Dual of vector spaces and properties, Transpose of linear Transformation and it's matrix, row rank equal to column rank.	**9 + 3**
Unit II	**Elementary Canonical Forms:** Characteristic values and Characteristic vectors, Characteristic spaces, Diagonalizable Operators, Characterization of Diagonalizable operators using the Characteristic spaces.	**9 + 3**
Unit III	Annihilating polynomials, Minimal Polynomial, Caley Hamilton Theorem, Invariant subspaces, T-conductor, Triangulable operators, Characterization of Triangulable and Diagonalizable operators using the Minimal polynomial.	**9 + 3**
	Simultaneous Triangulation & Simultaneous Diagonalization, Independent Subspaces, Projections, Invariant direct sums, Primary Decomposition Theorem, Nilpotent operators, T=D+N decomposition.	**9 + 3**
Unit IV	**Rational and Jordan Forms:** Cyclic subspaces and Annihilators, Companion matrix, Complementary subspace, T-admissible subspace, Cyclic Decomposition theorem (without proof), Generalized Cayley Hamilton theorem, Rational form, Invariant factors, Elementary Jordan matrices, Jordan Canonical form.	**9 + 3**
Principal Text	**Kenneth Hoffmann and Ray Kunze, Linear Algebra, Second edition, PHI, 1997.**	
Pedagogy:	Lectures/Tutorials/Self-study. Lectures to be dedicated for theory and problems. Tutorials shall be exclusively for solving problems.	
Reference Reading:	1. I.R. Shafarevich and A. O. Remiz Linear Algebra and Geometry, Springer Verlag. 2. S. Friedberg, A. Insel, L. Spence Linear Algebra (5th Edition), Pearson 2022.	

	3. S. Kumaresan, Linear Algebra, PHI, 2000. 4. Y. I. Manim, Linear Algebra and Geometry, CRC Press.
Course Outcomes:	1. Display familiarity and knowledge of the concepts in the syllabus. 2. Demonstrate proofs to establish truths related to the concepts in the syllabus. 3. Choose the appropriate procedures and modify them, if needed, to solve method-based problems on the concepts in the syllabus. 4. Analyze and solve unseen problems in Linear Algebra and invent mathematically precise arguments to justify their solutions.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-403**
Title of the Course : **Advanced Complex Analysis**
Number of Credits : **3L+1T**
Effective from AY : **2026-27**

Pre-requisites for the Course:	A First Course in Complex Analysis	
Course Objectives:	To introduce students to advanced concepts in complex integration, understand conformal mappings and apply calculus of residues to solve problems in integration.	
Units	**Content**	**No. of Hours (L +T)**
Unit I	**Power Series:** Uniform Convergence of Power Series; Exponential and Trigonometric Functions; Logarithmic Functions.	**6+2**
Unit II	**Complex Integration:** Curves in the complex plane; Properties of complex line integrals [without proof] ; Cauchy - Goursat Theorem; Consequences of Simply Connectivity; Winding number of a curve; Homotopic Version of Cauchy's Theorem; Cauchy Integral Formula; Taylor's Theorem [Statement and Proof]; Zeroes of analytic functions; Laurent's Theorem [Statement and Proof] **Maximum Principle and Schwarz Lemma:** Maximum Modulus Principle and Minimum Modulus Theorem [statements only]; Schwarz Lemma and its consequences; Zeroes of Certain Polynomials;	**15+5**
Unit III	**Conformal Mappings and Mobius Transformations:** Principle of Conformal Mapping; Basic properties of Mobius maps; Fixed points and Mobius maps; Triples to Triples under Mobius maps; Cross ratio and its invariance property; Principle of Symmetry.	**9+3**
Unit IV	**Classification of Singularities:** Isolated and Non-Isolated singularities; Removable singularities; Poles; Isolated singularities at infinity; Meromorphic functions; Essential singularities and Picard's Theorem **Calculus of Residues and Applications:** Residue at a finite point [statements without proof]; Residue at a point at infinity **;** Residue theorem [statement only]; Number of Zeroes and Poles (Argument Principle); Rouche's Theorem; Open mapping theorem; Definite integrals involving sines and cosines; Evaluation of improper integrals; Singularities along the Real Axis; Integrating along branch cuts; Estimation of Sums**,** open mapping theorem.	**15+5**
Pedagogy:	Lectures/Tutorials/Self-study. Lectures should include theory and examples. Tutorial to be exclusively dedicated for problem solving.	

Reference/ Reading:	**PRINCIPAL TEXT:** S. Ponnusamy: Foundations of Complex Analysis, 2nd Edition, Narosa Publishing House, 2005. **REFERENCES:** 1. A. R. Shastri: Complex Analysis, Laxmi Publications, 2010. 2. E. B. Saff and A. D. Snider: Fundamentals of Complex Analysis with Applications to Engineering and Science, 3rd Edition, Pearson Education, 2008. 3. E. M. Stein and R. Shakarchi: Complex Analysis, Princeton University Press, 2005. 4. J. B. Conway: Functions of a Complex Variable, Springer – Verlag, 1973. 5. J. Brown and R. Churchill: Complex Variables and Applications, 8th Edition, McGraw Hill Education, 2017. 6. L. V. Ahlfors: Complex Analysis, McGraw-Hill Book Company, 1979.
Course Outcomes:	The student will be able to: 1. Discuss uniform convergence of Power Series 2. Prove various results in complex integration 3. Solve problems in and illustrate the concept of Conformal Mappings 4. Classify singularities and apply residues to solve integrals.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-404**
Title of the Course : **Functions of Several Variables**
Number of Credits : **3L+1T**
Effective from AY : **2026-2027**

Pre-requisites of the Course:	A Course in Real Analysis and Linear Algebra.	
Course Objectives:	To develop the ability to understand and analyze the concepts of functions of several variables.	
Content		**No. of Hours (L+T)**
Unit I	**Differentiation in $\mathbb{R}^n$:** Partial Derivatives, Directional derivative, Directional derivatives and Continuity, Total derivative, Total derivative expressed in terms of partial derivatives, Jacobian matrix, Chain rule, Matrix form of the chain rule, Mean Value theorem for differentiable functions, Sufficient condition for differentiability. Higher order partial derivatives, Sufficient condition for equality of mixed partial derivatives, Taylor's formula for functions from $\mathbb{R}^n$ to $\mathbb{R}$.	**15 + 5**
Unit II	**Extrema of real valued functions of several variables:** Local (relative) Maxima & Minima, Global (absolute) maxima and minima, extrema, Saddle (Inflexion) point, Necessary condition for a differentiable function to have local maxima (minima), critical points, Stationary point, Second Derivative test for extrema, Extremum problems with side conditions: Lagrange's multipliers.	**9 + 4**
Unit III	**Inverse & Implicit Function Theorem:** Implicit function, Functions with non-zero Jacobian determinant, Inverse Function Theorem, Implicit Function Theorem.	**7 + 2**
Unit IV	**Multiple Riemann Integrals:** Measure of a bounded interval in $\mathbb{R}^n$ .Riemann integral of a bounded function defined on a compact interval in $\mathbb{R}^n$. Sets of measure zero and Lebesgue's criterion for existence of a multiple Riemann integral (Only statement), Evaluation of a multiple Riemann integral by iterated integration: Fubini's Theorem, Jordan measurable sets in $\mathbb{R}^n$**,** Multiple Riemann integral over Jordan measurable sets, Jordan content expressed as a Riemann integral, Additive property of the Riemann integral, Mean value theorem for multiple integrals.	**14 + 4**
Pedagogy	Classroom lectures, tutorials, self-study, assignments and library references.	
Reference/ Reading	**PRINCIPAL TEXT:** Tom M Apostol, *Mathematical Analysis*, Narosa Publishing House, 1985. **REFERENCES:**	

	1. B. V Limaye & S. Ghorpade: *A course in multivariable calculus*, Springer. 2. C. H Edwards, Jr.: *Advanced Calculus of several variables*, Dover Publications. 3. J. E Marsden, A.J. Tromba, Alan Weinstein: *Basic Multivariable Calculus*, W.H. Freeman & Co Ltd. 4. James Munkres: *Analysis on Manifolds*, Addison Wesley Publishing Company, 1991. 5. Joel Hass, Christopher Heil and Maurice D. Weir, Thomas' Calculus, Fourteenth Edition, Pearson Education, 2018 6. M. Spivak: *Calculus on Manifolds*, Benjamin Cummings, London. 7. Martin Moskowitz, Fotios Paliogiannis: *Functions of several real variables*, World Scientific. 8. T. M. Apostol: *Calculus Vol II*. John Wiley and Sons.
Course Outcomes:	The students will be able to, 1. Examine the differentiability of functions and Find directional and total derivative and prove results related to differentiability. 2. Determine extremum of real valued function of several variables. 3. Prove Inverse and Implicit function theorems. 4. Define Riemann integral over Jordan measurable sets and Evaluate Multiple Riemann integral. 5. Understand and Explain the concepts of functions of several variables.

Name of the Programme : B.Sc. Mathematics
Course Code : MAT-405
Title of the Course : Topology
Number of Credits : 3L+1T
Effective from AY : 2026-2027

Pre-requisites for the Course:	A First course in Real Analysis.	
Course Objectives:	To introduce the learner to the general setting Topology, in which powerful results can be proved using only the minimum required assumptions, thus letting the learner see and appreciate cause-effect with much more clarity.	
Content		**No. of Hours**
Unit I	**Topological Spaces and Continuous Functions:** Definition of Topological spaces, Basis, Subbasis, Order Topology, Product topology on XxY, Subspace topology, Closed sets, Limit points, Closure, Interior, Boundary, Hausdorff Space and T1 axiom.	**9 + 3**
	Continuous functions, Homeomorphisms, Imbeddings, Construction of continuous functions, Maps into products, The Product Topology, Comparison of Box and Product Topology, Metric topology, Diameter, Standard bounded metric, Euclidean metric, Square metric, Topologies in R^n induced by Euclidean and square metric are same as product topology.	**8 + 2**
Unit II	**Connectedness**: Connected spaces, connected subsets of $\mathbb{R}$, path connected spaces, Product and continuous images of connected spaces, locally connected spaces, components and path components.	**9 + 3**
Unit III	**Compactness**: Compact subsets of topological spaces, Compact subsets of $\mathbb{R}$, Products and continuous images of compact subsets, Compact Hausdorff spaces, Limit point compactness, Sequential compactness, Compact metric spaces, Lebesgue number lemma, Locally compact spaces and one-point compactification.	**10+4**
Unit IV	**Countability** Properties: First and second countable spaces, Separable spaces, Metric spaces and countability properties. **Separation** Properties: Hausdorff spaces, Regular spaces and normal spaces, Product, subspace and continuous images of regular and normal spaces.	**9 + 3**
Pedagogy:	Lectures/Tutorials/Self-study. Lectures should include theory and examples. Tutorial to be exclusively dedicated for problem solving.	
Reference/ Reading:	**PRINCIPAL TEXT:** James Munkres, Topology and Introduction, Pearson Education, 2002. **REFERENCES:** 1. John L. Kelley, General Topology, First Edition, Springer, 1955	

	2. K. Parthasarathy, Topology: An Invitation, First Edition, Springer, 2022 3. K. D. Joshi, Introduction to General Topology, First Edition, New Age International Publishers, 1983 4. M. A. Amstrong, Basic Topology, Springer Verlag, 1983.
Course Outcomes:	1. Display familiarity and knowledge of the concepts in the syllabus. 2. Demonstrate proofs to establish truths related to the concepts in the syllabus. 3. Choose the appropriate procedures and modify them, if needed, to solve method-based problems on the concepts in the syllabus. 4. Analyze and solve unseen problems in Topology and invent mathematically precise arguments to justify their solutions.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-406**
Title of the Course : **Functional Analysis**
Number of Credits : **3L+1T**
Effective from AY : **2026-27**

Pre-requisites for Course:	A first course in Real Analysis, Linear Algebra and Metric Topology. Basic understanding of Lebesgue Integral Theory is desirable.	
Course Objectives:	Starting with the basics this course will cover the foundations of Functional Analysis such as normed spaces, inner product spaces, Banach spaces, Hilbert spaces, bounded linear operators and bounded functional, and the four fundamental theorems-Hahn-Banach Theorem. Uniform Boundedness Principle, Open Mapping Theorem and Closed Graph Theorem	
Content		**No. of Hours**
Unit I	**Preliminaries from Metric Spaces** Definition of the standard sequence spaces $s, c, c_0\,, c_{00}, l^p; 1 \leq p \leq \infty$, and standard function spaces $C[a,b]$ and $B[a,b]$. Idea of completion of a metric space, completeness and separability properties of these standard spaces.	**12**
Unit II	**Normed Spaces, Banach Spaces** Normed spaces- Properties and Banach spaces, Standard normed spaces –Sequence spaces , Function spaces and subspaces, Finite dimensional normed spaces and subspaces, Equivalence of norms, Compactness and finite dimension, Linear Operators-Boundedness and Continuity. Linear functional. Normed spaces of Operators, Dual space Algebraic and Topological duals.	**16**
Unit III	**Inner Product Spaces, Hilbert Spaces** Inner Product Spaces- Properties and Hilbert spaces, Orthogonal Complement and Direct Sums, Orthonormal Sets and Sequences, Total Orthonormal Sets and Sequences, Representation of Functional on Hilbert Spaces, Hilbert - Adjoint Operator, Self Adjoint, Unitary and Normal Operators.	**16**
Unit IV	**Fundamental Theorems for Normed and Banach Spaces** Hahn-Banach Theorem (Statements and idea of proof for the case of vector spaces, statement and proof for normed spaces), Applications to Existence of Functionals, Adjoint Operators, Reflexivity of Spaces, Baire Category Theorem (Statement only), Uniform Boundedness Theorem, Open Mapping Theorem, Closed Graph Theorem.	**16**
Pedagogy:	Lectures/ Tutorials/Assignments/Self-study. Lectures should include theory and examples. Tutorial to be exclusively dedicated for problem solving.	
Reference/ Reading:	**<u>Principal Text</u>**	

	Ervin Kreyszig: *Introductory Functional Analysis with Applications*, John Wiley & Sons, 1978. **References** 1. Balmohan V. Limaye: *Functional Analysis*, 3rd edition, New Age International Private Limited, 2014 2. Balmohan V. Limaye: *Linear Real analysis for Scientists and Engineers*, Springer. 2016 3. George Bachman and Lawrence Narici: *Functional Analysis*, Dover Publishing House, 2000 4. Israel Gohberg and Seymour Goldberg: *Basic Operator Theory*, Birkhäuser, 1981. 5. S. Kumaresan and D. Sukumar: *Functional Analysis, A First Course*, Narosa, 2020
Course Outcomes:	Student will be able to 1. Understand the basic concepts and fundamental theorems of Functional Analysis 2. Prove important theorems in functional analysis. 3. Relate and apply the concepts learnt in the course to problems. 4. Analyse and solve unseen problems in normed spaces and inner product spaces and invent mathematically precise arguments to justify their solutions.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-407**
Title of the Course : **Advanced Differential Equations**
Number of Credits : **3L+1T**
Effective from AY : **2026-2027**

Pre-requisites for the Course:	A First Course in Ordinary Differential Equations.	
Course Objectives:	This course helps in understanding advanced concepts of Differential Equations. It develops the ability to solve system of differential equations and study qualitative property of differential equations	
Content		**No. of Hours (L+T)**
Unit I	Review: Linear differential equations of the first and higher order; Linear differential equations with constant and variable coefficients; Exact equations; Wronskian; Separable equations; Euler's equation; Reduction of order of equation; Variation of parameters.	**7+3**
Unit II	System of Linear Differential Equations: System of first order Equations, Existence and Uniqueness Theorem, Fundamental Matrix, Non – Homogeneous Linear Systems, Linear Systems with Constant Coefficients Linear Systems with Periodic Coefficients.	**10+4**
Unit III	Existence and Uniqueness of Solutions: Picard's Successive Approximations, Picard's Theorem – Some Examples, Continuation and Dependence on Initial Conditions, Existence of Solutions in the Large, Existence and Uniqueness for Systems, Fixed Point Method.	**14+4**
Unit IV	Boundary – Value Problems: Sturm – Liouville Problem, Green's Functions, Application of BVPs. Picard's theorem. Oscillation Theory: Self-adjoint second order differential equation; Sturm Liouville Problem; Green's function; Picard's theorem; Zeros of solutions; Comparison Theorems; Linear oscillations; Oscillations of $x''(t) + a(t)x(t) = 0$.	**14+4**
Pedagogy	Lectures/ tutorials/assignments/self-study. Lectures should include theory and examples. Tutorial to be exclusively dedicated for problem solving.	
Reference/ Reading	<u>**PRINCIPAL TEXT:**</u> Deo, S. G., Raghvendra, V., Kar, R., and Lakshmikantham, V.: Textbook of Ordinary Differential Equations, 3rd Edition, McGraw Hill Education, 2017. <u>**REFERENCES:**</u> 1. Ahmad, S. and Rao, M. R. M.: Theory of Ordinary Differential Equations With Applications in Biology and Engineering, Affiliated East – West Press Private Limited, 2014.	

	2. Coddington, E. A.: An Introduction to Ordinary Differential Equations, Prentice Hall, India, 2003. 3. Kelly, W., and Petterson, A. C.: Theory of Differential Equations, Springer, 2010. 4. Kreyszig, E.: Advanced Engineering Mathematics (Ed.), United States of America: Laurie Rosatone John Wiley & Sons. (2011). 5. Simmons, G. F.: Differential Equations with Applications and Historical Notes, 2nd Edition, McGraw Hill Education, 2017.
Course Outcomes:	1. Identify the type of a given differential equation and system of linear differential equations and select and apply appropriate analytical techniques for finding the solution. 2. Determine whether the existence and uniqueness of solutions are guaranteed to exist. 3. Learn about Equilibrium points giving interpretation of phase plane. 4. Explain the Oscillation theory of differential equations and understand the qualitative properties of solutions of differential equations .

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-411**
Title of the Course : **Difference Equations**
Number of Credits : **3L+1P**
Effective from AY : **2026-2027**

Pre-requisites of the Course:	Basic 12th standard Mathematics.	
Course Objectives:	This course helps in understanding basic concepts of discrete calculus. It develops the ability to solve Difference Equations by standard methods.	
Content		**No. of Hours**
Unit I	**Calculus of finite differences** Introduction to difference operator, shift operator and their properties, The Power Shift, Factorial Polynomials, The Anti-difference Operator and properties	**08**
Unit II	**Linear Difference Equations** Linear First-Order Difference Equations (homogenous and non-homogenous), The logistic equation, General Theory of Linear Difference Equations, Casoration and fundamental set of solutions, Abel's Lemma (statement and proof), The fundamental theorem (statement and proof), Superposition Principle, Linear Homogeneous Equations with Constant Coefficients, Linear Nonhomogeneous Equations: Method of Undetermined Coefficients, annihilator, The Method of Variation of Constants (Parameters), equilibrium points, Limiting Behavior of Solutions. Nonlinear Equations Transformable to Linear Equations, Higher order equations	**20**
Unit III	**Systems of Linear Difference Equations:** Autonomous and Non-autonomous Systems, Putzer Algorithm, Stability theory of Linear Systems	**10**
Unit IV	**Z-Transforms:** properties, inverse z-transforms and their application in solving difference equations. (The Power Series Method, The Partial Fractions Method)	**07**
Practicals	**30 Hours to be dedicated for solving problems on the following topics:** 1. Difference operators of logarithmic, exponential, trigonometric functions. 2. Antidifference Operator of logarithmic, exponential, trigonometric functions. 3. Casoration and fundamental set of solutions 4. Linear Homogeneous Equations with Constant Coefficients 5. Method of Undetermined Coefficients 6. The Method of Variation of Constants (Parameters)	**30**

	7. Nonlinear Equations Transformable to Linear Equations Part I 8. Nonlinear Equations Transformable to Linear Equations Part II 9. Equilibrium points and their stability 10. Solution of Autonomous Systems 11. Solution of difference equation using z-transform Part I 12. Solution of difference equation using z-transform Part II	
Pedagogy	Lecture/Practical/ self-study. Lectures should include theory and examples. Practical to be exclusively dedicated for problem solving.	
Reference Reading	**Principal Text**: Elaydi, Saber N., An Introduction to Difference Equations, Springer, Third edition, 2005 **References**: 1. K. S. Miller, Linear Difference equations, W. A. Benjamin Publishers, 1968. 2. Kelley, W., Allen Peterson, Difference Equations: An introduction with applications, Second edition, Academic Press, 2000 3. M. A. Radin, Difference Equations for Scientists and Engineering: Interdisciplinary Difference Equations, World Scientific Publishers, 2020. 4. S. Goldberg, Introduction to Difference equations, Dover Publications, 1987.	
Course Outcomes:	Student will be able to 1. Solve difference equations using appropriate methods. 2. Analyze the properties of solutions of difference equations. 3. Test the stability of equilibrium points of linear systems. 4. Find Z-Transform of various difference equation	

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-412**
Title of the Course : **Measure Theory**
Number of Credits : **3L+1P**
Effective from AY : **2026-2027**

Pre-requisites for the Course:	A First Course in Real Analysis	
Course Objectives:	To prepare students to handle Functional Analysis, Fourier series and their convergence, Laplace and Fourier transforms Wavelets analysis and Continuous probability theory.	
Content		**No. of Hours**
Unit I	**Lebesgue Measure:** Lebesgue outer measure, Riemann integrability, Measurable sets, The structure of measurable sets, A non-measurable sets.	**10**
Unit II	**Measurable Functions:** Measurable functions, Extended real valued functions, Sequence of measurable functions, Approximation of measurable functions.	**08**
Unit III	**The Lebesgue Integral:** Simple functions, Non-negative functions, The general case, Lebesgue Dominated convergence theorem, Approximation of integrable functions.	**15**
Unit IV	**Lp Spaces:** The Lp -spaces for , and their completeness. Approximation of Lp-functions by simple functions, continuous functions, step functions	**12**
Practicals	At Least 10 of the following practicals should be completed: 1. Find the outer Lebesgue Measure of subsets formed by finite unions of intervals and countable sets. 2. Prove the subadditivity property for finite and countable subsets of real numbers. 3. Prove that countable union of Lebesgue measurable sets is measurable. 4. Prove that the Cantor's set is measurable and find its measure. 5. Prove that the given function is Lebesgue measurable. 6. Prove that the sum and product of two measurable functions are measurable. 7. Prove that the lub and glb of a sequence of measurable functions are measurable. 8. Find the Lebesgue Integral of a given function. 9. Prove that every Riemann Integrable function is Lebesgue Integrable and the two integrals coincide. 10. Illustration of Monotone Convergence Theorem. 11. Illustration of Dominated Convergence Theorem. 12. Illustration of Fatou's Lemma.	**30**

Pedagogy	Lectures, Practical, Self-Study, Assignments. Lectures should include theory and examples. Practical to be exclusively dedicated for problem solving/computing/proving fundamental results.
Reference/ Reading:	<u>**PRINCIPAL TEXT:**</u> N. L. Carothers, Real Analysis, Cambridge University Press, 2006. <u>**REFERENCES:**</u> 1. Charalambos D Aliprantis, Owen Burkinshaw, Principles of Real Analysis, Academic Press/Elsevier, 2004. 2. G. de Bara, Measure Theory and Integration, New Age International Edition, 2022. 3. H. L. Royden, Real Analysis, PHI, 1995. 4. Murray R. Spiegel Ph.D., Real Variables, Lebesgue Measure and Integration with Applications to Fourier Series, Schaum's Outline Series, McGraw Hill Inc., 1990 5. Paul Halmos, Measure Theory, Springer – Verlag, 2014.
Course Outcomes:	At the end of this course the student will be able to 1. Recollect the basic definitions and theorems in Measure Theory. 2. Explain the various proofs and concepts in the course. 3. Solve the various computations problems in the course 4. Solve problems using the concepts learnt in the course.

Name of the Programme : **B.Sc. Mathematics**
Course Code : **MAT-413**
Title of the Course : **Integral Equations**
Number of Credits : **3L+1P**
Effective from AY : **2026-27**

Pre-requisites for the Course:	A First Course in Real Analysis and Ordinary Differential Equations	
Course Objectives:	This course helps in understanding basic concepts of Integral Equations. It develops the ability to solve integral equations by standard methods	
Content:		**No. of Hours**
Unit I	Integral equations definition, Classification of Integral Equations, Special kinds of kernels, Convolution type, Iterated kernels, Resolvent kernel, Eigenvalues and Eigenfunctions, Leibnitz's rule and its application for multiple integrals, Regularity conditions, Solution of Integral Equations, Converting Differential equations to Integral Equations,	**9**
Unit II	Fredholm Integral Equation of second kind with separable kernel, Fredholm Theorem, Fredholm Alternative theorem, Approximation Method, Iterated Kernels, Resolvent Kernel, results on iterated kernel, Neumann's series for Fredholm Integral Equation (along with proof), problems on Iterative Method for Fredholm and Volterra Integral Equations, Volterra Integral equation of First Kind and its solution.	**12**
Unit III	Fredholm's First Fundamental Theorem (Statement Only), Problems on Fredholm's First Fundamental Theorem, Fredholm's Second Fundamental Theorem (Statement Only), Fredholm's Third Fundamental Theorem (Statement Only) Properties of Eigenvalues and Eigenfunctions for symmetric kernel, Expansion in Eigenfunctions and Bilinear Form, Hilbert-Schmidt Theorem, Mercer's Theorem, Schmidt's Solution, Problems on Hilbert-Schmidt Theorem	**12**
Unit IV	Singular Integral Equation, Abel's Integral Equation, General form Abel's Integral Equation, Problems on Abel's Equation, Cauchy Principal Value of Integrals, Poincare-Bertrand transformation formula (Statement only), solution of Cauchy Type Equation (Closed contour only), Hilbert formula (without proof), Solution of Hilbert- Type Equation of Second Kind, Laplace Transform, Laplace Transform to solve Volterra Integral Equation, problems on Laplace Transform, Fourier Transform, Fourier Transform to solve Integral Equations, Hilbert Transform.	**12**
Practical	**30 hours are to be dedicated for working with exercises and solving problems on the following:**	**30**

	1. Solution of Integral Equations 2. Converting Differential equations to Integral Equations 3. Solution of Integral equation with separable kernel 4. Fredholm Alternative theorem to Solve Integral equation with separable kernel 5. Iterative Method (Neumann’s series) for Fredholm and Volterra Integral Equations 6. Problems on Fredholm’s First Fundamental Theorem 7. Problems on Hilbert-Schmidt Theorem 8. Problems on Abel’s Equation 9. solution of Cauchy Type Equation (**Closed contour only**) 10. Laplace Transform to solve Volterra Integral Equation 11. Fourier and Hilbert Transform to solve Integral Equations	
Pedagogy:	Lectures/ practical/assignments/self-study. Lectures should include theory and examples. Practical to be exclusively dedicated for problem solving.	
Reference/ Reading:	**Principal Text:** M. D. Raisinghania: *Integral Equations and Boundary Value Problems*, 6th Edition, S. Chand Publication, 2013. **References:** 1. A. J. Jerri: Introduction to Integral Equations with Applications, 2nd Edition, Wiley Interscience, 1999. 2. A. M. Wazwaz: *A First Course in Integral Equations*, World Scientific, 1997. 3. F. G. Tricomi: Integral Equations, Levant Books - Kolkata, 2015 4. I. G. Petrovsky, Lectures on the theory of Integral equations. 5. K. Yoshida, Lectures on Differential and Integral Equations. 6. R. P. Kanwal: *Linear Integral Equations – Theory & Technique*, 2nd Edition, Birkhauser Publishers, 2012 7. Sudir K. Pundir and Rimple Pundir, Integral Equations and Boundary Value Problems. Pragati Prakasam, Meerut, 2005.	
Course Outcomes:	1. Understand Basic concepts of Integral equations, Classify them, study and solve Integral Equations with Separable Kernels 2. Prove important theorems in Integral Equations and establish Fredholm theory. 3. Apply the above theory to Ordinary Differential Equations, Initial Value Problems and Boundary Value Problems. 4. Analyze and solve problems in Integral Equations and create appropriate arguments to justify the proofs.	

Name of the Programme **: B.Sc. Mathematics**
Course Code **: MAT-414**
Title of the Course **: Partial Differential Equations**
Number of Credits **: 3L+1P**
Effective from AY **: 2026-2027**

Pre-requisites for the Course:	A First Course in Ordinary Differential Equations and Real Analysis.	
Course Objectives:	This course develops the ability to solve partial differential equations of first and second order by standard methods.	
Content		**No. of Hours**
Unit I	**First Order Partial Differential Equations:** Surfaces and curves; Genesis of First order PDE; Classification of integrals; Linear equations of first order; Pfaffian differential equations; Compatible systems; Charpit's method; Jacobi's method; Integral surfaces through a given curve; quasi – linear equations and nonlinear P.D.E.	**15+5**
Unit II	**Second Order Partial Differential Equations:** Classification of second order semi – linear P.D.E.; Hadamard's definition of well – posedness.	**4+1**
	One Dimensional Wave Equation: D'Alembert's solution; Vibrations of a finite string; Existence and uniqueness of solution; Riemann method.	**5+2**
Unit III	**Laplace's Equation:** Boundary value problems; Maximum and Minimum principles; Uniqueness and continuity theorems; Dirichlet problem for a circle; Dirichlet problem for a circular annulus; Neumann problem for a circle; Theory of Green's function for Laplace's equation.	**8+3**
	Heat Equation: Heat conduction problem for an infinite rod; Heat conduction in a finite rod; Existence and uniqueness of the solution.	**7+2**
Unit IV	**Duhamel's Principle:** Duhamel's principle for wave and heat equations; Variable separable methods for second order linear partial differential equations.	**6+2**
Practical	**30 hours are to be dedicated for working with exercises and solving problems on the following:** 1. Find the solution of PDE using Charpit's Method. 2. Find the solution of PDE using Jacobi's Method. 3. Finding the integral surface for a given PDE. 4. Solving second order PDE. 5. Solving Wave Equations. 6. Solving problems on Laplace's Equations 7. Solving problems on Heat Equations	**30**

	8. Solving problems on Duhamel's Principle.
Pedagogy:	Lectures/ practical/assignments/self-study. Lectures should include theory and examples. Practical to be exclusively dedicated for problem solving.
Reference/ Reading:	**PRINCIPAL TEXT:** T. Amarnath: Elementary Partial Differential Equations, 2nd Edition, Narosa Publishers, 2003. **REFERENCES:** 1. Daniel A. Murray: Introductory Course in Differential Equations, Orient (2003). 2. H. F. Weinberger: A First Course in Partial Differential Equations with Complex Variables and Transform Methods, Wiley, 1965. 3. I. N. Sneddon: Elements of Partial Differential Equations, Dover Publications, 2006. 4. J. Fritz: Partial Differential Equations, 2nd Edition, Applied Mathematical Sciences, Vol. 1, Springer – Verlag, 1978. 5. Kreyszig, Erwin: Advanced Engineering Mathematics (Ed.), United States of America: Laurie Rosatone John Wiley & Sons. (2011). 6. T. Myint – U, and L. Debnath: Partial Differential Equations for Scientists and Engineers, 3rd Edition, Appleton & Lange Publishers, 1987.
Course Outcomes:	1. Apply suitable techniques to solve a given first order/second order partial differential equations based on the type of the equation. 2. Explain the limitations of the characteristic method that is used to solve first order PDEs and the method of separation of variables which is used to solve second order linear PDEs. 3. Construct Green's function for the Laplacian with Dirichlet/Neumann boundary conditions when the geometry of the domain is simple. 4. Analyze the nature of the solutions to heat equation and the wave equations by observing phenomena like finite speed of propagation and propagation regularizing effect etc.