CENTRAL UNIVERSITY
OF KARNATAKA
(Established by an Act of the Parliament in 2009)

Department of Mathematics
School of Physical Sciences
Kadaganchi, Aland Road,
Kalaburagi District– 585367

Scheme of instructions for M.Sc. (Mathematics) from the academic year 2020-2021 onwards

Semester I

S.No	Course Code	Course title	Mode			Credits	Assessment	
			L	P	T		Internal (%)	End Sem. (%)
1	PMATC10001	Algebra	3	0	1	4	40	60
2	PMATC10002	Advanced Calculus	3	0	1	4	40	60
3	PMATC10003	Linear Algebra	3	0	1	4	40	60
4	PMATC10004	Ordinary Differential Equations	3	0	1	4	40	60
5	PMATC10005	Discrete Mathematics	3	0	1	4	40	60
6	PMACC10006	Computing Laboratory-I	1	3	0	2	40	60
7		Generic Elective	3	0	0	3	40	60
		TOTAL CREDITS				**25**		

Semester II

S.No	Course Code	Course title	Mode			Credits	Assessment	
			L	P	T		Internal (%)	End Sem. (%)
1	PMATC20007	Real Analysis	3	0	1	4	40	60
2	PMATC20008	Topology	3	0	1	4	40	60
3	PMATC20009	Numerical Analysis	3	0	1	4	40	60
4	PMATC20010	Partial Differential Equations	3	0	1	4	40	60
5	PMATC20011	Probability & Statistics	3	0	1	4	40	60
6	PMACA20101	Computing Laboratory-II	1	3	0	2	40	60
7		Soft Elective	3	0	0	3	40	60
		TOTAL CREDITS				**25**		

Semester III

S.No	Course Code	Course title	Mode			Credits	Assessment	
			L	P	T		Internal (%)	End Sem. (%)
1	PMATC30012	Functional Analysis	3	0	1	4	40	60
2	PMATC30013	Complex Analysis	3	0	1	4	40	60
3	PMATC30014	Fluid Mechanics	3	0	1	4	40	60
4		Discipline Specific Elective-I	3	0	0	3	40	60
5		Discipline Specific Elective-II	3	0	0	3	40	60
6	PMACA30102	Computing Laboratory-III	1	3	0	2	40	60
7	PMATA30103	Seminar	0	4	0	2	40	60
		TOTAL CREDITS				**22**		

Semester IV

S.No	Course Code	Course title	Mode			Credits	Assessment	
			L	P	T		Internal (%)	End Sem. (%)
1	PMATC40015	Measure & Integration	3	0	1	4	40	60
2	PMATC40016	Operations Research	3	0	1	4	40	60
3		Discipline Specific Elective-III	3	0	0	3	40	60
4		Discipline Specific Elective-IV	3	0	0	3	40	60
5	PMACA40104	Computing Laboratory-IV	1	3	0	2	40	60
6	PMARC40017	Research Training & Project Report	0	6	3	6	40	60
7	PMATA40105	Comprehensive Viva	0	0	2	2		100
		TOTAL CREDITS				**24**		

TOTAL NUMBER OF CREDITS FOR THE PROGRAMME IS 96

List of Electives

List of Generic Electives Offered for Other Departments

S. No	Course Code	Course title	Mode			Credits	Assessment	
			L	P	T		Internal (%)	End Sem. (%)
1	PMATG10301	Elementary Mathematical Programming	3	0	0	3	40	60
2	PMATG10302	Differential & Integral Calculus	3	0	0	3	40	60
3	PMATG10303	Mathematical Logic	3	0	0	3	40	60
4	PMATG10304	Mathematics for Everyone	3	0	0	3	40	60
5	PMATG10305	Elementary Mathematical Statistics	3	0	0	3	40	60

List of Soft Electives (II Semester)

S. No	Course Code	Course title	Mode			Credits	Assessment	
			L	P	T		Internal (%)	End Sem. (%)
1	PMATD20201	History of Mathematics & Mathematicians	3	0	0	3	40	60
2	PMATD20202	Elementary Mathematical Modeling	3	0	0	3	40	60
3	PMATD20203	Coordinate Geometry	3	0	0	3	40	60
4	PMATD20204	Elementary Number Theory	3	0	0	3	40	60
5	PMACD20205	Introduction to Computer Programming	3	0	0	3	40	60
6	PMATD20206	Mathematical Methods	3	0	0	3	40	60
7	PMATD20207	Mathematics for Biology	3	0	0	3	40	60
8	PMATD20208	Massive Open Online Courses (MOOCs)* through NPTEL, SWAYAM etc.				3	As per MOOCs*	

List of Discipline Specific Electives-I (III Semester)

S. No	Course Code	Course title	Mode			Credits	Assessment	
			L	P	T		Internal (%)	End Sem. (%)
1	PMATD30209	Advanced Algebra	3	0	0	3	40	60
2	PMATD30210	Classical Mechanics	3	0	0	3	40	60
3	PMATD30211	Number Theory	3	0	0	3	40	60
4	PMATD30212	Mathematical Modeling	3	0	0	3	40	60
5	PMATD30213	Data Structures	3	0	0	3	40	60
6	PMATD30214	Graph Theory	3	0	0	3	40	60
7	PMATD30215	Tensor Analysis	3	0	0	3	40	60
8	PMATD30216	Massive Open Online Courses (MOOCs)* through NPTEL, SWAYAM etc.				3	As per MOOCs*	

List of Discipline Specific Electives-II (III Semester)

S. No	Course Code	Course title	Mode			Credits	Assessment	
			L	P	T		Internal (%)	End Sem. (%)
1	PMATD30217	Finite Difference Methods	3	0	0	3	40	60
2	PMATD30218	Differential Geometry	3	0	0	3	40	60
3	PMATD30219	Design & Analysis of Algorithms	3	0	0	3	40	60
4	PMATD30220	Continuum Mechanics	3	0	0	3	40	60
5	PMATD30221	Ramanujan's Theta Functions	3	0	0	3	40	60
6	PMATD30222	Fuzzy Sets and Fuzzy logic	3	0	0	3	40	60
7	PMATD30223	Lie Group Theory and Applications	3	0	0	3	40	60
8	PMATD30224	Massive Open Online Courses (MOOCs)* through NPTEL, SWAYAM etc.				3	As per MOOCs*	

List of Discipline Specific Electives-III (IV Semester)

S. No	Course Code	Course title	Mode			Credits	Assessment	
			L	P	T		Internal (%)	End Sem. (%)
1	PMATD40225	Calculus of Variations and Finite Element Method	3	0	0	3	40	60
2	PMATD40226	Computational Fluid Dynamics	3	0	0	3	40	60
3	PMATD40227	Multi Objective Programming	3	0	0	3	40	60
4	PMATD40228	Theory of Automata	3	0	0	3	40	60
5	PMATD40229	Riemannian Geometry	3	0	0	3	40	60
6	PMATD40230	Special Functions	3	0	0	3	40	60
7	PMATD40231	Financial Mathematics	3	0	0	3	40	60
8	PMATD40232	Massive Open Online Courses (MOOCs)* through NPTEL, SWAYAM etc.				3	As per MOOCs*	

List of Discipline Specific Electives-IV (IV Semester)

S. No	Course Code	Course title	Mode			Credits	Assessment	
			L	P	T		Internal (%)	End Sem. (%)
1	PMATD40233	Integral Transforms and Integral Equations	3	0	0	3	40	60
2	PMATD40234	Cryptography	3	0	0	3	40	60
3	PMACD40235	Object Oriented Programming	3	0	0	3	40	60
4	PMATD40236	Finite Volume Method	3	0	0	3	40	60
5	PMATD40237	Algebraic Topology	3	0	0	3	40	60
6	PMATD40238	Computer Graphics	3	0	0	3	40	60
7	PMATD40239	Theory of Partitions	3	0	0	3	40	60
8	PMATD40240	Massive Open Online Courses (MOOCs)* through NPTEL, SWAYAM etc.				3	As per MOOCs*	

Note: * MOOCs courses (NPTEL, SWAYAM etc.) must be approved by the Department.

Learning Outcomes-Based Curriculum Framework

Name of the School: School of Physical Sciences

Department: Mathematics

Vision Statement:

To be a global centre of excellence for research and teaching in mathematics for the growth of science and technology.

Mission Statements:

1. To provide a stimulating teaching and research environment in Mathematics through updated curriculum, effective teaching and research learning process.
2. To inculcate innovative skills and ethical practices among students so as to meet the societal expectations.
3. To provide the best possible facilities and produce the professionally competent, socially committed students through quality education and research.

Qualification Descriptors (QDs)

QD-1: Ability to understand the use of various mathematical concepts for problem solving and interpretation.

QD-2: Becoming familiar with the usage of C, C++, Fortran, Mathematica, Matlab, Maple and free open source software for problem solving purposes.

QD-3: Building the professional competence in terms of applying the mathematical techniques for science and engineering problem solving.

QD-4: Developing specialized skills suited to newer domains and facing the competitive world.

QD-5: Ability to apply the mathematics knowledge in interdisciplinary projects and research.

QD-6: Ability to transfer the knowledge of mathematics relevant to job trends and employment opportunities.

Mapping Qualification Descriptors (QDs) with Mission Statements (MS)

	MS-1	**MS-2**	**MS-3**
QD-1	3	3	1
QD-2	3	3	2
QD-3	1	3	3
QD-4	1	3	2
QD-5	1	2	3
QD-6	1	3	2

Write ‘3’ in the box for ‘High-level’ mapping, 2 for ‘Medium-level’ mapping, 1 for ‘Low-level’ mapping.

Name of the Department: Mathematics

Name of the Academic Program: M.Sc. Mathematics

Program Learning Outcomes (PLOs)

PLO-1: Students should demonstrate an understanding of the foundations of mathematics as well as the ability to think logically and critically.

PLO-2: Ability to formulate, analyze, and solve problems through analytical, semi-analytical & numerical techniques and apply them to other disciplines when appropriate.

PLO-3: Ability to attain the needed written and oral communication skills to translate their degree into a viable career path.

PLO-4: Ability to use mathematical ideas to model real-world problems

PLO-5: Explain the knowledge of contemporary issues in the field of Mathematics and applied sciences.

PLO-6: Ability to utilize the technology to address mathematical ideas.

PLO-7: Ability to perform computations in higher mathematics.

PLO-8: Perform research in conjunction with others as well as individually.

PLO-9: Crack lectureship and fellowship exams approved by UGC & MHRD like CSIR, NET, GATE and SET etc.

PLO-10: Work effectively as an individual, and also as a member or leader in multi-disciplinary teams.

Mapping of Program Learning Outcomes (PLOs)

with Qualification Descriptors (QDs)

	QD-1	QD-2	QD-3	QD-4	QD-5	QD-6
PLO-1	3	1	2	3	3	2
PLO-2	3	3	3	3	2	2
PLO-3	1	2	2	3	3	3
PLO-4	2	3	3	3	3	3
PLO-5	1	2	3	3	3	3
PLO-6	2	3	3	3	3	3
PLO-7	2	3	2	3	3	2
PLO-8	1	1	2	3	3	3
PLO-9	2	1	1	3	1	3
PLO-10	1	1	1	3	1	3

Write ‘3’ in the box for ‘High-level’ mapping, 2 for ‘Medium-level’ mapping, 1 for ‘Low-level’ mapping.

Name of the Department: **Mathematics**

Name of the Academic Program**: M.Sc. Mathematics**

Semester-I

Course code: PMATC10001 **Title of the Course: Algebra**

L-T-P: 3-1-0 **Credits:4**

Prerequisite course/knowledge: Sets and Equivalence relations and partitions, Division algorithm for integers, primes, unique factorizations, Chinese Remainder Theorem, Euler ϕ-function. Groups, subgroups, normal subgroups, quotient groups, cyclic groups, permutation groups, cosets and Lagrange's theorem, definition and examples of rings, subrings and ideals, integral domains and fields.

Course Learning Outcomes (CLOs)

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

CLO-1: apply the knowledge of Algebra to attain a good mathematical maturity and enables to build mathematical thinking and skill.

CLO-2: understand the concepts of homomorphism and isomorphism between groups.

CLO-3: apply class equation and Sylow theorems to solve different problems.

CLO-4: explore the properties of principle ideal domain, Euclidean domain and Unique factorization domain, polynomial rings and field extensions.

CLO-5: design, analyze and implement the concepts of Gauss Lemma, Einstein's irreducibility criterion etc.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	2	3	3	2	2	1		1	3	1
CLO2	2	3	2	1	2	1		1	3	1
CLO3	2	3	2	2	1	1		1	3	1
CLO4	2	3	2	1	2	1		1	3	1
CLO5	2	3	2	1	2	1		1	3	1

Each Course Learning Outcome (CLOs) may be mapped with one or more Program Learning Outcomes (PLOs). Write '3' in the box for 'High-level' mapping, 2 for 'Medium-level' mapping, 1 for 'Low-level' mapping.

Course Details:

Unit 1: Group homomoprhisms, Automorphisms, Isomorphisms, Fundamental theorems of group homomoprhisms, Cayley's Theorem, class equations, Sylow theorems. Direct Products, Fundamental Theorem of Finite Abelian groups.

Unit 2: Rings, ideals, prime and maximal ideals, quotient rings, unique factorization domain, principal ideal domain, Euclidean domain.

Unit 3: Polynomial rings and irreducibility criteria.

Unit 4: Fields, finite fields, field extensions, basic properties of degree of field extensions.

Course References:

1. G. A. Gallian (2013), Contemporary Abstract Algebra, Narosa Publishers.
2. I. N. Herstein (1975), Topics in Abstract Algebra, Wiley Eastern Limited.
3. D. S. Dummit, R. M. Foote (1999), Abstract Algebra, Second Edition, John Wiley & Sons, Inc.
4. Surjeet Singh and Qazi Zameeruddin (1994), Modern Algebra, Vikas Publishing House.
5. N. Jacobson (2009), Basic Algebra-I, 2nd ed., Dover Publications.
6. Darek F. Holt, Bettina Eick and Eamonaa. Obrien. (2005), Handbook of computational group theory, Chapman & Hall/CRC Press.
7. J. B. Fraleigh (2002), A first course in abstract algebra, 7th ed., Addison-Wesley Longman.

Course Code: **PMATC10002** Title of the Course: **Advanced Calculus**

L-T-P: **3-1-0** Credits: **4**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: describe the real line as a complete, ordered field.

CLO-2: identify challenging problems in real variable theory and find their appropriate solutions.

CLO-3: deal with axiomatic structure of metric spaces and generalize the concepts of sequences and series, and continuous functions in metric spaces.

CLO-4: test whether a given improper integral can be convergent.

CLO-5: use theory of Multiplications of series and infinite products in solving problems arising in different fields of science and engineering.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	2	1		2	2				3	1
CLO2	1	2		2	2		1	2	3	2
CLO3	3	3		3	2		2	3	3	2
CLO4				2	3		2	2	3	2
CLO5	2	3		3	3			2		3

Course Details:

Unit 1: Elementary set theory, finite, infinite, bounded, unbounded, countable and uncountable sets, Cantor set. Real number system as a complete ordered field, Archimedean property, Dedekind cuts, supremum, infimum. Continuity, differentiability, functions of bounded variation, absolutely continuous, uniform continuous of a function of a single variable.

Unit 2: Power series, radius of convergence, product of series, re-arrangements, arbitrary series, absolute and conditional convergence.

Unit 3: Metric space, limit, continuity, connectedness, compactness.

Unit 4: Classification of Riemann integration, classification of improper integral, tests for convergence of Beta and Gamma functions, differentiation of integral with variable limits.

Course References:

1. Walter Rudin (1976), Principles of Mathematical Analysis, McGraw Hill Book Co.
2. S.Thomson Brian, Andrew M. Bruckner and Judith B. Bruner (2008), Real Analysis, Prentice Hall International.
3. T. M. Apostol (1987), Mathematical Analysis, Narosa Publications.
4. Richard R. Goldberg (1976), Methods of Real Analysis, second edition, John Wiley & Sons.
5. J. Dieudonne (1960), Treatise on Analysis, Vol. I, Academic Press.
6. Robert G. Bartle (1976), The Elements of Real Analysis, second edition, John Wiley & Sons.
7. Kenneth A. Ross (2013), Elementary Analysis: The Theory of Calculus, second edition, Springer, New York.
8. Torence Tao (2006), Analysis I, Hindustan Book Agency, India.
9. Torence Tao (2006), Analysis II, Hindustan Book Agency, India.
10. S.C. Malik (1984), Mathematical Analysis, Wiley – Eastern.

Course Code: PMATC10003 **Title of the Course: Linear Algebra**

L-T-P: 3-1-0 **Credits: 4**

Course Learning Outcomes (CLOs):

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

CLO-1: recognize the concepts of the terms span, linear independence, basis, and dimension, and apply these concepts to various vector spaces and subspaces.

CLO-2: explain the applications of canonical forms.

CLO-3: write down the matrix representing a linear transformation under a given basis, and determine how the matrix changes if the basis is changed.

CLO-4: identify the importance of orthogonal property in the spectral theory.

CLO-5: discusses the quadratic forms and Sylvester's law of inertia.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	1	2	2	2	1			3	
CLO2	3	1	2	2	2	1			3	
CLO3	3	1	2	2	2	1			3	
CLO4	3	1	2	2	2	1			3	
CLO5	3	1	2	2	2	1			3	

Course Details:

Unit 1: Vector spaces, subspaces, linear dependence, basis, dimension, algebra of linear transformations. Algebra of matrices, rank and determinant of matrices, linear equations.

Unit 2: Eigenvalues and eigenvectors, Cayley-Hamilton theorem. Matrix representation of linear transformations. Change of basis, canonical forms, diagonal forms, triangular forms, Jordan forms.

Unit 3: Inner product spaces, Gram-Schmidt orthonormalization, orthogonal projections, linear functional and adjoints, Hermitian, self-adjoint, unitary and normal operators, Spectral Theorem for normal operators, Rayleigh quotient, Min-Max Principle.

Unit 4: Bilinear forms, symmetric and skew symmetric bilinear forms, quadratic forms, reduction and classification of quadratic forms, Sylvester's law of inertia.

Course References:

1. K. Hoffman and R. Kunze (2003), Linear Algebra, Prentice Hall of India, New Delhi.
2. M. Artin (1994), Algebra, Prentice Hall of India.
3. S. Kumeresan (2000), Linear Algebra, A Geometric approach, Prentice Hall India.
4. A.R. Vasishtha and A. K. Vasishtha (2004), Matrices, Krishna’s educational publishers.
5. I. N. Herstein (1964), Topics in Algebra, Vikas Publishing House, New Delhi.
6. K.B. Datta (2006), Matrix and Linear Algebra, Prentice Hall of India, New Delhi.
7. L. Lipschutz and M. Lipson, Linear Algebra, McGraw Hill Education, India.

Course Code: **PMATC10004** Title of the Course: **Ordinary Differential Equations**
L-T-P: **3-1-0** Credits: **4**

Prerequisite Course / Knowledge (If any):

Definition of ordinary differential equation, formation and solution of first order ordinary differential equations, order and degree of ordinary differential equations, integrating factors, rules to find an integrating factor, basic theory of linear differential equations, solving a differential equation by reducing its order. Linear homogenous equations with constant coefficients, Linear non-homogenous equations (first order).

Course Learning Outcomes (CLOs)

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

CLO-1: solve the ordinary differential equations having constant and variable coefficients.

CLO-2: obtain the solutions of second order differential equations using various methods.

CLO-3: find the series solution of the linear differential equations.

CLO-4: solve the system of differential equations using eigen value and matrix methods.

CLO-5: evaluating the existence and uniqueness of the solutions using Picard's concept.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3			2				3	1
CLO2	1	3		2	2		1		3	2
CLO3	1	3		2	2		1		3	2
CLO4	2	3		2	2		1	1	3	2
CLO5	3			2				2	3	2

Course Details:

Unit 1: Second Order Equations: General solution of Homogeneous equations, Non-homogeneous equations, Wronskian, Method of variation of parameters, Sturm comparison and separation theorems, Boundary value problems, Green's functions, Sturm-Liouville problems.

Unit 2: Series Solution of Linear Differential Equations: Ordinary points, Singular points, Regular singular points, Frobenius method, Legendre polynomials and properties, Bessel functions and properties.

Unit 3: Systems of Differential Equations: Algebraic properties of solutions of linear systems, the eigenvalue eigenvector method of finding solutions, Complex eigenvalues, Equal eigenvalues, Fundamental matrix solutions, Matrix exponential.

Unit 4: The existence and uniqueness of solutions: The method of successive Approximations-Picard Theorem-systems, Non-local existence theorem.

Course References:

1. G.F. Simmons (1974), Differential Equations, TMH Edition, New Delhi.
2. E.A. Coddington (1999), An Introduction to Ordinary Differential Equations, PHI Learning.
3. U. Tyn Myint (1978), Ordinary Differential Equations, Elesvier North- Holland.
4. S. G. Deo and V. Raghavendra (2006), Ordinary differential equations, Tata McGraw Hill, New Delhi.
5. E.D. Rainville and P.E. Bedient (1969), Elementary Differential Equations, McGraw Hill, NewYork.
6. E.A. Coddington and N. Levinson (1955), Theory of ordinary differential equations, McGraw Hill.
7. A.C.King, J.Billingham and S.R.Otto (2006), Differential equations, Cambridge University Press.
8. S.L. Ross (1984), Differential equations, 3rd edition, John Wiley & Sons, NewYork.

Course Code: **PMATC10005** Title of the Course: **Discrete Mathematics**

L-T-P: **3-1-0** Credits: **4**

Course Learning Outcomes (CLOs)

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

CLO-1: apply propositional logic and first order logic to solve problems. Also, determine if a logical argument is valid or invalid.

CLO-2: construct induction proofs involving summations, inequalities, and divisibility arguments. Also, implement the principles of counting, permutations and combinatory to solve real world problems.

CLO-3: formulate and solve recurrence relations. Prove whether a given relation is an equivalence relation/poset and will be able to draw a Hasse diagram.

CLO-4: develop and analyze the concepts of Boolean algebra

CLO-5: develop and analyze the concepts of graph theory.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	2	1		1	2	1
CLO2	3	3	1	2	2		1	2	1	2
CLO3	2	3		3	2	1	1	1	1	1
CLO4	3	3		2	2		1	1	1	1
CLO5	3	3	2	3	2	3	1	2		2

Course Details:

Unit 1: Sets and propositions: Combinations of sets, Finite and Infinite sets, uncountable infinite sets, principle of inclusion and exclusion, mathematical induction. Propositions, fundamentals of logic, first order logic, ordered sets. **Counting:** Basics of counting, Pigeonhole principle- Permutations and combinations – Pascal's Identity- Vandermonde's Identity- Generalized Permutations and combinations.

Unit 2: Generating functions: coefficients of generating functions – applications of generating functions. **Recurrence relations:** Solving Recurrence Relations- Linear Homogeneous and Non-Homogeneous Recurrence relations, solution by the method of generating functions, sorting algorithm. **Relations and functions:** properties of binary relations, equivalence relations and partitions, partial and total ordering relations, Transitive closure and Warshal's algorithm.

Unit 3: Boolean algebra: Chains, Lattices and algebraic systems, principle of duality, basic properties of algebraic systems, distributive and complemented lattices, Boolean lattices and algebras, uniqueness of finite Boolean algebras, Boolean expressions and functions.

Unit 4: Graph Theory: Graphs and planar graphs, multigraphs and weighted graphs, Trees and cut sets.

Course References:

1. J. R. Mott, A. Kandel and Baker (2006), Discrete Mathematics for Computer Scientists, PHI.
2. C. L. Liu (1985), Elements of Discrete Mathematics, McGraw Hill.
3. J. P. Tremblay and R. Manohar (2004), Discrete Mathematical Structures with applications to Computer Science, McGraw Hill Book Co.

Course Code: **PMACC10006** Title of the Course: **Computing Laboratory-I**

L-T-P: **1-0-3** Credits: **2**

Course Learning Outcomes (CLOs)

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

CLO-1: plot and visualize the graph of function in single, multivariable using MS-Excel.

CLO-2: understand the use of input, output functions and structure of C program.

CLO-3: develop modular programs using control statements.

CLO-4: write programs to solve real world problems using arrays and functions.

CLO-5: implement sorting and searching algorithms.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	2	1				2		1		1
CLO2	3	1		2	1	2	3	2		1
CLO3	3	3		2	1	1	3	1		1
CLO4	3	3		2	1	1	2	1		1
CLO5	3	3		3	3		3	2		1

Course Details:

Unit 1: Introduction to MS-Excel through the plotting and visualizing the graph of function in single and multivariable, phi charts, bar diagrams.

Unit 2: Introduction to C and explain the concepts: conditional, statements, do loops, while loops, go to, continue, switch, arrays, pointers, function arguments, return values, subscripted variables, function subprograms and subroutines.

Unit 3: C- Programs on basic Calculus.

Unit 4: C-Programs on Linear Algebra.

Course Reference:

1. Yashavant Kanethkar (2017), Let Us C, 16^{th} edition, BPB Publications.

2. E. Balagurusamy (2019), Programming in ANSI C, 8^{th} Edition, McGraw Hill Education.

3. Lipschitz (2003), Programming in C ,Schaum's Series, McGraw Hill.

4. Subrata Saha and Subhodip Mukherjee (2017), Basic Computation and Programming with C, Cambridge.

List of Generic Electives Offered for Other Departments

Course Code: **PMATG10301** Title of the Course: **Elementary Mathematical Programming**
L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understanding the basic definitions basic feasible solution, feasible regions and optimality.

CLO-2: apply the graphical method on linear programming.

CLO-3: apply the simplex method, revised simplex method on linear programming.

CLO-4: apply the dual simplex method, primal-dual method on linear programming.

CLO-5: apply the transportation problems, assignment problems, network maximum flow problems on real life problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	2	1	1	2	3	1
CLO2	1	3		3	2	2	1	2	3	1
CLO3	1	3	1	2	2	2	1	2	2	2
CLO4	1	3	1	2	2	2	1	2	2	2
CLO5	2	3	1	2	2	2	1	2	3	2

Course Details:

Unit 1: Linear programs formulation through examples from engineering / business decision making problems; preliminary theory and geometry of linear programs, graphical method, basic feasible solution, feasible regions and optimality.

Unit 2: simplex method, variants of simplex method, like two phase method and revised simplex method.

Unit 3: Duality and its principles, interpretation of dual variables, dual simplex method, primal-dual method;

Unit 4: linear integer programs, their applications in real decision making problems, cutting plane and branch and bound methods, transportation problems, assignment problems, network maximum flow problems;

Course References:

1. H.A.Taha , Operations Research, An Introduction , PHI, 2008
2. H.M.Wagner, Principles of Operations Research, PHI, Delhi, 1982.
3. J.C.Pant, Introduction to Optimisation: Operations Research, Jain Brothers, Delhi, 2008.
4. B. S. Grewal, Higher Engineering Mathematics, Khanna Publications, Latest Edition.

Course Code: **PMATG10302** Title of the Course: **Differential & Integral Calculus**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understanding the basic definitions of calculus.

CLO-2: analyse the applications of calculus.

CLO-3: develop the concepts of differential calculus.

CLO-4: develop the concepts of integral calculus.

CLO-5: develop the concepts of vector calculus.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	2	1	1	2	3	1
CLO2	1	3		3	2	2	2	2	2	2
CLO3	1	3		2	2	2	1	2	2	2
CLO4	1	3		2	2	2	1	2	2	2
CLO5	2	3		2	2	2	1	2	3	2

Course Details:

Unit 1: Basics of Analysis, Limit, Continuity, Differentiability and Integrability of a function.

Unit 2: Differential Calculus: Rolle's theorem; Mean value theorem; Taylor's and Maclaurin's theorems with remainders, Expansions; Indeterminate forms; Asymptotes and curvature; Curve tracing; Functions of several variables, Partial Differentiation, Total Differentiation, Euler's theorem and generalization, maxima and minima of functions of several variables – Lagrange's method of Multipliers; Change of variables – Jacobians.

Unit 3: Integral Calculus: Fundamental theorem of integral calculus and mean value theorems; Evaluation of plane areas, volume and surface area of a solid of revolution and lengths. Convergence of Improper integrals – Beta and Gamma functions – properties – Differentiation under integral sign. Double and triple integrals – evaluation of surface areas and volumes – change of order of integration- change of variables in double and triple integrals.

Unit 4: Vector Calculus: Scalar and Vector fields; Vector Differentiation; Level surfaces – directional derivative - Gradient of scalar field; Divergence and Curl of a vector field - Laplacian - Line and surface integrals; Green's theorem in plane- Gauss Divergence Theorem-Stokes' theorem (without proofs).

Course References:

1. R. K. Jain and S. R. K. Iyengar (2002), Advanced Engineering Mathematics, Narosa Publishing House.
2. Erwyn Kreyszig (2010), Advanced Engineering Mathematics, John Wiley and Sons, 8th Edition.
3. B. S. Grewal, Higher Engineering Mathematics, Khanna Publications, Latest Edition.
4. Joel Hass, Christopher Heil, Maurice D. Weir (2019), Thomas's Calculus, Pearson Publication, 14th edition.

Course Code: **PMATG10303** Title of the Course: **Mathematical Logic**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understanding the concepts sets, maps, proportional logics, logical axioms and rules consistency, completeness, elementary equivalence/substructure.

CLO-2: understand the concepts some elementary results of predicate logic, equational classes and universal algebra.

CLO-3: understand the completeness theorem, the compactness theorem, conditions which are equivalent to the axiom of choice, the Löwenheim-Skolem theorems, Vaught's criterion for completeness.

CLO-4: understand the Computable Functions, the Church-Turing Thesis, primitive recursive functions, representability, decidability and G¨odel numbering.

CLO-5: undrstand theorems of G¨odel and Church, A more explicit incompleteness, Undecidable

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Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2		2	1	1	1	1	1	1
CLO2	3	3		2	1	1	2	2	1	2
CLO3	3	3		3	2	2	1	1		2
CLO4	2	3		2	2	1	1	1		2
CLO5	1	2		2	1	3	1	2		1

Course Details:

Unit 1: A brief overview of Sets and Maps, Propositional Logic, Completeness for Propositional Logic, Languages and Structures, Variables and Terms, Formulas and Sentences, Logical Axioms and Rules; Formal Proofs.

Unit 2: Another Form of Completeness, Proof of the Completeness Theorem, Some Elementary Results of Predicate Logic, Equational Classes and Universal Algebra.

Unit 3. L¨owenheim-Skolem; Vaught's Test, Elementary Equivalence and Back-and-Forth, Quantifier Elimination, Presburger Arithmetic, Skolemization and Extension by Definition.

Unit 4: Computable Functions, The Church-Turing Thesis, Primitive Recursive Functions, Representability, Decidability and G¨odel Numbering, Theorems of G¨odel and Church, A more explicit incompleteness theorem, Undecidable Theories.

Course References:

1. Herbert Enderton (1977), A mathematical introduction to logic, Academic Press.
2. Robert Causey (2006), Logic, Sets, and Recursion, 2nd edition.
3. Hedman, Shawn (2004), A first course in logic: An introduction to model theory, proof theory, computability, and complexity, Oxford: Oxford University Press.
4. Wolfgang Rautenberg (2006), A Concise Introduction to Mathematical Logic, Springer.

Course Code: **PMATG10304** Title of the Course: **Mathematics for Everyone**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understanding the concepts sets, derivative, integration, trigonometric.

CLO-2: apply the concept of integration to find the areas, volume, and surface area.
CLO-3: apply regression, least square method on discrete the data.

CLO-4: apply the statistical tool on small, big sampling data.

CLO-5: apply derivatives, integration, Trigonometric concepts in science, engineering, economics, real life.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	3		2	1	1	1	1	1	1
CLO2	3	3		2	1	1	2	2	1	3
CLO3	3	3		3	2	2	1	1	1	3
CLO4	2	3		2	2	1	1	1	1	3
CLO5	1	2		2	1	3	1	2	1	1

Course Details:

Unit 1: Set**,** function, limit, continuity, derivative of a function, Taylor's and Maclaurin's series, minima max. in function of single and mutli variables. Basic concepts of Trigonometric.

Unit 2: Fundamental theorem of integral calculus and mean value theorems; Evaluation of plane areas, volume and surface area of a solid of revolution and lengths.

Unit 3. Sampling and large sample tests - Introduction to testing of hypothesis - tests of significance for large samples - chi-square test - t and F tests - theory of estimation - characteristics of estimation. Linear and polynomial fitting by the method of least squares - linear correlation and linear regression

Unit 4: Applications of derivatives, integration, Trigonometric in science, engineering, economics, real life.

Course References:

1. R. K. Jain and S. R. K. Iyengar (2002), Advanced Engineering Mathematics, Narosa Publishing House.
2. Erwyn Kreyszig (2010), Advanced Engineering Mathematics, John Wiley and Sons, 8th Edition.
3. B. S. Grewal, Higher Engineering Mathematics, Khanna Publications, Latest Edition.
4. Joel Hass, Christopher Heil, Maurice D. Weir (2019), Thomas's Calculus, Pearson Publication, 14th edition.

Course Code: **PMATG10305** Title of the Course: **Elementary Mathematical Statistics**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understanding the basic definitions and principles of probability and statistics.

CLO-2: determine the mean, standard deviation and m^{th} moment of a probability distribution.

CLO-3: use the method of testing of hypothesis for examining the validity of a hypothesis.

CLO-4: estimate the parameters of a population from knowledge of statistics of a sample.

CLO-5: find a curve of best fit for given data.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2	1	2	1	1	1	1	3	1
CLO2	1	3		2	1	1	2	2	3	2
CLO3	1	3	1	3	2	2	1	1	3	2
CLO4	2	3		2	2	1	1	1	3	2
CLO5	1	2	2	2	1	3	1	2	3	1

Course Details:

Unit 1: Random variable and sample space - notion of probability - axioms of probability - empirical approach to probability - conditional probability - independent events - Bayes' Theorem.

Unit 2: Probability distributions with discrete and continuous random variables - joint probability mass function, marginal distribution function, joint density function.

Unit 3: Mathematical expectation - moment generating function - Chebyshev's inequality - weak law of large numbers - Bernoulli trials - the Binomial, Poisson and normal, distributions and their moment generating functions.

Unit 4: Sampling and large sample tests - Introduction to testing of hypothesis - tests of significance for large samples - chi-square test - t and F tests - theory of estimation - characteristics of estimation. Linear and polynomial fitting by the method of least squares - linear correlation and linear regression

Course References:

1. S. C. Gupta and V. K. Kapur (2008), Fundamentals of Mathematical Statistics, S. Chand & Sons, New Delhi, 2008.
2. V. K. Rohatgi and A.K. Md. Ehsanes Saleh (2001), An Introduction to Probability theory and Mathematical Sciences, Wiley.
3. Richard A Johnson (2005), Probability and Statistics for Engineers, Pearson Education.
4. W. Feller (1978), Introduction to Probability Theory and its Applications, third edition, Wiley Eastern.
5. S. Ross (2007), A First Course in Probability, sixth edition , Pearson Education.
6. B. L. S. Prakasa Rao (2009), A First Course in Probability and Statistics, World Scientific.

Semester-II

Course Code: **PMATC20007** Title of the Course: **Real Analysis**

L-T-P: **3-1-0** Credits: **4**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: illustrate the effect of uniform convergence on the limit function with respect to continuity, differentiability, and integrability.

CLO-2: understand the concept of equi-continuity, pointwise and uniform boundedness, Arzela-Ascoli's theorem.

CLO-3: understand the concept of Minima and Maxima, implicit and inverse mapping theorems.

CLO-4: use theory of Riemann Stieltjes integral in solving definite integrals arising in different fields of science and engineering**.**

CLO-5: Extend their knowledge of real variable theory for further exploration of the subject for going into research.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	3			2		2	2	3	1
CLO2	3	2		2	2		3	1	3	2
CLO3	3	2		2	3	1	2	1	3	2
CLO4	2	2		2	2		1	1	2	1
CLO5	2						2	2		2

Course Details:

Unit 1: Sequences and series of functions: pointwise and uniform convergence, Weierstrass M-test, Dini's theorem, equicontinuity, pointwise and uniform boundedness, Arzela-Ascoli's theorem, Weierstrass approximation theorem.

Unit 2: Functions of several variables: Limit, continuity, partial derivatives, total derivative, directional derivative, chain rule, mean value theorems, Taylor theorem, minima and maxima, inverse and implicit mapping theorems.

Unit 3: The Riemann Stieltjes Integral: Existence of the integral, properties, integration of vector valued functions, first and second mean value theorems, change of variable rectifiable curves.

Unit 4: Multiple integrals, properties of integrals, existence of integrals, iterated integrals, change of variables (Cartesian, polar, cylindrical and spherical coordinates) and its properties, Surface integration, surface area, Green’s theorem, Stokes theorem, Gauss divergence theorem.

Course References:

1. Walter Rudin (1976), Principles of Mathematical Analysis, McGraw Hill Book Co.
2. T. M. Apostol (1987), Mathematical Analysis, Narosa Publications.
3. Richard R. Goldberg (1976), Methods of Real Analysis, second edition, John Wiley & Sons.
4. M. Moskowitz, F. Paliogiannis (2011), Functions of Several Real Variables, World Scientific.
5. R. Spiegel Murray (1959), Schaum's Outline of Vector Analysis, Schaum's Outline Series.
6. Tom M. Apostol, (1969), Calculus. Vol. II: Multi-variable Calculus and Linear Algebra, with Applications to Differential Equations and Probability, second edition, Wiley student edition.
7. Munkres, James R. (1991), Analysis on Manifolds, Addison-Wesley Publishing Company, Advanced Book Program, Redwood City, CA.
8. Wendell H. Fleming (1987), Functions of several variables (3/e), Springer-Verlag, New York.

Course code: **PMATC20008** Title of the Course**: Topology**

L-T-P: **3-1-0** Credits:**4**

Course Learning Outcomes (CLOs)

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

CLO-1: acquire knowledge about various types of topological spaces and their properties.

CLO-2: determine closure of set, interior, limit, boundary points of given sets, basis and subbasis of topological spaces.

CLO-3: know the definition and basic properties of connected spaces and compactness.

CLO-4: familiar with the Tietze extension theorem and the Urysohn lemma, and they can characterize metrizable spaces.

CLO-5: know interesting results on Hausdorff spaces, Lindelöf spaces, regular spaces and normal Spaces.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	3	3	1	2	1		1	3	1
CLO2	3	3	3	1	2	1		1	3	1
CLO3	3	3	3	1	2	1		1	3	1
CLO4	3	3	3	1	2	1		1	3	1
CLO5	3	3	3	1	2	1		1	3	1

Course Details:

Unit 1: Topological spaces, basis for a topology, the order topology, the product topology, the subspace topology, metric topology.

Unit 2: Closed sets, Limit points, Closure of a set, Hausdorff spaces, Continuous functions, metrizable space, Quotient spaces.

Unit 3: Connected spaces and compact spaces.

Unit 4: Countability Axioms, The Separation Axioms, Lindelöf spaces, Regular spaces, Normal spaces, Urysohn Lemma, Tietze Extension Theorem, Tychonoff theorem.

References:

1. James R. Munkres (2000), Topology, A first course, Prentice Hall of India Pvt. Ltd., New Delhi.
2. W.J. Pervin (1964), Foundations of General Topology - Academic Press.
3. G. F. Simmons (1963), Introduction to Topology and Modern Analysis, Tata Mc Graw Hill.
4. J. Dugundji (1975), Topology - Prentice Hall of India.
5. G J.L. Kelley (1955), General Topology, Van Nostrand, Princeton.

Course Code: **PMATC20009** Title of the Course: **Numerical Analysis**

L-T-P: **3-1-0** Credits: **4**

Prerequisite Course / Knowledge : Principles of floating-point computations, Errors: Roundoff error, Local truncation error, Global truncation error, order of a method, convergence and terminal conditions. Solution of nonlinear and transcendental equations: Bisection, Fixed point iteration, Regula-Falsi, Secant, Newton-Raphson, Chebyshev's and Muller's methods. Solution of system of nonlinear equations.

Course Learning Outcomes (CLOs)

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

CLO-1: interpolate the given data and approximate the function by a polynomial. Develop the applications of interpolation.

CLO-2: determine the numerical differentiation of a function.

CLO-3: evaluate the integrals numerically.

CLO-4: solve initial value problems numerically.

CLO-5: find the roots of nonlinear equations.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	1	3	2	2	3	2	3	1
CLO2	1	3		2	2	2	3	2	3	2
CLO3	1	3	1	2	2	2	3	2	3	2
CLO4	2	3		2	2	2	3	1	3	1
CLO5	2	3		2	2	2	3	2	3	2

Course Details:

Unit 1: Interpolation: Existence, Uniqueness of interpolating polynomial, error of interpolation -unequally spaced data; Lagrange's, Newton's divided difference formulae. **Equally spaced data:** finite difference operators and their properties, Gauss's forward and backward formulae -Inverse interpolation - Hermite interpolation. **Differentiation:** Finite difference approximations for first and second order derivatives. **Integration:** Newton-cotes closed type methods; particular cases, error terms - Newton cotes open type methods - Romberg integration, Gaussian quadrature; Legendre, Chebyshev formulae.

Unit 2: Solution of nonlinear and transcendental equations: Regula-Falsi, Newton-Raphson method, Chebyshev's, method, Muller's method, Birge-Vita method, solution of system of nonlinear equations (Advanced Level). **Approximation:** Norms, least square (using monomials and orthogonal polynomials), uniform and Chebyshev approximations.

Unit 3: Solution of linear algebraic system of equations: LU Decomposition, Gauss Seidal methods; solution of tridiagonal system. Ill conditioned equations. Eigen values and Eigen vectors: Power and Jacobi methods.

Unit 4: Solution of Ordinary differential equations: Initial value problems: Single step methods; Taylor's, Euler's, Runge-Kutta methods, error analysis; Multi-step methods: Adams Bashforth, Nystorm's, Adams- Moulton methods, Milne's predictor-corrector methods. System of IVP's and higher orders IVP's.

Course References:

1. M.K. Jain, S.R. K Iyengar and R. K Jain (2008), Numerical Methods for Engineers and Scientists, New Age International.
2. C.F. Gerald and P.O. Wheatley (1984), Applied Numerical Analysis, Addison-Wesley.
3. K. Atkinson (1978), Numerical Analysis, John Wiley, Singapore.

Course Code: **PMATC20010** Title of the Course: **Partial Differential Equations**
L-T-P: **3-1-0** Credits: **4**

Prerequisite Course / Knowledge : Definition of partial differential equations, order and degree of partial differential equations, Concept of linear and non-linear partial differential equations, Formation of first order partial differential equations.

Course Learning Outcomes (CLOs)

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

CLO-1: analyze the origin of first order partial differential equations, classification and geometrical interpretation of PDEs.

CLO-2: classify the second order differential equations and ability to solve the homogeneous & non-homogeneous linear partial differential equations.

CLO-3: solve the wave equation using separation of variables and integral transforms.

CLO-4: solution of Laplace equation in Cartesian and polar coordinates in Rectangular and circular regions

CLO-5: solve the Diffusion equation on the whole line and half-line.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	1		2					3	
CLO2	2	3		2	2				3	
CLO3	2	3		2	2			2	3	
CLO4	3	3		3	3				3	
CLO5	2			2	3				3	

Course Details:

Unit 1: First order partial differential equations: Basic definitions, Origin of PDEs, Classification, Geometrical interpretation, Linear, quasi-linear, nonlinear Equations-Method of characteristics, Lagrange method.

Unit 2: Second order partial differential equations: Definitions of Linear and Non-Linear equations, Classification of second-order linear partial differential equations, Canonical forms of equations in two independent variables, solutions of linear Homogeneous and non-homogeneous with constant coefficients, Variable coefficients, Monge's method.

Unit 3: Wave equation: Solution by the method of separation of variables and integral transforms, wave equation in cylindrical and spherical polar coordinates.

Laplace equation: Solution by the method of separation of variables and integral transforms, Solution by Cartesian and polar coordinates-Rectangular regions, circular regions.

Unit 4: Diffusion equation: Solution by the method of separation of variables and integral transforms, Maximum Minimum principle for the diffusion equation, Diffusion equation on the whole line, Diffusion on the half-line.

Course References:

1. I. N. Sneddon (2006), Elements of partial differential equations, McGraw-Hill, New York.

2. L Debnath (2007), Nonlinear PDE's for Scientists and Engineers, Birkhauser, Boston.

3. F. John (1971), Partial differential equations, Springer.

4. Jeffery Cooper (1998), Introduction to partial differential equations with matlab, Birkhauser,

5. Clive R Chester (1971), Techniques in partial differential equations, McGraw-Hill.

6. W. E. Williams (1980), Partial differential equations, Clarendon Press, Oxford.

7. Tyn Myint-U and Lokenath Debnath (2007), Linear Partial Differential Equations for Scientists and Engineers, Fourth Edition, Birkhauser.

8. R.P. Agarwal and D. O'Regan (2009), Ordinary and Partial Differential Equations, Springer-Verlag.

9. Ioannis P Stavroulakis and Stepan A Tersian (1999), Partial differential equations- an introduction with mathematica and maple, world - Scientific, Singapore.

10. F. Treves (1975), Basic linear partial differential equations, Academic Press.

11. M.G. Smith(1967), Introduction to the theory of partial differential equations, Van Nostrand.

Course Code: **PMATC20011** Title of the Course: **Probability and Statistics**

L-T-P: **3-1-0** Credits: **4**

Course Learning Outcomes (CLOs)

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

CLO-1: determine the mean, standard deviation and mth moment of a probability distribution.

CLO-2: find a curve of best fit for given data.

CLO-3: use the method of testing of hypothesis for examining the validity of a hypothesis.

CLO-4: estimate the parameters of a population from knowledge of statistics of a sample.

CLO-5: use the method of ANOVA for one factor experiments.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	2	2	1	2	3	1
CLO2	1	3		3	2	2	1	2	3	2
CLO3	2	3	2	3	2	2	1	2	3	2
CLO4	2	3	2	3	2	2	1	2	3	2
CLO5	1	3	1	3	2	2	2	2	3	2

Course Details:

Unit 1: Random variable and sample space - notion of probability - axioms of probability - empirical approach to probability - conditional probability - independent events - Bayes' Theorem- probability distributions with discrete and continuous random variables - joint probability mass function, marginal distribution function, joint density function.

Unit 2: Mathematical expectation - moment generating function - Chebyshev's inequality - weak law of large numbers - Bernoulli trials - the Binomial, negative binomial, geometric, Poisson, normal, rectangular, exponential, Gaussian, beta and gamma distributions and their moment generating functions - fit of a given theoretical model to an empirical data.

Unit 3: Sampling and large sample tests - Introduction to testing of hypothesis - tests of significance for large samples - chi-square test - SQC - analysis of variance - t and F tests - theory of estimation - characteristics of estimation - minimum variance unbiased estimator - method of maximum likelihood estimation.

Unit 4: Scatter diagram - linear and polynomial fitting by the method of least squares - linear correlation and linear regression - rank correlation - correlation of bivariate frequency distribution.

Reference Books:

1. S. C. Gupta and V. K. Kapur (2008), *Fundamentals of Mathematical Statistics*, S. Chand & Sons, New Delhi, 2008.
2. V. K. Rohatgi and A.K. Md. Ehsanes Saleh (2001), *An Introduction to Probability theory and Mathematical Sciences*, Wiley.
3. Richard A Johnson (2005), *Probability and Statistics for Engineers*, Pearson Education.

Course Code: PMACA20101 Title of the Course: **Computing Laboratory-II**

L-T-P: **1-0-3** Credits: **2**

Course Learning Outcomes (CLOs)

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

CLO-1: understanding the basics of computational software and its usage of commands.

CLO-2: solve basic numerical and symbolic mathematics problems. Also, visualize and present data.

CLO-3: create simple programming using functions.

CLO-4: understand and apply basic programming techniques and paradigms.

CLO-5: writing the programs on Numerical methods.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	3	2	3	2	3	3	3		2
CLO2	2	3	3	3	3	3	3	3		2
CLO3	3	3	3	3	2	2	3	3		2
CLO4	3	3	2	3	3	3	3	3		2
CLO5	3	3	1	3	3	3	3	2		2

Course Details:

This course is designed to familiarize students with the use of software resources commonly utilized in the mathematical sciences. Students will learn how to use modern computing environments such as Mathematica for the purpose of symbolic and numerical problem solving and visualization. Students will become acquainted with the syntax and usage of each system through computer-aided lectures as well as through projects. The relative merits and disadvantages of each system will also be discussed. Basic programming paradigms and concepts will be introduced where appropriate. This course will also introduce to write the programs on numerical methods using Mathematica.

Unit 1: Introduction to Mathematica and to the Wolfram Language (knowl- edge-based language, built-in support for real-world entities, Wolfram Alpha and the Wolfram Demonstrations Project). Numerical and symbolic computations, Lists, strings, rules, patterns and pattern matching.

Unit 2: Working with matrices, creation of tables, plotting 2D, 3D graphs etc. Linear and polynomial algebra. Exact and numerical optimization. Calculus and differential equations (analytic and numerical solutions of ODEs and PDEs).

Unit 3: Basic Programs to be written in Mathematica on Conditional Control constructs, Loops, User defined functions and Library functions, Arrays (Single and Multi-dimensional), Structures etc.

Unit 4: Mathematica programs on Numerical methods for finding solution of Algebraic and Transcendental Equations, Interpolation, Numerical Differentiation & Numerical Integration and Numerical solutions of Differential Equations.

Reference Books:

1. Eugene Don (2009), *Mathematica 2nd edition*, Schaums Outlines, McGraw-Hill.
2. S. Hassani (2009), *Mathematical Methods Using Mathematica*, Springer, New York.
3. For the Mathematica module: https://www.wolfram.com/language/elementary-introduction/
4. https://www.wolfram.com/books/profile.cgi?id=8962
5. https://library.wolfram.com/infocenter/Books/4804/

List of Soft Electives (II Semester)

Course Code: **PMATD20201** Title of the Course: **History of Mathematics & Mathematicians**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understanding the biography of Euler, Fourier, Gauss, Able, Jacobi, Hilbert, Banach, Poincare, Galois, Laplace, Ramanujan and Lagrange, Pythagoras, Euclid, Archimedes.

CLO-2: understand the concepts Rene Descartes and the Idea of Coordinates.

CLO-3: understand the concepts real and complex number system.

CLO-4: understand the concepts derivative, Maximum/Minimum Problems.

CLO-5: understand the concept of Rubber Sheet Geometry, Idea of Homotopy, Brouwar fixed Point theorem, Generalized Ham Sandwich theorem.

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Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2	1	2	1	1	1	1		1
CLO2	3	3		2	1	1	2	2		2
CLO3	3	3	1	3	2	2	1	1		2
CLO4	3	3		2	2	1	1	1		2
CLO5	1	2	2	2	1	3	1	2		1

Course Details:

Unit 1: Brief Biography of Euler, Fourier, Gauss, Able, Jacobi, Hilbert, Banach, Poincare, Galois, Laplace, Ramanujan and Lagrange. Mathematics of Ancient Greeks: Pythagoras, Euclid, Archimedes.

The Arabs and the Development of Algebra: Introductory Remarks, The Development of Algebra – Al- Khwarizmi and the Basics of Algebra, The Life of Al- Khwarizmi, The Ideas of Al-Khwarizmi, Omar Khayyam and the Resolution of the Cubic.

Unit 2: Rene Descartes and the Idea of Coordinates: Introductory Remarks, The Life of Rene Descartes, The Real Number Line, The Cartesian Plane, Cartesian Coordinates and Euclidean Geometry, Coordinates in Three- Dimensional Space.

The Invention of Differential Calculus: The Life of Fermat, Fermat's Method, More Advanced Ideas of Calculus, The Derivative and the Tangent Line, Fermat's Lemma and Maximum/Minimum Problems.

Unit 3 Complex Numbers and Polynomials: A new number system, Progenitors of the Complex Number System, Cardano, Euler, Argand, Cauchy, Riemann, Complex Number Basics, The Fundamental Theorem of Algebra, Finding the Roots of a Polynomial.

Cauchy and the foundations of analysis: Introduction, properties of the real number system – bounded sequences, maxima and minima, Intermediate value property.

Unit 4: The Number Systems: The Natural numbers, integers, rational numbers, real numbers, complex numbers. Henri Poincare, Child Prodigy: Introductory Remarks, Rubber Sheet Geometry, Idea of Homotopy, Brouwar Fixed Point theorem, Generalized Ham Sandwich theorem.

Methods of Proof: Axiomatics – undefinables, definitions, axioms, theorems, modus ponendo ponens, and modus tollens, proof by induction, proof by contradiction, direct Proof, other methods of proof.

Course References:

1. Dirk J. Struik (1987), A Concise History of Mathematics: Fourth Revised Edition (Dover Books on Mathematics).
2. Ronald S. Calinger , Leonhard Euler: Mathematical Genius in the Enlightenment.
3. John Fauvel (1987), The History of Mathematics: An Open University Course Reader.
4. Dodgson Charles Lutwidge , Francine F. Abeles (1994), The Mathematical Pamphlets of Charles Lutwidge Dodgson and Related Pieces.
5. H.M. Cundy, A.R. Rollett (1981), Mathematical Models.

Course Code: **PMATD20202** Title of the Course: **Elementary Mathematical Modeling**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understand the concept of first order and higher derivatives, integration with physical meaning.

CLO-2: understand the concepts different steps involving in mathematical modeling.

CLO-3: apply basic calculus on growth and decay linear models, Chemical reaction, Drug absorption models.

CLO-4: solve LCR equation, Motion of a projectile, Model for deduction of diabetes models.

CLO-5: solve the Vibration of string, Vibration of drum, Heat equation and Laplace equation and Poisson equation, Burger's equation, Fisher's equation, Telegraph equations.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		3	3	1		2	1	2
CLO2		2		3	2	1			1	
CLO3	3	3		2	2	2		3		1
CLO4	3	3		2	2	2		3		1
CLO5	3	3		2	2	2		3		1

Course Details:

Pre-request: Meaning of first and second order ordinary derivatives – slope of a tangent and curvature. Connecting these concepts to practical observation.

Unit-1: Basic concepts. Real world problems, (Physics, Chemistry, Biology, Economics, and others) Approximation of the problem, Steps involved in modeling.

Unit-2: Mathematical models : Linear growth and decay model, Logistic model, model of Mass-spring-dashpot (present in shock absorbed, mechanical engineering problems), Chemical reaction, Drug absorption from blood stream.

Unit-3: Motion of a projectile. Current flow in electrical circuits(LCR), Model for deduction of diabetes, Nonlinear system of equation- Combat models- predator- prey equations, spread of epidemics.

Unit-4: Models leading to linear and nonlinear partial differential equations - Vibration of string, Vibration of drum, Heat equation and Laplace equation and Poisson equation, Burger's equation, Fisher's equation, Telegraph equations.

Course References:

1. J. N. Kapur (1998), Mathematical Moodelling, Wiley Eastern Ltd.
2. E. Kreyszig (2002), Advanced Engineering Mathematics, Wileyeastem.
3. Andrea Prosperetti, Advanced Mathematics for Applications, Cambridge.

Course code**: PMATD20203** Title of the Course**: Coordinate Geometry**

L-T-P: **3-0-0** Credits:**3**

Course Learning Outcomes (CLOs)

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

CLO-1: understand geometry and its applications in the real world.

CLO-2: know how to communicate geometric ideas in the language of the mathematician.

CLO-3: analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships.

CLO-4: apply transformations and use symmetry to analyze mathematical situations.

CLO-5: apply appropriate techniques, tools, and formulas to determine measurements.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	3	3	2	2	2		1	3	2
CLO2	3	3	3	2	2	2		1	3	2
CLO3	3	3	3	2	2	2		1	3	2
CLO4	3	3	3	2	2	2		1	3	2
CLO5	3	3	3	2	2	2		1	3	2

Course Details:

Preliminaries: Rectangular coordinates- Distance between two points- Division of a line joining two points in a given ratio - Angle between two lines- Direction cosines and ratios of a straight line- Condition for parallelism and perpendicularity of two lines- Projection of a line segment on another line. The plane- The general equation of the first degree in three variables always represents a plane Surface-Direction cosine of the normal to a plane- Equation of a plane in intercept form- The form $lx + my + nz = p$ - Angle between two planes- Pair of planes- Image of a point in a plane - Length of perpendicular from a point to a plane.

The equation to a straight line- Symmetrical form- Parametric coordinates of any point on a line Transformation from un-symmetrical form to the symmetric form- Condition for a line to be parallel to a plane- Angle between a line and a plane- Coplanar Lines, intersecting two lines –Skew lines – Shortest distance between two lines. The sphere- The equation of a sphere with given center and radius- The equation of a sphere on the line joining two given points as diameter- Plane section of a sphere- Equation of a sphere passing through a given circle- The intersection of two spheres- The equation of a tangent plane to a sphere- Length of tangent to a sphere- Orthogonal spheres. Hyperbolic functions- Inverse hyperbolic functions- Separation into real and imaginary parts.

References:

1. S. L. Loney, The Elements of Coordinate Geometry, Macmillan India, 2010.
2. R. J. T. Bill, Elementary Treatise on Coordinate Geometry of Three Dimensions, Macmillan India, 1918.

Course Code: **PMATD20204** Title of the Course: **Elementary Number Theory**

L-T-P: **3-0-0** Credits:**3**

Course Learning Outcomes (CLOs):

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

CLO-1: know about open problems in number theory, namely, the Goldbach conjecture and twin-prime conjecture.

CLO-2: demonstrate a basic understanding of number theoretic functions including Euler's Φ-function and the Mobius μ-function.

CLO-3: apply the Law of Quadratic Reciprocity and other methods to classify numbers as primitive roots, quadratic residues, and quadratic non-residues.

CLO-4: apply public crypto systems, in particular, RSA.

CLO-5: learn methods and techniques used in number theory and communicate effectively in both written and oral form.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	2	3	2	2	2	3	1	2	2
CLO2	3	2	3	2	2	2	3	1	2	2
CLO3	3	2	3	2	2	2	3	1	2	2
CLO4	3	2	3	2	2	2	3	1	2	2
CLO5	3	2	3	2	2	2	3	1	2	2

Course Details:

Unit 1: Division algorithm, Euclid's algorithm, prime numbers, fundamental theorem of arithmetic, distribution of primes, discussion of the Prime Number Theorem, the series of Reciprocals of primes, congruences, Goldbach conjecture, Twin-prime conjecture, Linear Congruence, Chinese remainder theorem, Fermat's little theorem, Wilson's theorem, Euler's theorem.

Unit 2: Elementary arithmetical functions, perfect numbers, Mersenne primes and Fermat numbers, Irrational numbers-Irrationality of m^{th} root of N, e and π.

Unit 3: Primitive roots and indices, Quadratic residues, Legendre symbol, Gauss's Lemma, Quadratic reciprocity law, Jacobi symbol.

Unit 4: Fermat's two square theorems, Lagrange's four square theorem, Diophantine equations: $ax + by = c$, $x^2 + y^2 = z^2$, $x^4 + y^4 = z^2$, sums of two and four squares. Applications: Public key encryption, RSA encryption and decryption with applications in security systems.

Course References:

1. D.M. Burton (2010), Elementary Number Theory, 7th Edition. McGraw-Hill Education.
2. G.H. Hardy and E.M. Wright (1975), An introduction to the Theory of Numbers, 4th Edition. Oxford University Press.
3. I. Niven, H. S. Zuckerman and H. L. Montgomery (2004), An Introduction to the Theory of Numbers, New York, John Wiley and Sons, Inc., 5thEd.
4. T. M. Apostol (1998), Introduction to Analytic Number Theory, Narosa Publishing House, New Delhi.
5. W.W. Adams and L.J. Goldstein (1972), Introduction to the Theory of Numbers, 3rd ed., Wiley Eastern.
6. Neal Koblitz (1994). A Course in Number Theory and Cryptography (2nd edition). Springer-Verlag.
7. A. Baker (1984), A Concise Introduction to the Theory of Numbers, Cambridge University Press, Cambridge.

Course Code: **PMACD20205** Title of the Course: **Introduction to Computer Programming**
L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: learn fundamental knowledge of computer hardware and number systems.

CLO-2: learn basic terminology used in computer programming.

CLO-3: develop ability to write, compile and debug programs in C language. Also, design programs involving decision structures, loops and functions.

CLO-4: understand the dynamics of memory by the use of pointers.

CLO-5: learn the basic concepts of object oriented programming.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	2	1	2	1	1	1	1	3	1
CLO2	1	3		2	1	1	2	2	3	2
CLO3	1	3	1	3	2	2	1	1	3	2
CLO4	2	3		2	2	1	1	1	3	2
CLO5	1	2	2	2	1	3	1	2	3	1

Course Details:

Unit 1: Concepts, definitions, taxonomy and history of computer programming.

Unit 2: Operating systems and program execution, Unix system, Input/output devices, storage devices, flow chart and algorithm development, computer program.

Unit 3: Basic C programming, statements, arrays, functions and pointers.

Unit 4: Introduction to Object Oriented Programming, concepts of objects and classes.

Reference Books:

1. C programming by Ritchie & Kernighan.
2. UNIX programming by Kernighan & Pike.
3. Object Oriented Programming with C++ by Balaguruswamy.
4. Programming with C by Gottfried.

Course code: **PMATD20206** Title of the Course**: Mathematical Methods**

L-T-P: **3-0-0** Credits:**3**

Course Learning Outcomes (CLOs)

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

CLO-1: provide knowledge of a wide range of mathematical techniques and application of mathematical methods/tools in other scientific and engineering domains.

CLO-2: know the connections between the mathematical series and other scientific and humoristic disciplines.

CLO-3: know principles of mathematical reasoning and their use in understanding analyzing and developing formal arguments.

CLO-4: use Fourier series, Laplace transform and Z-transform.

CLO-5: learn how to expand a function in a Fourier series, and under what conditions such an expansion is valid. They will be aware of the connection between this and integral transforms (Fourier and Laplace) and be able to use the latter to solve mathematical problems relevant to the physical sciences.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	3	2	2	1				3	1
CLO2	3	2	2	2	1	2			3	1
CLO3	3	3	2	2	1	2			3	1
CLO4	3	2	2	2	1	2			3	1
CLO5	3	3	2	2	1	2			3	1

Course Details:

Unit I: Introduction to Laplace transform**,** Laplace of some standard functions, Existence conditions for the Laplace Transform, Shifting theorems, Laplace transform of derivatives and integrals, Inverse Laplace transform and their properties, Convolution theorem, Initial and final value theorem, Laplace transform of periodic functions, error functions, Heaviside unit step function and Dirac delta function, Applications of Laplace transform to solve ODEs and PDEs, Finite Laplace Transform: Definition and properties, Shifting and scaling theorem.

Unit II: Introduction to Fourier series, Trigonometric Fourier series and its convergence. Fourier series of even and odd functions, Gibbs phenomenon, Fourier half-range series, Parseval`s identity, Complex form of Fourier series.

Unit III: Introduction to Fourier Transforms, Fourier integrals, Fourier sine and cosine integrals, Complex form of Fourier integral representation, Fourier transform, Fourier transform of derivatives and integrals, Fourier sine and cosine transforms and their properties, Convolution theorem, Application of Fourier transforms to Boundary Value Problems.

Unit IV: Introduction to Z–transform, inverse Z-transform of elementary functions, Shifting theorems, Convolution theorem, Initial and final value theorem, Application of Z-transforms to solve difference equations, Hankel Transform: Basic properties of Hankel Transform, Hankel Transform of derivatives, Application of Hankel transform to PDE, Mellin Transform: Definition and properties of Mellin transform, Shifting and scaling properties, Mellin transforms of derivatives and integrals, Applications of Mellin transform

References:

1. Kreyszig, E., "Advanced Engineering Mathematics", John Wiley & Sons, 2011.
2. Jain, R.K. and Iyengar, S.R.K., "Advanced Engineering Mathematics", Narosa Publishing House, 2009.
3. Hildebrand F. B., "Methods of Applied Mathematics", Courier Dover Publications, 1992.
4. Debanth L. and Bhatta D., Integral Tranforms and Their Applications, 2nd edition, Taylor and Francis Group, 2007.
5. Hwei p. hsu., “Schaum's outlines of theory and problems of signals and systems”.
6. Murray r. Spiegel., “Schaum's outline of theory and problems of Laplace transforms”.

Course Code: **PMATD20207** Title of the Course: **Mathematics for Biology**
L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: formulate discrete and differential equation models that represent a range of biological problems.
CLO-2: apply computational tools to perform parameter estimation and to solve discrete models.
CLO-3: interpret model and data output in terms of the original biological problem.
CLO-4: perform appropriate data manipulations, and graphically display model output.

CLO-5: apply the mathematical knowledge to understand the biological structure.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	3		2	3			1		1
CLO2	2			2	1	2	1			
CLO3	1	2			2	2		1		
CLO4		2		2	2	1		2		
CLO5	1	2		2	2	1		2		2

Course Details:

Concepts of Population biology, physiology and in the biomedical sciences including single and competing species ecological models, enzyme reaction kinetics, molecular motors, epidemiology, and infectious diseases.

Mathematical modeling techniques of formulation, implementation, validation, and analysis.

Course References:

1. Mathematical Models in Biology, Leah Edelstein-Keshet, 1988

<u>**Semester-III**</u>

Course Code: **PMATC30012** Title of the Course: **Functional Analysis**

L-T-P: **3-1-0** Credits: **4**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: verify the requirements of a norm, completeness with respect to a norm, relation between compactness and dimension of a space, check boundedness of a linear operator and relate to continuity, convergence of operators by using a suitable norm, compute the dual spaces.

CLO-2: distinguish between Banach spaces and Hilbert spaces, decompose a Hilbert space in terms of orthogonal complements, check totality of orthonormal sets and sequences, represent a bounded linear functional in terms of inner product, classify operators into self-adjoint, unitary and normal operators.

CLO-3: extend a linear functional under suitable conditions, compute adjoint of operators, check reflexivity of a space, ability to apply uniform boundedness theorem, open mapping theorem and closed graph theorem, check the convergence of operators and functional and weak and strong convergence of sequences.

CLO-4: compute the spectrum of operators and classify the set into subclasses, show the spectrum to be nonempty, give expansion of resolvent operator.

CLO-5: compute the spectrum of operators and classify the set into subclasses, show the spectrum to be nonempty, give expansion of resolvent operator.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		1	2		2	1	3	1
CLO2	3	3		2	2		1	2	3	2
CLO3	3	3		2	2		1	1	3	2
CLO4	2	2		2	2		2	1	2	1
CLO5				2				2		1

Course Details:

Unit 1: Normed spaces, Holder's inequality, Minkowski's inequality, Banach spaces, Finite dimensional normed spaces and subspaces, Compactness and finite dimension, Bounded and continuous linear operators, Linear operators and functionals on finite dimensional spaces, Normed spaces of operators, Dual spaces.

Unit 2: Hilbert spaces, projections on a Hilbert space, invariant subspace, Orthogonality of projections. Orthogonal complements and direct sums, Bessel's inequality, total orthonormal sets and sequences, Representation of functionals on Hilbert spaces, Hilbert adjoint operators, Self-adjoint, unitary and normal operators.

Unit 3: Hahn Banach theorems for real and complex normed spaces, Adjoint operator, Reflexive spaces, Uniform boundedness theorem strong and weak convergence, Convergence of sequences of operators and functionals, Open mapping theorem, Closed graph theorem.

Unit 4: Spectrum of an operator, Spectral properties of bounded linear operators, Nonemptiness of the spectrum.

Course References:

1. G. Bachman and L. Narici (2000), Functional Analysis, Dover Publications.
2. R. Bhatia (2009), Notes on Functional Analysis, Hindustan Book Agency, India.
3. E. Kreyszig (2006), Introductory Functional Analysis with Applications, John Wiley & Sons, India.
4. M. Schechter (2001), Principles of Functional Analysis, Second Edition, American Mathematical Society.
5. G. F. Simmons (1998), Introduction to Topology and Modern Analysis, McGraw-Hill.
6. B. V. Limaye (1998), Functional Analysis, Wiley Eastern.
7. S. Kesavan, (2009), Functional Analysis, Trim series, Hindustan Book Agency.
8. I.J. Maddox (1992), Elements of Functional Analysis, Cambridge Univ. Press, New Delhi.
9. J. B. Conway (1985), A Course in Functional Analysis, GTM, Vol. 96, Springer,.
10. A. E. Taylor (1958), Introduction to Functional Analysis, Wiley, New York.

Course Code: **PMATC30013** Title of the Course: **Complex Analysis**

L-T-P: **3-1-0** Credits: **4**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: understand how complex numbers provide a satisfying extension of the real numbers.

CLO-2: understand analytic function as a mapping on the plane, Mobius transformation, branch of logarithm and learn techniques of complex analysis that make practical problems easy (graphical rotation and scaling as an example of complex multiplication).

CLO-3: understand Cauchy's theorems and integral formulas on open subsets of the plane.

CLO-4: understand how to count the number of zeros of analytic function giving rise to open mapping theorem. Evaluate improper/definite integrals by residue theorem

CLO-5: extend their knowledge of complex variable theory for further exploration of the subject for going into research.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	2	1			1					
CLO2	2	2		2	2	1	1		2	2
CLO3	3	3		2	2		1		3	2
CLO4	2	2		2	2		1	1	3	2
CLO5				2			2	2		3

Course Details:

Unit 1: Extended complex numbers, Riemann sphere, stereographic projection, lines, circles. Limit, continuity, analytic functions, harmonic conjugates, elementary functions, conformal mapping, Mobius transformations.

Unit 2: Series, uniform convergence, power series, radius of convergences, power series representation of analytic function, relation between power series and analytic function. Maximum modulus theorem, index of a closed curve, simple connectedness.

Unit 3: Cauchy's theorem for triangle, rectangle, in a disk, Goursat's theorem and Cauchy's integral formula, Liouville's theorem, fundaments theorem of algebra, counting zeros and open mapping theorem, classification of singularities, poles, Taylor's series, Laurent series.

Unit 4: Residue, contour integration, evaluation of definite integrals, argument principle, Rouche's theorem, maximum principles, Schwarz's lemma.

Course References:

1. L.V. Ahlfors (2017), Complex Analysis, Mc Graw Hill Co., Indian Edition.

2. J.B. Conway (1996), Functions of One Complex Variable, Second Edition, Narosa Publications, New Delhi.

3. T.W. Gamelin (2001), Complex Analysis, Springer.

4. R.V. Churchill, Brown (1974), Complex Variables and Applications. McGraw Hill.

5. D.C. Ullrich (2008), Complex Made Simple, American Mathematical Society.

6. S. Ponnaswamy (2019), Functions of Complex variable, Narosa Publications.

7. R. Nevanlinna (1970), Analystic functions, Springer.

8. E. Hille (1959), Analytic Theory, Vol. I, Ginn.

9. Narasimhan, Raghavan and Nievergelt, Yves (2001), Complex Analysis in One Variable, 2nd edition, Birkhauser Boston, Inc., MA.

Course Code: **PMATC30014** Title of the Course: **Fluid Mechanics**

L-T-P: **3-1-0** Credits: **4**

Course Learning Outcomes (CLOs)

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

CLO-1: analyze the classification of fluids, Methods of describing fluid motion and fluid flow conditions.

CLO-2: understand the Euler's and Bernoulli's equations, and real world applications of it.

CLO-3: apply Milne-Thomson circle theorem and the theorem of Blasius for real world problems.

CLO-4: understand the concept of three-dimensional flows, sources, sinks, doublets, and applications of Butler sphere theorem, Kelvin's inversion theorem and Weiss's sphere theorem.

CLO-5: understand the relation between stress and rate of strain, and apply the Navier−Stokes equations of motion to real world applications.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	1	3	3			3	2	2
CLO2	3	3		2	2			3	3	3
CLO3	2			3	2			2	3	2
CLO4	3		1	2	3			3	3	3
CLO5	2	2	1	3	2			3	3	2

Course Details:

Unit 1: Classification of fluids, Methods of describing fluid motion, velocity of a fluid at a point, stream lines and path lines, steady and unsteady flows, the velocity potential, the velocity vector, local and particle rates of change, the equation of continuity, acceleration of fluid, conditions at a rigid boundary.

Unit 2: Euler's equation of motion, Bernoulli's equation, Theory of irrotational motion, Kelvin’s minimum energy and circulation theorems, Two-dimensional flows of irrotational, incompressible fluids, Complex potential, Sources, sinks, doublets and vortices, Two-dimensional motion of rigid bodies, the Milne-Thomson circle theorem, the theorem of Blasius, applications.

Unit 3: Three-dimensional flows, Sources, sinks, doublets, Axi-symmetric flow and Stokes stream function, Butler sphere theorem, Kelvin’s inversion theorem, Weiss’s sphere theorem, Images with respect to a plane and sphere.

Unit 4: Viscous flow, stress and strain analysis, Stokes hypothesis, Navier−Stokes equations of motion, Some problems in viscous flows, Steady flow between parallel plates, Poiseuille flow, Steady flow between concentric rotating cylinders.

Course References:

1. Frank Chorlton (2004), Fluid Dynamics, CBS Publishers, Delhi.
2. S. W. Yuan(1976), Foundations of Fluid Mechanics, Prentice Hall.
3. C.S.Yih(1969), Fluid Mechanics, McGraw-Hill.
4. G. K. Batchelor (2000), An Introduction to Fluid Dynamics, Cambridge.
5. D. Tritton (1977), Physical Fluid Dynamics, Oxford.
6. L.M.Milne Thomson (1960), Theoretical Hydrodynamics, Macmillan Company, New York.
7. R.W. Fox, P.J. Pritchard and A.T. McDonald (2009), Introduction to Fluid Mechanics, Seventh Edition, John Wiley & Sons.
8. P.K. Kundu, I.M. Cohen, D.R. Dowling (2016), Fluid Mechanics, Sixth Edition, Academic Press.

Course Code: **PMACA30102** Title of the Course: **Computing Laboratory-III**

L-T-P: **1-0-3** Credits: **2**

Course Learning Outcomes (CLOs)

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

CLO-1: plot and visualize the general mathematical functions.

CLO-2: perform the basic mathematical operations using Matlab and solve the differential equations.

CLO-3: evaluate and visualize the Laplace transforms and inverse Laplace transforms of functions including Heaviside's, Dirac delta functions using Matlab.

CLO-4: evaluate the gradient, curl and divergence, line integrals and visualization.

CLO-5: apply the Matlab Programming for solving the real world problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3			2		2	2	2		1
CLO2	2	2		2	2	2	3	2		1
CLO3	2	3		2	1	1	3	1		1
CLO4	2	3		2	1	1	2	1		1
CLO5	3	3		3	3		3	2		1

Course Details:

Unit 1: Introduction to Matlab.

Unit 2: Plotting and visualizing the general functions.

Unit 3: Understanding the concept of integration, evaluating the double and triple integration, solving the first and higher order ordinary differential equations, evaluating the maxima and minima of single and multi-variable functions, visualization.

Unit 4: Evaluating Laplace transforms and inverse Laplace transforms of functions including Heaviside's, Dirac delta. Evaluating the gradient, curl and divergence, line integrals, visualization.

Course Reference:

1. Rudra Pratap (2019), Getting Started with Matlab, A quick introduction for Scientists and Engineers, Oxford University Press.
2. Raj Kumar Bansal (2009), Ashok Kumar Goel, Manoj Kumar Sharma, Matlab and its Applications in Engineering, Pearson Education India.
3. Amos Gilat, Matlab (2011), An introduction with applications, 4^{th} Edition, Wiley.
4. Misza Kalechman (2009), Practical Matlab Applications for Engineers, City University of New York, CRC Press.

Course Code: **PMATA30103** Title of the Course: **Seminar**

L-T-P: **0-0-4** Credits: **2**

Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will

CLO-1: learn knowledge and understanding of core material

CLO-2: learn conceptual grasp of issues, quality of argument and ability to answer questions.

CLO-3: learn how to maintain quality of management.

CLO-4: learn how to improve quality of communication.

CLO-5: learn how to become a good teacher or researcher.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	3	2	3	3	3	3	3		3
CLO2	3	3	3	3	3	2	3	3		3
CLO3	1	1	3	1	1	3	1	2		3
CLO4	1	1	3	1	1	3	1	2		3
CLO5	1	1	3	1	1	3	1	3		3

Course Details: Seminar component is included in 3rd Semester to train students for self-study and to deliver lectures. Every student has to give a seminar and a committee of staff members from the department shall evaluate the same. Also, the student has to choose the seminar topic related to mathematics subject other than M.Sc. Mathematics syllabus under the supervision of a faculty in the Dept. of Mathematics.

List of Discipline Specific Electives-I (III Semester)

Course code: **PMATD30209** Title of the Course**: Advanced Algebra**

L-T-P: **3-0-0** Credits: **3**

Prerequisite course/knowledge: Rings, Some special classes of rings (Integral domain, division ring, field, maximal and prime ideals).

Course Learning Outcomes (CLOs)

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

CLO-1: design, analyze and implement the concepts of Gauss Lemma, Einstein's irreducibility criterion, separable extensions etc.

CLO-2: create, select and apply appropriate algebraic structures such as Galois extensions, Auto morphisms of groups and fixed fields, Fundamental theorem

CLO-3: comprehend the important concepts and results of Rings and Ideals and apply standard theorems on Homeomorphisms to algebraic problems.

CLO-4: prove deep theorems on different kinds of Ideals.

CLO-5: learn advanced concepts such as Artinian and Noetherian modules.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	2	3	1	2	1	1	1	3	1
CLO2	3	2	3	1	2	1	1	1	3	1
CLO3	3	2	3	1	2	1	1	1	3	1
CLO4	3	2	3	1	2	1	1	1	3	1
CLO5	3	2	3	1	2	1	1	1	3	1

Course Details:

Unit 1: Extension fields, Finite and Algebraic extensions. Degree of extension, Algebraic elements and algebraic extensions, Adjunction of an element of a field. Roots of a polynomial, Splitting fields, Construction with straight edge and compass more about roots, Simple and separable extensions, Finite fields.

Unit 2: Elements of Galois Theory, Fixed fields, Normal extension, Galois groups over the rationales.

Unit 3: The prime spectrum of a ring, the nil radical and Jacobson, radical, operation on ideals, extension and contraction. Modules - Modules and modules homomorphism's, submodules and quotient modules, Direct sums, Free modules Finitely generated modules, Nakayama Lemma, Simple modules, Exact sequences of modules.

Unit 4: Modules with chain conditions - Artinian and Noetherian modules, modules of finite length, Artnian rings, Noetherian rings, Hilbert basis theorem. **References:**

1. M. F. Atiyah and I. G. Macdonald – Introduction to Commutative Algebra, Addison-Wesley. (Part A)

2. I. N. Herstein: Topics in Algebra, 2nd Edition, Vikas Publishing House, 1976. (Part B)

3. C. Musili: Introduction to Rings and Modules, Narosa Publishing House, 1997.

4. Miles Reid – Under-graduate Commutative Algebra, Cambridge University Press, 1996.

5. M. Artin: Algebra, Prentice Hall of India, 1991.

6. N. Jacobson: Basic Algebra-I, HPC, 1984.

7. J. B. Fraleigh: A first courses in Algebra, 3rd edition, Narosa 1996.

Course Code: **PMATD30210** Title of the Course: **Classical Mechanics**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understanding the basic concepts of Mechanics to develop the equations of motion for a system of particles

CLO-2: analyse the motion of a rigid body under translation.

CLO-3: analyse the motion of a rigid body under rotation about a fixed point.

CLO-4: develop Euler's and Lagrange's equations of motion

CLO-5: develop Hamiltonian equation of motion

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	3		2	2	1	1	1	3	1
CLO2	1	3	1	3	2	1	1	1	3	1
CLO3	1	3	1	2	2	1	1	1	3	2
CLO4	2	3		2	2	1	1	1	3	2
CLO5	1	3		2	2	1	1	2	3	1

Course Details:

Unit 1: Generalized coordinates, the Principle of least action, Galileo's relativity principle, the Lagrangian for a free particle, Lagrangian for a system of particle, energy, momentum, centre of mass, angular momentum, motion in one dimension, determination of the potential energy from the period of oscillation, the reduced mass, motion in a central field.

Unit 2: Free oscillation in one-dimension, angular velocity, the inertia tensor, angular momentum of a rigid body, the equation of motion of a rigid body, Eulerian angle, Euler's equation.

Unit 3: The Hamilton's equation, the Routhian, Poisson brackets, the action as a function of the coordinates, Maupertui's principle.

Unit 4: The Canonical transformation, Liouville's theorem, the Hamiltonian – Jacobi equation, separation of the variables, adiabatic invariants, canonical Variables.

Reference Books:

1. F. Chorlton (1985), *Textbook on Dynamics*, CBS Pubs, New Delhi.
2. L. D. Landau and E. M. Lifshitz (1984) - *Mechanics*, (Third Edition), Butter worth – Heinenann.
3. J. L. Synge and B. A. Griffith (1987), *Principles of Mechanics*, McGraw Hill.
4. G. R. Fowles and G. L. Cassiday (2004), *Analytical Mechanics*, Cengage.
5. Herbert Goldstein, *Classical mechanics*, Narosa.
6. K. C. Gupta, *Classical mechanics of particles and Rigid Bodies*, Wiley Eastern.
7. M. G. Calkin, *Lagrangian and Hamiltonian Mechanics*, World Scientific.

Course code: **PMATD30211** Title of the Course**: Number Theory**

L-T-P: **3-0-0** Credits:**3**

Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will able to

CLO-1: understand better the distribution of prime numbers.

CLO-2: learn different arithmetical functions and apply to the distribution to lattice point visible from the origin.

CLO-3: understand finite and infinite continued fractions.

CLO-4: learn some of the fundamental results in the number theory due to Euler, Jacobi and Ramanujan.

CLO-5: work effectively as part of a group to solve challenging problems in Number Theory.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	2	1	2	3	1	1	1	3	1
CLO2	3	2	1	2	3	1	1	1	3	1
CLO3	3	2	1	2	3	1	1	1	3	1
CLO4	3	2	1	2	3	1	1	1	1	1
CLO5	3	2	1	2	3	1	1	1		1

Course Details:

Unit 1: Prime numbers, The Fundamental theorem of Arithmetic, The series of Reciprocals of primes, The Euclidean Algorithm. Fermat and Mersenne numbers. Farey series, Farey dissection of the continuum, Irrational numbers-Irrationality of m^{th} root of N, e and π.

Unit 2: Arithmetical Functions – The Mobius function, The Euler' function and Sigma function, The Dirichlets product of Arithmetical functions, Multiplicative functions. Averages of Arithmetical functions – Euler summation formula, Some elementary asymptotic formulas, The average orders of d(n), σ(n), φ(n), μ(n). An application to the distribution of lattice points visible from the origin.

Unit 3: Continued fractions - Finite continued fractions, Convergent of a continued fraction, Continued fractions with positive quotients. Simple continued fractions, The representation of an irreducible rational fraction by a simple continued fraction. The continued fraction algorithm and Euclid's algorithm. The difference between the fraction and its convergents, Infinite simple continued fractions, the representation of an irrational number by an infinite continued fraction, Equivalent numbers and periodic continued fractions, some special quadratic surds, The Riemann zeta function and Dirichlets theorem.

Unit 4: Introduction to partitions, geometric representation, generation functions, Euler's pentagonal number theorem, Jacobi triple product identity, recurrence formula for p(n), Ramanujan's congruences-$p(5n+4) \equiv 0 \pmod 5$, $p(7n+5) \equiv 0 \pmod 7$ and $p(11n+6) \equiv 0 \ (\mathrm{mod} 11)$.

Course References:

1. G. E. Andrews (1976), The Theory of Partitions, Addison Wesley.
2. G. H. Hardy and E. M. Wright (1979), An Introduction to Theory of Numbers, Oxford University Press, 5thEd.
3. I. Niven, H. S. Zuckerman and H. L. Montgomery (2004), An Introduction to the Theory of Numbers, New York, John Wiley and Sons, Inc., 5thEd.
4. Bruce C. Berndt – Ramanujan's Note Books Volume-1 to 5, Springer.
5. G. E. Andrews (1995), Number Theory, Dover Books.
6. T. M. Apostol, Introduction to Analytic Number Theory, Narosa Publishing House, New Delhi.

Course Code: **PMATD30212** Title of the Course: **Mathematical Modeling**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understand what a mathematical model is and explain the series of steps involved in a mathematical modelling process.

CLO-2: explain the essential features of a good model and discuss the benefits of using a mathematical model.

CLO-3: identify some simple real-life problems that can be solved using mathematical models, model the problem(s), solve the resulting problem, and interpret the solution.

CLO-4: mention and discuss some applications of mathematical modelling in solving problems in engineering, physical, biological, social and behavioral sciences.

CLO-5: acquire basic mathematical modelling skills that will enable them carry out simple modelling tasks individually or as a group.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	2	2	1	1		
CLO2		3			3		3			
CLO3	1	2				2	2			
CLO4		1		2	2			2		2
CLO5					5	2		2		3

Course Details:

Meaning of first and second order ordinary derivatives – slope of a tangent and curvature. Connecting these concepts to practical observation. Basic concepts. Real world problems, (Physics, Chemistry, Biology, Economics, and others) Approximation of the problem, Steps involved in modeling. Microbial population models – Single species nonage-structured population models – age structured population models – two species population models – multispecies population models – optimal exploitation models – epidemic models – models in genetics – mathematical models in pharmacokinetics – models for blood flows – models for other biofluids – diffusion and diffusion reaction models – optimization models in biology and medicine.

Course References:

1. J. N. Kapur : Mathematical Moodelling, Wiley Eastern Ltd., 1998.

2. W.J.Meyer, Concepts of Mathematical Modelling, McGraw Hill, Tokyo, 1985.

3. Neil Gerschenfeld : The nature of Mathematical modeling, Cambridge Univeristy Press, 1999.

4. A. C. Fowler : Mathematical Models in Applied Sciences, Cambridge Univeristy Press, 1997.

Course Code: **PMATD30213** Title of the Course: **Data Structures**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: choose appropriate data structure as applied to specified problem definition.

CLO-2: handle operations like searching, insertion, deletion, traversing mechanism etc. on various data structures.

CLO-3: apply concepts learned in various domains like DBMS, compiler construction etc.

CLO-4: use linear and non-linear data structures like stacks, queues, linked list.

CLO-5: learn searching and sorting techniques.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	2	1	2	1	1	1	1	3	1
CLO2	1	3		2	1	1	2	2	3	2
CLO3	1	3	1	3	2	2	1	1	3	2
CLO4	2	3		2	2	1	1	1	3	2
CLO5	1	2	2	2	1	3	1	2	3	1

Course Details:

Unit 1: Basic programming, time and space complexity, Data Structures – Introduction to Data Structures, abstract data types, Linear list – singly linked list implementation, insertion, deletion and searching operations on linear list, circular linked list implementation, Double linked list implementation, insertion, deletion and searching operations. Applications of linked lists.

Unit 2: Stacks-Operations, array and linked representations of stacks, stack applications -infix to postfix conversion, postfix expression evaluation, recursion implementation. .

Unit 3: Queues-operations, array and linked representations. Circular Queue operations, Dequeues, applications of queues.

Unit 4: Searching and Sorting – Sorting- selection sort, bubble sort, insertion sort, quick sort, merge sort, shell sort, radix sort, Searching-linear and binary search methods, comparison of sorting and searching methods. Trees – Definitions, tree representation, properties of trees, Binary tree, Binary tree representation, binary tree properties, binary tree traversals, binary tree implementation, applications of trees.

TEXT BOOKS:

1. Fundamentals of Data structures in C, 2nd Edition, E.Horowitz, S.Sahni and Susan Anderson-Freed, Universities Press.

2. Data structures A Programming Approach with C, D.S.Kushwaha and A.K.Misra, PHI.

REFERENCE BOOKS:

1. Data structures: A Pseudocode Approach with C, 2nd edition,

2. R.F.GilbergAndB.A.Forouzan, CengageLearning.

3. Data structures and Algorithm Analysis in C, 2nd edition, M.A.Weiss, Pearson.

4. Data Structures using C, A.M.Tanenbaum,Y. Langsam, M.J.Augenstein, Pearson.

5. Data structures and Program Design in C, 2nd edition, R.Kruse, C.L.Tondo and B.Leung,Pearson

Course code**: PMATD30214** Title of the Course**: Graph Theory**
L-T-P: **3-0-0** Credits:**3**

Course Learning Outcomes (CLOs)

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

CLO-1: know some important classes of graph theoretic problems
CLO-2: formulate and prove central theorems about trees, matching, connectivity, colouring and planar graphs

CLO-3: describe and apply some basic algorithms for graphs

CLO-4: use graph theory as a modelling tool

CLO-5: discuss and understand the importance of the concepts of Coverings and Independence.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	2	1	1	1	1	1	2	3	1
CLO2	3	1	1	2	1	1	1	2	3	1
CLO3	3	2	1	1	1	1	1	2	3	1
CLO4	3	2	1	2	1	1	1	2	3	1
CLO5	3	2	1	2	1	1	1	2	3	1

Course Details:

Unit 1: Connectivity: - Cut- vertex, Bridge, Blocks, Vertex-connectivity, Edge-connectivity and some external problems, Mengers Theorems, Properties of n-connected graphs with respect to vertices and edges. Planarity: - Plane and Planar graphs, Euler Identity, Non planar graphs, Maximal planar graph Outer planar graphs, Maximal outer planar graphs, Characterization of planar graphs, Geometric dual, Crossing number.

Unit 2: Colorability: - Vertex Coloring, Color class, n-coloring, Chromatic index of a graph, Chromatic number of standard graphs, Bichromatic graphs, Colorings in critical graphs, Relation between chromatic number and clique number/independence number/maximum degree, Edge coloring, Edge chromatic number of standard graphs Coloring of a plane map, Four color problem, Five color theorem, Uniquely colorable graph. Chromatic polynomial. Matchings and factorization: -Matching- perfect matching, augmenting paths, maximum matching, Hall's theorem for bipartite graphs, the personnel assignment problem, a matching algorithm for bipartite graphs, Factorizations, 1-factorization, 2-factorization. Partitions-degree sequence, Havel's and Hakimi algorithms and graphical related problems.

Unit 3: Directed Graphs: - Preliminaries of digraph, Oriented graph, in degree and out degree, Elementary theorems in digraph, Types of digraph, Tournament, Cyclic and transitive tournament, Spanning path in a tournament, Tournament with a Hamiltonian path, strongly connected tournaments.

Unit 4: Domination concepts and other variants: - Dominating sets in graphs, domination number of standard graphs, Minimal dominating set, Bounds of domination number in terms of size, order, degree, diameter, covering and independence number, Domatic number, domatic number of standard graphs.

References:

1. F. Harary: Graph Theory, Addison -Wesley,1969
2. G. Chartrand and Ping Zhang: Introduction to Graph Theory. McGraw-Hill, International edition (2005)
3. J. A. Bondy and V. S. R. Murthy: Graph Theory with Applications, Macmillan, London, (2004)
4. D. B. West, Introduction to Graph Theory, Pearson Education Asia, 2nd Edition, 2002.
5. Charatrand and L. Lesnaik-Foster: Graph and Digraphs, CRC Press (Third Edition), 2010.

6. T.W. Haynes, S.T. Hedetneime and P. J. Slater: Fundamental of domination in graphs, Marcel Dekker. Inc. New York.1998.
7. J. Gross and J. Yellen: Graph Theory and its application, CRC Press LLC, Boca Raton, Florida, 2000. 5. Norman Biggs: Algebraic Graph Theory, Cambridge University Press (2nd Ed.)1996.
8. Godsil and Royle: Algebraic Graph Theory: Springer Verlag, 2002.
9. N. Deo: Graph Theory: Prentice Hall of India Pvt. Ltd. New Delhi – 1990.

Course Code: **PMATD30215** Title of the Course: **Tensor Analysis**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understanding the basic definitions of tensors.

CLO-2: analyse the applications of tensors.

CLO-3: expose students to mathematical applications of tensor algebra to handle diverse problems which occur in real life situations.

CLO-4: competently use tensor algebra as a tool in the field of applied sciences and related fields.

CLO-5: develop the concepts of tensors.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	3		2	2	1	1	2	3	1
CLO2	1	3		3	2	2	2	2	2	2
CLO3	1	3	1	2	2	2	1	2	2	2
CLO4	1	3	1	2	2	2	1	2	2	2
CLO5	2	3	1	2	2	2	1	2	3	2

Course Details:

Unit 1: N-dimensional space, summation convention and indicial notation, coordinate transformation and Jacobian, covariant and contravariant vectors, contraction.

Unit 2: Second and higher order tensors, quotient law, fundamental tensor, associate tensor etc.

Unit 3: Angle between the vectors, principal directions, Christoffel symbols, parallel propagation of vectors.

Unit 4: Covariant and intrinsic derivatives, geodesics. Curvature tensor and its properties, Bianchi identity, Curl, Divergence and Laplacian operators in tensor form, Physical components. Applications of tensors.

Reference Books:

1. Barry Spain, Tensor Calculus, Dover Publications, 2003.
2. K.K. Dube, Differential Geometry and Tensors, I.K. Int. Publ. house Pvt. Ltd. New Delhi, 2009.
3. B.P. Singh et al., Differential Geometry and Tensor analysis, Krishna Prakashan, Meerut, 2013.

List of Discipline Specific Electives-II (III Semester)

Course Code: **PMATD30217** Title of the Course: **Finite Difference Methods**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: solve the linear and non-linear initial value problems in ordinary differential equations using the shooting method.

CLO-2: solve the linear and non-linear initial value problems in ordinary differential equations using the explicit and implicit multistep methods.

CLO-3: solve the heat equation, wave equation and the Laplace equation in one dimensional and 2- dimensional space using the finite difference methods.

CLO-4: find the stability, convergence and the error analysis of the finite difference methods**.**

CLO-5: extend their knowledge of finite difference techniques for further exploration of the subject for going into research.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		1	2		2	1		2
CLO2	3	3		2	2		2	2	1	2
CLO3	3	3		3	3		2	2		3
CLO4	3	3		2	2		2	1		3
CLO5				2	2		2	2	3	2

Course Details:

Unit 1: Multistep (Explicit and Implicit) methods for Initial value problems, stability and convergence analysis, linear and nonlinear boundary value problems, shooting methods.

Unit 2: Finite difference approximations for ordinary derivatives and finite difference scheme for ordinary differential equations with explicit boundary conditions, implicit boundary conditions, error analysis, stability analysis, convergence analysis.

Unit 3: Finite difference approximations for partial derivatives and finite difference schemes for Parabolic equations: Schmidt's two level, multilevel explicit methods, Crank-Nicolson's two level, multilevel implicit methods, Dirichlet's problem, Neumann problem, mixed boundary value problem.

Unit 4: Hyperbolic Equations: Explicit methods, implicit methods, one space dimension, two space dimensions, ADI methods. Elliptic equations: Laplace equation, Poisson equation, iterative schemes, Dirichlet's problem, Neumann problem, mixed boundary value problem, ADI methods

Course Reference:

1. M.K. Jain (1985), Numerical Solution of Differential Equations, Wiley Eastern, Delhi.
2. G.D. Smith (2004), Numerical Solution of Partial Differential Equations, Oxford University Press.
3. M.K. Jain, S.R.K. Iyengar and R.K. Jain (2002), Computational Methods for Partial Differential Equations, Wiley Eastern.
4. J. D. Lambert (1991), Numerical methods for Ordinary Differential equations, John Wiley & Sons.
5. P. Henrici (1962), Discrete Variable Methods in Ordinary Differential Equations, John Wiley & Sons, New York.
6. Richard K. Miller (1991), Introduction to Differential Equations, Prentice Hall, New Jersey.
7. J. D. Hoffman (2000), Numerical methods for Engineers and Scientists, Mc-Graw Hill.

Course code: **PMATD30218** Title of the Course**: Differential Geometry**

L-T-P: **3-0-0** Credits:**3**

Course Learning Outcomes (CLOs)

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

CLO-1: explain the concepts and language of differential geometry and its role in modern mathematics.

CLO-2: analyze and solve complex problems using appropriate techniques from differential geometry.

CLO-3: apply problem-solving with differential geometry to diverse situations in physics, engineering or other mathematical contexts.

CLO-4: apply differential geometry techniques to specific research problems in mathematics or other fields.

CLO-5: compute quantities of geometric interest such as curvature, as well as develop a facility to compute in various specialized systems, such as semi geodesic coordinates or ones representing asymptotic lines or principal curvatures.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	2	2	2	2	2	1	1	1	1
CLO2	3	2	2	2	2	2	1	1	2	1
CLO3	3	2	2	2	2	2	1	1	1	1
CLO4	3	2	2	2	2	2	1	1	1	1
CLO5	3	2	2	2	2	2	1	1	1	1

Course Details:

Unit 1: Plane curves and Space curves – Frenet-Serret Formulae. Global properties of curves – Simple closed curves, The isoperimetric inequality, The Four Vertex theorem. Surfaces in three dimensions – Smooth surfaces, Tangents, Normals and Orientability, Quadric surfaces.

UNIT 2: The First Fundamental form – The lengths of curves on surfaces, Isometries of surfaces, Conformal mappings of surfaces, Surface area, Equiareal Maps and a theorem of Archimedes.

UNIT 3: Curvature of surfaces – The Second Fundamental form, The Curvature of curves on a surface, Normal and Principal Curvatures.

UNIT 4: Gaussian Curvature and The Gauss' Map – The Gaussian and The Mean Curvatures, The Pseudo sphere, Flat surfaces, Surfaces of Constant Mean Curvature, Gaussian Curvature of Compact surfaces, The Gauss' Map.

References:

1. Pressley, Elementary Differential Geometry, Under-graduate Mathematics Series, Springer.
2. T. J. Willmore, An Introduction to Differential Geometry, Oxford University Press.
3. D. Somasundaram, Differential Geometry: A First Course, Narosa, 2000.
4. M. doCarmo, Differential Geometry of Curves and Surfaces, Prentice Hall, 1976.
5. O'Neill, Elementary Differential Geometry, Academic Press, New York,1966.
6. J.J. Stoker, Differential Geometry, Wiley-Interscience, 1969.
7. J.A. Thorpe, Elementary Topics in Differential Geometry, Springer (India), 2004.

Course Code: **PMATD30219** Title of the Course: **Design & Analysis of Algorithms**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understand the basic concepts of algorithms and analysis.

CLO-2: analyse time and space complexity.

CLO-3: understand algorithm design methodology.

CLO-4: apply important algorithm methodology to solve problems.

CLO-5: understand the difference between P and NP classes of problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	2	1	2	1	1	1	1	3	1
CLO2	1	3		2	1	1	2	2	3	2
CLO3	1	3	1	3	2	2	1	1	3	2
CLO4	2	3		2	2	1	1	1	3	2
CLO5	1	2	2	2	1	3	1	2	3	1

Course Details:

Unit 1: Analyzing Algorithms: Concepts in Algorithms Analysis – asymptotic complexity of algorithms –Growth functions Recurrences. Master Theorem.

Divide and Conquer Method: Binary Search, Quick Sort, Expected Running Time of Randomized Quick Sort, Merge Sort, Strassen's Matrix Multiplication Algorithm.

Unit 2: Data Structures for Set manipulation problems: Binary tree traversal algorithms, disjoint-set union algorithms.

Graph Algorithms: Representations of graphs – Breadth-first search – Depth-first search – Minimum spanning tree – The algorithms of Kruskal and Prim – Shortest paths – Dijkstra's algorithm.

Unit 3: Greedy Method: Activity Selection Problem, Knapsack Problem, single source shortest path problem.

Dynamic Programming: Solution to 0-1 Knapsack Problem, multistage graphs, TSP using Dynamic Programming Backtracking: Basic examples, N-Queen's Problem, sum of subsets problem.

Unit 4: Complexity Classes: Example NP-complete problems

Reference Books:

1. Cormen T.H., Leiserson C.E., Rivest R.L. and C. Stein, Introduction to Algorithms, 3rd Edition, PHI, New Delhi, 2004.
2. Horowitz E., Sahni S. and Rajasekaran S., Fundamentals of Computer Algorithms, Second Edition, Universities Press, 2011.
3. Aho A V, Hopcroft J E, and Ullman J.D., The Design and Analysis of Computer Algorithms, Pearson, 10 th Impression, New Delhi, 2012.
4. Baase S. and Gelder A.V., Computer Algorithms: Introduction to Design and Analysis, 3rd Edition, Addison and Wesley, 2000.
5. Levitin A., Introduction to the Design and Analysis of Algorithms, 2nd Impression, Pearson Education, New Delhi, 2009.

Course Code: **PMATD30220** Title of the Course: **Continuum Mechanics**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understand the concept of components of a tensor, Transpose of a tensor, Symmetric & Anti-symmetric tensor, Principal values and directions.

CLO-2: understand and apply the concepts Rate of deformation, Conservation of mass, Compatibility conditions.

CLO-3: understand the Principal Stresses, Equations of motion, Boundary conditions.

CLO-4: understand the concepts of Isotropic solid and Equations of infinitesimal theory.

CLO-5: solve the Examples of elastodynamics electrostatics.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		3	2	1		2	1	
CLO2	3	3		3	2	1		2	1	
CLO3	3	2		2	2	1		2	1	
CLO4	3	3		3	2	1		2	1	
CLO5	3	3		2	2	1		2	1	

Course Details:

Unit-1: Tensors: Summation Convention, Components of a tensor, Transpose of a tensor, Symmetric & anti-symmetric tensor, Principal values and directions, Scalar invariants.

Unit-2: Kinematics of a Continuum: Material and Spatial descriptions, Material derivative, Deformation, Principal Strain, Rate of deformation, Conservation of mass, Compatibility conditions.

Unit-3: Stress: Stress vector and tensor, Components of a stress tensor, Symmetry, Principal Stresses, Equations of motion, Boundary conditions.

Unit-4: Linear Elastic Solid: Isotropic solid, Equations of infinitesimal theory, Examples of elastodynamics electrostatics.

Course References:

1. W.M. Lai, Rubin D. and Krempel E. (1974), Introduction to Continuum Mechanics, Pergamon Unified Engineering Series,
2. S.C. Hunter (1983), Mechanics of Continuous Media, Ellis Harwood Series.
3. T.J.Chung (1988), Continuum Mechanic, Prentice Hall.
4. D.S. Chandrasekhraiah and Loknath Debnath (1995), Contiuum Mechanics, Academic Press.

Course code: **PMATD30221** Title of the Course: **Ramanujan's Theta Functions**

L-T-P: **3-0-0** Credits:**3**

Course Learning Outcomes (CLOs)

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

CLO-1: know the importance of Jacobi's triple product identity and Ramanujan's continued fractions.

CLO-2: prove deep theorems on q-series.

CLO-3: discuss and understand the importance of the concepts of Ramanujan's mathematics.

CLO-4: understand some theta function identities mentioned in the Chapter 16 of Ramanujan's notebook III.

CLO-5: work effectively as part of a group to solve challenging problems in Number Theory.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	2	1	2	1	1	1	1		1
CLO2	3	2	1	2	1	1	1	1		1
CLO3	3	2	1	2	1	1	1	1		1
CLO4	3	2	1	2	1	1	1	1		1
CLO5	3	2	1	2	1	1	1	1		1

Course Details:

Unit-1: Ramanujan's general theta-function, special cases and their relations, q-series and infinite products, Jacobi triple product identity.
Unit-2: Schröter's formulae and theta-function identities and Ramanujan's Modular equations.
Unit-3: Class invariants, Evaluation of class invariants, Explicit values of theta-functions.
Unit-4: Ramanujan's continued fractions and explicit values.

References:

1. Berndt, B. C. Number Theory in the Spirit of Ramanujan (AMS, 2006).
2. Andrews, George E., The Theory of Partitions (Addition-Wesley, Reading, MA, 1976).
3. Berndt, Bruce C., Ramanujan's Notebooks, Part III, IV and V (Springer, 1991, 1994, 1998).
4. Whittaker, E. T. and Wilson, G. N., A Course in Modern Analysis (Cambridge University Press, Cambridge, 1966. Indian edition is published by Universal Book Stall, New Delhi, 1991).
5. Agarwal, R. P., Resonance of Ramanujan's Mathematics, Vol. I & II (New Age International (P) Limited, New Delhi, 1996).
6. Hardy, G. H., Ramanujan (AMS-Chelsea, New York 1999).

Course Code: **PMATD30222** Title of the Course: **Fuzzy Sets and Fuzzy logic**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understand basic knowledge of the Fuzzy sets, operations and their properties.

CLO-2: understand the fundamental concepts of Fuzzy functions and Fuzzy logic.

CLO-3: determine the maximum and minimum of fuzzy functions.

CLO-4: understand the concepts of classical logic, multi-valued logics, Fuzzy quantifiers, linguistic hedges.

CLO-5: apply the concepts of Fuzzy sets in image processing, Pattern reorganization and decision making.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	3	3	2	2	1	3		1
CLO2	3	3	1	3	2	2	1	2		1
CLO3	3	3	2	3	2	2	2	3		1
CLO4	3	3	1	3	2	2	1	2		1
CLO5	2	3	1	3	2	2	3	2		3

Course Details:

Unit 1: Basic concepts of fuzzy set, t-norm, t-conorms, membership function, α-cut, Algebra of fuzzy sets, distance between fuzzy sets, fuzzy relation. Fuzzy numbers, Arithmetic operations of fuzzy numbers, Extension principle, Interval arithmetic, Defuzzification.

Unit 2: Fuzzy valued functions, fuzzy equations, fuzzy inequalities, system of fuzzy. Linear equations, maximum and minimum of fuzzy functions.

Unit 3: Classical Logic – Multi-valued Logics – Fuzzy Propositions – Fuzzy Quantifiers – Linguistic hedges – Inference from conditional Fuzzy proposition.

Unit 4: Fuzzy sets in Decision making, Optimization in Fuzzy environment, Fuzzy set application in image processing , Fuzzy set application in Pattern reorganization.

Course References:

1. George J.Klir and Bu Yuan, Fuzzy sets and Fuzzy logic Theory and applications, Prentice Hall of India, New Delhi.
2. Didier Bubois and Henri Prade , Fuzzy sets and systems , Academic Press.
3. James J Buckley, Esfandiar Eslami ,An Introduction to Fuzzy logic and Fuzzy sets, Springer.
4. J. C. Pant (2012), Introduction to Operations Research, Jain Brothers, New Delhi.
5. H.J.Zimmernman, Fuzzy set theory and application (Allied Publication in Association with KLUWER).

Course Code: **PMATD30223** Title of the Course: **Lie Group Theory and Applications**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understand basic knowledge of group, group of transformations.

CLO-2: understand the fundamental concepts Lie group, infinitesimal generators, invariant functions, canonical coordinates.

CLO-3: understand the fundamental invariance curves, invariant surfaces, invariant point, mapping of curves and surfaces, canonical coordinates.

CLO-4: determination of first order ordinary differential equations invariant under a given group.

CLO-5: determination of higher order ordinary differential equations invariant under a given group.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	1	3	2	1	1	2		1
CLO2	3	3	1	3	2	1	1	2		1
CLO3	3	3	1	3	2	1	2	3		1
CLO4	2	3	1	3	2	2	3	3		3
CLO5	2	3	1	3	2	2	3	3		3

Course Details:

Unit 1: Basic concepts of group, group of transformations, one-parameter Lie groups of transformations. Fundamental theorems of Lie group, infinitesimal generators, invariant functions, canonical coordinates.

Unit 2: Extended group of point transformations, extended infinitesimal transformations for one independent variable and one dependence variable, n independent variable and one dependence variable, n independent variable and n dependence variable; multi point Lie group of transformations, Lie algebras, solvable lie algebras.

Unit 3: Invariance curves, invariant surfaces, invariant point, mapping of curves and surfaces, canonical coordinates, determining equation for symmetries of a first order ODE, Invariance of an first ODE under a given group.

Unit 4: Reduction of order of the second and higher order ODEs through canonical coordinates and differential invariants, Determine the second and higher order ODEs invariant under lie group, multiparameter lie group. Invariance of overdetermined system of ODEs under an mutliparameter lie group with solvable Lie algebra.

Course References:

1. Bluman, G. W. and Kumei, S.(1989), Symmetries and Differential Equations, Springer Verlag, Heidelberg, Berlin,.
2. Bluman, G. W. and Cole, J. D.(1974) , Similarity Methods for Differential Equations, Applied Mathematical Sciences, Vol. 13. Springer-Verlag, New York-Heidelberg,
3. Hydon, P.E. (2000), Symmetry methods for differential equations: a beginner's guide, Cambridge University Press.
4. P. Olver(1993), Application of lie Groups to Differential Equations, Springer, NY.
5. H. Stephani(1989), Differential Equations: Their Solutions Using Symmetries, Cambridge Univ. Press, NY.
6. Bluman, G. W., Cheviakov, A. F. and Anco, S. C.(2010), Applications of Symmetry Methods to Partial Differential Equations, Applied Mathematical Sciences, 168, Springer.

Semester-IV

Course code**: PMATC40015** Title of the Course**: Measure & Integration**
L-T-P: **3-1-0** Credits:**4**

Course Learning Outcomes (CLOs)

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

CLO-1: know the Lebesgue measure can be viewed as a natural generalization of length to sets that are more complicated than intervals or finite unions of intervals.

CLO-2: understand the construction of the Lebesgue integral and know its key properties.

CLO-3: verify whether a given subset of R or a real valued function is measurable.

CLO-4: understanding that Lebesgue integration can solve certain problems for which Riemann integration does not provide adequate answers.

CLO-5: prove the basic results of measure theory and integration theory.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2	1	1	2	2	1	1	3	1
CLO2	3	2	1	1	2	1	1	1	3	1
CLO3	3	2	1	1	2	1	1	1	3	1
CLO4	3	2	1	1	2	2	1	1	3	1
CLO5	3	2	1	1	2	1	1	1	3	1

Course Details:

Unit 1: Algebra of sets, sigma algebras of sets, Borel subsets of R, F_σ and G_δ sets, Lebesgue outer measure and its properties, algebra of measurable sets in R, Existence of a non-measurable set, Measurability of Cantor set, Lebesgue measure and its properties.

Unit 2: Lebesgue Measurable functions and their properties, Convergence pointwise and convergence in measures of a sequence of measurable functions, Littlewood's three principles and Egoroff's Theorem, Characteristic function of a set, simple function.

Unit 3: Lebesgue integral of simple functions, Lebesgue integral of bounded functions, Bounded convergence theorem, Comparison of Riemann and Lebesgue integral. Lebesgue integral of non-negative functions, Fatou's Lemma, Monotone convergence theorem, Lebesgue general integral, Lebesgue dominated convergence theorem.

Unit 4: Differentiation of Monotone functions, Vitali covering lemma, Differentiability of an integral, Absolute continuity and indefinite integrals, L^p spaces, Holder and Minkowski inequalities, Convergence and completeness, Riesz – Fischer Theorem, Bounded linear functionals Riesz representation theorem and illustrative examples, Measure spaces, Signed measures, the Radon Nikodyn theorem.

References:

1. H.L. Royden (1995), Real Analysis, 3rd Edition, Prentice-Hall of India.
2. G. de Barra (2014), Measure and Integration, 2nd Edition, New Age International (P) Ltd., New Delhi.
3. Inder K Rana (2005), An Introduction to Measure and Integration, Narosa Publishing House India.
4. P.R. Halmos (1962), Measure Theory, East West Press.
5. W. Rudin (1966), Real & Complex Analysis, McGraw Hill.

Course Code: **PMATC40016** Title of the Course: **Operations Research**

L-T-P: **3-1-0** Credits: **4**

Course Learning Outcomes (CLOs)

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

CLO-1: formulation of an LPP and understand graphical solution. Also, understand Optimization models and apply them to real life problems.

CLO-2: determine the solution of an LPP by simplex methods.

CLO-3: application of post optimality analysis. Determine the solution of transportation and assignment problems.

CLO-4: determine the characteristics of a queuing model.

CLO-5: determine the EOQ for an inventory model.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	3	3	2	2	2	3	3	2
CLO2	2	3	1	3	2	2	3	2	3	2
CLO3	1	3	2	3	2	2	2	3	3	2
CLO4	1	3	1	3	2	2	1	2	3	1
CLO5	2	3	1	3	2	2	1	2	3	2

Course Details:

Unit 1: Linear Programming: Lines and hyperplanes - convex sets, convex hull -Formulation of a Linear Programming Problem - Theorems dealing with vertices of feasible regions and optimality - Graphical solution - Simplex method (including Big M method and two phase method) – Dual problem - duality theory - dual simplex method - sensitivity analysis - revised simplex method - parametric programming.

Unit 2: Transportation problem - existence of solution - degeneracy - MODI method (including the theory). Assignment problem – travelling salesman problem.

Unit 3: Queuing theory: Characteristics of queueing systems - the birth and death process - steady state solutions – single server model (finite and infinite capacities) - single server model (with SIRO) - models with state dependent arrival and service rates- waiting time distributions.

Unit 4: Inventory Control: Inventory control for single commodity - deterministic inventory models (without and with shortages) - Probabilistic inventory (both discrete and continuous) control models.

Reference Books:

1. H. A. Taha (2014), *Operations Research, An Introduction*, PHI, New Delhi.
2. N. S. Kambo (1991), *Mathematical Programming Techniques*, East-West Pub., Delhi.
3. Kanti Swarup, P. K. Gupta and Man Mohan (2010), *Operations Research*, Sultan Chand and Co, New Delhi.
4. J. C. Pant (2012), *Introduction to Operations Research*, Jain Brothers, New Delhi.
5. H. M. Wagner (2010), *Principles of Operations Research*, PHI, Delhi.
6. J. C. Pant (2015), *Introduction to Optimization: Operations Research*, Jain Brothers, Delhi.

Course Code: **PMACA40104** Title of the Course: **Computing Laboratory-IV**

L-T-P: **1-0-3** Credits: **2**

Course Learning Outcomes (CLOs)

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

CLO-1: understand the basic operations in Scilab.

CLO-2: perform the mathematical operations using Scilab.

CLO-3: understand the usage of Tec plot and Latex.

CLO-4: perform the mathematical operations using above software.

CLO-5: apply the above Programming knowledge for solving the problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3			2		2	2	2		1
CLO2	2	2		2	2	2	3	2		1
CLO3	2	3		2	1	1	3	1		1
CLO4	2	3		2	1	1	2	1		1
CLO5	3	3		3	3		3	2		1

Course Details:

Introduction to open source Software like scilab, maxima, octave, geogebraand etc.

Introduction to Tecplot 360 CFD Software.

Introduction to LATEX Software.

8-10 Programs on Operations Research, Computational Fluid Dynamics & Finite element method using Any Software.

Course Reference:

1. Latex: A Document Preparation System, 2/E, Lamport , 1994.
2. Introduction to Scilab For Engineers and Scientists, Sandeep Nagar · 2017
3. TECHPLOT, Graphics Production Software, Charlotte H. Middlebrooks · 1985

Course Code: **PMARC40017** Title of the Course: **Research Training & Project Report**

L-T-P: **0-3-6** Credits: **6**

Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will

CLO-1: learn basic mathematical and research knowledge and understanding of core research material, literature etc.

CLO-2: learn conceptual grasp of issues, quality of argument and ability to answer questions in the viva-voce examination.

CLO-3: learn how to maintain quality of management in terms of pacing of presentation, effective use of research material, organization/structure of research material etc.

CLO-4: learn how to improve quality of communication.

CLO-5: learn how to become a good researcher or teacher.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	3	2	3	3	3	3	3		3
CLO2	3	3	3	3	3	3	3	3		3
CLO3	2	2	3	2	2	3	1	3		3
CLO4	1	1	3	1	1	3		2		3
CLO5	2	2	3	2	2	3	1	3		3

Course Details: Research Training & Project Report course is included in the 4th Semester to train/expose students to the research activity. The project report must be carried out on a topic chosen by the student under the guidance of a faculty member from the Department. In case of interdisciplinary projects, a co-guide can be chosen from other Departments, if necessary. The project supervisor will periodically review the student progress over the semester. The progress of the work will be evaluated in the middle of the semester by the department committee. Students have to submit two copies of project report to the Head of Department before the last working day of the Semester. Finally, the student has to present the findings of his research project for the final evaluation.

Evaluation scheme: 40 % Continuous Evaluation by the Guide and 60% by the Expert Committee at the end of the Semester. The Expert Committee may be constituted by the Department with at least four members; i) HOD, ii) supervisor, iii) subject expert of the Department and iv) programme coordinator of the Department. The expert committee can invite the additional subject experts for the evaluation of the project report or viva voce, if necessary.

Course Code: **PMATA40105** Title of the Course: **Comprehensive Viva**

L-T-P: **0-0-2** Credits: **2**

Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will

CLO-1: learn Mathematical knowledge and understanding of core material.

CLO-2: learn conceptual grasp of issues, quality of argument and ability to answer questions.

CLO-3: learn how to face the interviews.

CLO-4: learn how to improve quality of communication.

CLO-5: learn how to become a good teacher or researcher. Also, students will learn to clear competitive exams like CSIR, NET/SET and Gate etc.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3	2	3	3	3	3	3	3	3
CLO2	3	3	3	3	3	2	3	3	3	3
CLO3	1	1	3	1	1	1	1	1		3
CLO4	1	1	3	1	1	1	1	1		3
CLO5	3	3	3	3	3	3	3	3	3	3

Course Details: Comprehensive Viva (ORAL Examination) is included in the 4th Semester to assess the overall Mathematical knowledge of the students in the subjects they have studied during the 2-year programme. Each student has to appear for comprehensive viva in front of the panel of examiners. Also, a mentor faculty will be allotted for each student to train the Comprehensive Viva course. 100% Evaluation by the Expert Committee at the end of the Semester. The Expert Committee may be constituted by the Department with at least three members; i) HOD, ii) programme coordinator of the Department and iii) subject experts of the Department. The expert committee can invite the additional subject experts for the evaluation, if necessary. The comprehensive viva helps the students to face the interview or any other competitive exams.

List of Discipline Specific Electives-III (IV Semester)

Course Code: **PMATD40225** Title of the Course: **Calculus of Variations and Finite Element Method**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: determine an extremum by calculus of variations approach

CLO-2: formation of a variational problem for a boundary value problem

CLO-3: solution of one dimensional problem

CLO-4: solution of two dimensional problems by rectangular and triangular elements

CLO-5: extend their knowledge of finite difference techniques for further exploration of the subject for going into research.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3			2		2		3	3
CLO2	3	3		2	2		1		1	1
CLO3	3	3		2	2		2	1		2
CLO4	3	3		2	2		3	1		2
CLO5				2				2		3

Course Details:

Unit 1: Introduction to calculus of variations, variation of a functional, Euler-Lagrange equation, Necessary and sufficient conditions for extrema, weak, strong minima and maxima.

Unit 2: Variational formulation, Rayleigh-Ritz method, weighted residuals methods- Collocation method, least square method, Galerkin method, Petrov-Galerkin method for boundary value problems.

Unit 3: Finite element analysis for one dimension problems using linear, quadratic, cubic shape functions.

Unit 4: Finite element analysis for two dimension problems using rectangle elements (linear, quadratic, cubic shape functions, serendipity) and triangular elements and it is implementation on steady state problems.

Course References:

1. J.N. Reddy (2005), An introduction to the Finite Element Method, McGraw Hill, NY.
2. I.J. Chung (1978), Finite element analysis in Fluid Dynamics, McGraw Hill Inc.
3. O.C. Zienkiewiez and K. Morgan, Finite Elements and approximation, John Wieley, 1983.
4. P.E. Lewis and J.P. Ward (1991), The Finite element method- Principles and applications, Addison Weley.
5. L.J. Segerlind (1984), Applied finite element analysis (2nd Edition), John Wiley.
6. A.S. Gupta (2003), Calculus of Variation, Prentice Hall of India Pvt. Ltd.
7. I.M. Gelfand and S. V. Francis (2000), Calculus of Variation, Prentice Hall, New Jersey.

Course Code: **PMATD40226** Title of the Course: **Computational Fluid dynamics**
L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

After studying this course the student will be able to

CLO-1: understand the concept of governing equations of Incompressible viscous flows.

CLO-2: understand and apply the staggered grid, artificial compressibility, pressure correction and vortex methods.

CLO-3: understand Compressible inviscid flows, central schemes with combined and independent space time discretization.

CLO-4: apply the concept of Compressible viscous flows, Explicit, implicit and PISO methods.

CLO-5: apply the Structured and unstructured grid generation methods.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2		3	2			2	1	
CLO2	3	2		3	2			2	1	
CLO3	3	2		3	2			2		
CLO4	3	2		3	2			2		
CLO5	3	2		3	2			2		

Course Details:

Unit-1: Review of the governing equations of Incompressible viscous flows, Stream function - vorticity approach.

Unit-2: Upwind schemes, Primitive variables, Staggered grid, Artificial compressibility, pressure correction and vortex methods.

Unit-3: Compressible inviscid flows, central schemes with combined and independent space time discretisation, Compressible viscous flows, Explicit, implicit and PISO methods.

Unit-4: Grid generation: Structured and unstructured grid generation methods; Finite volume method: Finite volume method to convection-diffusion equations.

Course References:

1. P Wessling (1991), Principles of Computational Fluid Dynamics, Springer.

2. John D Anderson, Jr. (1995), Computational Fluid Dynamics, The Basics with Applications, McGraw-Hill.

Course Code: **PMATD40227** Title of the Course: **Multi Objective Programming**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will able to

CLO-1: learn the concepts behind multi-objective optimization.

CLO-2: understand Optimization models and apply them to real life problems.

CLO-3: understand the applications to problems in project management and other areas of engineering.

CLO-4: understand the concept of Fuzzy programming.

CLO-5: understand the applications of multi-objective programming to some real-world problems.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	3	3	3	2	2	2	3	3	2
CLO2	2	3	1	3	2	2	3	2	3	2
CLO3	1	3	2	3	2	2	2	3	3	2
CLO4	1	3	1	3	2	2	1	2	3	1
CLO5	2	3	1	3	2	2	1	2	3	2

Course Details:

Unit 1: Prerequisite: Operations Research Formulation of multi-objective (linear and non-linear programming) problems and related terms, dominated and non-dominated solutions. Mathematics courses including: multi-variable Calculus, linear algebra.

Unit 2: Goal programming - Graphical method, sequential goal programming method, multiphase simplex method.

Unit 3: Fuzzy programming, vector maximum and vector minimum problems, linear and non-linear membership functions, compromise solutions, utility function method, weighting method.

Unit 4: Analytic hierarchy process, ranking method, surrogate worth trade off method, step method, e-constrained method, global criterion method, group decision making. Applications of multi-objective programming to some real-world problems.

Reference Books:

1. Multiple Criteria Optimization: Theory, Computation, and Application," Ralph E. Steuer, John Wiley & Sons, 1986.
2. Multi objective Programming and Planning, Jared L. Cohon, Academic Press, 1978.
3. Nonlinear Multi objective Optimization, Kaisa M. Miettinen, Kluwer Academic Press, 1999.
4. Operations Research Applications and Algorithms, Wayne L. Winston, Duxbury Press, 1994.
5. H. A. Taha (2014), *Operations Research, An Introduction*, PHI, New Delhi.
6. N. S. Kambo (1991), *Mathematical Programming Techniques*, East-West Pub., Delhi.
7. Kanti Swarup, P. K. Gupta and Man Mohan (2010), *Operations Research*, Sultan Chand and Co, New Delhi.
8. J. C. Pant (2012), *Introduction to Operations Research*, Jain Brothers, New Delhi.
9. H. M. Wagner (2010), *Principles of Operations Research*, PHI, Delhi.
10. J. C. Pant (2015), *Introduction to Optimization: Operations Research*, Jain Brothers, Delhi.

Course Code: **PMATD40228** Title of the Course: **Theory of Automata**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understand the basic concepts of Automata.

CLO-2: classify and create the Languages.

CLO-3: design the Automata to accept the given language.

CLO-4: design the Turing machine.

CLO-5: find the equivalences among machines.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	2	1	2	1	1	1	1	3	1
CLO2	1	2		2	1	1	2	2	3	2
CLO3	1	3	1	3	2	2	1	1	3	3
CLO4	2	2		3	2	1	1	1	3	2
CLO5	1	2	2	2	1	3	1	2	3	1

Course Details:

Unit 1: Preliminaries: Sets, Relations, Equivalence relation, partition, Transitive closures, Kleene' closure, Strings, Alphabets, Languages, Recursive definitions.

Unit 2: Regular Languages and Finite Automata: Regular Expressions, Regular Languages, Finite State Machines, Deterministic finite automata (DFA), Non-deterministic finite automata (NFA), Nondeterministic finite automata with e moves (NFA-epsilon), epsilon -closure, Equivalence of DFA, NFA and NFA- epsilon, Language accepted by Finite Automata, Kleene's Theorem.

Unit 3: Properties of Regular Sets: Properties of the Languages accepted by finite automata, Regular and non-regular languages, Minimal finite automata, Pumping lemma, Myhill - Nerode theorem. Closure properties of Regular languages.

Unit 4: Context Free Languages and Pushdown Automata: Context free grammars (CFG), context free languages (CFL), closure properties of context free languages, Chomsky normal form, Greibach normal form, Pumping lemma for CFL, parsing, Pushdown automata (PDA), CFG for PDA, PDA for CFG, phrase structured grammars and languages and context sensitive grammars and languages. **Turing Machines:** Turing machine model, example, Modification of Turing machines, Church's hypothesis and Non-deterministic Turing machines.

Reference Books:

1. Hopcroft J. and Ullman J.D., Introduction to Automata Theory, Languages and Computation, Narosa Publishing, 1989.

2. Martin, J.C., Introduction to Languages and the Theory of Computation, Tata McGraw Hill, 2009.

3. Carrel J. and Long D., Theory of finite automata with an introduction to formal languages, Prentice Hall, 1989.

Course code**: PMATD40229** Title of the Course**: Riemannian Geometry**
L-T-P:**3-0-0** Credits:**3**

Course Learning Outcomes (CLOs)

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

CLO-1: define the various geometrical and algebraic concepts that are introduced in the course, and be able to use and interpret them in specific examples.

CLO-2: use and formulate central theorems in Riemannian geometry and Topology, and be able to give an account of their proofs.

CLO-3: understanding of Riemannian sub manifolds, Jacobi fields, completeness, and be able to prove and apply fundamental results in the subject.

CLO-4: use the theory, methods and techniques of the course to solve problems.

CLO-5: understand and work manifolds, tangent spaces and curvature.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	2	2	1	1	1	1	2	1	1
CLO2	3	2	2	1	1	1	1	1	1	1
CLO3	3	2	1	1	1	1	1	2	1	1
CLO4	3	2	2	1	1	1	1	2	1	1
CLO5	3	2	1	1	1	1	1	1	1	1

Course Details:

Unit 1: Differentiable manifolds: - Charts, Atlases, Differentiable structures, Topology induced by differentiable structures, equivalent atlases, complete atlases. Manifolds. Examples of manifolds. Properties of induced topology on manifolds.

Unit 2: Tangent and cotangent spaces to a manifold. Vector fields. Lie bracket of vector fields. Smooth maps and diffeomorphism. Derivative(Jacobi) of smooth maps and their matrix representation. Pull back functions. Tensor fields and their components. Transformation formula for components of tensors. Operations on tensors. Contraction, Covariant derivatives of tensor fields.

Unit 3: Riemannian Metric. Connections. Riemannian connections and their components, Parallel translation, Fundamental theorem of Riemannian Geometry. Curvature and torsion tensors. Bianchi identities, Curvature tensor of second kind. Sectional curvature. Space of constant curvature. Schur's theorem. Curves and geodesics in Riemannian manifold. Geodesic curvature, Frenet formula.

Unit 4: Hypersurfaces of Riemannian Manifolds Gauss formula, Gauss equation, Codazzi equation, Sectional curvature for a hyper surface of a Riemannian manifold, Gauss map, Weingartan map and Fundamental forms on hypersurface. Equations of Gauss and Codazzi. Gauss theorem egregium.

References:

1. Y. Matsushima: Differentiable manifolds. Marcel Dekker Inc. New, York,1972.
2. W.M. Boothby: An introduction to differentiable manifolds and Riemannian Geometry. Academic Press Inc. New York, 1975.
3. N.J. Hicks: Notes on differential Geometry D. Van Nostrand company Inc. Princeton, New Jersey, New York, London (Affiliated East-West Press Pvt. Ltd. New Delhi), 1998. REFERENCE BOOKS
4. R.L. Bishop and Grittendo: Geometry of manifolds. Acamedic Press, New York, 1964.
5. L.P. Eisenhart: Riemannian Geometry. Princeton University Press, Princetion, New Jersey, 1949.

6. H. Flanders: Differential forms with applications to the physical science, Academic Press, New York, 1963.
7. R.L. Bishop and S.J. Goldberg: Tensor analysis on manifolds, Macmillan Co., 1968.
8. K. S. Amur, D.J. Shetty and C. S. Bagewadi, An introduction to differential Geometry, Narosa Pub. New Dehli, 2010.

Course code**: PMATD40230** Title of the Course**: Special Functions**
L-T-P:**3-0-0** Credits:**3**

Course Learning Outcomes (CLOs)

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

CLO-1: understand the importance of Heine's transformation and Jackson transformation formula.

CLO-2: explain the application of Jacobi's triple product identity and Quintuple product identity.

CLO-3: learn the importance of Ramanujan ${}_1\Psi_1$ summation formula.

CLO-4: understand some theta function identities mentioned in the Chapter 16 of Ramanujan's notebook III.

CLO-5: work effectively as part of a group to solve challenging problems in Number Theory.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	2	1	2	1	2	1	1		1
CLO2	3	2	1	2	1	1	1	1		1
CLO3	3	2	1	2	1	2	1	1		1
CLO4	3	2	1	2	1	1	1	1		1
CLO5	3	2	1	2	1	2	1	1		1

Syllabus:

Unit 1: Hypergeometric series: Definition- convergence- Solution of second order ordinary differential: equation or Gauss equation- Confluent hypergeometric series- Binomial theorem, Integral Representation- Gauss's Summation formula- Chu-Vandermonde Summation formula- PfaffKummer Transformation Formula- Euler's transformation formula.

Unit 2: Basic-hypergeometric series: Definition- Convergence- q-binomial theorem- Heines transformation formula and its q-analogue- Jackson transformation formula- Jacobi's triple product identity and its applications - Quintuple product identity - Ramanujan's 1 ψ1 summation formula and its applications- A new identity for $(q;q)10$ with an application to Ramanujan partition congruence modulo 11- Ramanujan theta-function identities involving Lambert series.

Unit 3: $q-$series and Theta-functions: Ramanujan's general theta-function and special cases- Entries 18, 21, 23, 24, 25, 27, 29, 30 and 31 of Ramanujan's Second note book (as in text book reference 4).

Unit 4: Partitions: Definition of partition of a +ve integer- Graphical representation- Conjugate- Self conjugate- Generating function of $p(n)$- other generating functions- A theorem of JacobiTheorems 353 and 354- applications of theorem 353- Congruence properties of $p\,(n)$- $p\,(5n + 4) \equiv 0\,(mod\,5)$ and $p\,(7n + 4) \equiv 0\,(mod\,7)$- Two theorems of Euler- Rogers-Ramanujan Identitiescombinatorial proofs of Euler's identity, Euler's pentagonal number theorem. Franklin combinatorial proof. Restricted partitions- Gaussian. (portion to be covered as per Chapter-XIX of an Introduction to the Theory of Numbers written by G. H. Hardy and E. M. Wright).

References:

1. C. Adiga, B. C. Berndt, S. Bhargava and G. N. Watson, Chapter 16 of Ramanujan's second notebook: Theta-function and q-series, Mem. Amer. Math. Soc., 53, No.315, Amer. Math. Soc., Providence, 1985.

2. T. M. Apostol: Introduction to Analytical number theory, Oxford University Press, 2000.

3. G. E. Andrews, The theory of Partition, Cambridge University Press, 1984

4. B. C. Berndt, Ramanujan's notebooks, Part-III, Springer-Verlag, New York, 1991.

5. B. C. Berndt, Ramanujan's notebooks, Part-IV, Springer-Verlag, New York, 1994

6. B. C. Berndt, Ramanujan's notebooks, Part-V, Springer-Verlag, New York, 1998

7. George Gasper and Mizan Rahman, Basic hyper-geometric series, Cambridge University Press, 1990.
8. G. H. Hardy and E. M. Wright, An Introduction of the Theory of Numbers, Oxford University Press, 1996.

Course Code: **PMATD40231** Title of the Course: **Financial Mathematics**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: demonstrate understanding of basic concepts in discrete time models.

CLO-2: demonstrate understanding of concepts relating to continuous time models.

CLO-3: employ methods related to these concepts in a variety of financial applications.

CLO-4: apply logical thinking to problem solving in context.

CLO-5: use appropriate technology to aid problem solving.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	2		2		3		2		
CLO2	2	2		2		2		2		
CLO3	2	2		2		2		2		
CLO4	2	1		2		2		1		
CLO5	3			3		2		3		

Course Details:

Basic concepts of hedging and pricing by arbitrage in discrete time models, Setting of binomial tree models. Concepts of conditional expectation, martingale, change of measure, and representation. Mathematical models for the development and analysis of continuous time models. Brownian motion, stochastic calculus, change of measure, martingale representation theorem. Black-Scholes option pricing formula. Models for the interest rate in the national and international markets. Mathematical models of bond and stock prices, other derivative securities; Markowitz portfolio optimization theory and the Capital Asset Pricing Model; and interest rates and their term structures. Case studies.

Course References:

1. RJ Williams, Introduction to Mathematics of Finance, AMS, 2006

2. Marek Capiński, Tomasz Zastawniak, Mathematics for Finance: An Introduction to Financial Engineering, Springer, 2003

List of Discipline Specific Electives-IV (IV Semester)

Course Code: **PMATD4023,** Title of the Course: **Integral Transforms and Integral Equations**

L-T-P: **3-0-0** Credits: **3**

Prerequisite Course / Knowledge (If any): General integration and differentiation.

Course Learning Outcomes (CLOs)

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

CLO-1: understand the concept of Volterra integral equations and solve Volterra integral equations by applying various methods.

CLO-2: understand the Fredholm integral equation and solving methods of it.

CLO-3: apply the Laplace and inverse Laplace transform concepts for solving various special functions.

CLO-4: understand the concept of Fourier transform and Inverse Fourier transform.

CLO-5: learn the applications of correlation theorem, Parseval's theorem, Wave from sampling, sampling theorem, frequency sampling theorem.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	3		2	1			2	3	1
CLO2	3	3		2	1			2	3	1
CLO3	3	3		1	1			1	3	1
CLO4	3	3		1	1			1	3	1
CLO5	3	2		3	2			1	2	1

Course Details:

Unit 1: Integral equation, Introduction and relation with linear differential equation. Volterra integral equations and its solutions, Method of resolvent kernel, Method of successive approximations, Method of Laplace Transform, system of Volterra integral equations, Abel's integral equation and its generalizations.

Unit 2: Fredholm integral equations and its solutions, Characteristic numbers, Method of resolvent kernels, Method of successive approximations, Integral equations with degenerate kernels, Eigen values and eigen functions and their properties, Hilbert Schmidt theorem, Non homogeneous Fredholm integral equation with symmetric kernel.

Unit 3: Laplace Transform: Definition, Transform of some elementary functions, rules of manipulation of Laplace Transform, Transform of Derivatives, relation involving Integrals, the error function, Transform of Bessel functions, Periodic functions, convolution of two functions, Inverse Laplace Transform.

Unit 4: Fourier transform: The Fourier transform, Inverse Fourier transform, Fourier transform properties, Convolution integral, convolution theorem, correlation, correlation theorem, Parseval's theorem, Wave from sampling, sampling theorem, frequency sampling theorem.

Course References:

1. L. G. Chambers (1978). Integral Equations, International Text Book Company Ltd., London.
2. F. G. Tricomi (1957). Integral equations, Interscience, New York.
3. Ian N. Sneddon (1972), The use of Integral Transforms, McGraw Hill.
4. Ian N. Sneddon (2010), Fourier Transforms, Dover Publications.
5. Loknath Debnath (2006), Integral Transforms and their applications, Chapman and Hall/CRC.
6. Churchill (1972), Operational Mathematics, McGraw Hill.
7. Hildebrand (1960), Methods of Applied Mathematics, PHI, New Jercy.
8. E.O.Brigham (1988), The Fast Fourier Transforms, Prentice Hall, New Jersy.
9. E.I.Jury (1964), Theory and applications of Z transform method, John Wiley.

Course code**: PMATD40234** Title of the Course**: Cryptography**
L-T-P:**3-0-0** Credits:**3**

Course Learning Outcomes (CLOs)

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

CLO-1: understand basics of Cryptography and Network Security.

CLO-2 Identify the security issues in the network and resolve it and analyse the vulnerabilities in any computing system and hence be able to design a security solution.

CLO-3: learn about how to maintain the Confidentiality, Integrity and Availability of a data.

CLO-4: understand various protocols for network security to protect against the threats in the networks.

CLO-5: evaluate security mechanisms using rigorous approaches by key ciphers and Hash functions.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	3	2	3	2	1	3	3	3	1	1
CLO2	3	2	3	2	1	3	3	3	1	1
CLO3	3	2	3	2	1	3	3	3	1	1
CLO4	3	2	3	2	1	2	3	3	1	1
CLO5	3	2	3	2	1	3	3	3	1	1

Course Details:

Unit 1: Basic number theoretic & Algebraic concepts – Time Estimates of doing arithmetic, Divisibility, Euclidean & Extended Euclidean Algorithm, Congruences, Chinese Remainder Theorem, Euler's & Fermat's theorems, Finite ¹elds, Quadratic Residues and reciprocity.

Unit 2: Classical Cryptography – some simple cryptosystems and their cryptanalysis; Secret Key Cryptosystems – Block ciphers, DES & AES; Hash Functions; Stream ciphers.

Unit 3: Public Key Cryptosystems – RSA Cryptosystem, Primality testing, Factoring algorithms; Rabin Cryptosystem; Di·e-Hellman Keyexchange protocol; Discrete-log problem; ElGamal Cryptosystems.

Unit 4: Elliptic curves – basic facts; elliptic-curve cryptosystem; Digital Signature schemes; Zeroknowledge protocols, one-way functions; Advanced protocols for different applications, e.g. echeque, ecash etc.; Copyright protection; Current trends in Cryptography.

References:

1. Douglas R. Stinson, Cryptography: Theory and Practice, Chapman & Hall/CRC, 3 Edition, 2006
2. Neal Koblitz, A Course in Number Theory and Cryptography, Springer, 1994
3. Bruce Schneier, Applied Cryptography: Protocols, Algorithms and Source Code In C, John Wiley, 2002.
4. Ranjan Bose, "Information Theory, Coding and Cryptography", Tata McGraw-Hill Publishing, 2002

Course Code: **PMATD40235** Title of the Course: **Object Oriented Programming**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understand the basic concepts of OOPs.

CLO-2: implement programs using classes and objects.

CLO-3: able to understand the overloading concept.

CLO-4: specify the forms of inheritance and use them in programs.

CLO-5: analyze polymorphic behavior of objects.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	2	1	2	1	1	1	1	3	1
CLO2	1	3		2	1	2	2	2	2	2
CLO3	1	3	1	3	2	2	1	1	2	2
CLO4	3	2		3	3	1	1	1	3	2
CLO5	1	2	2	2	1	3	1	2	3	1

Course Details:

Unit 1: Basic concepts of object oriented programming – Benefits of oops- Object oriented languages –Applications of oops.

Unit 2: Classes and Objects-C++ Program with class-Nesting of member functions-private member functions-Arrays within a class- memory allocation for objects-Static data members-Arrays of objects-objects as Function arguments-Friendly functions, Returning objects.

Unit 3: Constructors and Destructors- Multiple constructors in class-Constructors with default arguments copy constructor-Dynamic constructors.

Unit 4: Operator overloading-overloading unary operators-overloading binary operators-overloading binary operators using Friends-Rules for overloading operators – Type conversions Inheritance-Defining derived classes-Single inheritance-multilevel inheritance-Multiple inheritance-Hierarchical inheritance-Virtual base classes – Abstract classes. Pointers, Virtual functions and Polymorphism.

Reference Books:

1. E. Balaguruswamy, Object oriented programming with C++, 4th Edition, Tata McGraw Hill, 2008.
2. Barkakati Nabajyoti, Object-Oriented programming in C++, PHI, 1991.
3. Stroustroup Bjarne. The C++ Programming Language, 2nd Edition, Addison-Wesley,1991.

Course Code: **PMATD40236** Title of the Course: **Finite Volume Method**

L-T-P: **3-0-0** Credits: **3**

Prerequisite Course / Knowledge (If any): Basics of Numerical Analysis concepts, Finite Difference and Finite Element Methods etc.

Course Learning Outcomes (CLOs)

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

CLO-1: derive the Conservation Equations.

CLO-2: discretize linear partial differential equations (PDE).

CLO-3: identify source terms in PDE and their linearization.

CLO-4: solve diffusive problems: Steady and unsteady 1D, Steady 2D and 3D problems.

CLO-5: solve convective problems using upwind, QUICK and hybrid schemes. Also, solve the velocity and pressure coupling using SIMPLE, SIMPLER, SIMPLEC algorithms.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	3		1	2	2	2	2		1
CLO2	1	3		2	2	2	2	2		2
CLO3	1	3	1	2	2	2	3	2		2
CLO4	2	3		2	2	2	2	1		1
CLO5	2	3		3	2	2	3	2		2

Course Details:

Unit 1: Introduction - Obtaining the Integral Form from the Differential Form - Finite Volume Meshes - Discretising the Semi-Integral Equation – Implementation.

Unit 2: Finite Volume Schemes - FVM on a Cartesian Mesh - Finite Volume Schemes in 1D and 3D – Time Step Calculation for a Finite Volume Scheme - Finite Volume FOU 2D Scheme – Boundary Conditions - Coding a Finite Volume Solver

Unit 3: Derivation of Equations - Conservation Laws - Control Volume Approach - Deriving the Integral Form of the 2D Linear Advection Equation - Further Finite Volume Schemes - Linear Interpolation - Quadratic Interpolation - Converting from Finite Difference to Finite Volume Systems of Equations.

Unit 4: The Shallow Water Equations - General FVS for the SWE - FVS for the 2D SWE on a Structured Mesh - Heuristic Time Step for a 2D SWE FVS.

Reference Books:

1. D. M. Causon, C. G. Mingham, & L.Own (2009), *Introductory Finite Volume Methods for Partial Differential Equations*, Springer.
2. H.Versteeg & W. Malalasekera (2009), *An introduction to CFD: The Finite Volume Method*, Pearson.

Course code**: PMATD40237** Title of the Course**: Algebraic Topology**

L-T-P:**3-0-0** Credits:**3**

Course Learning Outcomes (CLOs)

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

CLO-1: explain the fundamental concepts of algebraic topology and their role in modern mathematics and applied contexts.

CLO-2: demonstrate accurate and efficient use of algebraic topology techniques.

CLO-3: demonstrate capacity for mathematical reasoning through analyzing, proving and explaining concepts from algebraic topology.

CLO-4: apply problem-solving using algebraic topology techniques applied to diverse situations in physics, engineering and other mathematical contexts.

CLO-5: provide an elementary example illustrating specified behaviour in relation to a given combination of basic definitions and key theorems across the course.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	2	1	1	1	2	2	1		1
CLO2	3	2	1	2	1	2	2	1		1
CLO3	3	2	1	1	2	2	2	1		1
CLO4	3	2	1	1	2	2	2	1		1
CLO5	3	2	1	1	2	2	2	1		1

Course Details:

Unit 1: Paths and homotopy, homotopy equivalence,contractibility, deformation retracts. Basic constructions: cones, mapping cones,mapping cylinders, suspension. Cell complexes, subcomplexes, CW pairs. Fundamental groups. Examples (including the fundamental group of the circle) and applications (including Fundamental Theorem of Algebra, Brouwer Fixed Point Theorem and Borsuk-Ulam Theorem, both in dimension two). Van Kampen's Theorem, covering spaces, lifting properties, deck transformations. universal coverings (existence theorem optional).

Unit 2: Simplicial complexes, barycentric subdivision, stars and links, simplicial approximation. Simplicial Homology. Singular Homology. Mayer-Vietoris Sequences. Long exact sequence of pairs and triples. Homotopy invariance and excision (without proof).

Unit 3: Degree. Cellular Homology. Applications of homology: Jordan-Brouwer separation theorem, Invariance of dimension, Hopf's Theorem for commutative division algebras with identity, Borsuk-Ulam Theorem, Lefschetz Fixed Point Theorem.

Unit 4: Outline of the theory of: cohomology groups, cup products, Kunneth formulas, Poincare duality.

References:

1. M. J. Greenberg and J. R. Harper, Algebraic Topology, Benjamin, 1981.
2. W. Fulton, Algebraic topology: A First Course, Springer-Verlag, 1995.
3. A. Hatcher, Algebraic Topology, Cambridge Univ. Press, Cambridge, 2002.
4. W. Massey, A Basic Course in Algebraic Topology, Springer-Verlag, Berlin, 1991.
5. J.R. Munkres, Elements of Algebraic Topology, Addison Wesley, 1984.
6. J.J. Rotman, An Introduction to Algebraic Topology, Springer (India), 2004.
7. H. Seifert and W. Threlfall, A Textbook of Topology, translated by M. A. Goldman, Academic Press, 1980.
8. J.W. Vick, Homology Theory, Springer-Verlag, 1994.

Course Code: **PMATD40238** Title of the Course: **Computer Graphics**

L-T-P: **3-0-0** Credits: **3**

Course Learning Outcomes (CLOs)

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

CLO-1: understand the structure of an interactive computer graphics system, and the separation of system components.

CLO-2: develop and analyses the algorithms for generation lines and polygons.

CLO-3: apply the geometrical transformations on objects.

CLO-4: implement the techniques for segmentation.

CLO-5: differentiate different techniques for windowing and clipping.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6	PLO 7	PLO 8	PLO 9	PLO 10
CLO1	2	3	1	2	1	1	1	1	3	1
CLO2	1	2		2	1	1	2	2	3	2
CLO3	1	3	1	3	2	2	1	1	3	2
CLO4	3	2		2	2	1	1	1	3	2
CLO5	1	3	2	2	1	3	1	2	3	1

Course Details:

Unit 1: Introduction: Pixels and frame buffers - Coordinate systems - vector generation - line drawing and circle generation - algorithms and initializing of lines - thick line segments - character generation -display file and its structure. **Polygons:** Polygon representation - inside test - filling of polygon. 2D Transformations: Matrices - coordinate transformations - rotation about an arbitrary point – other transformations and inverse transformations.

Unit 2: Segments: Segment table - operations on segments - image transformation and other display file structures. **Windowing and Clipping:** The viewing transformations - clipping - the cohen sutherland outcode algorithm - the sutherland Hodgman algorithm - clipping of polygons and multiple windowing.

Unit 3: 3D Transformations: Rotation about an arbitrary axis - parallel projection - respective projection -Clipping in three dimensions - clipping planes and 3D viewing transformations. **Hidden surfaces and Lines:** Back face algorithms, Z buffers - scan line algorithms - the painter's algorithms - warnock's algorithm - Franklin algorithm and hidden line methods.

Unit 4: Shading: Shading equations - smooth shading - Gouraud and phong shading methods - shadows. **Curves and Fractals:** Curve generation - interpolation - B-Splines - Benzier curves - fractal lines and fractal surfaces.

Reference Books:

1. S.Harrington, Computer Graphics - A Programming Approach, McGraw Hill, New York, 1983.
2. D.F.Rogers & J.A.Adams, Mathematical Elements of Computer Graphics, McGraw Hill, New York, 1990.

Course code**: PMATD40239** Title of the Course**: Theory of Partitions**

L-T-P:**3-0-0** Credits:**3**

Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will able to

CLO-1: explain the applications and the usefulness of Jacobi's triple product identity.

CLO-2: understand how to count the number of partitions via Euler's Pentagonal Theorem.

CLO-3: learn the work of Ramanujan on partition function and get motivated towards the research.

CLO-4: prove combinatorically Euler's beautiful identity on pentagonal numbers.

CLO-5: work effectively as part of a group to solve challenging problems in Number Theory.

Mapping of Course Learning Outcomes (CLOs) with Program Learning Outcomes (PLOs) and Program Specific Outcomes (PSOs)

	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**	**PLO 8**	**PLO 9**	**PLO 10**
CLO1	3	2	2		3	1	2	1		1
CLO2	3	2	2		3	1	2	1		1
CLO3	3	2	2		3	1	2	1		1
CLO4	3	2	2		3	1	2	1		1
CLO5	3	2	2	1	3	1	2	1		1

Course Details:

Unit 1: Introduction to basic hyper geometric series, q- binomial theorem, Heine's transformation and Gaussian Polynomial, two theorems of Euler, Jacobi's triple product identity and its applications, bilateral series and its applications, theta functions.

Unit 2: Partitions, Graphical representation, Conjugate and self-conjugate, Generating function of p (n), recurrence relation for p (n), other generating functions, Euler theorem for partition.

Unit 3: Congruence properties of partition function, the Rogers - Ramanujan Identities.

Unit 4: Rank and crank of partitions and restricted partitions.

Course References:

1. G. H. Hardy and E. M. Wright (1979), An Introduction to Theory of Numbers, Oxford University Press, 5th Ed.
2. Bruce C. Berndt, Number Theory in the Spirit of Ramanujan, AMS.
3. Bruce C. Berndt, Ramanujan's Note Books Volumes-1 to 5.
4. G. E. Andrews (1976), The Theory of Partitions, Addison Wesley.
5. Gasper and Rahman (1990), Basic hypergeometric Series, Cambridge University Press.