

M.Sc. (Mathematics) Semester-IV (Jan 2027-June 2027)

Program	Subject	Year	Semester
M.Sc.	Mathematics	2	IV
Course Code	Course Title		Course Type
MAT410	FUNCTIONAL ANALYSIS (II)		Core
Credit	Hours Per Week (L-T-P)		
	L	T	P
5	5	1	0
Maximum Marks	CIA		ESE
100	30		70

Learning Objective (LO):

The aim of this course is to empower students with a profound understanding of advanced concepts in functional analysis and Hilbert spaces. Through this course, students will acquire the essential knowledge and skills necessary to proficiently work with various types of operators and variational problems.

Course Outcomes (CO):

CO No.	Expected Course Outcomes	CL
	At the end of the course, the students will be able to :	
1	Apply the Uniform Boundedness Theorem and describe its implications in various mathematical contexts. Analyze the Open Mapping Theorem and Closed Graph Theorem.	Ap
2	Describe the Hahn-Banach theorem in the contexts of real, complex and normed linear spaces. Explain the concept of reflexive spaces and sequential compactness. Express compact operators and the Closed Range Theorem.	U
3	Describe inner product spaces, including properties of inner products, orthogonality, and the concept of Hilbert spaces. Analyze and apply orthonormal sets, Bessel's inequality. Explain complete orthonormal sets and Parseval's identity.	An
4	Explain Hilbert spaces, apply Projection Theorem to solve problems related to orthogonal projections. Illustrate Riesz Representation Theorem. Describe concept of adjoint operators and significance of reflexivity of Hilbert spaces.	U
5	Analyze and apply concepts related to self-adjoint, positive, projection, normal, and unitary operators. Explain abstract variational boundary-value problems and apply the Generalized Lax-Milgram Theorem.	Ap

CL: Cognitive Levels (R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create).

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"3" - Strong; "2" - Moderate; "1" - Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Uniform boundedness theorem and some of its consequences. Open mapping and closed graph theorems.	15	1
II	Hahn-Banach theorem for real linear spaces, complex linear spaces and normed linear spaces. Reflexive spaces. Weak Sequential Compactness. Compact Operators. Solvability of linear equations in Banach spaces. The closed Range Theorem.	17	2
III	Inner product spaces. Hilbert spaces. Orthonormal Sets. Bessel's inequality. Complete orthonormal sets and Parseval's identity.	16	3
IV	Structure of Hilbert spaces. Projection theorem. Riesz representation theorem. Adjoint of an operator on a Hilbert space. Reflexivity of Hilbert spaces.	13	4
V	Self-adjoint operators, Positive, projection, normal and unitary operators. Abstract variational boundary-value problem. The generalized Lax-Milgram theorem.	14	5

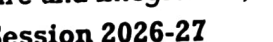
Books Recommended:

1. P.R. Halmos, *Measure Theory*, Van Nostrand, Princeton, 1950.
2. B.Choudhary and S.Nanda, *Functional Analysis with Applications*, Wiley Eastern Ltd. 1989.
3. H.L. Royden, *Real Analysis*, Macmillan Publishing Co. Inc., New York, 1993.

Reference Books:

- ### Reference Books:
1. S.K. Berberian, *Measure and integration*, Chelsea Publishing Company, New York, 1965.
 2. G. de Barra, *Measure Theory and Integration*, Wiley Eastern Limited, 1981.
 3. P.K. Jain and V.P. Gupta, *Lebesgue Measure and Integration*, New Age International Pvt. Ltd., New Delhi, 2000.
 4. Richard L. Wheeden and Antoni Zygmund, *Measure and Integral : An Introduction to Real Analysis*, Marcel Dekker Inc. 1977.
 5. J.H. Williamson, *Lebesgue Integration*, Holt Rinehart and Winston, Inc. New York. 1962.
 6. T.G. Hawkins, *Lebesgue's Theory of Integration: Its Origins and Development*, Chelsea, New York, 1979.
 7. K.R. Parthasarathy, *Introduction to Probability and Measure*, Macmillan Company of India Ltd., Delhi, 1977.
 8. R.G. Bartle, *The Elements of Integration*, John Wiley & Sons, Inc. New York, 1966.
 9. Serge Lang, *Analysis I & II*, Addison-Wesley Publishing Company, Inc. 1967.
 10. Inder K. Rana, *An Introduction to Measure and Integration*, Narosa Publishing House, Delhi,

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M.Sc. (Mathematics) Semester-IV (Jan 2027-June 2027)

Program	Subject	Year	Semester
M.Sc.	Mathematics	2	IV
Course Code	Course Title		Course Type
MAT420	PARTIAL DIFFERENTIAL EQUATIONS & MECHANICS (II)		Core
Credit	Hours Per Week (L-T-P)		
	L	T	P
5	5	1	0
Maximum Marks	CIA		ESE
100	30		70

Learning Objective (LO):

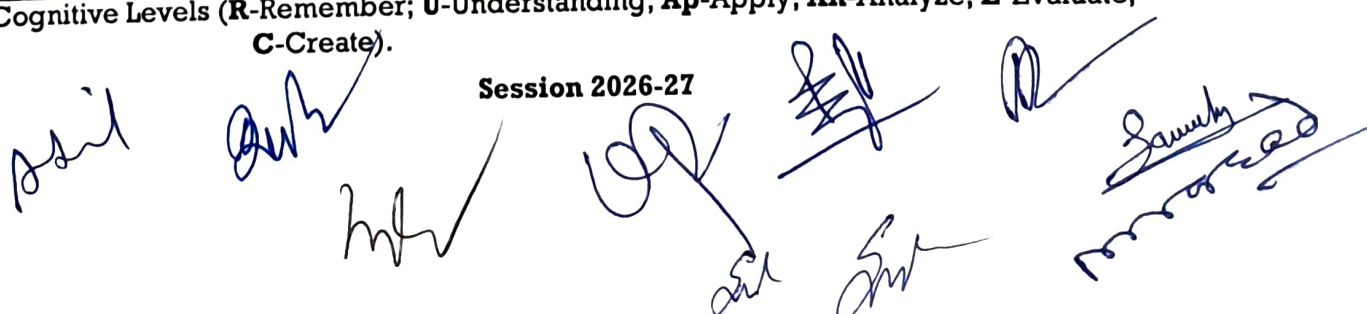
The objective of this course is to create a deep understanding of advanced topics in partial differential equations and analytical dynamics. It aims to equip students with the knowledge and skills to utilize techniques from nonlinear PDEs, analytical dynamics, and methods for asymptotic and power series solutions. Additionally, the course aims to develop students' understanding of principles related to Hamilton's equations, canonical transformations, and their applications.

Course Outcomes (CO):

CO No.	Expected Course Outcomes	CL
	At the end of the course, the students will be able to :	
1	Solve nonlinear first order PDE using complete integrals, envelopes, characteristics. Solve Hamilton-Jacobi equations. Apply calculus of variations to derive Hamilton's ODE, Legendre transforms, and the Hopf-Lax formula. Illustrate conservation laws, shocks, entropy conditions, and weak solutions.	Ap
2	Analyze and solve partial differential equations using Separation of Variables, Similarity Solutions. Transform PDE through Fourier and Laplace Transform, Hopf-Cole Transform, Hodograph and Legendre Transforms, and Potential Functions.	An
3	Apply asymptotic analysis to illustrate Singular Perturbations, Laplace's Method, Geometric Optics, Stationary Phase, and Homogenization. Employ Non-characteristic Surfaces, Real Analytic Functions, and the Cauchy-Kovalevskaya Theorem to obtain power series solution of PDEs.	U
4	Describe and apply Hamilton's Principle, the Principle of Least Action, Poincare Cartan Integral Invariant, Whittaker's Equations, Jacobi's Equations, Lee Hwa Chung's Theorem, Canonical Transformations, and the Properties of Generating Functions.	Ap
5	Explain Hamilton-Jacobi equation, Jacobi Theorem, Method of Separation of Variables, Lagrange Brackets, and the Conditions of Canonical Character of a transformation expressed through Lagrange Brackets and Poisson Brackets. Apply separation techniques, and evaluate canonical transformations.	Ap

CL: Cognitive Levels (R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create).

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CO-PO/PSO Mapping for the course:

CO	POs											PSO				
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5
CO1	3	3	3	1	2	1	2	1	-	1	2	3	3	2	-	2
CO2	3	3	3	1	2	1	2	1	-	1	2	3	3	2	-	1
CO3	3	3	3	1	2	1	2	1	-	1	2	3	3	2	-	-
CO4	3	3	3	1	2	1	2	2	-	1	2	3	3	2	-	-
CO5	3	3	3	1	2	1	2	2	-	1	2	3	3	2	-	-

"3" - Strong, "2" - Moderate; "1" - Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Nonlinear First Order PDE-Complete Integrals, Envelopes, Characteristics, Hamilton Jacobi Equations (Calculus of Variations, Hamilton's ODE, Legendre Transform, Hopf-Lax Formula, Weak Solutions, Uniqueness), Conservation Laws (Shocks, Entropy Condition, Lax-Oleinik formula, Weak Solutions, Uniqueness, Riemann's Problem, Long Time Behaviour)	18	1
II	Representation of Solutions-Separation of Variables, Similarity Solutions (Plane and Travelling Waves, Solitons, Similarity under Scaling), Fourier and Laplace Transform, Hopf-Cole Transform, Hodograph and Legendre Transforms, Potential Functions.	15	2
III	Asymptotics (Singular Perturbations, Laplace's Method, Geometric Optics, Stationary Phase, Homogenization), Power Series (Non-characteristic Surfaces, Real Analytic Functions, Cauchy-Kovalevskaya Theorem).	15	3
IV	Hamilton's Principle. Principle of least action. Poincare Cartan Integral invariant. Whittaker's equations. Jacobi's equations. Lee Hwa Chung's theorem, canonical transformations and properties of generating functions.	13	4
V	Hamilton-Jacobi equation. Jacobi theorem. Method of separation of variables. Lagrange Brackets. Condition of canonical character of a transformation in terms of Lagrange brackets and Poisson brackets, invariance of Lagrange brackets and Poisson brackets under canonical transformations.	14	5

Books Recommended:

1. L.C. Evans, *Partial Differential Equations*, American Mathematical Society, 1998.
2. F. Gantmacher, *Lectures in Analytic Mechanics*, MIR Publishers, Moscow, 1975.
3. R.C.Mondal, *Classical Mechanics*, Prentice Hall of India, 2001

Reference Books:

1. I.N.Sneddon, *Elements of Partial Differential Equations*, Dover Publication, 2006.
2. F. John, *Partial Differential Equations*, Springer, 1991
3. P.Prasad & R.Ravindran, *Partial Differential Equations*, New Age International Publishers, 1985.
4. T.Amarnath, *Elementary Course in Partial Differential Equations*, Alpha Science International

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M.Sc. (Mathematics) Semester-IV (Jan 2027-June 2027)

Program	Subject	Year	Semester
M.Sc.	Mathematics	2	IV
Course Code	Course Title		Course Type
MAT432	FUZZY SET THEORY & ITS APPLICATIONS (II)		Elective
Credit	Hours Per Week (L-T-P)		
	L	T	P
5	5	1	--
Maximum Marks	CIA		ESE
100	30		70

Learning Objective (LO):

The aim of this course is to provide students with a strong foundation in fuzzy logic, approximate reasoning, and their practical applications across various domains, encompassing control systems and decision-making in uncertain environments.

Course Outcomes (CO):

CO No.	Expected Course Outcomes	CL
	At the end of the course, the students will be able to :	
1	Describe fuzzy logic, including an overview of classical logic, multivalued logics, and the fundamental principles of fuzzy logic. Illustrate fuzzy propositions, fuzzy quantifiers, linguistic variables, and hedges, and perform inference from conditional fuzzy propositions using the compositional rule of inference.	U
2	Employ approximate reasoning techniques in the context of Fuzzy Expert Systems. Select appropriate fuzzy implications and utilize them in multiconditional approximate reasoning scenarios. Indicate the crucial role of fuzzy relation equations in facilitating approximate reasoning processes.	Ap
3	Describe the principles of Fuzzy Control. Illustrate fuzzy controllers, fuzzification, and defuzzification methods. Design and implement fuzzy control systems for various applications.	An
4	Apply fuzzy mathematics principles to decision-making processes in various contexts including individual, multiperson, multicriteria, and multistage decision-making in a fuzzy environment. Model and analyze decision problems involving uncertainty and imprecision.	Ap
5	Apply fuzzy ranking methods to prioritize and rank alternatives under conditions of uncertainty and imprecision. Use fuzzy linear programming techniques to solve optimization problems with fuzzy constraints and objectives.	Ap

CL: Cognitive Levels (R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create).

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CO-PO/PSO Mapping for the course:

CO \ PO	POs											PSO				
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5
CO1	3	3	3	1	1	1	2	1	-	2	2	3	2	2	-	-
CO2	3	3	3	1	1	1	2	1	-	2	2	3	2	2	-	-
CO3	3	3	3	1	1	1	2	1	-	2	2	3	2	2	-	-
CO4	3	3	3	1	1	1	2	1	-	2	2	3	2	2	-	-
CO5	3	3	3	1	1	1	2	1	-	2	2	3	2	2	-	-

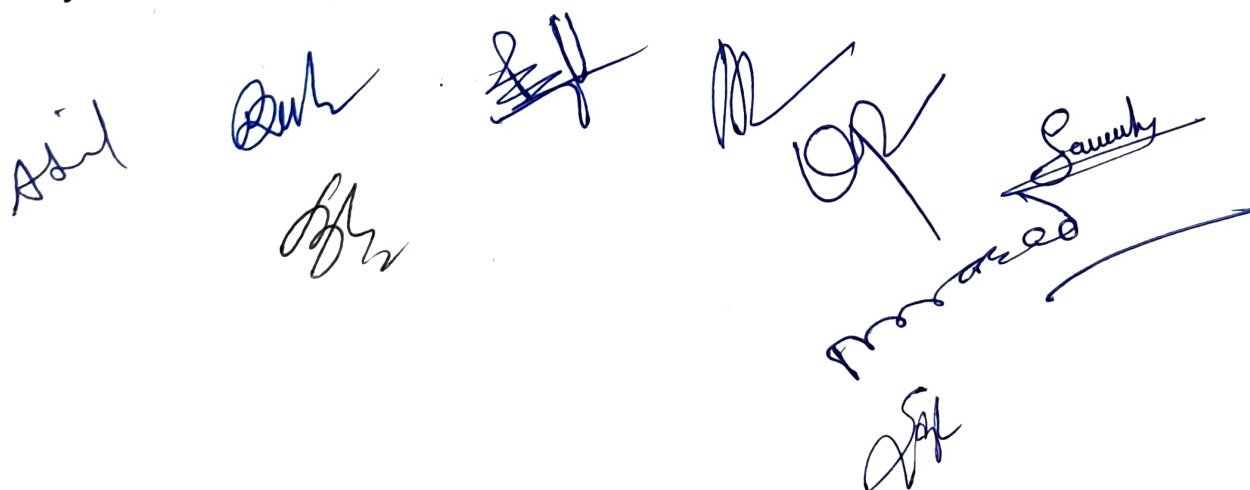
"3" – Strong; "2" – Moderate; "1" – Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Fuzzy Logic-An overview of classical logic, Multivalued logics, Fuzzy propositions. Fuzzy quantifiers. Linguistic variables and hedges. Inference from conditional fuzzy propositions, the compositional rule of inference.	15	1
II	Approximate Reasoning-An overview of fuzzy expert system. Fuzzy implications and their selection. Multiconditional approximate reasoning. The role of fuzzy relation equation.	15	2
III	An introduction to Fuzzy Control-Fuzzy controllers. Fuzzification. Defuzzification and the various defuzzitication methods.	15	3
IV	Decision Making in Fuzzy Environment-Individual decision making. Multiperson decision making. Multicriteria decision making. Multistage decision making.	15	4
V	Fuzzy ranking methods. Fuzzy linear programming.	15	5

Reference Books:

1. H.J. Zmmemann, *Fuzzy Set Theory and Its Applications*, Allied Publishers Ltd. New Delhi, 1991.
2. G.J. Klir & B. Yuan, *Fuzzy Sets and Fuzzy Logic*, Prentice-Hall of India, New Delhi, 1995.



M.Sc. (Mathematics) Semester-IV (Jan 2027-June 2027)

Program	Subject	Year	Semester
M.Sc.	Mathematics	2	IV
Course Code	Course Title		Course Type
MAT441	OPERATIONS RESEARCH (II)		Elective
Credit	Hours Per Week (L-T-P)		
	L	T	P
5	5	1	--
Maximum Marks	CIA		ESE
100	30		70

Learning Objective (LO):

The objective of this course is to provide students with a comprehensive understanding of various mathematical optimization techniques and their applications in decision-making processes. The course aims to equip students with the knowledge and skills to apply dynamic programming, game theory, integer programming, queueing theory, and nonlinear programming to real-world problems effectively.

Course Outcomes (CO):

CO No.	Expected Course Outcomes	CL
	At the end of the course, the students will be able to :	
1	Employ Dynamic Programming techniques, encompassing recursive equation and dynamic linear programming approaches. Describe Deterministic and Probabilistic Dynamic Programming methodologies.	Ap
2	Analyze and solve Two-Person, Zero-Sum Games and Games with Mixed Strategies. Apply Graphical Solution methods and employ Linear Programming techniques for strategic decision-making.	An
3	Solve Integer Programming problems, encompassing Pure and Mixed Integer Programming scenarios. Apply Gomory's All-I P.P. Method, construct Gomory's Constraints, and employ the Fractional Cut Method for both All Integer LPP and Mixed Integer LPP cases. Utilize the Branch and Bound Technique to tackle complex optimization problems.	Ap
4	Analyze Deterministic Queueing Systems, apply probability distributions in Queueing Models, and categorize diverse Queueing scenarios. Explain Poisson Queueing Systems.	Ap
5	Analyze Nonlinear Programming problems, both in one-variable and multi-variable unconstrained optimization scenarios. Apply the Kuhn-Tucker Conditions for Constrained Optimization and solve complex optimization challenges using Quadratic Programming, Separable Programming, Convex Programming, and handling the intricacies of Non-convex Programming.	An

CL: Cognitive Levels (R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create).

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CO-PO/PSO Mapping for the course:

PO CO	POs											PSO				
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5
CO1	3	2	3	2	2	2	2	1	1	2	2	1	3	2	1	-
CO2	3	2	3	2	3	2	2	1	1	3	2	1	3	2	1	1
CO3	3	2	3	2	3	2	2	1	1	2	2	1	3	2	1	-
CO4	3	2	3	2	3	2	2	2	1	3	2	1	3	2	1	2
CO5	3	2	3	2	2	2	3	1	1	2	2	1	3	2	1	-

"3" – Strong; "2" – Moderate; "1" – Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Dynamic Programming, recursive equation approach, dynamic linear programming approach. Deterministic and Probabilistic Dynamic programming.	15	1
II	Game Theory-Two-Person, Zero-Sum Games. Games with Mixed Strategies. Graphical Solution. Solution by Linear Programming	12	2
III	Integer Programming-Pure and Mixed Integer Programming Problem, Gomory's All-I P.P. Method, Construction of Gomory's Constraints, Fractional Cut Method-All Integer LPP, Fractional Cut Method- Mixed Integer LPP, Branch and Bound Technique.	15	3
IV	Queueing system: Deterministic Queueing system, probability distribution in Queueing, classification of Queueing models, Poisson Queueing system.	16	4
V	Nonlinear Programming-One/and Multi-Variable Unconstrained Optimization. Kuhn-Tucker Conditions for Constrained Optimization. Quadratic Programming. Separable Programming. Convex Programming. Non-convex Programming.	17	5

Books Recommended:

1. F.S. Hillier & G.J. Lieberman. *Introduction to Operations Research*, McGraw Hill International Edition, 1995.
2. G. Hadley, *Linear Programming*, Narosa Publishing House, 1995.
3. G. Hadley, *Nonlinear and Dynamic Programming*, Addison-Wesley, 1964
4. H.A. Taha, *Operations Research -An introduction*, Pearson Education, 2019.
5. Kanti Swarup, P.K. Gupta & Man Mohan, *Operations Research*, S. Chand & Sons, 2010.
6. Mokhtar S. Bazaraa, John J. Jarvis & Hanif D. Sherali, *Linear Programming and Network Flows*, John Wiley & Sons, New York, 1990.

Reference Books:

1. S.S. Rao, *Optimization Theory and Applications*, Wiley Eastern Ltd., 1979.
2. P.K. Gupta & D.S. Hira, *Operations Research-An Introduction*. S. Chand & Sons., 1976.
3. N.S. Kambo, *Mathematical Programming Techniques*, Affiliated East-West Press Pvt. Ltd., 2008.
4. M.S. Bazara, J.J. Jarvis, & H.D. Sherali, *Linear Programming and Network Flows*, Wiley, 2004.
5. S.J. Chandra & A. Mehra, *Numerical Optimization with Applications*, Narosa Publishing, 2009
6. S.I., Cass, *Linear Programming- Methods and Applications*, Dover Publishers, 2003.

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M.Sc. (Mathematics) Semester-IV (Jan 2027-June 2027)

Program	Subject	Year	Semester
M.Sc.	Mathematics	2	IV
Course Code	Course Title		Course Type
MAT452	GRAPH THEORY (II)		Elective
Credit	Hours Per Week (L-T-P)		
	L	T	P
5	5	1	--
Maximum Marks	CIA		ESE
100	30		70

Learning Objective (LO):

The course aims to equip students with the knowledge and skills necessary to explore Ramsey Theory, groups and their applications in graph theory, polynomials and graph enumeration techniques, as well as digraphs and network analysis.

Course Outcomes (CO):

CO No.	Expected Course Outcomes	CL
	At the end of the course, the students will be able to :	
1	Apply Ramsey theory to analyze perfectness-preserving operations, forbidden subgraph orientations, Ramsey numbers, and Ramsey graphs.	Ap
2	Apply group theory concepts within the context of graph theory, including permutation groups, automorphism groups, and graphs with given groups.	Ap
3	Utilize polynomial methods for graph enumeration, focusing on color, chromatic, and bivariate coloring polynomials. Implement polynomial techniques to enumerate and analyze various graph structures.	An
4	Analyze chromatic properties of graphs, including co-chromatic (co-dichromatic) graphs and chromatically unique graphs.	An
5	Describe digraphs, including different types of connectedness and flows in networks. Illustrate Menger's and Konig's Theorems.	U

CL: Cognitive Levels (R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create).

CO-PO/PSO Mapping for the course:

PO \ CO	POs											PSO				
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5
CO1	3	3	3	-	1	-	2	1	-	2	2	3	1	2	-	-
CO2	3	3	3	-	2	-	2	1	-	2	2	3	1	2	-	-
CO3	3	3	3	-	3	-	2	1	-	2	2	3	1	2	-	-
CO4	3	3	3	-	1	-	2	1	-	2	2	3	1	2	-	-
CO5	3	3	3	-	1	-	2	1	-	2	2	3	1	2	-	-

"3" - Strong; "2" - Moderate; "1" - Low; "-" No Correlation

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Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Ramsey Theory: Perfectness-preserving operations, Forbidden Subgraph orientations, Ramsey numbers and Ramsey graphs.	15	1
II	Groups: Permutation groups, The automorphism group, graphs with given group, symmetry concepts, pseudo-similarity and stability, spectral studies of the Automorphism group.	15	2
III	Polynomials and Graph Enumeration: The colour polynomials, The chromatic polynomial, The bivariate colouring polynomials.	15	3
IV	Graph Enumeration: Co-chromatic (co-dichromatic) graphs and chromatically unique graphs, Graph Enumeration.	15	4
V	Digraphs & Networks: Digraphs, Types of connectedness, Flows in Networks, Menger's and Konig's Theorem, Degree sequences.	15	5

Books Recommended:

1. K.R.Parthasarathy, *Basic graph theory*, Tata Mcgraw Hill Publishing Company Limited , 1994.

Reference Books:

1. R.J.Wilson, *Introduction to Graph Theory*, Longman Harlow, 1985.
2. J. Clark, D.A. Holton, *A First Look at Graph Theory*, World Scientific Singapore, 1991.
3. F. Harary, *Graph Theory*, Narosa, New Delhi, 1995.
4. R. Gould, *Graph Theory*, The Benjamin/Cummins Publ. Company, 1988.
5. N. Deo, *Graph Theory with Applications to Engineering and Computer Science*, Prentice-Hall of India, 2002.

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M.Sc. (Mathematics) Semester-I (July 2026-Dec 2026)

(Offered to PG students in Mathematics)

Program	Subject	Year	Semester
M.Sc.	Mathematics	1	I
Course Code	Course Title		Course Type
MAT710	Typesetting in LATEX		Value Added
Credit	Hours Per Week (L-T-P)		
	L	T	P
2	--	--	4
Maximum Marks	CIA		ESE
100	30		70

Learning Objective (LO):

The purpose of this course is to acquaint students with the latest typesetting skills, which shall enable them to prepare high quality typesetting and beamer presentation.

Course Outcomes (CO):

CO No.	Expected Course Outcomes	CL
	At the end of the course, the students will be able to :	
1	Create and typeset a mathematical document using LaTeX document.	Ap
2	Make various types of lists and tables in a document using LaTeX.	Ap
3	Typeset and format equations using various types of environments, such as equations, align, gather etc., Define and use macros.	Ap
4	Insert and format figures in a document including its position, orientation and size. Make presentation using beamer.	An

CL: Cognitive Levels (R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create).

Detailed Syllabus:

Unit No.	Topics	No. of Contact Hours	CO No.
I	Getting Started with LaTeX, Page Layout and Style: Introduction to TeX and LaTeX, Overview, Fonts Selection, Formatting text, Standard Page Layout, Formatting Page Layout, Increasing the Height of a Page, Page Style, Running Header and Footer, Page Breaking and Adjustment, Page Numbering. (Chapter 1-5).	6	1
II	Listing and Tabbing Texts, Table Preparation: Listing Texts, Tabbing Texts Through the tabbing Environment. Table Through the tabular, Table Through the tabularx Environment, Vertical Positioning of Tables, Sideways (Rotated) Texts in Tables, Adjusting Column Width in Tables, Additional Provisions for Customizing	6	2

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