

## **Annexure: MT7**

**Central University of Rajasthan  
School of Mathematics, Statistics & Computational Sciences  
Department of Mathematics**

### **Details of Revised/new Structure and Syllabus of M.Sc. Mathematics w.e.f. 2023**

#### **POs (Programme Outcomes)**

##### **Students should be able to:**

**PO 1.** Knowledge: Apply the knowledge of mathematics and science to the solution of complex mathematical problems.

**PO 2.** Problem analysis: Identify, formulate and analyze complex mathematical problems using mathematical principles.

**PO 3.** Development of solution: Formulate solutions for the complex mathematical problems, process, and its components.

**PO 4:** Conduct investigation of complex problems: Use research methods including design of experiment, analysis and observation of results to investigate and solve complex problems.

**PO 5:** Tool and software usages: Create, select and apply appropriate mathematical techniques, resources and software tools including modelling and prediction to complex mathematical models.

**PO 6:** Environment and sustainability: Understand the role of mathematics and its impact in societal and environmental contexts and demonstrate the knowledge of, and need for sustainable development.

**PO 7:** Individual and teamwork: Function effectively as an individual and as a member of team.

**PO 8:** Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

## Mapping from Mission to Programme Outcomes

The mapping is based on marks 1 to 3, where “1” indicates low level matching of mission with programme outcome, “2” indicates medium level matching, and “3” indicate high level matching.

<b>PO/Mission</b>	<b>M 1</b>	<b>M 2</b>	<b>M 3</b>
<b>PO 1</b>	2	2	3
<b>PO 2</b>	2	2	2
<b>PO 3</b>	1	2	2
<b>PO 4</b>	1	3	3
<b>PO 5</b>	2	3	3
<b>PO 6</b>	3	1	2
<b>PO 7</b>	3	2	2
<b>PO 8</b>	3	2	2

## Mapping from Programme Outcomes to Courses

The mapping is based on marks 1 to 3, where “1” indicates low level matching of course outcome with programme outcome, “2” indicates medium level matching, and “3” indicate high level matching.

<b>Course/PO</b>	<b>PO 1</b>	<b>PO 2</b>	<b>PO 3</b>	<b>PO 4</b>	<b>PO 5</b>	<b>PO 6</b>	<b>PO 7</b>	<b>PO 8</b>
<b>MAT401</b>	3	3	3	2	1	1	1	1
<b>MAT402</b>	3	3	3	2	1	1	1	1
<b>MAT403</b>	3	3	2	2	1	1	1	1
<b>MAT404</b>	3	3	3	2	1	1	2	1
<b>MAT405</b>	3	3	3	2	1	1	2	1
<b>MAT406</b>	3	3	2	1	1	1	2	1
<b>MAT407</b>	3	3	3	2	1	1	2	1

<b>MAT431</b>	3	3	3	2	1	2	2	2
<b>MAT432</b>	3	3	3	2	1	1	2	2
<b>MAT433</b>	2	1	1	1	3	1	3	3
<b>MAT434</b>	2	1	2	2	3	1	3	3
<b>MAT435</b>	3	3	3	2	2	1	2	2
<b>MAT436</b>	3	3	3	2	1	1	2	2
<b>MAT437</b>	3	3	3	3	1	1	2	3
<b>MAT438</b>	3	3	3	2	1	2	2	3
<b>MAT439</b>	3	3	3	3	2	1	2	3
<b>MAT501</b>	3	3	3	1	1	1	2	3
<b>MAT502</b>	3	1	3	3	3	1	3	3
<b>MAT503*</b>								
<b>MAT504</b>	3	2	2	1	2	2	3	3
<b>MAT581</b>	2	3	3	3	3	3	3	3
<b>MAT531</b>	3	3	3	2	1	2	2	3
<b>MAT532</b>	3	3	3	2	1	1	2	2
<b>MAT533</b>	3	3	3	1	1	1	2	2
<b>MAT534</b>	3	1	2	2	1	1	2	2
<b>MAT535</b>	3	3	2	1	1	1	1	2
<b>MAT536</b>	3	1	2	2	3	3	2	2
<b>MAT537</b>	3	3	3	3	1	1	2	3
<b>MAT538</b>	3	3	3	2	2	1	2	2
<b>MAT539</b>	3	3	3	3	2	1	2	2
<b>MAT540</b>	3	3	2	2	1	1	2	2
<b>MAT541</b>	3	2	3	2	3	1	2	3
<b>MAT542</b>	3	2	3	2	3	1	2	3
<b>MAT543</b>	3	3	3	2	1	1	2	3
<b>MAT544</b>	3	3	3	2	2	1	2	2
<b>MAT545</b>	3	1	2	2	1	2	3	3
<b>MAT546</b>	3	3	3	3	1	1	2	2
<b>MAT547</b>	3	3	3	1	1	1	2	2
<b>MAT548</b>	3	3	3	2	1	1	2	2

<b>MAT549</b>	3	2	3	2	2	1	2	2
<b>MAT550</b>	3	3	3	2	1	2	2	2
<b>MAT551</b>	3	3	3	2	1	1	2	2
<b>MAT552</b>	3	1	2	3	2	1	2	3
<b>MAT553</b>	3	3	3	2	1	1	2	2
<b>MAT554</b>	3	2	2	3	1	1	2	2

## Course Scheme-

### LEVEL-4

Semester-I (M.Sc.)							
S. No.	Course Code	Course Title	Type of Course (C/E)	L	T	P	Credits
Semester-I							
1	MAT401	Linear Algebra	CC	3	1	0	4
2	MAT402	Real Analysis	CC	3	1	0	4
3	MAT403	Topology	CC	3	1	0	4
4		Elective	DE	3	1	0	4
5		Elective	DE	1	0	1	2
6		Elective	DE	1	0	1	2
7		Elective	GE	3	1	0	4
<b>Total</b>				<b>17</b>	<b>5</b>	<b>4</b>	<b>24</b>

Semester-II (M.Sc.)							
S. No.	Course Code	Course Title	Type of Course (C/E)	L	T	P	Credits

1	MAT404	Complex Analysis	CC	3	1	0	4
2	MAT405	Mathematical Programming	CC	3	1	0	4
3	MAT406	Abstract Algebra	CC	3	1	0	4
4	MAT407	Qualitative Theory of Ordinary Differential Equations	CC	3	1	0	4
5		Elective	DE	3	1	0	4
6		MOOC	GE	3	1	0	4
<b>Total</b>				<b>18</b>	<b>6</b>	<b>0</b>	<b>24</b>

<u>Course-Code: MAT-401</u> <u>Course Title: Linear Algebra</u>		
Teaching Scheme	Examination Scheme	Credits Allotted
Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b> The student should have knowledge of		
1.	Basic concepts in Linear Algebra and Matrices	
<b>Course Objective:</b>		

1	To introduce the fundamental notions of algebra of linear transformations, diagonalizability, and different canonical forms	
2	To teach the students different characterization of diagonalization of a linear operator	
3	To introduce the concept of orthonormal basis and their existence	
4	To create orthogonal and orthonormal bases: Gram-Schmidt process and use bases and orthonormal bases to solve application problems	
5	To introduce adjoints of linear operators, unitary and normal operators.	
<b>Course Outcomes:</b> The students will be able to		
1.	learn algebra of linear transformations, significance and use of eigenvalue and eigenvectors	
2.	explain different concepts about linear transformations and inner product spaces,	
3.	learn different characterization of diagonalization and canonical forms of a given linear transformation	
4	use different concepts associated with vector spaces, linear transformations, diagonalization and inner product spaces in other courses like functional analysis, differential equations	
<b>Course Content:</b>		
Unit-I	Review of vector spaces, The algebra of linear transformations, Isomorphism, Linear functionals, Annihilator, Double dual, Transpose of a linear transformation, Eigenvalues and Eigenvectors, and Eigenvectors.	15 Hours
Unit-II	Diagonalizability, Minimal Polynomial, Cayley Hamilton theorem. Invariant subspaces, Triangulability and Diagonalization in terms of the minimal polynomial, Direct-sum decompositions, Invariant direct sums.	15 Hours

Unit-III	The primary decomposition theorem, Cyclic Subspaces And annihilators, Cyclic decomposition, Rational and Jordan forms. Symmetric and Skew-symmetric Bilinear Forms, Diagonalization of symmetric bilinear forms.	15 Hours
Unit-IV	Inner product spaces: Best approximation, The adjoint of linear transformation, Unitary operators, Self adjoint, Normal operators, Spectral theorem for self adjoint operators.	15 Hours
<b>Internal Assessment:</b>		
CIA*-1	Unit -I	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III	
EoSE**	Unit-I, II, III, IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
1. Hoffmann K. and Kunze R., 1992, <i>Linear Algebra</i> , Prentice Hall of India.		
2. Friedberg S. H., Insel A.J., Spence L.E., 2019, <i>Linear Algebra</i> , Pearson Education.		
3. Kumaresan S., 2000, <i>Linear Algebra: A Geometric Approach</i> , Prentice Hall of India.		
4. Halmos, P.R., 2011, <i>Finite Dimensional Vector Spaces</i> , Springer.		
5. Lang, S., 2005, <i>Introduction to Linear Algebra</i> , Springer.		
<b>Reference Books:</b>		

6. Artin M., 2010, <i>Algebra</i> , Pearson Education. 7. Cooperstein B., 2015, <i>Advanced Linear Algebra</i> , CRC Press.		
<b>E-resources:</b>		
<a href="https://archive.nptel.ac.in/courses/111/106/111106051/">https://archive.nptel.ac.in/courses/111/106/111106051/</a>		

<u>Course-Code: MAT402</u> <u>Course Title: Real Analysis</u>		
Teaching Scheme	Examination Scheme	Credits Allotted
Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b>		
	Basics of real analysis, metric space and integral and differential calculus.	
<b>Course Objectives:</b> To develop the concept of		



1.	understanding and applications of different aspects of the real number system $\mathbb{R}$ , in the Euclidean space $\mathbb{R}^n$ .
2.	Riemann-Stieltjes integrability, properties of R-S integration and its applications.
3.	uniform convergence of sequence and series of functions, solving problems and their applications.
4.	bounded variation functions and their basic properties, development of derivatives as a linear transformation and understanding of important associated results.
<b>Course Outcomes:</b> Students will be able to	
1.	understand and analyze the different aspects of $\mathbb{R}$ , in $\mathbb{R}^n$ along with their applications.
2.	solve the problems of Riemann-Stieltjes integration and will be able to apply/verify its properties.
3.	understand and apply the tests of uniform convergence of sequence and series of functions along with solving problems.
4.	verify the conditions of bounded variation functions along with applications, understand the concept of derivatives as linear transformation in $\mathbb{R}^n$ and know about the important associated results.
<b>Course Content:</b>	

Unit-I	Introduction to Euclidean space, Open ball, Open and closed sets, Adherent points, accumulation points and isolated points, Closure and derived sets, Bolzano Weierstrass theorem, Cantor intersection theorem, Lindeloff covering theorem, Heine-Borel theorem, Compactness in $\mathbb{R}^n$ , Compact subsets of a metric space.	15 Hours
Unit-II	Basics of Riemann-Stieltjes (R-S) integration, Existence of R-S integration, Conditions of R-S integrability, Properties of R-S integrals, First and second mean value theorems, Some important results on R-S integrability.	15 Hours
Unit-III	Introduction to sequence and series of functions, Concept of pointwise and uniform convergence, Important tests for uniform convergence of a sequence and series of functions, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation, Uniform convergence and R-S integration. Term by term differentiability and term by term integrability of series.	15 Hours
Unit-IV	Functions of bounded variations and its properties, total variations. Continuity, partial derivatives, differentiability, derivatives of functions in an open set of $\mathbb{R}^n$ into $\mathbb{R}^n$ as a linear transformations, chain rule, Jacobians and its properties. Introduction to important theorems such as Inverse function theorem, Implicit function theorem etc.	15 Hours
<b>Internal Assessment:</b>		
CIA*-1	Unit I	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III	
EoSE**	Unit-I, II, III, & IV	

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Somasundaram, D. and Chaudhary, B., 2018, *A First Course in Mathematical Analysis (A Corrected Edition)*, Narosa Publishing House, New Delhi.
2. Malik S. C. and Arora S, 2017, *Mathematical Analysis*, New Age Int. Ltd. Publishers, New Delhi.
3. Mapa, S.K., 2019, *Introduction to Real Analysis*, Levant Books, Kolkata.

**Reference Books:**

1. Rudin W., 2016, *Principles of Mathematical Analysis* (3rd Ed.), McGraw Hill International Edition.
2. Apostol T. M., 1996, *Mathematical Analysis* (2nd Ed.), Narosa Publishing House, New Delhi.

**E-resources:**

3. <https://nptel.ac.in/courses/111106053>
4. <https://nptel.ac.in/courses/111106153>

**Course Code: MAT403**

**Course Title: Topology**

<b>Teaching Scheme</b>	<b>Examination Scheme</b>	<b>Credits Allotted</b>
Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3

Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b> The student should have knowledge of		
1.	Basic concepts of sets, relations	
2.	Basic concepts of functions and congruences	
<b>Course Objectives:</b>		
1	To provide motivation for topology through geometry.	
2	To develop understanding of geometric and topological properties.	
3	To develop understanding of the concepts of general topology as simply as possible.	
<b>Course Outcomes:</b> The students will be able to understand		
1.	what are objects of study in topology and geometry?	
2	the concepts and topics in hand without haste;	
3	the significance of the concepts defined and the theorems proved here;	
4	how this course is useful in other courses e.g., analysis, geometry and algebraic topology.	
<b>Course Content:</b>		
Unit-I	Topological spaces. Open sets, closed sets. Interior points, Closure points. Limit points, Boundary points, Exterior points of a set, Closure of a set, Derived set, Dense subsets. Basis, sub base, Relative topology.	15 Hours

Unit-II	Product space, Quotient space. Continuous functions, open & closed functions, homeomorphism, Lindelof space, Separable spaces, Connected Spaces, locally connectedness, Connectedness on the real line, Components, Path connected space,	15 Hours
Unit-III	Complete space, Compact Spaces, one point compactification, compact sets, properties of Compactness and Connectedness under a continuous function, Compactness, Equivalence of Compactness.	15 Hours
Unit-IV	Separation Axioms: $T_0$ , $T_1$ , and $T_2$ spaces, examples and basic properties, First and Second Countable Spaces, Regular, normal, $T_3$ & $T_4$ spaces, Tychonoff spaces, Urysohn's Lemma, Tietze Extension Theorem, Tychonoff Theorem.	15 Hours
<b>Internal Assessment:</b>		
CIA*-1	Unit -I	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III	
EoSE**	Unit-I, II, III, IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
1. Simmons G.F., 1963, <i>Topology and Modern Analysis</i> , McGraw Hill.		
2. Vicker, 1996, <i>Topology via Logic</i> , Cambridge University Press.		
3. Munkers, J.R., 2015, <i>Topology- A First Course</i> , Pearson Education India.		

4. Joshi, K.D., 2017, *Introduction To General Topology*, New Age International Private Limited.

**Reference Books:**

5. Kell, J.L., 2017, *General Topology*, Dover Publications.

**E-resources:**

1. <https://archive.nptel.ac.in/courses/111/106/111106159/>

<u>Course-Code: MAT404</u> <u>Course Title: Complex Analysis</u>		
Teaching Scheme	Examination Scheme	Credits Allotted
Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
<b>Course Prerequisite:</b> The student should have knowledge of		
	complex numbers and their properties, basic foundation of real analysis and concepts of limit, continuity and differentiability for functions of complex variables.	
<b>Course Objectives:</b>		
1.	To introduce some topics of contemporary complex analysis.	
2.	To provide a solid, classical foundation for the subject while exposing trails leading off in interesting directions.	

3.	To prepare the student to work independently in these topics and especially to use the methods of complex analysis in other areas of mathematics.	
<b>Course Outcomes:</b> Student will be able to		
1.	learn the basic techniques of contemporary complex analysis as well as applications of these techniques in harmonic analysis, univalent functions theory and special functions.	
2.	evaluate integrals along a path, compute the Taylor and Laurent expansions, determine the nature of the singularities and calculating residues,	
3.	use of residue theorem to evaluate integrals.	
<b>Course Content:</b>		
Unit-I	Functions of a complex variable, Differentiability and Analyticity, Harmonic Functions, Contour integrals, Antiderivative, Cauchy theorem, Cauchy-Goursat theorem, Simply and multiply connected domains, Cauchy integral formula, Higher order derivatives, Morera's theorem.	15 Hours
Unit-II	Cauchy's inequality, Liouville's theorem, Fundamental theorem of algebra, Maximum modulus principle, Minimum modulus principle, Taylor's series, Laurent series, Absolute and uniform convergence of power series, Weierstrass theorem for sequence of functions. Removable singularities, poles, order and singular part of a pole, Laurent expansions, essential singularities.	15 Hours
Unit-III	Cauchy residue theorem, Residue at infinity, Evaluation of integrals, Definite integrals involving sines and cosines, Zeros of analytic functions, Uniqueness theorem, Zeros of polynomials, Argument principle, Rouché's theorem, Schwarz lemma, Schwarz-Pick lemma.	15 Hours
Unit-IV	Conformal mappings, Scale factor, Local inverses, Mappings by elementary functions, Bilinear transformation, Basic properties of Bilinear transformation, Fixed points, Cross-ratio, Mappings of half planes onto disks, Automorphisms of unit disk, Automorphism of half planes, Mappings by $w=e^z$ , Mappings by $w=\log z$ , Mappings by $w=\sin z$ , Mappings by $z^2$ and branches of $z^{1/2}$ .	15 Hours
<b>Internal Assessment:</b>		
CIA*-1	Unit -I	

CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III	
EoSE**	Unit-I, II, III, IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
<ol style="list-style-type: none"> <li>1. Brown J.W. and Churchill R.V., 2009, <i>Complex Variables and Applications</i>, Tata McGraw Hill.</li> <li>2. Ponnusamy S., 2005, <i>Foundations of Complex Analysis</i>, Narosa Publication House.</li> <li>3. Kasana H.S., 2005, <i>Complex Variables: Theory and Applications</i>, PHI.</li> </ol>		
<b>Reference Books:</b>		
<ol style="list-style-type: none"> <li>1. Rudin W., 2006, <i>Real and Complex Analysis (3rd Addition)</i>, Tata McGraw Hill.</li> </ol>		
<b>E-resources:</b>		
<a href="https://archive.nptel.ac.in/noc/courses/noc21/SEM2/noc21-ma39">https://archive.nptel.ac.in/noc/courses/noc21/SEM2/noc21-ma39</a>		

<b>Course-Code: MAT405</b>		
<b>Course Title: Mathematical Programming</b>		
<b>Teaching Scheme</b>	<b>Examination Scheme</b>	<b>Credits Allotted</b>
Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b> The student should have knowledge of		
1.	basic Concepts of Linear Algebra	



2.	basic Concepts of Calculus	
<b>Course Objectives:</b>		
1	To teach the students the skills to formulate real-world problems as linear and nonlinear programs,	
2	To teach the students the theoretical principles of linear programming problems.	
3	To introduce different types of methodologies to solve linear programming problems, e.g., simplex method, dual simplex method, revised simplex method, branch and bound method, cutting plane method.	
4	To teach how to handle multi objective optimization problems.	
5.	To introduce the concept of dynamic programming	
6.	To introduce the concepts of nonlinear programming and its underlying structure.	
<b>Course Outcomes:</b> The students will be able to understand		
1.	the theoretical foundations of simplex and revised simplex method.	
2	duality in LPP and Integer LPP.	
3	how to solve an optimization problem over recursion and a multi objective optimization problem.	
4	solution methodologies of nonlinear programming problems, specifically convex programming problems and quadratic programming problems.	
<b>Course Content:</b>		
Unit-I	Review of Linear Programming Problems-Graphical Method and Simplex Method, Theoretical foundation of Simplex Method, Revised Simplex Method,	15 Hours

Unit-II	Duality in linear programming problem, Primal-dual method, Duality theorems, Dual simplex method; Post optimality analysis. Integer Linear programming, Gomory's Cutting Plane Method, Branch & Bound Method, Integer Programming Duality,	15 Hours
Unit-III	Dynamic Programming, Bellman's principle of optimality, Applications of dynamic programming, Multi-objective optimization problem, Goal Programming. Nonlinear programming, Solution of nonlinear programming problems with equality constraints and with not all equality constraints.	15 Hours
Unit-IV	Convex Programming Problem, Constraint qualification, Lagrange Multiplier method, Kuhn-Tucker necessary and sufficient conditions for optimality of the objective function in NLPP. Quadratic programming, Wolfe's method and Beale's Method, Separable Programming.	15 Hours
<b>Internal Assessment:</b>		
CIA*-1	Unit -I	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III	
EoSE**	Unit-I, II, III, IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
<ol style="list-style-type: none"> <li>1. Chandra S., Jayadeva and Mehra A., 2009, <i>Numerical Optimization with Applications</i>, Narosa Publishing House Pvt. Ltd.</li> <li>2. Hadley G., 1987, <i>Linear Programming</i>, Narosa Publishing House Pvt. Ltd.</li> <li>3. Taha H. A., 2007, <i>Operations Research-An Introduction</i>, Prentice Hall of India Pvt. Ltd.</li> <li>4. Hillier F. S., Lieberman G. J., Nag B. and Basu P., 2012, <i>Introduction to Operations Research</i>, Tata McGraw Hill Education Pvt. Ltd.</li> <li>5. Bazaraa M.S., Sherali H.D. and Shetty C.M., 2006, <i>Nonlinear Programming Theory and Algorithms</i>, Wiley.</li> </ol>		

<b>Reference Books:</b>
6. Bertsimas D. and Tsitsiklis J.N., 1997, <i>Introduction to Linear Optimization</i> , Athena Scientific, Belmont, Massachusetts. 7. Bradley, H., Magnanti, 1977, <i>Applied Mathematical Programming</i> , Addison-Wesley
<b>E-resources:</b>
1. <a href="https://onlinecourses.swayam2.ac.in/cec22_ma17/">https://onlinecourses.swayam2.ac.in/cec22_ma17/</a> 2. <a href="https://archive.nptel.ac.in/courses/111/107/111107128/">https://archive.nptel.ac.in/courses/111/107/111107128/</a>

<u>Course-Code: MAT406</u> <u>Course Title: Abstract Algebra</u>		
Teaching Scheme	Examination Scheme	Credits Allotted
Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b> The student should have knowledge of		
1.	Basic concepts of groups and rings	
<b>Course Objectives:</b>		
1	To teach the students isomorphism theorems	
2	To teach the students the Sylow theorems	

3	To teach the students the properties of rings	
4	To teach the students Chinese remainder theorem	
<b>Course Outcomes:</b> The students will be able to understand		
1.	the concepts of group action	
2	The class equation of groups	
3	The properties of solvable groups	
4	The arithmetic in rings	
<b>Course Content:</b>		
Unit-I	Review of groups and properties, First and second Isomorphism theorems, Conjugacy relation, Group Action, Equivalent formulation of action as a homomorphism of $G$ to Symmetric group, Stabilizer (Isotropy) subgroups	15 Hours
Unit-II	Orbit decomposition, Class equation of an action, Conjugacy class equation, Transitive actions, core of a subgroup, Sylow subgroups, Sylow's Theorem I, II and III, $p$ -groups and applications, Direct and inverse images of Sylow subgroups, Commutator subgroup, Normal and subnormal series, composition series, Jordan-Holder theorem.	15 Hours
Unit-III	Solvable groups, Properties of solvable groups, Simple groups, simplicity of $A_n$ , Review of Rings and properties, Left and right ideal, prime ideals, maximal ideals, Prime and irreducible elements, Divisibility in an Integral Domain, Units and Associates, Irreducible	15 Hours

	elements	
Unit-IV	Greatest Common divisor, Least Common Multiple, Euclidean domains, Maximal and prime ideals, Principal ideal domains, Divisor chain condition, Unique factorization domains, Examples and counterexamples, Chinese remainder theorem for rings and PID's, Polynomial rings over domains, Unique factorization in polynomial rings over UFD's.	15 Hours
<b>Internal Assessment:</b>		
CIA*-1	Unit I and Unit - II	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit III	
EoSE**	Unit-I, II, III, IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
1. Bhattacharya P. B., Jain S. K. and Nagpal S. R., <i>Basic Abstract Algebra (2<sup>nd</sup> Ed.)</i> , Cambridge University Press.		
2. Gallian J. A., 1999, <i>Contemporary Abstract Algebra</i> , Narosa Publication House, New Delhi.		
3. Artin M., 2011, <i>Algebra</i> , Prentice Hall India, New Delhi.		
4. Dummit D. S. and Foote R. M., 2008, <i>Abstract Algebra</i> , Wiley India Pvt. Ltd.		
<b>Reference Books:</b>		

Robinson, D. J. S., 1996, *A Course in the Theory of Groups*, Springer New York, New York

**E-resources:**

<https://archive.nptel.ac.in/courses/>

<b>Course-Code: MAT407</b>		
<b>Course Title: Qualitative Theory of Ordinary Differential Equations</b>		
<b>Teaching Scheme</b>	<b>Examination Scheme</b>	<b>Credits Allotted</b>
Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b> The student should have knowledge of		
1.	basic concepts in Linear Algebra and Real Analysis	
2.	elementary theory of ordinary differential equations	
<b>Course Objective:</b>		
1.	To introduce the theory of existence and uniqueness theory of IVPs and system of differential equations.	
2	To teach different types of boundary conditions and boundary value problems	

3.	To introduce stability theory of linear and nonlinear differential equations.	
4.	To develop some of the methods used to explore qualitative information about the behaviour of solutions of differential equations	
<b>Course Outcomes:</b> The students will be able to		
1.	explain different existence and uniqueness theorems for initial value problems	
2.	learn how to solve a given boundary value problem	
3.	use different analytical and geometrical methods to analyze the stability of solutions of a given differential equation	
4.	use qualitative theory for modeling different real life problems via differential equations	
<b>Course Content:</b>		
Unit-I	General existence and uniqueness theory: Well-posedness and examples of Initial Value Problems (IVPs), Gronwall's lemma, Basic lemma and uniqueness theorem, Picard's existence and uniqueness theorem, Cauchy Peano existence theorem, Continuation of solutions.	15 Hours
Unit-II	System of linear differential equations: existence and uniqueness theorem, homogeneous linear systems, Non-homogeneous linear system, Linear systems with constant coefficients, General system and diagonalization.	15 Hours

Unit-III	Boundary-value problems (BVPs): Different types of Boundary conditions and examples of BVPs, Green's functions, Sturm-Liouville BVPs: Characteristic values and characteristic functions, Orthogonality of characteristic functions, Expansion of a function in a series of orthonormal functions. System of nonlinear differential equations	15 Hours
Unit-IV	Autonomous system, equilibrium points and their stability, Paths of autonomous linear systems, Paths of nonlinear systems, Lyapunov functions and their construction, Limit cycles and Periodic solutions, Poincare-Bendixson theory.	15 Hours
<b>Internal Assessment:</b>		
CIA*-1	Unit -I	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III	
EoSE**	Unit-I, II, III, IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
1. Ross S.L., 2007, <i>Differential Equations</i> , Wiley.		
2. Nandakumaran A.K., Dutti P.S. and George R.K., 2017, <i>Ordinary Differential Equations: Principles and Applications</i> , Cambridge University Press.		
3. Brauer F. and Nohel J.A., 2005, <i>Qualitative Theory of Differential Equations</i> , Dover Publications.		



4. Coddington E.R. and Levinson N., 2010, <i>Theory of Ordinary Differential Equations</i> , McGraw Hill Education.
<b>Reference Books:</b>
5. Nemytskii V.V., 2005, <i>Qualitative Theory of Differential Equations</i> , Princeton University Press
<b>E-resources:</b>
<a href="https://nptel.ac.in/courses/111108081">https://nptel.ac.in/courses/111108081</a>

<b>LEVEL-4 (Electives)</b>				
<b>S. No.</b>	<b>Course Code</b>	<b>Course Title</b>	<b>Credit</b>	<b>Remarks</b>
<b>1</b>	MAT431	Biomathematics	4	
<b>2</b>	MAT432	Probability and Mathematical Statistics	4	
<b>3</b>	MAT 433	Scientific Writing by LaTeX	2	
<b>4</b>	MAT434	Basic Programming in MATLAB	2	
<b>5</b>	MAT435	Numerical Analysis	4	
<b>6</b>	MAT436	Integral Transforms	4	
<b>7</b>	MAT437	Elementary Number Theory	4	
<b>8</b>	MAT438	Introduction to Space Dynamics	4	
<b>9</b>	MAT439	Fluid Dynamics	4	

**Course-Code: MAT-431**  
**Course Title: Biomathematics**

Teaching Scheme	Examination Scheme	Credits Allotted
Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4

**Course Prerequisite:** The student should have knowledge of

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|----|--|
| 1. | basic concepts in elementary Calculus and Linear Algebra |
|----|--|

**Course Objectives:**

1	To introduce basic principles, assumptions and hypotheses for mathematical formulations of different biological systems
2	To teach the students the mathematical modeling of growth of single species and interacting populations
3	To introduce the compartmental epidemic models e.g., SIR, SEIR and SIS
4	To discuss the dynamical analysis of different models using linearization, stability analysis and bifurcation theory
5	To introduce the modeling of chemical kinetics

**Course Outcomes:** The students will be able to

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|----|---|
| 1. | use results from differential equations, dynamical systems, bifurcation and stability theory to analyze a given biological system |
|----|---|

2.	model a particular biological system and to predict its different dynamical behaviour	
3.	learn modeling and analysis of single species and interacting population models	
4.	do modeling and analysis of different compartmental epidemic models	
5.	predict the disease burden and prevalence of a particular disease, long term persistence of a species	
<b>Course Content:</b>		
Unit-I	Introduction: Goals and Challenges of mathematical modeling in biology. Idealization and general principles of model building, Different types of mathematical models in biology, Bacterial growth, Relevant mathematical techniques: Non-dimensionalization, Steady states and linearization	15 Hours
Unit-II	Review of linear systems, Stability analysis, Phase diagrams, Single Species population models (discrete and continuous): Exponential, Logistic, and Gompertz growth, Allee effect, Harvesting models and bifurcations, Delay models	15 Hours
Unit-III	Models with interacting populations: Different types of interactions and examples, Lotka Volterra Competition, Predator-prey model, Chemostat models, Structured (spatial, age and sex) population models, Population biology of infectious diseases: Classification of infectious diseases, SIR, SIRS and SIS epidemic models,	15 Hours
Unit-IV	Basic reproduction number, Models for molecular events: Michaelis-Menten enzyme example, Timescale decomposition, Quasi steady state analysis, sigmoidal functions, multisite systems, Chemical kinetics: Mass action law, Hopf-bifurcations, Subcritical Hopf, Poincare-Bendixson-I, Poincare-Bendixson-II, Index Theory.	15 Hours
<b>Internal Assessment:</b>		

CIA*-1	Unit -I	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III	
EoSE**	Unit-I, II, III, IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
1. Brauer F. and Chavez C. C., 2000, <i>Mathematical Models in Population Biology and Epidemiology</i> , Springer.		
2. Kot M., 2001, <i>Elements of Mathematical Ecology</i> , Cambridge University Press.		
3. Keshet L. E., 2005, <i>Mathematical Models in Biology</i> , SIAM.		
4. Keeling M. J. and Rohani P., 2008, <i>Modeling Infectious Diseases in Humans and Animals</i> , Princeton University Press.		
5. Martcheva M., 2010, <i>An Introduction to Mathematical Epidemiology</i> , Springer.		
<b>Reference Books:</b>		
6. Murray J. D., 2007, <i>Mathematical Biology: An Introduction</i> , Springer.		
7. Smith H., 2010, <i>An Introduction to Delay Differential Equations with Applications to Life Sciences</i> , Springer.		
<b>E-resources:</b>		
<a href="https://open.uci.edu/courses/math_113b_intro_to_mathematical_modeling_in_biology.html">https://open.uci.edu/courses/math_113b_intro_to_mathematical_modeling_in_biology.html</a>		
<a href="https://www.youtube.com/playlist?list=PL5zWDs2j0YF3kPPvs4L5FGlLc7x13Uwjn">https://www.youtube.com/playlist?list=PL5zWDs2j0YF3kPPvs4L5FGlLc7x13Uwjn</a>		

<b>Course-Code: MAT432</b>		
<b>Course Title: Probability Theory and Mathematical Statistics</b>		
<b>Teaching Scheme</b>	<b>Examination Scheme</b>	<b>Credits Allotted</b>
Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b> The student should have knowledge of		
1.	basic concepts of linear algebra and calculus	
<b>Course Objectives:</b>		
1.	To present the type of the data and tabulate statistical information given in descriptive form and to use graphical techniques to interpret.	
2.	To discuss probability, probability distributions, joint probability distributions and concepts associated with a random variable.	
3.	To explain essential tools for statistical analyses.	
4.	To discuss central limit theorem and order statistics.	
<b>Course Outcomes:</b> Students will be able to		
1.	learn descriptive statistics and to calculate probability for various types of problems.	
2.	work out various probability distributions and statistical tools.	
3.	explain order statistics and central limit theorem	
<b>Course Content:</b>		
Unit-I	Exploratory data analysis: summary statistics, box and whisker plots, histogram, P-P and Q-Q plots. Random Experiment and its sample space, probability as a set function on a collection of events, stating basic axioms,	15 Hours

	random variables, c.d.f., p.d.f., p.m.f.	
Unit-II	absolutely continuous and discrete distributions, Some common distributions (Negative Binomial, Pareto, lognormal, beta, etc). Transformations, moments, m.g.f., p.g.f., quantiles and symmetry. Random vectors, Joint distributions, copula, joint m.g.f. mixed moments, variance covariance matrix.	15 Hours
Unit-III	Independence, sums of independent random variables, conditional expectation and variances, compound distributions, prior and posterior distribution, best predictors. Sampling distributions of statistics from univariate normal random samples, chi-square, t and F distributions.	15 Hours
Unit-IV	Order statistics and the distribution of rth order statistics, joint distribution of rth and sth order statistics. Statement and application of central limit theorem for a sequence of independent and identically distributed random variables.	15 Hours
<b>Internal Assessment:</b>		
CIA*-1	Unit -I	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III	
EoSE**	Unit-I, II, III, IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		

1. Sheldon R.M., 2010, *Introductory Statistics*, Academic Press.
2. Rohatgi V.K. and Md. Ehsanes Saleh A.K., 2015, *An Introduction to Probability and Statistics (3<sup>rd</sup> Ed.)*, John Wiley & Sons.
3. Rao C. R., 1965, *Linear Statistical Inference and its Applications (2<sup>nd</sup> Ed.)*, John Wiley & Sons, INC.
4. Dharmaraja S. and Das D., 2018, *Introduction to Statistical Methods, Design of Experiments and Statistical Quality Control*, Springer.
5. Mayer P. L., 1970, *Introductory Probability and Statistical Applications*, Addison-Wesley.

**Reference Books**

1. Feller W., 2000, *An Introduction to Probability Theory and its Applications (3<sup>rd</sup> Ed.)*, Wiley Eastern.

**E-resources:**

1. <https://archive.nptel.ac.in/courses/111/105/111105090/>
2. <https://archive.nptel.ac.in/courses/111/102/111102160/>

<b><u>Course-Code: MAT433</u></b> <b><u>Course Title: Scientific Writing by LaTeX</u></b>		
<b>Teaching Scheme</b>	<b>Examination Scheme</b>	<b>Credits Allotted</b>
Theory: 1 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 1
Practical: 2 Hours/Week		Practical: 1
		Total: 2

<b>Course Prerequisite:</b> The student should have knowledge of		
	Basic computer skills to download the required files and programmes needed for the course	
<b>Course Objectives:</b>		
1.	Installation of scientific typing tools and writing environment to create documents	
2.	To introduce typing tools e.g., LaTeX, Open office	
3.	To introduce different commands and mathematical symbols	
4.	To discuss the use of template to create impressive documents for Master and PhD thesis	
5.	To make students learn how to write equations, plot graphs, and prepare presentations.	
<b>Course Outcomes:</b> Students will be able to		
1.	learn how to create a scientific document	
2.	write equations, letters and do different types of mathematical calculations	
3.	include Tables, Figures and Plots in a documents	
4.	create professional presentations	
5.	cite a paper and build Bibliography	
<b>Course Content:</b>		
Unit-I	Installing LaTeX and Class files, Creating first LaTeX document, creating documents in overleaf, Basic document spacing, Basic typesetting	11 Hours (4 Hours Theory and 7 Hours Practical)
Unit-II	mathematical Symbols and Commands, Writing of simple article, letters and applications, Mathematical symbols and commands, arrays, formulas and equations, Spacing, Borders and Colors	11 Hours (3 Hours Theory and 8 Hours Practical)



Unit-III	Figure environments, Subfigures, Tables, LateX presentations using Beamer, Creating different templates, Preparation of template of thesis and books	11 Hours (4 Hours Theory and 7 Hours Practical)
Unit-IV	Poster and CV templates, Pictures and Graphics, Bibliography, Writing of research articles and reports etc.	12 Hours (4 Hours Theory and 8 Hours Practical)
<b>Internal Assessment:</b>		
CIA*-1	Unit -I	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on II and III units	
EoSE**	Unit-I, II, III and IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
1. Lamport, L.W., 1994, <i>LaTeX: A document Preparation Systems</i> , Addison-Wesley Publishing Company.		
2. Kopka, H., Daly, P.W., 2004, <i>Guide to LaTeX</i> , Fourth Edition, Addison Wesley.		
<b>Reference Books:</b>		
1. Shirore C., <i>A Beginner guide to LaTeX</i> , Lullu.com		
<b>E-resources:</b>		
1. <a href="https://www.udemy.com/course/become-a-good-latex-user-to-create-professional-documents/">https://www.udemy.com/course/become-a-good-latex-user-to-create-professional-documents/</a> 2. <a href="https://www.overleaf.com/learn">https://www.overleaf.com/learn</a>		

**Course-Code: MAT434**  
**Course Title: Basic Programming in MATLAB**

Teaching Scheme	Examination Scheme	Credits Allotted
Theory: 1 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 1
Practical: 2 Hours/Week		Practical: 1
		Total: 2
<b>Course Prerequisite:</b>		
	Basic computer skills to download the required files and programmes needed for the course	
<b>Course Objectives:</b>		
1.	To introduce students to computational methods using MATLAB	
2.	To teach the basis of computational techniques for solving ordinary differential equations	
3.	To introduce the use of MATLAB for numerical integration and interpolations	
4.	To discuss different types of plotting (2D, 3D, contour etc.) using MATLAB	
<b>Course Outcomes:</b> Students will be able to		
	learn different environment of MATLAB	
2	do symbolic computations using MATLAB	
3	solve a system of differential equations via MATLAB	
4	learn different types of plotting namely, 2D, 3D, contour etc.	

5	do numerical integration and interpolation with unequal intervals	
<b>Course Content:</b>		
Unit-I	The MATLAB Environment, MATLAB Basics: Variables, Numbers, Operators, Expressions, Input and output, Vectors, Arrays: Matrices. Built-in Functions and User defined Functions,	11 Hours (4 Hours Theory and 7 Hours Practical)
Unit-II	Files and File Management: Import/Export, Basic 2D, 3D plots, Graphic handling, Use of MATLAB in Matrix Addition, multiplication, subtraction. Symbolic Calculation-symbols, differentiation, integration, etc. Conditional Statements, Loops.	11 Hours (3 Hours Theory and 8 Hours Practical)
Unit-III	MATLAB Programs: Programming and Debugging. Mathematical Computing with MATLAB-Algebraic equations. Basic Symbolic Calculus and Differential equations, Ordinary Differential Equations: A first order and first degree ODE.	11 Hours (4 Hours Theory and 7 Hours Practical)
Unit-IV	Interpolation with equal Interval: Newton –Gregory forward and backward interpolation formula. Numerical Integration: Trapezoidal method, Numerical Integration: Simpson method (1/3 and 3/8).	12 Hours (4 Hours Theory and 8 Hours Practical)
<b>Internal Assessment:</b>		
CIA*-1	Unit -I	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III	
EoSE**	Unit-I, II, III and IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		

1. Pratap R., *Getting started with MATLAB*, Oxford University Press.

2. Lynch, S., 2014, *Dynamical Systems with Applications using MATLAB*, Birkhäuser.

3. Fouseff, L.V., 2007, *Applied Numerical Analysis using MATLAB*, Pearson Education.

4. Chapara S.C., Canale, R.P., 2006, *Numerical Methods for Engineers*, McGraw Hill

**Reference Books:**

Gilat A, 2012, *MATLAB: An Introduction with Applications*, Wiley.

**E-resources:**

[https://onlinecourses.nptel.ac.in/noc20\\_ge05/preview](https://onlinecourses.nptel.ac.in/noc20_ge05/preview)

**Course-Code: MAT435**  
**Course Title: Numerical Analysis**

**Teaching Scheme**

**Examination Scheme**

**Credits Allotted**

Theory: 3 Hours/Week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory:3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b> Students should have knowledge of		
1.	differential calculus	
2.	difference operator, ODE	
<b>Course Objectives:</b>		
1	To introduce different numerical methods and their error to solve systems of linear equations, nonlinear equations, initial value problems and eigenvalue problems.	
2	To analyze the notion of interpolation and approximation.	
3	To provide the numerical treatment for the BVP governed by ODE	
<b>Course Outcomes:</b> Students will be able to		
1	apply a finite difference method to find the interpolation, differentiation and integration for the given discrete data values.	
2	analyze and choose the best suitable numerical method for the given mathematical problem.	
3	apply the numerical techniques to solve research problems of fluid dynamics, mathematical modeling.	
<b>Course Content:</b>		
Unit-I	Introduction to significant digits and errors, Solution of system of linear Equations (direct methods, Iterative methods, Ill-conditioned systems), Eigenvalue problem: Gershgorin circle theorem, power method, Jacobi method, Householder method.	15 Hours

Unit-II	Finite difference operators, difference tables, Lagrange interpolation, Newton's divided difference interpolation, Hermite interpolation, Cubic spline interpolation.	15 Hours
Unit-III	Numerical solution of ordinary differential equations: initial value problems, existence and uniqueness of the solution of initial value problem, Single step methods- Taylor series, Picard's method, Euler's method, modified Euler method, Runge-Kutta method, Multi-step methods: Predictor-corrector method, Stability Analysis.	15 Hours
Unit-IV	Boundary value problems (BVPs), Methods to solve BVPs: Finite-difference method, The Shooting method, The Cubic Spline method.	15 Hours
<b>Internal Assessment:</b>		
CIA*-I	Unit-I, II	
CIA*-II	Written Exams/ Quizzes/Assignment/Presentation/Viva-Voce based on Unit II and Unit III	
EoSE**	Unit-I, II, III, IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
1. Atkinson K. E., 1989, <i>An Introduction to Numerical Analysis</i> (2 <sup>nd</sup> Ed.), Wiley-India.		
2. Jain M. K., Iyengar S. R. K. Jain R. K., 2012, <i>Numerical Methods for Scientific and Engineering Computation</i> (6 <sup>th</sup> Ed.), New Age International Publishers.		
3. Sastry S. S. 2019, <i>Introductory Methods of Numerical Analysis</i> , PHI.		
<b>Reference Books:</b>		
1. Buchaman J.I., Turner P. R., 1992, <i>Numerical Methods and Analysis</i> , McGraw-Hill.		
<b>E-resources:</b>		

<https://archive.nptel.ac.in/courses/111/107/111107105/>

<b>Course-Code: MAT436</b> <b>Course Title: Integral Transforms</b>		
Teaching Scheme	Examination Scheme	Credits Allotted
Theory: 3 Hours/Week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory:3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b> Students should have knowledge of		
1.	basic concepts of Differential Calculus	
2.	basic concepts of Integral Calculus	
<b>Course Objectives:</b>		
1	To describe the ideas of Laplace transform, Fourier transform, Z-transform and Wavelet Transform	
2	To familiarize the students with the applications of the Laplace and Fourier transforms in the fields such as application of PDE, Digital Signal Processing, Theory of wave equations.	
3	To familiarize the students with the applications of the Z-transform to solve the difference equations.	
<b>Course Outcomes:</b> Students will be able to		

1	gain the idea that by applying the theory of Integral transform the problem from its original domain can be mapped into a new domain where solving problems becomes easier.	
2	apply these techniques to solve research problems of signal processing, data analysis and processing, image processing, in scientific simulation algorithms etc.	
3	apply these transform techniques to solve the physical problem governed by ODE, PDE and difference equations.	
<b>Course Content:</b>		
Unit-I	Laplace Transform-Definition and its properties, Laplace transform of some standard functions, Existence conditions for the Laplace Transform, Shifting theorems, Laplace transform of derivatives and integrals, Inverse Laplace transform and their properties.	15 Hours
Unit-II	Laplace Transform—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.	15 Hours
Unit-III	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, Applications of Fourier transforms to Boundary Value Problems.	15 Hours
Unit-IV	Z-Transform: Z–transform and inverse Z-transform of elementary functions, Shifting theorems, Convolution theorem, Initial and final value theorem, Application of Z-transforms to solve difference equations.	15 Hours
<b>Internal Assessment:</b>		
CIA*-I	Unit-I	
CIA*-II	Written Exams/ Quizzes/Assignment/Presentation/Viva-Voce based on Unit II and Unit III	
EoSE**	Unit-I, II, III, IV	



\*: Continuous Internal Assessment;

\*\* : End of Semester Examination

**Text Books:**

1. Lokenath D., Bhatta, D., 2014, *Integral Transforms and Their Applications*, Taylor and Francis.

2. John M.W., 2008, *Integral Transforms in Applied Mathematics*, Cambridge University Press.

3. Murrey R.S., 1965, *Laplace Transforms (SCHAUM Outline Series)*, McGraw Hill.

**Reference Books:**

1. Hildebrand F. B., 1992, *Methods of Applied Mathematics*, Dover Publications.

**E-resources:**

<https://nptel.ac.in/courses/111106111>

<b>Course-Code: MAT437</b>		
<b>Course Title: Elementary Number Theory</b>		
<b>Teaching Scheme</b>	<b>Examination Scheme</b>	<b>Credits Allotted</b>
Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b> Student should have knowledge of		
1.	basic Concepts of sets	
<b>Course Objectives:</b>		

1	To teach the students integers and their properties	
2	To teach the students the congruences	
3	To teach the students the arithmetic functions	
4	To teach the students binary quadratic forms	
<b>Course Outcomes:</b> Students will be able to		
1.	learn the concepts of linear Diophantine equation	
2	use the modular arithmetic	
3	learn primitive root theorem	
4	discuss binary quadratic forms	
<b>Course Content:</b>		
Unit-I	Division in integers, Greatest common divisor, Euclid's Algorithm, Linear Diophantine equations, Prime numbers, Fundamental Theorem of arithmetic, Distribution of primes, Greatest integer functions	15 Hours
Unit-II	Congruence relation, Properties of Congruence relation, Linear Congruences, Solvability of Linear congruence, modular arithmetic, Residue classes and reduced residue classes, Fermat's little theorem, Wilson's theorem, Euler's theorem Chinese remainder theorem, Higher degree polynomial congruence, Polynomial congruence mod $p^r$	15 Hours

Unit-III	Quadratic residues, Legendre Symbol, Primitive root theorem, Arithmetic functions $\chi(\square)$ , $\chi(\square)$ , $\chi(\square)$ , $\chi(\square)$ , Ring of Arithmetic functions, Multiplicative arithmetic functions, Möbius inversion formula, Perfect numbers	15 Hours
Unit-IV	Representation of an integer as a sum of two and four squares, Diophantine equations $x^2+y^2=z^2$ and $x^4+y^4=z^4$ . Binary quadratic forms and Equivalence of quadratic forms, Farey sequences	15 Hours
<b>Internal Assessment:</b>		
CIA*-1	Unit -I, II	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit III	
EoSE**	Unit-I, II, III, IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
1. Burton D. M., 1989, <i>Elementary Number Theory</i> , Wm. C. Brown Publishers, Dubuque, Iowa.		
2. Jones G.A. and J.M. Jones , 1998, <i>Elementary Number Theory</i> , Springer-Verlag, New York		
3. Sierpinski W., 1998, <i>Elementary Theory of Numbers</i> , North-Holland, Ireland.		
4. Koshy T., 2007, <i>Elementary Number Theory with Applications</i> , Academic Press, New York.		
<b>Reference Books:</b>		
1. Zuckerman N.S.H. and Montgomery L.H., 1991, <i>An Introduction to the Theory of Numbers</i> , John Wiley.		

<b>E-resources:</b>
<a href="https://archive.nptel.ac.in/courses/">https://archive.nptel.ac.in/courses/</a>

<b>Course-Code: MAT438</b>		
<b>Course Title: Introduction to Space Dynamics</b>		
<b>Teaching Scheme</b>	<b>Examination Scheme</b>	<b>Credits Allotted</b>
Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b>		
	Basics of linear algebra, analytical geometry, differential equations, and vector calculus.	
<b>Course Objective:</b> To develop the concept of		
1.	kinematics of particles, understanding of different orbital paths and elaboration of conservation laws.	
2.	two body problems and its application in space and visualization of Kepler's laws of planetary motion.	
3.	existence of integrals in three-body problem, applications of stable equilibrium points of the restricted problem of three bodies and importance of the Jacobi integral.	

4.	rocket dynamics, performance measuring parameters and needs multi-stages rockets.	
<b>Course Outcomes:</b> Students will be able to		
1.	know about the kinematics of particles, understand about different orbital paths of particles and verify the conservation laws.	
2.	solve the two body problem, verify Kepler's laws of planetary motion and visualize the application of two body problems in space.	
3.	verify the existence of integrals in a three-body problem, determine and examine the stability of equilibrium points in the restricted problem of three bodies and know the importance of the Jacobi integral.	
4.	know about rocket dynamics, estimate the performance parameters and understand about the needs of optimized multi-stages rockets.	
<b>Course Content:</b>		
Unit-I	Some basic definitions, Conservation laws, Newton's laws of motion, Kinematics of particles, Conic-section, Central force motion, Differential equation of orbit and its solution, Geometry of different kinds of orbits.	15 Hours
Unit-II	Formulation of problem of two-body and equations of motion, relative equation of motion of two body problem, Solution of two body problem and its application. Kepler's law of planetary motion, Kepler's equation and its solution, Uniform rotating frame.	15 Hours

Unit-III	Introduction of three body problem, Ten known integrals, Stationary solutions of three body problem and applications, Restricted problem of three body, Jacobi integral, prohibited regions of motion, collinear and noncollinear equilibrium points, Stability analysis of equilibrium points, Applications of restricted problem of three body in space.	15 Hours
Unit-IV	Equation of variable mass, introduction of rocket theory, governing equation of a rocket, Single-stage rocket and its performance, Effect of gravity on the dynamics of a rocket, two-stage rocket and its performance, multi-stage rocket, Optimization of multi-stage rocket.	15 Hours
<b>Internal Assessment:</b>		
CIA*-1	Written Exam.	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III	
EoSE**	Written Exam. for Unit-I, II, III, & IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
<ol style="list-style-type: none"> <li>1. McCuskey S. W., 1963, <i>Introduction to Celestial Mechanics</i>, Addison-Wesley Publishing Company.</li> <li>2. Murray C. D., Dermott S.F., 2000, <i>Solar System Dynamics</i>, Cambridge University Press.</li> <li>3. Rao K.S., 2009, <i>Classical Mechanics</i>, PHI Learning, Pvt. Ltd.</li> <li>4. Goldstein H., Poole C.P. and Safko J.L., 2019, <i>Classical Mechanics</i> (Third edition), Pearson India Education Pvt. Ltd.</li> <li>5. Battin, Richard H., 1999, <i>An Introduction to The Mathematics and Methods of Astrodynamics</i>, AIAA Education Series.</li> </ol>		
<b>Reference Books:</b>		

1. Szebehely V., 1967, *Theory of orbits. The restricted problem of three bodies*, New York Acad. Press.
2. Thomson, William T., 1986, *Introduction to Space Dynamics*, Dover Publication, Inc. New York

**E-resources:**

<https://nptel.ac.in/courses/101105029>  
<https://nptel.ac.in/courses/101104078>

<b><u>Course-Code: MAT-439</u></b>		
<b><u>Course Title: FLUID DYNAMICS</u></b>		
<b>Teaching Scheme</b>	<b>Examination Scheme</b>	<b>Credits Allotted</b>
<b>Theory: 3</b> Hours/week	<b>EoSE: 60 Marks</b> <b>Internal Assessment: 40 Marks</b>	<b>Theory: 3</b>
<b>Tutorial: 1</b> Hour/week		<b>Tutorial: 1</b>
		<b>Total: 4</b>
<b>Course Prerequisite:</b> Student should have knowledge of		
<b>1.</b>	basic concepts of differential equations.	
<b>2.</b>	basic concepts of calculus	
<b>Course Objectives:</b> This course aims to learn		
<b>1.</b>	basics characteristics of fluid, continuum hypothesis, kinematics of fluids.	
<b>2.</b>	Eulerian and Lagrangian methods for fluid motion.	

3.	conservation Laws in different coordinate systems and boundary conditions.	
4.	irrotational and rotational flows	
5.	solution process of simplified examples.	
<b>Course Outcomes:</b> Students will be able to learn		
1.	fluid properties, continuum hypothesis, strain rate tensor, streamline, path line, streak lines, stream function and vortex lines.	
2.	stress tensor, symmetry of stress tensor, transformation of stress	
3.	Eulerian and Lagrangian hypothesis and their differences.	
4.	conservation law and their equations.	
5.	methods of implementing fluid dynamics laws.	
6.	a number of fundamental mathematical ideas and techniques for the solution of related problems.	
<b>Course Content:</b>		
Unit-I	Physical Properties of fluids. Concept of fluids, continuum hypothesis, density, specific weight, specific volume, kinematics of fluids: Eulerian and Lagrangian methods of description of fluids, equivalence of Eulerian and Lagrangian method, general motion of fluid element, integrability and compatibility conditions,	15 Hours
Unit-II	Strain rate tensor, streamline, path line, streak lines, stream function, vortex lines, circulation. Stresses in Fluids: Stress tensor, symmetry of stress tensor, transformation of stress components from one coordinate system to another, principal axes and principal values of stress tensor, conservation of mass,	15 Hours
Unit-III	Conservation of momentum, Navier Stokes equation, conservation of moments of momentum, equation of energy, basic equations in different coordinate systems, boundary conditions.	15 Hours
Unit-IV	Irrotational and Rotational Flows : Bernoulli's equation, Bernoulli's equation for irrotational flows, two dimensional irrotational incompressible flows, Blasius theorem, circle theorem, sources and sinks, sources sinks and doublets in two dimensional flows.	15 Hours
<b>Internal Assessment:</b>		



<b>CIA-I*</b>	Unit-I	
<b>CIA-II</b>	Written Exams/ Quizzes/ Assignment/ Presentations/ Viva-Voce based on Unit II and Unit III	
<b>EoS E**</b>	Unit-I, II, III, IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
1. Rathy R.K., 1976, <i>An Introduction to Fluid Dynamics</i> , Oxford and IBH Publishing Co.		
2. Thomson L.N.M., 1962, <i>Theoretical Hydrodynamics</i> , Macmillan and Co. Ltd.		
3. Chorlton F., 1985, <i>Textbook of Fluid Dynamics</i> , CBS Publishers.		
4. Landau L. D., Lipschitz E.N., 1985, <i>Fluid Mechanics</i> , Pergamon Press.		
<b>Reference Books:</b>		
1. Emanuel, G. 2000, <i>Analytical Fluid Dynamics</i> , CRC Press.		
2. Nakayama, Y. and Boucher, R. F., 2000, <i>Introduction to Fluid Mechanics</i> , Butterworth-Heinemann		
<b>E-resources:</b>		
<a href="https://onlinecourses.nptel.ac.in/noc19_ce28/preview">https://onlinecourses.nptel.ac.in/noc19_ce28/preview</a>		

## LEVEL-5

Semester-III (M.Sc.)							
S. No.	Course Code	Course Title	Type of Course (C/E)	L	T	P	Credits
1	MAT501	Functional Analysis	CC	3	1	0	4

2	MAT502	Mathematical Modeling	CC	3	1	0	4
3	MAT503	MOOC (list will be provided)	CC	3	1	0	4
4		Elective Paper	DE	3	1	0	4
5	-	Elective Paper (Self Study)	DE	3	1	0	4
6	MAT504	Summer Internship (at least 6 weeks)	CC	3	1	0	4
<b>Total</b>				<b>18</b>	<b>6</b>	<b>0</b>	<b>24</b>
<b>Semester-IV (M.Sc.)</b>							
1	MAT581	Major Project Dissertation in Mathematics	AECC	0	0	16	16
3		Elective Paper	GE	3	1	0	4
2		Elective Paper	GE	3	1	0	4
<b>Total</b>							<b>24</b>

<u>Course-Code: MAT501</u> <u>Course Title: Functional Analysis</u>		
Teaching Scheme	Examination Scheme	Credits Allotted
Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4

<b>Course Prerequisite:</b>		
	basics of linear algebra, metric space and real analysis.	
<b>Course Objectives:</b> To develop the concept of		
1.	the normed linear space and its completeness property.	
2.	linear transformation and operator in normed linear spaces and its properties along with elaboration of open mapping theorem, closed graph theorem, uniform boundedness principle, Hahn Banach theorem, and natural Embedding of normed linear spaces.	
3.	Hilbert spaces and its different properties, orthogonality and elaboration of Projection theorem, Bessel's inequality and Riesz's theorem.	
4.	different operators in a Hilbert space and elaboration of spectral theorem on a finite dimensional Hilbert space.	
<b>Course Outcomes:</b> Students will be able to		
1.	verify the conditions of normed linear space and test the completeness property	
2.	verify the different properties of linear transformation and operators and understand the open mapping theorem, closed graph theorem, uniform boundedness principle, Hahn Banach theorem, and natural Embedding of normed linear spaces.	
3.	recognize the different properties of Hilbert space and orthogonal sets and understand the Projection theorem, Bessel's inequality and Riesz's theorem.	
4.	learn about different operators and understand the spectral theorem on a finite dimensional Hilbert space.	
<b>Course Content:</b>		
Unit-I	Normed linear spaces, Examples and properties, Equivalent norms, Convexity and completeness, Banach spaces, Examples and properties, $l^p$ spaces, $L^p$ spaces, Function space, Quotient Space	15 Hours

Unit-II	Operators on normed linear space, Continuous linear transformations, Bounded linear transformations, The open mapping Theorem, The closed graph theorem, The conjugate of an operator, The uniform boundedness principle, Hahn Banach Theorem, Embedding of normed spaces.	15 Hours
Unit-III	Inner product spaces, Examples and properties, Hilbert spaces, Examples and properties, Polarization identity, Orthogonality, Orthogonal complements, Orthogonal Projection on Hilbert spaces, Projection theorem, Bessel's inequality, Riesz's theorem, Existence of orthogonal basis in Hilbert spaces.	15 Hours
Unit-IV	The adjoint of an operator, Self adjoint operators, Normal and unitary operators, projections, Eigenvalues and eigenvectors of an operator on a Hilbert space, The spectral theorem on a finite dimensional Hilbert space.	15 Hours
<b>Internal Assessment:</b>		
CIA*-1	Unit I	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit I and Unit II	
EoSE**	Written Exam. for Unit-I, II, III, & IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
<ol style="list-style-type: none"> <li>1. Bachman G. and Narici, 1964, <i>Functional Analysis</i>, Academic Press.</li> <li>2. Taylor A. E., 1958, <i>Introduction to Functional Analysis</i>, John Wiley and Sons.</li> <li>3. M.T. Nair, <i>Functional Analysis: A first Course</i>, Prentice Hall of India, New Delhi, 2002 (Second Printing: 2008)</li> </ol>		
<b>Reference Books:</b>		
<ol style="list-style-type: none"> <li>1. Simmons G. F., 1963, <i>Topology and Modern Analysis</i>, McGraw Hill.</li> <li>2. Erwin Kreyszig E., 1978, <i>Introductory Functional Analysis with Application</i>, Wiley</li> </ol>		
<b>E-resources:</b>		

<https://nptel.ac.in/courses/111106047>

<https://nptel.ac.in/courses/111106147>

<b><u>Course-Code: MAT 502</u></b> <b><u>Course Title: Mathematical Modeling</u></b>		
<b>Teaching Scheme</b>	<b>Examination Scheme</b>	<b>Credits Allotted</b>
Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b> Student should have knowledge of		
1.	basic concepts in Linear Algebra and Real Analysis and Differential Equations	
<b>Course Objectives:</b>		
1.	To introduce students to the elements of the mathematical modeling process	
2.	To learn different types of mathematical models and their nature.	
3.	To exemplify the value of mathematics in problem solving	
4.	To develop students' capacity to solve problems through the use of mathematical models as a transferable process that will equip them to address novel problems in future.	
4.	To develop some of the methods used to explore qualitative information about the	

	behaviour of solutions of differential equations	
<b>Course Outcomes:</b> Students will be able to learn		
1.	the unique system characterization approach for a given system	
2.	identify assumptions which are consistent with the context of the problem and which in turn shape and define the mathematical characterization of the problem	
3.	how to analyze a given model system using mathematical analysis results.	
4.	to revise and improve mathematical models so that they will better correspond to empirical information and/or will support more realistic assumptions	
2.	different types of mathematical models in ecology, epidemiology, chemistry, Physics, Life Sciences, Engineering etc.	
<b>Course Content:</b>		
Unit-I	Introduction to modeling. Definition of System, classification of systems, classification and limitations of mathematical models, Methodology of model building, modeling through ordinary differential equations:	15 Hours
Unit-II	Linear growth and decay models, non-linear growth and decay models, Compartment models, Checking model validity, verification of models, Stability analysis, Basic model relevant to population dynamics, Epidemics modeling.	15 Hours
Unit-III	Ecology, Environment Biology through ordinary differential equation, Partial differential equation, Basic theory of linear difference equations with constant coefficients	15 Hours

Unit-IV	Mathematical modeling through difference equations in population dynamics, genetics, Markov chains model, Gambler's ruin model, Stochastic models, Monte Carlo methods.	15 Hours
<b>Internal Assessment:</b>		
CIA*-1	Unit -I	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III	
EoSE**	Unit-I, II, III, IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
1. Murthy D.N.P., Page N. W. and Rodin E. Y., 1990, <i>Mathematical Modelling: A Tool for Problem Solving in Engineering, Physics, Biological and Social Sciences</i> , Pergamon Press		
2. Kapur J.N., 2008, <i>Mathematical Modelling</i> , New Age Int. Pub		
3. Law A.M., Kelton W.D., 1991, <i>Simulation Modeling and Analysis</i> , McGraw-Hill.		
4. Meerscheart M.M., 2007, <i>Mathematical Modeling</i> , Academic Press		
<b>Reference Books:</b>		
5. Nemytskii V.V., 2005, <i>A Course in Mathematical Modeling</i> , Mathematical Association of America		
<b>E-resources:</b>		
<a href="https://nptel.ac.in/courses/111108081">https://nptel.ac.in/courses/111108081</a>		

<b>LEVEL-5 (Electives and Self Study)</b>				
<b>S. No.</b>	<b>Course Code</b>	<b>Course Title</b>	<b>Credit</b>	<b>Remarks</b>
1	MAT531	Partial Differential Equations	4	
2.	MAT532	GAME THEORY	4	
3.	MAT533	GRAPH THEORY	4	
4.	MAT534	AUTOMATA THEORY AND FORMAL LANGUAGES	4	
5.	MAT535	FOUNDATIONS OF SET THEORY	4	
6.	MAT536	PROGRAMMING IN C	4	
7.	MAT 537	ALGEBRAIC NUMBER THEORY	4	
8	MAT 538	ALGEBRAIC TOPOLOGY	4	
9.	MAT 539	AN INTRODUCTION TO FUZZY SET THEORY AND FUZZY LOGIC	4	
10	MAT 540	CELESTIAL MECHANICS	4	
11	MAT 541	COMPUTATIONAL ODE	4	
12	MAT 542	COMPUTATIONAL PDE	4	
13	MAT 543	DIFFERENTIAL GEOMETRY	4	
14	MAT 544	DIFFERENTIAL EQUATIONS & DYNAMICAL SYSTEMS	4	
15	MAT 545	FINANCIAL MATHEMATICS	4	



16	MAT 546	ADVANCED COMPLEX ANALYSIS	4	
17	MAT 547	FUNCTIONS OF SEVERAL REAL VARIABLES	4	
18	MAT 548	LIE ALGEBRAS	4	
19	MAT 549	MODULE THEORY	4	
20	MAT 550	NONLINEAR DYNAMICS & CHAOS	4	
21	MAT 551	FIELDS AND GALOIS THEORY	4	
22	MAT 552	OPERATIONS RESEARCH	4	
23	MAT 553	REPRESENTATION THEORY OF FINITE GROUPS	4	
24	MAT 554	SPECIAL FUNCTIONS	4	

<b>Course-Code: MAT531</b>		
<b>Course Title: Partial Differential Equations</b>		
<b>Teaching Scheme</b>	<b>Examination Scheme</b>	<b>Credits Allotted</b>
Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b> student should have knowledge of		
1.	Solution methods of ODE	

2.	differential calculus	
<b>Course Objectives:</b> To each		
1	theory of partial differential equations and solution methods.	
2	the nature of PDEs like parabolic, elliptic, hyperbolic.	
3	Green's Function method to find the solution of Non-homogeneous PDE	
4	Variational formulation of boundary value problems.	
<b>Course Outcomes:</b> Students will be able to		
1.	solve the PDEs independently	
2	convert partial differential equations to canonical form.	
3	use Green's function method to solve non-homogeneous PDE	
4	apply to Variational formulation of boundary value problems	
<b>Course Content:</b>		
Unit-I	Formation of PDEs: First order PDE in two and more independent variables, Derivation of PDE by elimination method of arbitrary constants and arbitrary functions. Lagrange's first order linear PDEs, Charpit's method for non-linear PDE of first order, Jacobi's method and Cauchy problem for first order PDEs.	15 Hours
Unit-II	PDEs of second order with variable coefficients: Classification of second order PDEs, Canonical forms of Parabolic, Elliptic and Hyperbolic PDEs, Method of separation of variables for Laplace, Heat and Wave equations.	15 Hours
Unit-III	Eigenvalues and Eigenfunctions of BVP, Orthogonality of Eigen function, D-Almbert's solutions to wave equations, Fundamental solution of Laplace Equation, Green's function for Laplace Equation, Wave equation, Diffusion Equation, Solution of BVP in spherical and cylindrical coordinates.	15 Hours
Unit-IV	General solution of higher order PDEs,, Variational formulation of boundary value problem.	15 Hours

<b>Internal Assessment:</b>		
CIA*-1	Unit -I, II	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and III	
EoSE**	Unit-I, II, III, IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
1. Rao, S.K., <i>Introduction to Partial Differential Equations</i> , PHI Learning.		
2. Sneddon, I.N., <i>Elements of Partial Differential Equations</i> , Dover Publications.		
3. Birkhoff G., Rota, G.C., <i>Ordinary Differential Equations</i> , Wiley.		
<b>Reference Books:</b>		
1. Amaranath, T., <i>An Elementary Course in Partial Differential Equations</i> , Narosa Publication.		
<b>E-resources:</b>		
1. <a href="https://archive.nptel.ac.in/courses/111/105/111105093">https://archive.nptel.ac.in/courses/111/105/111105093</a>		

<b>Course-Code: MAT532</b> <b>Course Title: Game Theory</b>		
<b>Teaching Scheme</b>	<b>Examination Scheme</b>	<b>Credits Allotted</b>

Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b> Students should have		
1.	knowledge of linear programming and simplex methods.	
<b>Course Objectives:</b>		
1.	To provide a rigorous treatment of solution concepts for games with perfect and imperfect information including Nash and subgame perfect Nash equilibria.	
2.	To cover topics such as auction, VNM utility function, bargaining game, etc.	
3.	To provide detailed knowledge about cooperative games.	
4.	To teach about games with imperfect information.	
<b>Course Outcomes:</b> Students will be able to		
1.	model competitive real world phenomena using concepts from game theory and identify optimal strategy and equilibrium solutions for such models.	
2.	learn the two person zero-sum game and its equilibrium solution.	
3.	discuss dynamic games and cooperative games.	
4.	work on strategic and dynamic games with imperfect information.	
<b>Course Content:</b>		

Unit-I	A General Introduction to Game Theory-its Origin, Representation of Games, Type of Game, Games with Perfect Information-Strategic Form Game, Solution Concept- Pure and Mixed Strategies, Dominance and Best Response, Pareto Optimality, Maxmin and Minmax Strategies,	15 Hours
Unit-II	Pure and Mixed Strategies Nash Equilibrium, Existence of a Nash Equilibrium, Two-person Zero-Sum Games-its Solution, Market Equilibrium and Pricing: Cournot and Bertrand Game, Auctions.	15 Hours
Unit-III	Decision Making and Utility Theory, Von Neumann and Morgenstern Utility Function, Theory of Risk Aversion, Equilibrium Theory. Dynamic Games of Perfect Information-Extensive Form Game, Subgame Perfect Nash Equilibrium, Backward Induction, Stackelberg Model of Duopoly. Coalition Games, Core and Shapley Value, Bargaining Game, Illustrations.	15 Hours
Unit-IV	Strategic Games with Imperfect Information -Bayesian Games, Cournot's Duopoly with Imperfect Information. Dynamic Games with Imperfect Information. Finitely and Infinitely Repeated Games, The Folk Theorem, Illustrations.	15 Hours
<b>Internal Assessment:</b>		
CIA*-1	Unit -I	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and III	
EoSE**	Unit-I,II,III,IV	
*: Continuous Internal Assessment **: End of Semester Examination		

<b>Text Books:</b>
<ol style="list-style-type: none"> <li>1. Osborne M.J., 2003, <i>An Introduction in Game Theory</i>, Oxford University Press.</li> <li>2. Osborne M. J. and Rubinstein A., 1994, <i>A Course in Game Theory</i>, MIT Press.</li> <li>3. Fudenberg D. and Tirole J., 1991, <i>Game Theory</i>, MIT Press.</li> <li>4. Von Neumann J. and Morgenstern O., 1944, <i>Theory of Games and Economic Behaviour</i>, New York: John Wiley and Sons.</li> </ol>
<b>Reference Books:</b>
<ol style="list-style-type: none"> <li>1. Watson J., 2013, <i>Strategy: An Introduction to Game Theory (3<sup>rd</sup> Ed.)</i>, W.W. Norton &amp; Company, London.</li> </ol>
<b>E-resources:</b>
<ol style="list-style-type: none"> <li>1. <a href="https://archive.nptel.ac.in/courses/110/104/110104063/">https://archive.nptel.ac.in/courses/110/104/110104063/</a></li> </ol>

<b>Course-Code: MAT533</b>		
<b>Course Title: Graph Theory</b>		
<b>Teaching Scheme</b>	<b>Examination Scheme</b>	<b>Credits Allotted</b>
Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b> Student should have knowledge of		
1.	basic concepts of sets	

<b>Course Objectives:</b>		
1	To teach the students basics of graphs	
2	To teach the students the connectivity	
3	To teach the students the planar graph	
4	To teach the students incidence matrix	
<b>Course Outcomes:</b> Students will be able to learn		
1.	the concepts of operation on graphs	
2	the Eulerian graphs	
3	the Kuratowski's theorem	
4	the automorphism of graphs	
<b>Course Content:</b>		
Unit-I	Graphs, Isomorphism of graphs, subgraph, walk, connectedness, degree, bipartite graph, Intersection graph, Operations on graphs, graph products, cut point, bridges, blocks	15 Hours
Unit-II	Tree, Center, Centroid, Connectivity, Line connectivity, Partition, Graphical partition, Eulerian graphs, Hamiltonian graphs, Line graph, Characterization of line graph	15 Hours
Unit-III	Covering, Independence, Planar graphs, Kuratowski's theorem, Chromatic Number, Chromatic polynomial	15 Hours
Unit-IV	Adjacency matrix, Incidence matrix, automorphism groups of graphs, group of composite graph	15 Hours

<b>Internal Assessment:</b>		
CIA*-1	Unit -I, II	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit III	
EoSE**	Unit-I, II, III, IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
1. Harary F., 1969, <i>Graph Theory</i> , Narosa Publication House, New Delhi		
2. Balakrishnan R., Ranganathan K., 2012, <i>A Textbook of Graph Theory</i> , Springer, New York		
3. Deo N., 1974, <i>Graph Theory with Applications to Engineering and Computer Science</i> , Prentice-Hall of India, New Delhi		
<b>Reference Books:</b>		
1. Diestel R., 2000, <i>Graph Theory</i> , Springer, New York		
<b>E-resources:</b>		
<a href="https://archive.nptel.ac.in/courses/">https://archive.nptel.ac.in/courses/</a>		

<b>Course Code: MAT534</b>		
<b>Course Title: AUTOMATA THEORY AND FORMAL LANGUAGES</b>		
<b>Teaching Scheme</b>	<b>Examination Scheme</b>	<b>Credits Allotted</b>



Theory: 3 hours/ week	EoSE: 60 Marks Internal Assessment: 40 Marks	Theory: 3
Tutorial: 1 Hour/Week		Tutorial: 1
		Total: 4
<b>Course Prerequisite:</b> The student should have knowledge of		
1.	basic concepts of sets, relations, functions	
2.	basic concepts of propositional logics	
<b>Course Objectives:</b>		
1	To explain why the study of automata is an important part of the core of computer science.	
2	To explain how finite automata are useful models in science and technology.	
3	To develop understanding of the concepts of automata theory and formal languages.	
<b>Course Outcomes:</b> Students will be able to learn		
1.	how automata and formal languages impact our life.	
2	the concepts and topics in hand without haste.	
3	the significance of the concepts defined and the theorems proved here.	
4	the concepts in more generalized form to capture uncertainty and vagueness of complex systems.	
<b>Course Content:</b>		

Unit-I	Theory of Computation: Finite automata, Deterministic and non-deterministic finite automata, equivalence of deterministic and non-deterministic automata, Moore and Mealy machines, Minimization of Automata, Regular expressions.	15 Hours
Unit-II	Conversion of finite automata to Regular expression. Grammars and Languages, Derivations, Language generated by a grammar, Regular language and regular grammar, Context free grammar and context-free language.	15 Hours
Unit-III	Context sensitive grammars and Languages. Context-free grammar in Chomsky normal form, Regular expressions, Formal definition of regular expression, Equivalence of regular expression and finite automata, Kleene's theorem.	15 Hours
Unit-IV	Formal definition of a Turing Machine, Representation of a Turing Machine, Turing machines as language acceptors, Universal Turing machines, decidability, undecidability, Turing Machine halting problem, Rice Theorem.	15 Hours
<b>Internal Assessment:</b>		
CIA*-1	Unit -I	
CIA-II	Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and III	
EoSE**	Unit-I, II, III, IV	
*: Continuous Internal Assessment **: End of Semester Examination		
<b>Text Books:</b>		
6. Kelly D., 1995, <i>Automata and Formal Languages: An Introduction</i> , Prentice-Hall.		
7. Hopcroft J. E., Motwani R. and Ullman J. D., 2001, <i>Introduction to Automata, Languages, and Computation (2<sup>nd</sup> Ed.)</i> , Pearson Edition.		

8. Linz P., 2010, <i>An Introduction to Formal Languages and Automata</i> , Narosa.
<b>Reference Books:</b>
9. Sipser M., 2012, <i>Introduction to the Theory of Computation (3<sup>rd</sup> Ed.)</i> , Cengage Learning.
<b>E-resources:</b>

**Course-Code: MAT535**

**Course Title: FOUNDATIONS OF SET THEORY**

**Teaching Scheme      Examination Scheme      Credits Allotted**

Theory: 3 hours/ week      EoSE: 60 Marks

Internal Assessment: 40 Marks      Theory: 3

Tutorial: 1 Hour/Week      Tutorial: 1

Total: 4

**Course Prerequisite:** Student should have knowledge of

1.      basic concepts of sets

**Course Objective:**

- 1      To teach the students the mathematical statements
- 2      To teach the students the relation and map
- 3      To teach the students the construction of number systems
- 4      To teach the students ordinal numbers

**Course Outcomes:** Students will be able to learn

1.      the Zermelo-Fraenkel axioms of set theory
- 2      the Peano's axioms
- 3      the dedekind cut approach

**Course Content:**

Unit-I Mathematical statements, connectives, simple sentence and compound sentence, universal quantifiers, Functional Rule and Truth Table, Conjunction, Disjunction, Implication, Tautology and Contradiction, Rules of Inference and Replacement, method of contradiction, Zermelo-Fraenkel axioms of set theory, Class of sets, Russel's Paradox 15 Hours

Unit-II Successor set and natural numbers, Ordered pair, Cartesian product, Relations and Maps on sets, Indexing set, Arbitrary intersection and union, Extension of Maps, Fundamental Theorem of Maps, Number Systems, Natural Numbers, Peano's Axioms, Pigeonhole Principle, 15 Hours

Unit-III Construction of other number systems, Integers and Rational Numbers, Their arithmetic and ordering, Dedekind cut, Real number system as complete ordered field 15 Hours

Unit-IV  $\in$  15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I, II

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit III

EoSE\*\* Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

Levy A., 1979, *Basic Set Theory*, Springer-Verlag, New York.

Copi M., 1979, *Symbolic Logic*, Macmillan Publishing Co. Inc., New York.

Kakkar V., 2016, *Set Theory: Read it, Absorb it and Forget it*, Narosa Publication House, New Delhi.

Enderton H. B., 1977, *Elements of Set Theory*, Academic Press Inc., New York.

**Reference Books:**

Halmos P. R., 1960, *Naive Set Theory*, Von Nostrand Reinhold Company, New York.

**E-resources:**

<https://archive.nptel.ac.in/courses/>

**Course-Code: MAT-536**

**Course Title: PROGRAMMING IN C**

**Teaching Scheme    Examination Scheme    Credits Allotted**

**Theory:** 3 Hours/week            **EoSE:** 60 Marks

**Internal Assessment:** 40 Marks            **Theory:** 3

**Lab:** 2 Hour/week            **Lab:** 1

**Total:** 4

**Course Prerequisite:** Students should have knowledge of

1. basics of sets and functions

**Course Objective:** This course aims to learn

1. To introduce the basic concepts of computer programming languages.
2. To develop the logics for create programs.
3. To introduce basic programming constructs

**Course Outcomes:** Students will be able to learn

1. the concepts of computer programming languages
2. the codes the programmes in C language
3. the developing of the applications

**Course Content:**

Unit-I Basic concepts of programming languages: Programming domains, language evaluation criterion and language categories, Describing Syntax and Semantics, formal methods of describing syntax, recursive descent parsing, Dynamic semantics (operational semantics, denotational semantics, axiomatic semantics). 11 Hours Theory and 7 Hours Lab

Unit-II Names, Variables, Binding, Type checking, Scope and lifetime data types, array types, record types, union types, set types and pointer types, arithmetic expressions, type conversions, relational and Boolean expressions, assignment statements, mixed mode assignment. 11 Hours Theory and 8 Hours Lab

Unit-III Statement level control structures, compound statements, selection statements, iterative statements, unconditional branching, Character set, variables and constants, keywords, Instructions, assignment statements, arithmetic expression, comment statements, simple input and output. 11 Hours Theory and 7 Hours Lab

Unit-IV Relational operators, logical operators, control structures, decision control structure, loop control structure, case control structure, functions, subroutines, scope and lifetime of identifiers, parameter passing mechanism, arrays and strings. 12 Hours Theory and 8 Hours Lab

**Internal Assessment:**

**CIA-I\*** Unit-I

**CIA-II** Written Exams/ Quizzes/ Assignment/ Presentations/ Viva-Voce/ based on Unit II and Unit III

**EoSE\*\*** Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Sebesta R.W., 1999, *Concepts of Programming Language*, Addison Wesley, Pearson Education Asia.
2. Deitel P., Deitel H., 2010, *How to Program C (6th Ed.)*, Addison Wesley, Pearson Education Asia.
3. Toledo R.A.M., Cushman P. K., 2003, *Introduction to Computer Science*, Mc Graw Hill International Edition.

4. Appleby D., Kopple, J.J.V., 1997, *Programming Languages (2nd Ed.)*, Tata McGraw Hill, India.
5. King K. N., 2008, *C Programming a Modern Approach (2nd Ed.)*, W. W. Norton & Company.

**Reference Books:**

1. Kanetkar Y., 2018, *Let Us C (16th Ed.)*, B.P.B Publications.

**E-resources:**

[https://onlinecourses.nptel.ac.in/noc22\\_cs40/preview#:~:text=The%20course%20is%20free%20to,Aftersnoon%20Session%202pm%20to%205pm.&text=This%20course%20will%20have%20an,section%20for%20date%20and%20time](https://onlinecourses.nptel.ac.in/noc22_cs40/preview#:~:text=The%20course%20is%20free%20to,Aftersnoon%20Session%202pm%20to%205pm.&text=This%20course%20will%20have%20an,section%20for%20date%20and%20time)

**Course-Code: MAT537**

**Course Title: ALGEBRAIC NUMBER THEORY**

**Teaching Scheme Examination Scheme Credits Allotted**

Theory: 3 hours/ week EoSE: 60 Marks

Internal Assessment: 40 Marks Theory: 3

Tutorial: 1 Hour/Week Tutorial: 1

Total: 4

**Course Prerequisite:** Students should have knowledge of

1. Basic Concepts of ring and elementary number theory

**Course Objective:**

- 1 To teach the students properties of number fields
- 2 To teach the students the quadratic fields
- 3 To teach the students the class group

**Course Outcomes:** The students will be able to learn

1. the arithmetic of algebraic number fields
- 2 Minkowski's theorem
- 3 Dirichlet unit theorem
- 4 the diophantine equation

**Course Content:**

Unit-I Number fields, the ring of algebraic integers, calculation for quadratic, cubic and cyclotomic cases, norms and traces, integral bases and discriminants, 15 Hours

Unit-II Dedekind domains, unique factorization of ideals, norm of ideals, factorization of prime ideals in extensions, The ideal class group, lattices in  $\mathbb{R}^n$ , Minkowski's theorem, 15 Hours

Unit-III Finiteness of the class number and its consequences, some class number computations, Dirichlet unit theorem, units in real quadratic fields 15 Hours

Unit-IV Some Diophantine equations, Cubic residue symbol, Jacobi sums, Cubic reciprocity law, biquadratic reciprocity law and Eisenstein reciprocity law 15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I, II

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit III

EoSE\*\* Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Esmonde J. and Murty M. R., 1999, *Problems in Algebraic Number Theory*, GTM, Springer-Verlag.
2. Mollin R.A., 2001, *Algebraic Number Theory*, CRC Press.
3. Alaca S. and Williams K. S., 2004, *Introductory Algebraic Number theory*, Cambridge University Press.
4. Zuckerman N.S.H. and Montgomery L.H., 1991, *An Introduction to the Theory of Numbers*, John Wiley.

**Reference Books:**

Marcus D. A., 1977, *Number Fields*, Springer-Verlag.

**E-resources:**

<https://archive.nptel.ac.in/courses/>

**Course-Code: MAT538**

**Course Title: ALGEBRAIC TOPOLOGY**

**Teaching Scheme      Examination Scheme      Credits Allotted**

Theory: 3 hours/ week      EoSE: 60 Marks

Internal Assessment: 40 Marks      Theory: 3

Tutorial: 1 Hour/Week      Tutorial: 1

Total: 4

**Course Prerequisite:** Students should have knowledge of

1. concepts of general Topology

**Course Objectives:**

- 1 To teach the students one point compactification
- 2 To teach the students the fundamental groups
- 3 To teach the students the lifting problems and its uniqueness
- 4 To teach the students Van Kampen Theorem

**Course Outcomes:** Students will be able to learn

1. the concepts of pushout and adjunct spaces
2. the calculation of some fundamental groups
3. the Deck transformation
4. the homology groups

**Course Content:**

Unit-I Review of General Topology, Continuous maps, compactness, one point compactification, Locally compact spaces, Proper maps, Quotient space, Real Projective space, Mobius band, Klein's bottle, torus, Wedge product, Co-product of groups, pushout, adjunct spaces, Cone 15 Hours

Unit-II Path, Homotopy, Reparametrization, First fundamental groups, Simply connected spaces, Category and functors between categories, Category of pointed topological space, Functorial property of fundamental group, Retraction map, Brower's fixed point theorem, fundamental group of product spaces, 15 Hours

Unit-III Deformation Retract, Covering projections, the lifting problems and its uniqueness, lifting of path and homotopy, Action of fundamental groups on fibers, regular covering, Deck transformation, group of Deck transformations, its action on fibres 15 Hours

Unit-IV Van Kampen Theorem, fundamental group of some adjunct spaces, n-simplex, face maps, chain, boundary operator, Chain complexes, homology groups, Convex sets and barycentric coordinates, Homotopy invariance of homology, Mayer Vitory sequence and its applications, Maps on sphere and degree 15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I, II

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce, based on Unit III

EoSE\*\* Unit-I,II,III,IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Munkres J.R., 2000, *Topology*, Prentice-Hall of India.
2. Greenberg M.J., Harper J.R., 1997, *Algebraic Topology: A First Course*, Addison-Wesley Publishing company.
3. Deo S., 2006, *Algebraic Topology: A Primer*, Hindustan Book Agency.
4. Vick J.W., 1994, *Homology Theory, An Introduction to Algebraic Topology*, Springer Verlag.

**Reference Books:**

Hatcher A., 2002, *Algebraic Topology*, Cambridge University Press.

**E-resources:**

<https://archive.nptel.ac.in/courses/>



**Course-Code: MAT539**

**Course Title: An Introduction to Fuzzy Set Theory and Fuzzy Logic**

**Teaching Scheme      Examination Scheme      Credits Allotted**

Theory: 3 hours/ week      EoSE: 60 Marks

Internal Assessment: 40 Marks      Theory: 3

Tutorial: 1 Hour/Week      Tutorial: 1

Total: 4

**Course Prerequisite:** Students should have the knowledge of

1. classical set theory, and two-valued logic.

**Course Objectives:**

1. To provide the basic knowledge of the fuzzy sets, operations and their properties.
2. To teach them the fundamental concepts of fuzzy functions and fuzzy relational calculus.
3. To teach them fuzzy logic in detail.
4. To teach them fuzzy numbers and evidence theory.

**Course Outcomes:** Students should be able to learn

1. the significance, need and applications of concepts of fuzziness.
2. the fundamental concepts of Fuzzy functions and Fuzzy logic
3. the fuzzy numbers and its types.
4. how to apply evidence theory.

**Course Content:**

Unit-I Crisp sets vs fuzzy sets: Membership function types and properties, Chance versus fuzziness, Level sets, Cardinality and fuzzy cardinality, Set theoretic operations on fuzzy sets, Inclusion and Difference, Fuzzy compliments, Fuzzy intersections: t-Norms, Fuzzy unions: t-Conorms, Algebraic operations, Averaging operators. Alpha-cut decomposition principle, 15 Hours

Unit-II Extension principle. Crisp versus fuzzy relations, Projections, Composition of fuzzy relations, Fuzzy binary relations, Fuzzy n-ary relation, transitive closure, Fuzzy equivalence relations. Classical logic an overview, : Introduction to propositional Logic, Boolean Algebra, Multi valued logic, 15 Hours

Unit-III Fuzzy logic, Linguistic hedges, Fuzzy propositions (conditional and unconditional), Approximate reasoning, Implication operations, Natural language, Fuzzy qualifiers, Inference from conditional and qualified fuzzy propositions, Fuzzy Quantifiers, Inference from quantified fuzzy propositions. 15 Hours

Unit-IV Fuzzy numbers, Types of fuzzy numbers, Linguistic variables, Fuzzy arithmetic: Extension principle and Interval arithmetic, Fuzzification, Defuzzification, Methods of Defuzzification. Fuzzy measures, Evidence theory, Necessity and belief measures, Probability measures vs possibility measures. 15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce, based on Unit II and III

EoSE\*\* Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Klir, G. J., Yuan B., 1997, *Fuzzy Sets and Fuzzy Logic: Theory and Applications*, Prentice Hall.
2. Ross T. J., 1995, *Fuzzy Logic with Engineering Applications*, McGraw Hill.
3. Zimmermann H. J., 1990, *Fuzzy Set Theory and Its Application (2<sup>nd</sup> Ed.)*, Kluwer, Boston.
4. Lee. K. H., 2005, *First Course on Fuzzy Theory and Applications*, Springer-Verlag.

**Reference Books:**

5. Bojadziev, G. and Bojadziev, M., 1996, *Fuzzy Sets, Fuzzy Logic, Applications*, World Scientific.

**E-resources:**

1. <https://archive.nptel.ac.in/courses/108/104/108104157/>

**Course-Code: MAT540**

**Course Title: Celestial Mechanics**

**Teaching Scheme      Examination Scheme      Credits Allotted**

Theory: 3 hours/ week      EoSE: 60 Marks

Internal Assessment: 40 Marks      Theory: 3

Tutorial: 1 Hour/Week      Tutorial: 1

Total: 4

**Course Prerequisite:**

basics of linear algebra, analytical geometry, differential equations, and vector calculus.

**Course Objectives:** To develop the concept of

1. motion of space objects via Kepler's laws of planetary motion and Newton's laws of motion and visualization of different paths/orbits of moving mass.
2. moving frame of reference and its relation to fixed frame along with formulation and special solutions and applications of three body problems.
3. stable/unstable equilibrium points and their applications along with formulation and applications of different kinds of restricted three body problems.
4. different kinds of perturbations in space and their impacts on small space objects (e.g. asteroid, satellite, space craft etc.) along with normal form and its application.

**Course Outcomes:** Students will be able to

1. learn about planetary motion of space objects and visualize their orbits/paths.

2. know the need of different kinds of frames of reference and understand the formulation and importance of special solutions of three body problems.
3. verify the stable/unstable equilibrium points and understand the applications of stable points along in addition with applications of different kinds of restricted three body problems.
4. learn about the different kinds of perturbations in space and their impacts on small space objects (e.g. asteroid, satellite, space craft etc.) along with application of normal form for stable motion.

**Course Content:**

Unit-I Introduction, Kepler's Laws of Planetary Motion, Central force motion, Differential equation of orbit, Inverse square force and Geometry of orbits, Relative motion in two body problem, Earthbound satellite circular orbit, Classical orbital elements, Kepler's equation and its applications. 15 Hours

Unit-II Moving frame of reference, Derivative of a vector in a rotating frame, motion of a mass relative to rotating frame, Uniform rotating frame, General three body problem, Integrals of motion, Lagrange's special solutions. 15 Hours

Unit-III Circular RTBP, Lagrangian points and their stability, Zero velocity curves, Elliptic RTBP, Equilibrium points, Existence of ZVC, Introduction of Robe's RTBP, Hill's problem, Sitnikov problem and their applications. 15 Hours

Unit-IV Introduction of perturbations factors, potential of oblate body, effective force of radiating body, potential due to disc or belt like structure. Introduction of normal form, Hamiltonian function, Normalization of Hamiltonian function of Circular RTBP and its applications. 15 Hours

**Internal Assessment:**

CIA\*-1 Unit I

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and III

EoSE\*\* Written Exam. for Unit-I, II, III, & IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. McCuskey S. W., 1963, *Introduction to Celestial Mechanics*, Addison-Wesley Publishing Company.
2. Murray C. D. and Dermott S.F., 2000, *Solar System Dynamics*, Cambridge University Press.
3. Strogatz S.H., 1994, *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry and Engineering*, Addison-Wesley.
4. Rao K.S., 2009, *Classical Mechanics*, PHI Learning, Pvt. Ltd.

**Reference Books:**

1. Moulton F.R., 1914, *An Introduction to Celestial Mechanics*, the MacMillan Company.
2. Szebehely V., 1967, *Theory of orbits. The restricted problem of three bodies*, New York Acad. Press.

**E-resources:**

<https://mitpress.mit.edu/9780262080484/celestial-mechanics/>

**Course-Code: MAT-541**

**Course Title: COMPUTATIONAL ODE**

**Teaching Scheme    Examination Scheme    Credits Allotted**

**Theory:** 3 Hours/week                      **EoSE:** 60 Marks

**Internal Assessment:** 40 Marks                      **Theory:** 3

**Tutorial:** 1 Hour/week                      **Tutorial:** 1

**Total:** 4

**Course Prerequisite:** Student should have knowledge of

1. basics of Linear Algebra
2. basics of Differential Equations
3. basics of Numerical Methods

**Course Objectives:** This course aims to learn

1. The numerical techniques for IVP and BVP
2. The convergence and stability of finite difference schemes
3. The finite difference method for differential equations.
4. The finite element methods for differential equations.
5. The application of numerical techniques in real life problems.

**Course Outcomes:** Students will be able to

1. obtain numerical solutions and the concepts of consistency, stability, convergence and error analysis.
2. check the stability and convergence of numerical methods.
3. solve numerically linear and nonlinear ordinary differential equations.
4. find the numerical solution to ODEs by using a computer program.
5. apply various numerical methods in real life problems.

**Course Content:**

Unit-I Numerical solutions of systems of simultaneous first order differential equations and second order initial value problems (IVP) by Euler and Runge-Kutta explicit methods, numerical solutions of second order boundary value problems (BVP) of first, second and third types by shooting method.

15 hours

Unit-II            Types of finite difference schemes of second order BVP based on difference operators (solutions of tridiagonal system of equations), solutions of such BVP by Newton-Cotes and Gaussian integration rules, convergence and stability of finite difference schemes.                      15 hours

Unit-III           Variational principle, approximate solutions of second order BVP of first kind by Rayleigh-Ritz, Galerkin, collocation and finite difference methods,                      15 hours

Unit-IV Finite Element methods for BVP-line segment, triangular and rectangular elements, Ritz and Galerkin approximation over an element, assembly of element equations and imposition of boundary conditions. 15 hours

**Internal Assessment:**

**CIA-I\*** Unit-I

**CIA-II** Written Exams/ Quizzes/ Assignment/ Presentations/ Viva-Voce based on Unit II and Unit III

**EoSE\*\*** Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Jain M.K., Iyengar S.R.K., Jain R.K., 2003, *Numerical Methods for Scientific and Engineering Computations*, New Age Publications.
2. Jain M.K., 1984, *Numerical Solution of Differential Equations (2<sup>nd</sup> Ed.)*, Wiley-Eastern.
3. Sastry S.S., 2002, *Introductory Methods of Numerical Analysis*, Prentice-Hall of India.
4. Griffiths DV., Smith I.M., 1993, *Numerical Methods for Engineers*, Oxford University Press.
5. Gerald C.F., Wheatley P.O., 1998, *Applied Numerical Analysis*, Addison- Wesley.

**Reference Books:**

1. Singh, A. K. and Singh, A. K., 2018, *Numerical Methods for Differential Equations with Programs*, Narosa Publications.

**E-resources:**

<https://nptel.ac.in/courses/111107063>

**Course-Code: MAT-542**

**Course Title: COMPUTATIONAL PDE**

**Teaching Scheme Examination Scheme Credits Allotted**

**Theory:** 3 Hours/week **EoSE:** 60 Marks

**Internal Assessment:** 40 Marks **Theory:** 3

**Tutorial:** 1 Hour/week **Tutorial:** 1

**Total:** 4

**Course Prerequisite:** Student should have knowledge of

1. basic of Linear Algebra
2. basic of Differential Equations
3. basic of Numerical Methods

**Course Objective:** This course aims to learn

1. the numerical techniques for partial differential equations
2. the convergence, truncation errors and stability of finite difference schemes
3. the explicit methods for partial differential equations.
4. the implicit methods for partial differential equations
5. the finite element methods for partial differential equations.
6. the application of numerical techniques in real life problems.

**Course Outcomes:** Students will be able to

1. obtain numerical solutions and the concepts of truncation errors, stability, convergence.

2. check the stability and convergence of numerical methods.
3. solve numerically parabolic, elliptic and hyperbolic equations.
4. find the numerical solution to PDEs by using a computer program.
5. apply various numerical methods in real life problems.

**Course Content:**

Unit-I Numerical solutions of parabolic equations of second order in one space variable with constant coefficients:- two and three levels explicit and implicit difference schemes, truncation errors and stability, Difference schemes for diffusion convection equation, 15 Hours

Unit-II Numerical solution of parabolic equations of second order in two space variables with constant coefficients-improved explicit schemes, implicit methods, alternating direction implicit (ADI) methods. 15 Hours

Unit-III Numerical solution of hyperbolic equations of second order in one and two space variables with constant and variable coefficients-explicit and implicit methods, alternating direction implicit (ADI) methods. 15 Hours

Unit-IV Numerical solutions of elliptic equations, Solutions of Dirichlet, Neumann and mixed type problems with Laplace and Poisson equations in rectangular, circular and triangular regions, Finite element methods for Laplace, Poisson, heat flow and wave equations 15 Hours

**Internal Assessment:**

**CIA-I\*** Unit-I

**CIA-II** Written Exams/ Quizzes/ Assignment/ Presentations/ Viva-Voce based on Unit II and Unit III

**EoSE\*\*** Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Jain M. K., Iyengar S.R.K., Jain R. K., 1994, *Computational Methods for Partial Differential Equations*, Wiley Eastern.
2. Jain M. K., 1984, *Numerical Solution of Differential Equations (2<sup>nd</sup> Ed.)*, Wiley Eastern.
3. Sastry S.S., 2002, *Introductory Methods of Numerical Analysis*, Prentice-Hall of India.
4. Griffiths D.V. and Smith I.M., 1993, *Numerical Methods of Engineers*, Oxford University Press.
5. General C.F. and Wheatley P.O., 1998, *Applied Numerical Analysis*, Addison- Wesley.
6. Bathe K.J. and Wilson E.L., 1987, *Numerical Methods in Finite Element Analysis*, Prentice-Hall.

**Reference Books:**

1. Mazumder, S., 2016, *Numerical Methods for Partial Differential Equations: Finite Difference and Finite Volume Methods*, Academic Press.
2. Sewell, G., 2015, *The Numerical Solution of Ordinary and Partial Differential Equations*, 3rd Ed., World Scientific Publications.

**E-resources:**

<https://ocw.mit.edu/courses/18-336-numerical-methods-for-partial-differential-equations-spring-2009/>

**Course Code: MAT543**

**Course Title: DIFFERENTIAL GEOMETRY**

**Teaching Scheme      Examination Scheme      Credits Allotted**

Theory: 3 hours/ week    EoSE: 60 Marks

Internal Assessment: 40 Marks    Theory: 3

Tutorial: 1 Hour/Week                  Tutorial: 1

Total: 4

**Course Prerequisite:** Students should have knowledge of Calculus

**Course Objective:**

1. To introduce the basic concept of smooth manifolds with a variety of examples
2. To elaborate the basic notions of smooth maps between manifolds and tangent spaces.
3. To convey applications of manifolds

**Course Outcomes:** Students will be able to learn

1. the concepts of smooth manifold, smooth map, and tangent space.
2. the inverse function theorem to describe the local structure of immersions and submersions;
3. the applications and significance of the topic in hands.

**Course Content:**

Unit-I Smooth manifold, chart and atlas, Compatible charts, Smooth maps between manifolds, Diffeomorphisms, Partial derivatives on manifolds, the inverse function theorems, Quotient manifolds  
15 Hours

Unit-II Real projective spaces, Standard smooth atlas for real projective space, Tangent spaces, Differential of a map, local expressions for differentials, Immersions and submersions, Rank, critical and regular points, 15 Hours

Unit-III Submanifolds and level sets, the rank of a smooth maps, Whitney's embedding theorem; Tangent bundle, Smooth sections and smooth frames, Vector fields and local flows. 15 Hours

Unit-IV Differential 1-Forms, Cotangent bundle, Characterization of smooth 1-Forms, Pullback of 1-forms, Differential k-Forms, local expression for k-Form, Pullback of k-Forms, the Wedge Product, Differential forms on a circle. 15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III

EoSE\*\* Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Tu W. L., 2010, *An Introduction to Manifolds (2<sup>nd</sup> Ed.)*, Springer-Verlag, New York.
2. O'Neill B., 1966, *Elementary Differential Geometry*, Academic Press, New York.
3. Thorpe J. A., 1979, *Elementary Topics in Differential Geometry*, Springer Verlag.
4. Somasundaram D., 2010, *Differential Geometry: A First Course*, Narosa Pub. House.

**Reference Book:**

1. Willmore T. J., 1965, *An Introduction to Differential Geometry*, Oxford University Press.

**E-resources:**

<https://ocw.mit.edu/courses/18-950-differential-geometry-fall-2008/>

**Course-Code: MAT 544**

**Course Title: Differential Equations & Dynamical Systems**

**Teaching Scheme      Examination Scheme      Credits Allotted**

Theory: 3 hours/ week      EoSE: 60 Marks

Internal Assessment: 40 Marks      Theory: 3

Tutorial: 1 Hour/Week      Tutorial: 1

Total: 4

**Course Prerequisite:** Students should have knowledge of

1. Differential Equations, Calculus and Linear Algebra

**Course Objective:**

1. To introduce the theory, properties and applications of various dynamical systems
2. To make the students familiar with stable and unstable subspaces and manifolds
3. To teach an important theorems: Hartman-Grobman, stable manifold
4. To introduce center manifold theory and normal form theory
5. To discuss global existence theorem and Poincare-Bendixson theory

**Course Outcomes:** The students will be able

1. to analyze and solve system of linear differential equations
2. to learn theory of nonlinear system: existence, maximal interval of existence and linearization
3. to apply different important theorem and theories e.g., Hartman-Grobman, stable manifold theorems, centre and normal form theory
4. to learn global existence theorem
5. to discuss about limit sets, limit cycles and periodic orbits for a given dynamical system

**Course Content:**

Unit-I Linear Systems: Exponentials of operators, Planar linear systems and their phase portraits, complex eigenvalues, multiple eigenvalues, Jordan forms, Stability theory      15 Hours

Unit-II Generalized eigenvectors and invariant subspaces, Non-homogeneous linear systems, Nonlinear Systems: The fundamental existence-uniqueness theorem, The maximal interval of existence, The flow defined by a differential equation, Linearization, The stable manifold theorem, The Hartman-Grobman



theorem 15 Hours

Unit-III Stability and Lyapunov functions, Saddles, Nodes, Foci and Centers, Center manifold and Normal form theory, Dynamical systems and global existence theorems, Limit sets and Attractors, Periodic orbits 15 Hours

Unit-IV Limit Cycles, and Separatrix cycles, Poincare map, Stable manifold theorem for periodic orbits, Poincare-Bendixson theory in xy-plane, Linear Systems, Bendixson's Criteria. 15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III

EoSE\*\* Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Perko L., 2006, *Differential Equations and Dynamical Systems*, Springer-Verlag.
2. Hirsch M.W., Smale S. Robert L.D., 2013, *Differential Equations, Dynamical Systems and An Introduction to Chaos*, Academic Press.
3. Stuart A. M. Humphries A. R., 1998, *Dynamical Systems and Numerical Analysis*, Cambridge University Press.
4. Lynch S., 2004, *Dynamical Systems with Applications using MATLAB*, Birkhause Press.

**Reference Books:**

5. Strogatz, S. H., 2000, *Nonlinear Dynamics and Chaos with Applications to Physics, Biology, Chemistry and Engineering*, Westview Press.

**E-resources:**

[https://www.youtube.com/playlist?list=PLbN57C5Zdl6j\\_qJA-pARJnKsmROzPnO9V](https://www.youtube.com/playlist?list=PLbN57C5Zdl6j_qJA-pARJnKsmROzPnO9V)

<https://www.youtube.com/watch?v=BRaliLNuvNg&list=PL6hB9Fh0Z1ELbHIAL22dCk173qykDgeoz>

**Course-Code: MAT 545**

**Course Title: Financial Mathematics**

**Teaching Scheme Examination Scheme Credits Allotted**

Theory: 3 hours/ week EoSE: 60 Marks

Internal Assessment: 40 Marks Theory: 3

Tutorial: 1 Hour/Week Tutorial: 1

Total: 4

**Course Prerequisite:** Student should have knowledge of

1. elementary Mathematics and Probability

**Course Objective:**

1. To provide the theoretical foundations required to understand the financial mathematics
2. To make the students familiar with the concepts life insurance contracts.
3. To teach Black Scholes model and Black Scholes equation
4. To introduce Binomial methods and Monte Carlo simulation
5. To discuss finite difference methods

**Course Outcomes:** Students will be able to learn

1. theoretical foundations required to understand the financial mathematics
2. Binomial methods
3. how to do Monte Carlo simulation
4. Finite difference methods

**Course Content:**

Unit-I Introduction to options and markets: types of options, interest rates and present values, Black Scholes model : arbitrage, option values, pay offs and strategies, put call parity, Black Scholes equation  
15 Hours

Unit-II Similarity solution and exact formulae for European options, American option, call and put options, free boundary problem, Binomial methods: option valuation, dividend paying stock, general formulation and implementation 15 Hours

Unit-III Monte Carlo simulation : valuation by simulation, Lab component: implementation of the option pricing algorithms and evaluations for Indian companies, different concepts associated with Finite difference methods 15 Hours

Unit-IV Finite difference methods: explicit and implicit methods with stability and conversions analysis methods for American options- constrained matrix problem, projected SOR, time stepping algorithms with convergence and numerical examples 15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III  
EoSE\*\* Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Luenberger D. G., 1998, *Investment Science*, Oxford University Press.
2. Hull J.C., 2000, *Options, Futures and Other Derivatives (4<sup>th</sup> Ed.)*, Prentice-Hall New York.
3. Cox J. C., Rubinstein M., 1985, *Option Market*, Englewood Cliffs, N. J. Prentice-Hall.
4. Jones C.P., 1996, *Investments, Analysis and Measurement (5<sup>th</sup> Ed.)*, John Wiley and Sons.
5. Capinski M., Zastawnaik T., *Mathematics for Finance*, Springer

**Reference Books:**

6. Wahidudin A.N., , 2000, *Financial Mathematics and Its Applications*, Ventus Publishing ApS

**E-resources:**

<https://nptel.ac.in/courses/111103126>

**Course-Code: MAT546**

**Course Title: ADVANCED COMPLEX ANALYSIS**

**Teaching Scheme      Examination Scheme      Credits Allotted**

Theory: 3 hours/ week      EoSE: 60 Marks

Internal Assessment: 40 Marks      Theory: 3

Tutorial: 1 Hour/Week      Tutorial: 1

Total: 4

**Course Prerequisite:** The student should have knowledge of Complex Analysis.

**Course Objective:**

1. To teach some topics of contemporary complex analysis.
2. To prepare the student to independent work in these topics
3. to teach the methods of complex analysis in other areas of mathematics

**Course Outcomes:** Students will be able to learn

1. the basic techniques of contemporary complex analysis
2. applications of these techniques in harmonic analysis
3. univalent functions theory and special functions.

**Course Content:**

Unit-I Liouville's theorem and its different proofs, Picard's little theorem, Picard's great theorem, Weak form of Picard's great theorem, Casorati-Weierstrass theorem, Harmonic conjugate, Transformation of harmonic functions, Transformations of boundary conditions. 15 Hours

Unit-II Applications of conformal mappings, Steady temperatures, Steady temperature in a half plane and related problems, Electrostatic Potentials, Potential in cylindrical space, Open mapping theorem, Hurwitz' theorem, Analytic continuation, Direct analytic continuation Poisson integral formula, Dirichlet problem. 15 Hours

Unit-III Infinite sums, Mittag-Leffler theorem, Infinite product of complex numbers, Convergence of infinite products, Infinite product of analytic functions, Factorization of entire functions, Gamma functions, Riemann Zeta functions, Euler product formula, Riemann Functional equations, Riemann hypothesis. 15 Hours

Unit-IV Univalent functions, Basic results of univalent functions, Class  $S$ , Area theorem, Bieberbach theorem and conjecture, Koebe  $1/4$  theorem, Riemann mapping theorem. 15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I, II

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and III

EoSE\*\* Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Brown J.W., and Churchill R.V., 2009, *Complex Variables and Applications*, McGraw Hill
2. Ponnusamy S., 2005, *Foundations of Complex Analysis*, Narosa Publication House.
3. Kasana H.S., 2005, *Complex Variables: Theory and Applications*, PHI.

Reference Books:

1. Theodore G., 2003, *Complex Analysis*, Springer

**E-resources:**

<https://archive.nptel.ac.in/courses/111/106/111106084/>

**Course Code: MAT547**

**Course Title: FUNCTIONS OF SEVERAL REAL VARIABLES**

**Teaching Scheme      Examination Scheme      Credits Allotted**

Theory: 3 hours/ week      EoSE: 60 Marks

Internal Assessment: 40 Marks      Theory: 3

Tutorial: 1 Hour/Week      Tutorial: 1

Total: 4

**Course Prerequisite:** Student should have knowledge of

1. basic concepts of calculus of one variables

**Course Objectives:**

- 1 To explain how some concepts of calculus can be generalized in higher dimensions.
- 2 To introduce multivariable calculus: different types of derivatives, chain rule, mean value theorem, maxima and minima, implicit and inverse function theorems.
- 3 To explain how these generalized concepts impact inventions in science, technology and our daily life.

**Course Outcomes:** The students will be able to learn

1. how existing concepts of calculus of one variable or two variable can be generalized in higher dimensions
2. the significance of the concepts defined and the theorems proved here;
3. the importance of these generalized concepts impacts science, technology and our daily life.

**Course Content:**

Unit-I  $\mathbb{R}^n$  as inner product and as normed space, convergence of sequences, compactness, equivalence

of norms, connected and convex sets, Functions from  $\mathbb{R}^n$  to  $\mathbb{R}^m$ , limit and continuity, Directional derivatives, partial derivatives of a function of several real variables. 15 Hours

Unit-II Differentiability of a function of several real variables, sufficient conditions for continuity and differentiability of a function of several real variables in terms of partial derivatives, algebra of differentiable functions, Chain rule of differentiation, Total differentials. 15 Hours

Unit-III Mean value Theorem for real valued functions, homogeneous functions and Euler's Theorem, Equality of mixed derivatives, Young's and Schwarz Theorems, higher differentials, Taylor's Theorem. 15 Hours

Unit-IV Maxima and minima for real valued functions of several real variables, (necessary and sufficient conditions), saddle points, Lagrange's multipliers, Hessian matrix, Jacobian matrix and determinants, Implicit and Inverse function Theorems, Functional dependence.. 15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III

EoSE\*\* Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Lang S, 1987, *Calculus of Several Variables*, Springer-Verlag, New York.
2. Fleming W. H., 1977, *Functions of Several Variables*, Springer-Verlag, New York.
3. Ghorpade S. R., Limaye B. V., 2010, *A Course in Multivariable Calculus and Analysis*, Springer, New York.

**Reference Books:**

4. Giaquinta M., Modica G. 2009, *Mathematical Analysis: An Introduction to Functions of Several Variables*, Birkhauser, Boston.
5. Spivak M., 1965, *Calculus on Manifolds: A Modern Approach to Classical Theorems of Advanced Calculus*, CRC Press.

**E-resources:**

3. [https://onlinecourses.nptel.ac.in/noc20\\_ma27/preview](https://onlinecourses.nptel.ac.in/noc20_ma27/preview)

**Course-Code: MAT548**  
**Course Title: LIE ALGEBRAS**

**Teaching Scheme      Examination Scheme      Credits Allotted**

Theory: 3 hours/ week EoSE: 60 Marks  
Internal Assessment: 40 Marks Theory: 3  
Tutorial: 1 Hour/Week Tutorial: 1  
Total: 4

**Course Prerequisite:** Student should have knowledge of

1. concepts of linear algebra

**Course Objectives:**

- 1 To teach the students how to utilize various techniques for working with Lie algebras
- 2 To teach the students the parts of a major classification result
- 3 To teach the students the representations of  $sl(2, \mathbb{C})$
- 4 To teach the students root Space Decomposition

**Course Outcomes:** Students will be able to learn

1. the construction of Lie algebra
- 2 the low-dimensional Lie algebras
- 3 the semisimple Lie Algebras
- 4 the root system

**Course Content:**

Unit-I Definition of Lie Algebras, Some Examples, classical Lie Algebras, Subalgebras and Ideals, Homomorphisms, Derivations, Structure Constants, Ideals and Homomorphisms, Constructions with Ideals, Quotient Algebras, Correspondence between Ideals, 15 Hours

Unit-II Low-Dimensional Lie Algebras, Dimensions 1,2and3, Solvable Lie Algebras, Nilpotent Lie Algebras, Subalgebras of  $gl(V)$ , Weights, The Invariance Lemma, Engel's Theorem, Lie's Theorem, Some Representation Theory, Definitions, Examples of Representations, Modules for Lie Algebras, Irreducible and Indecomposable Modules, Schur's Lemma 15 Hours

Unit-III Representations of  $sl(2, \mathbb{C})$ , Classifying the Irreducible  $sl(2, \mathbb{C})$ -Modules, Weyl's Theorem, Cartan's Criteria, Jordan Decomposition, Testing for Solvability, The Killing Form, Testing for Semisimplicity, Derivations of Semisimple Lie Algebras 15 Hours

Unit-IV The Root Space Decomposition, Cartan Subalgebras, Subalgebras Isomorphic to  $sl(2, \mathbb{C})$ , Root Strings and Eigenvalues, Cartan Subalgebras as Inner-Product Spaces, Root Systems, Bases for Root Systems, Cartan Matrices and Dynkin Diagrams 15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I, II

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on UNIT III

EoSE\*\* Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

Humphreys J. E., 1972, *Introduction to Lie Algebras and Representation Theory*, Springer-Verlag New York.

Jacobson N., 1962, *Lie Algebras*, Wiley-Interscience, New York.

Erdmann K. and Wilson M.J., 2006, *Introduction to Lie Algebras*, Springer-Verlag, New York.

**Reference Books:**

Serre J. P., 1965, *Lie Algebras and Lie Groups*, Benjamin, New York.

**E-resources:**

<https://archive.nptel.ac.in/courses/>

**Course-Code: MAT549**

**Course Title: MODULE THEORY**

**Teaching Scheme      Examination Scheme      Credits Allotted**

Theory: 3 hours/ week      EoSE: 60 Marks

Internal Assessment: 40 Marks      Theory: 3

Tutorial: 1 Hour/Week      Tutorial: 1

Total: 4

**Course Prerequisite:** Student should have knowledge of

1. concepts of rings and linear algebra

**Course Objective:**

- 1 To teach the students linear algebra over certain rings
- 2 To teach the students the basic definitions and elementary results
- 3 To teach the students the classification of finitely generated abelian groups
- 4 To teach the students Jordan Canonical form

**Course Outcomes:** Students will be able to learn

1. the concepts of isomorphism theorems
2. the projective and injective modules
3. the torsion and torsion-free modules
4. the Jordan canonical form

**Course Content:**

Unit-I Modules over a ring, Endomorphism ring of an abelian group, R-Module structure on an abelian group M as a ring homomorphism from R to  $\text{End}_Z(M)$ , submodules, Direct summands, Annihilators, Faithful modules, Homomorphism, Factor modules, Isomorphism theorems      15 Hours

Unit-II Free Module, Noetherian and Artinian Module, Hilbert basis theorem, Wedderburn Artin

Theorem, Split exact sequences and their characterizations, Left exactness of Hom sequences and counterexamples for non-right exactness, Projective modules, Injective modules, Baer's characterization, Divisible groups, Examples of injective modules.  $(M, M)$  as a ring, Exact sequences, Five lemma, 15 Hours

Unit-III External and internal direct sums and their universal property, Submodules of finitely generated free modules over a PID, Torsion submodule, Torsion and torsion-free modules, Direct decomposition into  $T(M)$  and a free module, primary components, Decomposition of p-primary finitely generated torsion modules 15 Hours

Unit-IV Elementary divisors and their uniqueness, Decomposition into invariant factors and uniqueness, Reduction of matrices over polynomial rings over a field, Similarity of matrices and  $F[x]$ -module structure, Rational canonical form of matrices, Elementary Jordan matrices, Reduction to Jordan canonical form, Diagonalizable and nilpotent parts of a linear operator, Smith normal form over PID, Uniqueness of Smith normal form 15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I, II

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit III

EoSE\*\* Unit-I,II,III,IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Dummit D. S. and Foote R. M., 2003, *Abstract Algebra*, John Wiley NY.
2. Gopalakrishnan N. S., 1986, *University Algebra*, Wiley Eastern Ltd., New Delhi.
3. Lam T. Y., 2007, *Exercises in Module and Rings*, Springer.

**Reference Books:**

1. Anderson F. W. and Fuller K. R., 1974, *Rings and Categories of Modules*, Springer, N.Y.

**E-resources:**

<https://archive.nptel.ac.in/courses/>

**Course-Code: MAT 550**

**Course Title: NONLINEAR DYNAMICS & CHAOS**

**Teaching Scheme Examination Scheme Credits Allotted**

Theory: 3 hours/ week EoSE: 60 Marks

Internal Assessment: 40 Marks Theory: 3

Tutorial: 1 Hour/Week Tutorial: 1

Total: 4

**Course Prerequisite:** Student should have knowledge of

1. Differential Equations and Calculus



**Course Objectives:**

1. To provide knowledge of different topics in Nonlinear dynamics and chaos
2. To teach one dimensional systems and different types of bifurcations
3. To introduce some real model systems and applications of one dimensional bifurcations and stability theory
4. To introduce two dimensional systems and associated bifurcations
5. To discuss one dimensional maps and different topics in chaos

**Course Outcomes:** The students will be able to learn

1. different topics in nonlinear dynamics and chaos
2. bifurcations for one dimensional system and associated applications
3. bifurcation theory for two dimensional systems and application
4. different aspects associated with chaos and applications

**Course Content:**

Unit-I The importance of being nonlinear, A dynamical view of the world, One dimensional flows: Flows on the lines: a geometric way of thinking, Fixed points, Local stability analysis, Overdamped beam on a rotating hoop, Existence and Uniqueness, Impossibility of oscillations, Potentials, Bifurcations: Saddle-node bifurcations, Transcritical and Pitchfork bifurcations, Supercritical and Subcritical Pitchfork bifurcations, Laser threshold, Imperfect bifurcations and Catastrophes 15 Hours

Unit-II Insect outbreak: Model, Dimensionless formulation, Analysis of fixed points, Two dimensional flows: Linear systems, Definitions and examples, Classification of linear systems, Dynamics of love affairs, Rabbit Versus Sheep, Conservative Systems, Limit cycles, Ruling out closed orbits, Poincare-Bendixson theorem, Lienard systems, Weakly nonlinear oscillators, 15 Hours

Unit-III Bifurcations in case of two dimensional systems, Hopf-bifurcations in aeroelastic stabilities and chemical oscillators, Global bifurcations of cycles, chaotic waterwheels, waterwheel equations and Lorentz equations, Chaos in the Lorentz equations, Strange attractor of Lorentz equations 15 Hours

Unit-IV One dimensional map, Universal aspects of periodic doubling, Feigenbaum's renormalization analysis and periodic doubling, Renormalization: Function space and hands-on calculation, Fractals and the geometry of strange attractors, Henon map, Using chaos to send secret messages 15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III

EoSE\*\* Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Strogatz S., 2001, *Nonlinear Dynamics and Chaos*, Springer.
2. Ermentrout B., 2005, *Simulating Analyzing and Animating Dynamical Systems*, SIAM.
3. Hirsch M. W., Smale S., Devaney R. L., 2002, *Differential Equations, Dynamical Systems and an Introduction to Chaos*, Academic Press.
4. Guckenheimer J., Holmes P., 2000, *Nonlinear Oscillations, Dynamical Systems and Bifurcations of Vector Fields*, Springer, New York.

**Reference Books:**

6. Percival I., Richards, D., 1982, *Introduction to Dynamics*, Cambridge University Press
7. Guckenheimer J. and Holmes P., 2000, *Nonlinear Oscillations, Dynamical Systems and Bifurcations of Vector Fields*, Springer, New York.

**E-resources:**

[https://www.youtube.com/playlist?list=PLbN57C5Zdl6j\\_qJA-pARJnKsmROzPnO9V](https://www.youtube.com/playlist?list=PLbN57C5Zdl6j_qJA-pARJnKsmROzPnO9V)

**Course-Code: MAT551**

**Course Title: FIELDS AND GALOIS THEORY**

**Teaching Scheme      Examination Scheme      Credits Allotted**

Theory: 3 hours/ week      EoSE: 60 Marks

Internal Assessment: 40 Marks      Theory: 3

Tutorial: 1 Hour/Week      Tutorial: 1

Total: 4

**Course Prerequisite:** Student should have knowledge of

1. groups and rings

**Course Objective:**

- 1 To teach the students symmetries of roots of a polynomial
- 2 To teach the students the solubility in terms of simple algebraic formulae
- 3 To teach the students the algebraic properties of field extensions
- 4 To teach the students geometric problems such as doubling the cube

**Course Outcomes:** Students will be able to learn

1. the algebraic extension
- 2 the splitting field
- 3 the Finite field
- 4 the construction of regular polygon

**Course Content:**

Unit-I Eisenstein's irreducibility criterion, Characteristic of a field, Prime subfields, Field extensions, Finite extensions, Simple extensions, Algebraic and transcendental extensions. Factorization of polynomials in extension fields. Splitting fields and their uniqueness. 15 Hours

Unit-II Separable field extensions, Perfect fields, Separability over fields of prime characteristic, Transitivity of separability, Automorphisms of fields, Dedekind's theorem, Fixed fields, Normal extensions, Splitting fields and normality, normal closures, 15 Hours

Unit-III Galois extensions, Fundamental theorem of Galois theory, Computation of Galois groups of polynomials., Primitive element theorem, Finite fields, Existence and uniqueness, Subfields of finite fields, Characterization of cyclic Galois groups of finite extensions of finite fields, fundamental theorem of algebra 15 Hours

Unit-IV Cyclotomic extensions and polynomials, cyclic extensions, Solvability by radicals, Galois' characterization of such solvability, Generic polynomials, Abel-Ruffini theorem, geometrical constructions, construction of real number by ruler and compass, Impossibility of trisection of angle, Construction of regular polygon 15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I, II

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit III

EoSE\*\* Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Dummit D. S. and Foote R. M., 2003, *Abstract Algebra*, John Wiley & Sons, New York.

2. Hungerford T. W., 2004, *Algebra*, Springer (India), Pvt. Ltd.
3. Roman S., 2007, *Field Theory*, Springer, New York.
4. Stewart I. N., 2004, *Galois Theory*, Chapman & Hall, New York.

**Reference Books:**

Artin E., 1997, *Galois Theory*, Dover Publications.

**E-resources:**

<https://archive.nptel.ac.in/courses/>

**Course-Code: MAT552**

**Course Title: Operations Research**

<b>Teaching Scheme</b>	<b>Examination Scheme</b>	<b>Credits Allotted</b>
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Theory: 3 hours/ week	EoSE: 60 Marks	
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Internal Assessment: 40 Marks	Theory: 3	
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Tutorial: 1 Hour/Week	Tutorial: 1	
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Total: 4

**Course Prerequisite:** Students should have knowledge of

1. Mathematical Programming
2. Probability Theory

**Course Objective:**

1. To teach how to determine an optimal sequence out of a series of jobs.
2. To teach the PERT/CPM techniques to plan, schedule, and control project activities.
3. To teach solution methodologies for deterministic and probabilistic inventory models.
4. To introduce the basic concepts of stochastic processes.
5. To teach what is a queueing model and how to analyze some specific queueing models.

**Course Outcomes:** Students will be able

1. to find the optimal job sequencing.
2. to get a deep understanding of the PERT/CPM techniques to plan, schedule, and control project activities.
3. to learn deterministic and probabilistic inventory models.
4. to learn the basic concepts of stochastic processes.
5. to learn the theory behind queueing models and to characterize a queue & its key performance indicators.

**Course Content:**

Unit-I Job sequencing: Principal assumptions, processing  $n$  jobs through  $m$  machines. Project management by PERT-CPM technique: Network representation, critical path computations, construction

of the time schedule, project evaluation and report technique. 15 Hours

Unit-II Deterministic inventory models: General Inventory models, static economic order quantity (EOQ) model, dynamic EOQ models, deterministic models with price breaks. Review of Probability theory, Probabilistic Inventory models, Probabilistic EOQ model, Single period model. 15 Hours

Unit-III Stochastic processes, Classification and its properties, Markov process, types of Markov processes, infinitesimal generator matrix, transition probability matrix, steady state distributions, transient distributions. 15 Hours

Unit-IV Queueing models: Elements of Queueing models, Kendall notations, Poisson process, pure birth model, pure death model, birth-death model, Chapman-Kolmogorov equations, Little's Law, distribution of waiting time and response time, Burke's Theorem, M/M/1 model, M/M/1/N models. 15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III

EoSE\*\* Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Castaneda L. B., Arunachalam V., Dharmaraja S., 2012 *Introduction to Probability and Stochastic Processes with Applications*, Wiley, Hoboken, NJ, USA.
2. Hillier F. S., Lieberman G. J., Nag B., Basu P., 2012, *Introduction to Operations Research*, Tata McGraw Hill Education Pvt. Ltd.
3. Taha H. A., 2007, *Operations Research-An Introduction*, Prentice Hall of India Pvt. Ltd.

**Reference Books:**

1. Trivedi K.S., 2016, *Probability and Statistics with Reliability, Queuing and Computer Science Applications*, John Wiley & Sons, Inc., Hoboken, NJ, USA.
2. Medhi J., 2009, *Stochastic Processes (3<sup>rd</sup> Ed.)*, New Age International Publishers.

**E-resources:**

1. <https://archive.nptel.ac.in/courses/111/107/111107128/>

**Course-Code: MAT553**

**Course Title: REPRESENTATION THEORY OF FINITE GROUPS**

**Teaching Scheme Examination Scheme Credits Allotted**

Theory: 3 hours/ week EoSE: 60 Marks

Internal Assessment: 40 Marks Theory: 3

Tutorial: 1 Hour/Week Tutorial: 1

Total: 4

**Course Prerequisite:** Student should have knowledge of

1. concepts of groups and module

**Course Objective:**

- 1 To teach the students the representation theory of finite groups
- 2 To teach the students the finite dimensional algebras
- 3 To teach the students Maschke's Theorem
- 4 To teach the students the character of the representation

**Course Outcomes:** Students will be able to learn

1. the concepts of Faithful Representation
- 2 the group algebra
- 3 the Schur's lemma
- 4 the character of the representation

**Course Content:**

Unit-I Representation of into group of Matrices, Examples, Faithful Representation, Equivalent Representation, FG-module, Equivalent formulation of Representation as FG module, 15 Hours

Unit-II Permutation module, FG-submodule, Irreducible Representation, Group algebra, Regular FG-module, Action of FG on FG-module, FG-homomorphism, FG-isomorphism, Direct sum of FG-submodule 15 Hours

Unit-III Maschke's Theorem, Completely reducible FG-submodule, Schur's Lemma and its application, Representation of abelian groups, Irreducible submodules of CG-module, Composition factor, 15 Hours

Unit-IV Character of the representation, class function, Character table, irreducible characters, degree of character, regular and permutation character, Orthogonality relation between characters. 15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I, II

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit III

EoSE\*\* Unit-I,II,III,IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Burrow M., 1965, *Representation Theory of Finite Groups*, Academic Press.
2. Jacobson N., 1983, *Basic Algebra-II*, Hindustan Publishing Corporation, New Delhi
3. Lang S., 2004, *Algebra (3<sup>rd</sup> Ed.)*, Springer.

**Reference Books:**

1. Dornhoff L., 1971, *Group Representation Theory-Part A*, Marcel Dekker, Inc., New York.

**E-resources:**

<https://archive.nptel.ac.in/courses/>

**Course-Code: MAT554**

**Course Title: SPECIAL FUNCTIONS**

**Teaching Scheme      Examination Scheme      Credits Allotted**

Theory: 3 hours/ week      EoSE: 60 Marks

Internal Assessment: 40 Marks      Theory: 3

Tutorial: 1 Hour/Week      Tutorial: 1

Total: 4

**Course Prerequisite:** Student should have knowledge of Complex Analysis.

**Course Objectives:** To demonstrate

1. the fundamentals of special functions including Gamma functions
2. the Riemann Zeta functions, Hypergeometric functions, Generalized Hypergeometric functions
3. the Bessel functions, Legendre polynomials, Hermite Polynomials and Laguerre Polynomials.

**Course Outcomes:** Students will be able to learn

1. Gamma functions
2. hypergeometric functions
3. basic theory, properties and applications of special functions

**Course Content:**

Unit-I Infinite product of complex numbers, Factorization of entire functions, Gamma functions, Order symbols  $o$  and  $O$ , Beta functions, Euler reflection formula, Factorial function, Legendre's duplication formula, Gauss's multiplication formula, Integral representations for Gamma function and Beta functions, Walli's products, Stirling formula.      15 Hours

Unit-II Asymptotic expansion, Riemann Zeta functions, Euler product formula, Riemann Functional equations, Riemann hypothesis, Gauss Hypergeometric Function, Elementary Properties, Conditions of convergence, Contiguous function relations, Integral Representation, Simple transformation, Quadratic transformation. 15 Hours

Unit-III Generalized Hypergeometric Functions, Integral representation, Elementary Properties, Integral Representation, Legendre polynomials and functions, Solution of Legendre's differential equations, Generating Functions, Rodrigue's Formula, Orthogonality of Legendre polynomials, Recurrence relations.      15 Hours

Unit-IV Bessel functions, Bessel differential equation and its solution, Recurrence relation, Generating functions, Integral representation, Hermite Polynomials, Laguerre Polynomials.      15 Hours

**Internal Assessment:**

CIA\*-1 Unit -I, II

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit III

EoSE\*\*      Unit-I,II,III,IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Rainville E. D., 1960, *Special Functions, The MacMillan Comp.*
2. Bell W.W., 1968, *Special Functions for Scientists and Engineers, D. Van Nostrand Comp. Ltd.*

**Reference Books:**

1. Andrews G.E., Askey R. and Roy R., 1999, *Special Functions, Encyclopedia of Mathematics and Its Applications*, Cambridge University Press.

**E-resources:**

**Course-Code: MAT-555**

**Course Title: Mathematics for Machine Learning**

**Teaching Scheme      Examination Scheme      Credits Allotted**

Theory: 3 hours/ week      EoSE: 60 Marks

Internal Assessment: 40 Marks      Theory: 3

Practical: 2 Hours/Week      Practical: 1

Total: 4

**Course Prerequisite:** Student should have knowledge of

1. basic knowledge in Calculus, Linear Algebra and Probability Theory
2. basic knowledge in python programming

**Course Objective:**

- 1 To teach about Principal Component Analysis and Linear Discriminant Analysis.
- 2 To teach about different regression methodologies
- 3 To teach various optimization methodologies.
- 4 To teach support vector machines.

**Course Outcomes:** Students will be able to

1. apply theoretical and numerically PCA and LDA.
2. use regression techniques.
3. obtain the optimal solution by different optimization methodologies.
4. apply the concept of support vector machines in real life problems.

**Course Content:**

Unit-I Basics concepts of Calculus and Linear Algebra, Linear Transformations, Orthogonal Complement and Projection Mapping, Eigenvalues and Eigenvectors, Special Matrices and Properties. Spectral Decomposition, Singular Value Decomposition, Low Rank Approximations, Principal Component Analysis, Linear Discriminant Analysis, Python Implementation of these methodologies.

11 Hours Theory and 8 Hours Lab

Unit-II Review of Probability Concepts, Least Square Approximation and Minimum Normed Solution, Linear and Multiple Regression, Logistic Regression, Python Implementation. 11 Hours Theory and 7 Hours Lab

Unit-III Introduction to Optimization, Convex sets and convex functions, properties of convex functions, Various Optimization algorithms: Gradient Descent and others, Python Implementation of Optimization.

11 Hours Theory and 8 Hours Lab

Unit-IV Discrete and continuous distribution functions, joint probability and covariance, Separating Hyperplanes, Primal and Dual Support Vector Machines, Kernels and Python Implementation. 12 Hours Theory and 7 Hours Lab

**Internal Assessment:**

CIA\*-1 Unit -I

CIA-II Written Exams/ Quizzes /Assignment /Presentations/ Viva-Voce based on Unit II and Unit III  
EoSE\*\* Unit-I, II, III, IV

\*: Continuous Internal Assessment

\*\* : End of Semester Examination

**Text Books:**

1. Cheney W., 2001, *Analysis for Applied Mathematics*, New York: Springer Science+Business Medias.

2. Axler S., 2015, *Linear Algebra Done Right (3<sup>rd</sup> Ed.)*, Springer International Publishing.
3. Nocedal J. and Wright S. J., 2006, *Numerical Optimization*, New York: Springer Science+Business Media.
4. Rosenthal J. S., 2006, *A First Look at Rigorous Probability Theory (2<sup>nd</sup> Ed.)*, Singapore: World Scientific Publishing.

**Reference Books:**

5. Deisenroth M.P., Faisal A.A. and Ong C.S., 2020, *Mathematics For Machine Learning*, Cambridge University

**E-resources:**

4. <https://archive.nptel.ac.in/courses/111/107/111107137/>

CC - Core Course 44 Credits

AECC – Ability Enhancement Compulsory Course 16 Credits

Total Credits of Core Courses 44+16=60 Credits

DE- Departmental Specific Elective Courses offered by the Department 20 Credits

GE - Generic Elective Courses offered by any department of the University 16 Credits

Total Credits of Elective Courses 36 Credits

MOOC 08 Credits