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

Details of Revised/New Structure and Syllabus of Integrated M.Sc. B.Ed. 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 modeling 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.
PO 9. Teaching and learning skill: Expert in teaching and learning skills with interest in innovation and research in mathematics and education.
PO 10. Carrier Opportunities: Having opportunity to start career in academics and research institutions.

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.

PO/Mission	M 1	M 2	M 3
PO 1	2	2	3
PO 2	2	2	2
PO 3	1	2	2
PO 4	1	3	3
PO 5	2	3	3
PO 6	3	1	2
PO 7	3	2	2
PO 8	3	2	2
PO 9	3	2	3
PO 10	2	3	3

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.

Course/PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
MAT401	3	3	3	2	1	1	1	1	1	2
MAT402	3	3	3	2	1	1	1	1	1	2
MAT403	3	3	2	2	1	1	1	1	1	2
EDU401	2	1	1	1	1	2	2	2	3	2
EDU402	2	2	1	1	1	2	2	2	3	2
MAT404	3	3	3	2	1	1	2	1	1	2
MAT405	3	3	3	2	1	1	2	1	1	2
MAT406	3	3	2	1	1	1	2	1	1	2
MAT407	3	3	3	2	1	1	2	1	1	2
MOOC										

EDU403	3	3	2	2	1	2	2	3	3	2
EDU404	3	2	1	1	1	2	2	1	3	3
MAT501	3	3	3	1	1	1	2	3	1	2
MAT502	3	1	3	3	3	1	3	3	1	3
MAT503*										
EDU501	3	2	2	1	1	2	3	2	3	3
EDU502	3	1	1	1	1	2	2	2	3	3
MAT582	2	1	1	1	2	1	2	2	2	2
MAT505	3	3	3	2	1	1	2	2	1	2
MAT556*										
EDU503	3	1	1	1	1	2	3	1	3	3
EDU504	3	2	2	1	1	1	2	3	3	3
MAT531	3	3	3	2	1	2	2	3	1	2
MAT532	3	3	3	2	1	1	2	2	1	2
MAT533	3	3	3	1	1	1	2	2	1	2
MAT534	3	1	2	2	1	1	2	2	1	2
MAT535	3	3	2	1	1	1	1	2	1	2
MAT536	3	1	2	2	3	3	2	2	1	2
MAT537	3	3	3	3	1	1	2	3	1	2
MAT538	3	3	3	2	2	1	2	2	1	2
MAT539	3	3	3	3	2	1	2	2	1	2
MAT540	3	3	2	2	1	1	2	2	1	2
MAT541	3	2	3	2	3	1	2	3	1	2
MAT542	3	2	3	2	3	1	2	3	1	2
MAT543	3	3	3	2	1	1	2	3	1	2
MAT544	3	3	3	2	2	1	2	2	1	2
MAT545	3	1	2	2	1	2	3	3	1	2
MAT546	3	3	3	3	1	1	2	2	1	2
MAT547	3	3	3	1	1	1	2	2	1	2
MAT548	3	3	3	2	1	1	2	2	1	2
MAT549	3	2	3	2	2	1	2	2	1	2
MAT550	3	3	3	2	1	2	2	2	1	2
MAT551	3	3	3	2	1	1	2	2	1	2
MAT552	3	1	2	3	2	1	2	3	1	2
MAT553	3	3	3	2	1	1	2	2	1	2
MAT554	3	2	2	3	1	1	2	2	1	2
MAT555	3	2	2	3	3	1	2	3	1	3

LEVEL-4

Semester-I (Integrated M.Sc. B.Ed)							
S. No.	**Course Code**	**Course Title**	**Type of Course (C/E)**	**L**	**T**	**P**	**Credits**
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 Paper (Subjective)	DE	3	1	0	4
5		Elective Paper	DE	1	0	1	2
6	EDU 401	Basics of Education	CC	3	0	0	3
7	EDU 402	Senior Secondary Education in India: Status, Challenges & Strategies	CC	3	0	0	3
Total				**19**	**4**	**1**	**24**

Semester-II (Integrated M.Sc. B.Ed)							
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	MAT 407	Qualitative Theory of Ordinary Differential Equations	CC	3	1	0	4
5	MOOC	MOOC	GE	2	0	0	2
6	EDU403	Philosophy of Mathematics	CC	3	0	0	3
7	EDU404	Learner and Learning	CC	3	0	0	3
Total				**20**	**4**	**0**	**24**

Course-Code: MAT-401
Course Title: Linear Algebra

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

1.	basic concepts in Linear Algebra and Matrices: System of linear equations, Matrices, Rank, Vector Spaces, Basis and Dimension

Course Objectives:

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.

Course Outcomes: 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.

Course Content:

Unit-I	Review of vector spaces, The algebra of linear transformations, Isomorphism, Linear functionals, Annihilator, Double dual, Transpose	15 Hours

	of a linear transformation, Eigenvalues and Eigenvectors,and Eigenvectors.	
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
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. Hoffmann K. and Kunze R., 1992, *Linear Algebra*, Prentice Hall of India.		
2. Friedberg S. H., Insel A.J., Spence L.E., 2019, *Linear Algebra*, Pearson Education.		
3. Kumaresan S., 2000, *Linear Algebra: A Geometric Approach*, Prentice Hall of India.		
4. Halmos, P.R., 2011, *Finite Dimensional Vector Spaces*, Springer.		
5. Lang, S., 2005, *Introduction to Linear Algebra*, Springer.		
Reference Books:		
1. Artin M., 2010, *Algebra*, Pearson Education. 2. Cooperstein B., 2015, *Advanced Linear Algebra*, CRC Press.		

E-resources:
https://archive.nptel.ac.in/courses/111/106/111106051/

<table>
<tr><td colspan="3" align="center"><u>Course-Code: MAT402</u>
<u>Course Title: Real Analysis</u></td></tr>
<tr><td>Teaching Scheme</td><td>Examination Scheme</td><td>Credits Allotted</td></tr>
<tr><td>Theory: 3 hours/ week</td><td>EoSE: 60 Marks
Internal Assessment: 40 Marks</td><td>Theory: 3</td></tr>
<tr><td>Tutorial: 1 Hour/Week</td><td></td><td>Tutorial: 1</td></tr>
<tr><td></td><td></td><td>Total: 4</td></tr>
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Course Prerequisite:	
1.	Basics of real analysis, metric space and integral and differential calculus.

Course Objectives: 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.

Course Outcomes: 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.	
Course Content:		
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
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. 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:
1. https://nptel.ac.in/courses/111106053 2. https://nptel.ac.in/courses/111106153

Course Code: MAT403 **Course Title: 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: The student should have knowledge of	
1.	Basic concepts of sets, relations
2.	Basic concepts of functions and congruences
Course Objectives:	
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.

Course Outcomes: The students will be able to understand		
1	what are objects of study in topology and geometry?	
2	students will absorb the concepts and topics in hand without haste;	
3	students will be able to understand the significance of the concepts defined and the theorems proved here;	
4	The course will serve as a foundation for further study in analysis, in geometry and in algebraic topology.	
Course Content:		
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: T0 , T1, and T2 spaces, examples and basic properties, First and Second Countable Spaces, Regular, normal, T3 & T4 spaces, Tychnoff spaces, Urysohn‟s Lemma, Tietze Extension Theorem, Tychnoff Theorem.	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. Simmons G. F., 1963, *Topology and Modern Analysis*, McGraw Hill.
2. Vicker, 1996, *Topology via Logic*, Cambridge University Press.
3. Munkers, J. R., 2015, *Topology- A First Course*, Pearson Education India.
4. Joshi, K.D., 2017, *Introduction To General Topology*, New Age International Private Limited.
Reference Books:
1. Kelley J. L., 2017, *General Topology*, *Dover Publications Inc.*
E-resources:
1. https://archive.nptel.ac.in/courses/111/106/111106159/

Course-Code: MAT404 **Course Title: 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:	
1	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.
Course Objectives:	
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.	
Course Outcomes: Students 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.	
Course Content:		
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, Rouche's theorem, Schwarz lemma, Schwarz-Pick lemma, Open mapping theorem.	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*=□□, Mappings by $w=\log z$, Mappings by $w=\sin z$, Mappings by z^2 and branches of $z^{1/2}$.	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. Brown J.W. and Churchill R.V., 2009, *Complex Variables and Applications*, Tata 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. Rudin W., 2006, *Real and Complex Analysis (3rd Addition)*, Tata McGraw Hill.

E-resources:

1. https://archive.nptel.ac.in/noc/courses/noc21/SEM2/noc21-ma39

Course-Code: MAT405
Course Title: Mathematical Programming

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

1.	basic Concepts of Linear Algebra
2.	basic Concepts of Calculus

Course Objectives:

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.	
Course Outcomes: 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.	
Course Content:		
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	15 Hours

	Beale's Method, Separable Programming.	
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. Chandra S., Jayadeva and Mehra A., 2009, *Numerical Optimization with Applications*, Narosa Publishing House Pvt. Ltd. 2. Hadley G., 1987, *Linear Programming*, Narosa Publishing House Pvt. Ltd. 3. Taha H. A., 2007, *Operations Research-An Introduction*, Prentice Hall of India Pvt. Ltd. 4. Hillier F. S., Lieberman G. J., Nag B. and Basu P., 2012, *Introduction to Operations Research*, Tata McGraw Hill Education Pvt. Ltd. 5. Bazaraa M.S., Sherali H.D. and Shetty C.M.,2006, *Nonlinear Programming Theory and Algorithms*, Wiley.		
Reference Books:		
1. Bertsimas D. and Tsitsiklis J.N., 1997, *Introduction to Linear Optimization,* Athena Scientific, Belmont, Massachusetts. 2. Bradley, H., Magnanti, 1977, *Applied Mathematical Programming*, Addison-Wesley		
E-resources:		
1. https://onlinecourses.swayam2.ac.in/cec22_ma17/ 2. https://archive.nptel.ac.in/courses/111/107/111107128/		

Course-Code: MAT406 **Course Title: Abstract Algebra**		
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

1.	Basic Concepts of groups and rings

Course Objectives:

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

Course Outcomes: 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

Course Content:

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,	15 Hours

	simplicity of An, 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 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
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. Bhattacharya P. B., Jain S. K. and Nagpal S. R., *Basic Abstract Algebra (2^{nd} Ed.)*, Cambridge University Press.		
2. Gallian J. A., 1999, *Contemporary Abstract Algebra*, Narosa Publication House, New Delhi.		
3. Artin M., 2011, *Algebra*, Prentice Hall India, New Delhi.		
4. Dummit D. S. and Foote R. M., 2008, *Abstract Algebra*, Wiley India Pvt. Ltd.		
Reference Books:		
1. 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/		

Course-Code: MAT407
Course Title: Qualitative Theory of Ordinary Differential Equations

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

1.	basic concepts in Linear Algebra and Real Analysis e.g., continuity, uniform continuity, uniform convergence, system of linear equations, matrices, diagonalization
2.	elementary theory of ordinary differential equations

Course Objectives:

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

Course Outcomes: 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 how to use qualitative theory for modeling different real life problems via differential equations.

Course Content:

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	15 Hours

	existence and uniqueness theorem, Cauchy Peano existence theorem, Continuation of solutions.	
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
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. Ross S.L., 2007, *Differential Equations*, Wiley.
2. Nandakumaran A.K., Dutti P.S. and George R.K., 2017, *Ordinary Differential Equations: Principles and Applications*, Cambridge University Press.
3. Brauer F. and Nohel J.A., 2005, *Qualitative Theory of Differential Equations*, Dover Publications.
4. Coddington E.R. and Levinson N., 2010, *Theory of Ordinary Differential Equations*, McGraw Hill Education.

Reference Books:

1. Nemytskii V.V., 2005, *Qualitative Theory of Differential Equations*, Princeton University Press

E-resources:
https://nptel.ac.in/courses/111108081

LEVEL-4 (Electives)				
S. No.	**Course Code**	**Course Title**	**Credit**	**Remarks**
1	MAT431	Biomathematics	4	
2	MAT432	Probability and Mathematical Statistics	4	
3	MAT433	Scientific Writing by LaTeX	2	
4	MAT434	Basic Programming in MATLAB	2	
5	MAT435	Numerical Analysis	4	
6	MAT436	Integral Transforms	4	
7	MAT437	Elementary Number Theory	4	
8	MAT438	Introduction to Space Dynamics	4	
9	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

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

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

Course Content:

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	15 Hours

	Species population models (discrete and continuous): Exponential, Logistic, and Gompertz growth, Allee effect, Harvesting models and bifurcations, Delay models	
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
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. Brauer F. and Chavez C. C., 2000, *Mathematical Models in Population Biology and Epidemiology*, Springer.		
2. Kot M., 2001, *Elements of Mathematical Ecology*, Cambridge University Press.		
3. Keshet L. E., 2005, *Mathematical Models in Biology*, SIAM.		
4. Keeling M. J. and Rohani P., 2008, *Modeling Infectious Diseases in Humans and Animals*, Princeton University Press.		
5. Martcheva M., 2010, *An Introduction to Mathematical Epidemiology*, Springer.		
Reference Books:		
1. Murray J. D., 2007, *Mathematical Biology: An Introduction*, Springer. 2. Smith H., 2010, *An Introduction to Delay Differential Equations with Applications to Life Sciences*, Springer.		
E-resources:		

https://open.uci.edu/courses/math_113b_intro_to_mathematical_modeling_in_biology.htmlhttps://www.youtube.com/playlist?list=PL5zWDs2j0YF3kPPvs4L5FGlLc7x13Uwjn		

Course-Code: MAT432
Course Title: Probability Theory and Mathematical Statistics

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

1.	basic concepts of linear algebra and calculus

Course Objectives:

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 random variable concepts.
3.	To explain essential tools for statistical analyses.
4.	To discuss the central limit theorem and order statistics.

Course Outcomes: Students will be able to

1.	learn descriptive statistics and to calculate probability for various types of problems.
2.	workout various probability distributions and statistical tools.
3.	explain order statistics and central limit theorem

Course Content:

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, random variables, c.d.f., p.d.f., p.m.f.	15 Hours
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
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. 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 (3rd Ed.),* John Wiley & Sons.
3. Rao C. R., 1965, *Linear Statistical Inference and its Applications (2nd 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 (3rd 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/

Course-Code: MAT433 **Course Title: Scientific Writing by LaTeX**		
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

Course Prerequisite: The student should have knowledge of	
1.	basic computer skills to downloads the required files and programmes needed for the course

Course Objectives:	
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.

Course Outcomes: 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	
Course Content:		
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)
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. Lamport, L.W., 1994, *LaTeX: A document Preparation Systems,* Addison-Wesley Publishing Company.
2. Kopka, H., Daly, P.W., 2004, *Guide to LATEX*, Fourth Edition, Addison Wesley.

Reference Books:		
1. Shirore C., A *Beginner guide to LaTex*, Lullu.com		
E-resources:		
1. https://www.udemy.com/course/become-a-good-latex-user-to-create-professional-documents/ 2. https://www.overleaf.com/learn		

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
Course Prerequisite: The student should have knowledge of		
1.	basic computer skills to download the required files and programmes needed for the course.	
Course Objectives:		
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	
Course Outcomes: Students will be able to		
1.	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	
Course Content:		
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)
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 and IV	
*: Continuous Internal Assessment **: End of Semester Examination		
Text Books:		
1. Pratap R., *Getting started with MATLAB*, Oxford University Press.		

2. S. Lynch, 2014, *Dynamical Systems with Applications using MATLAB*, Birkhäuser.
3. Fousett, 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:
1. Gilat A, 2012, *MATLAB: An Introduction with Applications*, Wiley
E-resources:
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

Course Prerequisite: Students should have knowledge of

1.	differential calculus
2.	difference operator, ODE

Course Objectives:

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

Course Outcomes: 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.

Course Content:

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

Internal Assessment:

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

*: Continuous Internal Assessment
**: End of Semester Examination

Text Books:
1. Atkinson K. E., 1989, *An Introduction to Numerical Analysis (2^{nd} Ed.)*, Wiley-India.
2. Jain M. K., Iyengar S. R. K., Jain R. K., 2012, *Numerical Methods for Scientific and Engineering Computation (6^{th} Ed.)*, New Age International Publishers.
3. Sastry S. S. 2019, *Introductory Methods of Numerical Analysis*, PHI.
Reference Books:
1. Buchaman J. I., Turner P. R., 1992, *Numerical Methods and Analysis*, McGraw-Hill.
E-resources:
https://archive.nptel.ac.in/courses/111/107/111107105/

Course-Code: MAT436
Course Title: Integral Transforms

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 Differential Calculus
2.	basic concepts of Integral Calculus

Course Objectives:

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.

Course Outcomes: 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.

Course Content:

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

Internal Assessment:

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

*: Continuous Internal Assessment;
**: End of Semester Examination

Text Books:

1. Lokenath D., Dambaru, B., 2014, *Integral Transforms and Their Applications*, Taylor and Francis group, 2014.
2. John M. Wills, *Integral Transforms in Applied Mathematics*, Cambridge University Press, 2008.
3. Murrey R Spiegal, *Laplace Transforms (SCHAUM Outline Series)*, McGraw Hill,1965.

Reference Books:

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

E-resources:

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

Course-Code: MAT437
Course Title: Elementary 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: Student should have knowledge of

1.	basic Concepts of sets	
Course Objectives:		
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	
Course Outcomes: 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	
Course Content:		
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 □(□), □(□), □(□), □(□), 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
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. Burton D. M., 1989, *Elementary Number Theory*, Wm. C. Brown Publishers, Dubuque, Iowa.		
2. Jones G.A. and J.M. Jones , 1998, *Elementary Number Theory*, Springer-Verlag, New York		
3. Sierpinski W., 1998, *Elementary Theory of Numbers*, North-Holland, Ireland.		
4. Koshy T., 2007, *Elementary Number Theory with Applications*, Academic Press, New York.		
Reference Books:		
1. Zuckerman N.S.H., Montgomery L.H., 1991, *An Introduction to the Theory of Numbers*, John Wiley.		
E-resources:		
https://archive.nptel.ac.in/courses/		

Course-Code: MAT438 **Course Title: Introduction to Space Dynamics**		
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:		
1.	Basics of linear algebra, analytical geometry, differential equations, and vector calculus.	
Course Objectives: 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.	
Course Outcomes: 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.	
Course Content:		
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
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., Dermott S.F., 2000, *Solar System Dynamics*, Cambridge University Press.
3. Rao K.S., 2009, *Classical Mechanics*, PHI Learning, Pvt. Ltd.
4. Goldstein H., Poole C.P., Safko J.L., 2019, *Classical Mechanics (Third edition)*, Pearson India Education Pvt. Ltd.
5. Battin, Richard H., 1999, *An Introduction to The Mathematics and Methods of Astrodynamics*, AIAA Education Series.

Reference Books:

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

Course-Code: MAT-439
Course Title: FLUID DYNAMICS

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 differential equations.
2.	basic concepts of calculus

Course Objective: This course aims to learn

1.	basics characteristics of fluid, continuum hypothesis, kinematics of fluids.
2.	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.

Course Outcomes: 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.

Course Content:

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
Internal Assessment:		
CIA-I*	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. Rathy R.K., 1976, *An Introduction to Fluid Dynamics*, Oxford and IBH Publishing Co.
2. Thomson L. N. M., 1962, *Theoretical Hydrodynamics*, Macmillan and Co. Ltd.
3. Chorlton F., 1985, *Textbook of Fluid Dynamics*, CBS Publishers.
4. Landau L. D., Lipschitz E.N., 1985, *Fluid Mechanics*, Pergamon Press.

Reference Books:

1. Emanuel, G. 2000, *Analytical Fluid Dynamics*, CRC Press.
2. Nakayama, Y., Boucher, R. F., 2000, *Introduction to Fluid Mechanics*, Butterworth-Heinemann

E-resources:

https://onlinecourses.nptel.ac.in/noc19_ce28/preview

LEVEL-5

Semester-III (Integrated M.Sc. B.Ed)							
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	0	0	3
4		Elective Paper (Subjective)	DE	3	1	0	4
5		Elective Paper	GE	2	0	0	2
6	EDU501	Learning Assessment	CC	3	0	0	3
7	EDU502	Pedagogy of Science / Social Science	CC	4	0	0	4
Total				**21**	**3**	**0**	**24**

Semester-IV (Integrated M.Sc. B.Ed)							
S. No.	**Course Code**	**Course Title**	**Type of Course (C/E)**	**L**	**T**	**P**	**Credits**
1	MAT582	Seminar	AECC	2	0	0	2
2	MAT505	Classical Mechanics	CC	3	1	0	4
3		Elective Paper	GE	3	1	0	4
4		Elective Paper	GE	3	1	0	4
5	MAT556	MOOC (MOOC list will be provided at the end of the previous semester)	DE	3	0	0	3

6	EDU503	Classroom Organization and Management	CC	4	0	0	4
7	EDU504	Pedagogy of Mathematics / Physics / Chemistry / Economics	CC	3	0	0	3
Total				**21**	**3**	**0**	**24**

Course-Code: MAT501 **Course Title: Functional 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:		
1.	Basics of linear algebra, metric space and real analysis.	
Course Objectives: 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.	
Course Outcomes: 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.	
Course Content:		
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
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. Bachman G. and Narici, 1964, *Functional Analysis*, Academic Press.
2. Taylor A. E., 1958, *Introduction to Functional Analysis*, John Wiley and Sons.
3. M.T. Nair, *Functional Analysis: A first Course*, Prentice Hall of India, New Delhi, 2002 (Second Printing: 2008)

Reference Books:
1. Simmons G. F., 1963, *Topology and Modern Analysis*, McGraw Hill. 2. Erwin Kreyszig E., 1978, *Introductory Functional Analysis with Application*, Wiley
E-resources:
https://nptel.ac.in/courses/111106047 https://nptel.ac.in/courses/111106147

Course-Code: MAT 502 **Course Title: Mathematical Modeling**		
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 in Linear Algebra and Real Analysis and Differential Equations
Course Objectives:	
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.
5.	To develop some of the methods used to explore qualitative information about the behaviour of solutions of differential equations
Course Outcomes: 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.	revise and improve mathematical models so that they will better correspond to empirical information and/or will support more realistic assumptions	
5.	different types of mathematical models in ecology, epidemiology, chemistry, Physics, Life Sciences, Engineering etc.	
Course Content:		
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
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. Murthy D. N. P., Page N. W., Rodin E. Y., 1990, *Mathematical Modelling: A Tool for Problem Solving in Engineering, Physics, Biological and Social Sciences*, Pergamon Press
2. Kapur J. N., 2008, *Mathematical Modelling*, New Age Int. Pub
3. Law A. M., Kelton W. D., 1991, *Simulation Modeling and Analysis*, McGraw-Hill.
4. Meerscheart M.M., 2007, *Mathematical Modeling*, Academic Press
Reference Books:
1. Nemytskii V.V., 2005, *A Course in Mathematical Modeling*, Mathematical Association of America
E-resources:
https://nptel.ac.in/courses/111108081

Course Code: MAT503

Course Title: MOOC (list will be provided at the beginning of the semester)

Course-Code: MAT505 **Course Title: Classical 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:		

1.	Basics of linear algebra, differential equations, and vector calculus.	
Course Objective: To develop the concept of		
1.	kinematics of particles, frame of references and relative changes in equation of motion and moment of inertia.	
2.	of expressing kinetic energy and angular momentum about a fixed axis in terms of moment of inertia and in terms of Eulerian angle along with application of these.	
3.	of generalized coordinates and degree of freedom and understanding the differences between Lagrangian dynamics and Hamiltonian dynamics.	
4.	Hamilton's principle and its uses, applications of canonical transformations along with uses of Lagrange and Poisson brackets.	
Course Outcomes: Students will be able to		
1.	know about the kinematics of particles, describe the relative changes in the equation of motion in different frames, and calculate moment of inertia of a given mass about a line.	
2.	express kinetic energy and angular momentum of a mass about a fixed axis in terms of moment of inertia and in terms of Eulerian angle and use these expressions to describe the motion of Earth.	
3.	recognize the degree of freedom of a mass in motion and formulate the motion of a rigid body using Lagrangian function and Hamiltonian function.	
4.	use the Hamilton's principle, apply the canonical transformations and compute the Lagrange and Poisson brackets.	
Course Content:		
Unit-I	Introduction of conservation laws, equation of motion of a particle, Simple pendulum, Harmonic oscillator, Motion of system of particles, Principle of angular momentum, Motion of a rigid body about a fixed axis, Moving frames of reference, Moments and products of inertia, moment of inertia of a body about a line through the origin, Momental ellipsoid, rotation of coordinate axes, principal axes and principal moments.	15 Hours
Unit-II	K.E. of rigid body rotating about a fixed point, angular momentum of a rigid body, Eulerian angle, angular velocity, K.E. and angular momentum in terms of Eulerian angle. Euler's equations of motion for a rigid body rotating about a fixed point, torque free motion, symmetrical rigid body, rotational motion of Earth. Attitudinal stability of Earth's satellite.	15 Hours

Unit-III	Classification of dynamical systems, Generalized coordinates systems, geometrical equations, Lagrange's equation for a simple system using D'Alembert principle, Deduction of equation of energy, deduction of Euler's dynamical equations from Lagrange's equations, Hamilton's equations, Ignorable coordinates, Routhian Function.	15 Hours
Unit-IV	Hamiltonian principle for a conservative system, principle of least action, Hamilton- Jacobi equation, Phase space and Liouville's Theorem, Canonical transformation and its properties, Lagrange brackets, and Poisson brackets, Poisson-Jacobi identity.	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. Milne E. A., 1965, *Vectorial Mechanics*, Methuen & Co. Ltd. London.
2. Kumar N., 2004, *Generalized Motion of Rigid Body*, Narosa Pub. House, New Delhi.
3. Rao K. S., 2009, *Classical Mechanics*, PHI learning Private Ltd., New Delhi.

Reference Books:

1. Ramsey A. S., 2017, *Dynamics (Part II), (2nd Ed.)*, CBS Publishers & Distributors, Delhi.
2. Goldstein H., 1990, *Classical Mechanics*, Narosa Publishing House, New Delhi.

E-resources:

https://www.classcentral.com/course/rigid-body-dynamics-20108

LEVEL-5 (Electives and Self Study)				
S. No.	**Course Code**	**Precise Course Title**	**Credit**	**Remarks**
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	
25	MAT 555	Mathematics for Machine Learning	4	

Course Code: MAT556
Course Title: MOOC (list will be provided at the beginning of the semester)

Course-Code: MAT531 **Course Title: Partial Differential Equations**		
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.	solution methods of ODE	
2.	differential calculus	
Course Objectives: To teach		
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.	
Course Outcomes: 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	
Course Content:		
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
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. Rao, S.K., *Introduction to Partial Differential Equations*, Phi Learning.
2. Sneddon, I.N., *Elements of Partial Differential Equations*, Dover Publications.
3. Birkhoff, G., Rota, G.C., *Ordinary Differential Equations*, Wiley.
Reference Books:
1. Amaranath, T., *An Elementary Course in Partial Differential Equations,* Narosa Publication.
E-resources:
1. https://archive.nptel.ac.in/courses/111/105/111105093

Course-Code: MAT532 **Course Title: Game 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		
1.	knowledge of linear programming and simplex methods.	
Course Objectives:		
1.	To provide a rigorous treatment of solution concepts for games with perfect and imperfect information including Nash and subgame perfect Nash equilibria.	

<table>
<tr><td>2.</td><td colspan="2">To cover topics such as auction, VNM utility function, bargaining game, etc.</td></tr>
<tr><td>3.</td><td colspan="2">To provide detailed knowledge about cooperative games.</td></tr>
<tr><td>4.</td><td colspan="2">To teach about games with imperfect information.</td></tr>
<tr><td colspan="3">Course Outcomes: Students will be able to</td></tr>
<tr><td>1.</td><td colspan="2">model competitive real world phenomena using concepts from game theory and identify optimal strategy and equilibrium solutions for such models.</td></tr>
<tr><td>2.</td><td colspan="2">learn the two person zero-sum game and its equilibrium solution.</td></tr>
<tr><td>3.</td><td colspan="2">discuss dynamic games and cooperative games.</td></tr>
<tr><td>4.</td><td colspan="2">work on strategic and dynamic games with imperfect information.</td></tr>
<tr><td colspan="3">Course Content:</td></tr>
<tr><td>Unit-I</td><td>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,</td><td>15 Hours</td></tr>
<tr><td>Unit-II</td><td>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.</td><td>15 Hours</td></tr>
<tr><td>Unit-III</td><td>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.</td><td>15 Hours</td></tr>
<tr><td>Unit-IV</td><td>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.</td><td>15 Hours</td></tr>
<tr><td colspan="3">Internal Assessment:</td></tr>
</table>

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. Osborne M.J., 2003, *An Introduction in Game Theory*, Oxford University Press.
2. Osborne M. J. and Rubinstein A., 1994, *A Course in Game Theory*, MIT Press.
3. Fudenberg D. and Tirole J., 1991, *Game Theory*, MIT Press.
4. Von Neumann J. and Morgenstern O., 1944, *Theory of Games and Economic Behaviour*, New York: John Wiley and Sons.

Reference Books:

1. Watson J., 2013, *Strategy: An Introduction to Game Theory (3rd Ed.)*, W.W. Norton & Company, London.

E-resources:

1. https://archive.nptel.ac.in/courses/110/104/110104063/

Course-Code: MAT533
Course Title: Graph 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 Objectives:		
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	
Course Outcomes: 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	
Course Content:		
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
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. Harary F., 1969, *Graph Theory*, Narosa Publication House, New Delhi
2. Balakrishnan, R., Ranganathan K., 2012, *A Textbook of Graph Theory*, Springer, New York
3. Deo N., 1974, *Graph Theory with Applications to Engineering and Computer Science*, Prentice-Hall of India, New Delhi
Reference Books:
1. Diestel R., 2000, *Graph Theory*, Springer, New York
E-resources:
https://archive.nptel.ac.in/courses/

Course Code: MAT534 **Course Title: AUTOMATA THEORY AND FORMAL LANGUAGES**		
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, relations, functions	
2.	basic concepts of propositional logics	
Course Objectives:		

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.	
Course Outcomes: 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.	
Course Content:		
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
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. Kelly D., 1995, *Automata and Formal Languages: An Introduction*, Prentice-Hall.
2. Hopcroft J. E., Motwani R. and Ullman J. D., 2001, *Introduction to Automata, Languages, and Computation (2nd Ed.)*, Pearson Edition.
3. Linz P., 2010, *An Introduction to Formal Languages and Automata*, Narosa.

Reference Books:

1. Sipser M., 2012, *Introduction to the Theory of Computation (3rd Ed.)*, Cengage Learning.

E-resources:

1. https://archive.nptel.ac.in/courses/111/103/111103016/
2. https://nptel.ac.in/courses/106105196

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 Objectives:

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	
4	the cardinal arithmetic	
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	$\in$-transitive sets, Ordinals, class of ordinals, Trichotomy law between ordinals, characterization of an ordinal in terms of $\in$-transitive sets, successor and limit ordinals, Principle of Transfinite Induction, Ordinal Arithmetic, Ordinals and well ordered set, Axiom of Choice and its equivalence, The Banach-Tarski Paradox, Cardinals and its arithmetic, ordering of cardinals, countable and uncountable sets, continuum hypothesis	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. Levy A., 1979, *Basic Set Theory*, Springer-Verlag, New York.		
2. Copi M., 1979, *Symbolic Logic*, Macmillan Publishing Co. Inc., New York.		
3. Kakkar V., 2016, *Set Theory: Read it, Absorb it and Forget it*, Narosa Publication House, New Delhi.		
4. Enderton H. B., 1977, *Elements of Set Theory*, Academic Press Inc., New York.		
Reference Books:		
1. 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 set and functions	
Course Objectives: 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 + 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 + 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 + 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 + 8 Hours Lab
Internal Assessment:		
CIA-I*	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. 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,Afternoon%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 Objectives:		
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: 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 Rn , 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., 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., Williams K. S., 2004, *Introductory Algebraic Number theory*, Cambridge University Press.
4. Zuckerman N.S.H., Montgomery L.H., 1991, *An Introduction to the Theory of Numbers*, John Wiley.
Reference Books:
1. 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:

1. 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	15 Hours

	theory, Necessity and belief measures, Probability measures vs possibility measures.	
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 (2nd Ed.)*, Kluwer, Boston. 4. Lee. K. H., 2005, *First Course on Fuzzy Theory and Applications*, Springer-Verlag.		
Reference Books:		
1. 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:		
1.	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, S*olar 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: Students 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 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 (2nd Ed.)*, Wiley-Eastern.
3. Sastry, S. S., 2002, *Introductory Methods of Numerical Analysis*, Prentice-Hall of India.
4. Griffiths, D.V., 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: Students should have knowledge of

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

Course Objectives: 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 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^{nd} Ed.)*, Wiley Eastern.
3. Sastry S. S., 2002, *Introductory Methods of Numerical Analysis*, Prentice-Hall of India.
4. Griffiths D. V., Smith I. M., 1993, *Numerical Methods of Engineers*, Oxford University Press.
5. General C. F., Wheatley P. O., 1998, *Applied Numerical Analysis*, Addison- Wesley.
6. Bathe K. J., 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.

1. 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 Objectives:

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	15 Hours

	flows.	
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 (2nd 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 Objectives:		
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: Students will be able to		
1.	analyze and solve system of linear differential equations	
2.	learn theory of nonlinear system: existence, maximal interval of existence and linearization	
3.	apply different important theorem and theories e.g., Hartman-Grobman, stable manifold theorems, centre and normal form theory	
4.	learn global existence theorem	
5.	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, Jordon 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,	15 Hours

	Limit sets and Attractors, Periodic orbits	
Unit-IV	Limit Cycles, and Separatrix cycles, Poincare map, Stable manifold theorem for periodic orbits, Poincare-Bendixson theory in xy-plane, Lineard 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 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:		
1. 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/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: Students should have knowledge of	
1.	Elementary Mathematics and Probability
Course Objectives:	
1.	To provide the theoretical foundations required to understand the financial mathematics
2.	To make the students familiar with the concepts of 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	15 Hours

	and implementation	
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 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 (4th 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 (5th Ed.)*, John Wiley and Sons.		
5. Capinski M., Zastawnaik T., *Mathematics for Finance*, Springer		
Reference Books:		
1. Wahidudin A.N., , 2000, *Financial Mathematics and Its Applications*, Ventus Publishing ApS		
E-resources:		
https://nptel.ac.in/courses/111103126		

<u>**Course-Code: MAT546**</u>
<u>**Course Title: ADVANCED 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
		Total: 4

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

Course Objectives:

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, Week 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,	15 Hours

	Hurwitz' theorem, Analytic continuation, Direct analytic continuation Poisson integral formula, Dirichlet problem.	
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	
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: Students 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	R^n as inner product and as normed space, convergence of sequences, compactness, equivalence of norms, connected and convex sets, Functions from R^n to 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 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:

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

E-resources:

1. 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: Students 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, C)		
4	To teach the students root Space Decomposition		
Course Outcomes: The 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, C), Classifying the Irreducible sl(2, 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, 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:		
1. Humphreys J. E., 1972, *Introduction to Lie Algebras and Representation Theory*, Springer-Verlag New York.		
2. Jacobson N., 1962, *Lie Algebras*, Wiley-Interscience, New York.		
3. Erdmann K. and Wilson M.J., 2006, *Introduction to Lie Algebras*, Springer-Verlag, New York.		
Reference Books:		
1. 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: Students 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 EndZ (M), submodules, Direct summands, Annihilators,		15 Hours

	Faithful modules, Homomorphism, Factor modules, Isomorphism theorems	
Unit-II	Free Module, Noethrian 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: Students 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: 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 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. and Devaney R. L., 2002, *Differential Equations, Dynamical Systems and an Introduction to Chaos*, Academic Press.
4. Guckenheimer J. and Holmes P., 2000, *Nonlinear Oscillations, Dynamical Systems and Bifurcations of Vector Fields*, Springer, New York.

Reference Books:

1. Percival I., Richards, D., 1982, *Introduction to Dynamics*, Cambridge University Press
2. 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

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: Students should have knowledge of

1.	groups and rings

Course Objectives:		
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:

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

E-resources:

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

Course-Code: MAT552
Course Title: Operations Research

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.	Mathematical Programming

2.	Probability Theory	
Course Objectives:		
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 to		
1.	find the optimal job sequencing.	
2.	get a deep understanding of the PERT/CPM techniques to plan, schedule, and control project activities.	
3.	learn deterministic and probabilistic inventory models.	
4.	learn the basic concepts of stochastic processes.	
5.	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	15 Hours

	state distributions, transient distributions.	
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 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. and 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.
4. Trivedi K.S., 2016, *Probability and Statistics with Reliability, Queuing and Computer Science Applications,* John Wiley & Sons, Inc., Hoboken, NJ, USA.

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 (3rd 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: Students should have knowledge of

1.	concepts of groups and module

Course Objectives:

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-submdule.	15 Hours
Unit-III	Maschke's Theorem, Completely reducible FG-submodule, Schur's Lemma and its application, Representation of abelian groups,	15 Hours

	Irreducible submodules of CG-module, Composition factor.	
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 (3rd Ed.),* Springer.		
4. Serre J. P., 1977, *Linear Representation of Groups*, Springer-Verlag.		
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: Students 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. Bessel functions, Legendre polynomials, Hermite Polynomials and Laguerre Polynomials.

Course Outcomes: Students will be able to learn

1. Gamma function
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 it's solution,	15 Hours

	Recurrence relation, Generating functions, Integral representation, Hermite Polynomials, Laguerre Polynomials.	
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. 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:

<u>Course-Code: MAT-555</u>
<u>Course Title: Mathematics for Machine Learning</u>

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: Students should have knowledge of

<table>
<tr><td>1.</td><td colspan="2">basic knowledge in Calculus, LInear Algebra and Probability Theory</td></tr>
<tr><td>2.</td><td colspan="2">basic knowledge in python programming</td></tr>
<tr><td colspan="3">Course Objectives:</td></tr>
<tr><td>1</td><td colspan="2">To teach about Principal Component Analysis and Linear Discriminant Analysis.</td></tr>
<tr><td>2</td><td colspan="2">To teach about different regression methodologies</td></tr>
<tr><td>3</td><td colspan="2">To teach various optimization methodologies.</td></tr>
<tr><td>4</td><td colspan="2">To teach support vector machines.</td></tr>
<tr><td colspan="3">Course Outcomes: Students will be able to</td></tr>
<tr><td>1.</td><td colspan="2">apply theoretical and numerically PCA and LDA.</td></tr>
<tr><td>2</td><td colspan="2">use regression techniques.</td></tr>
<tr><td>3</td><td colspan="2">obtain the optimal solution by different optimization methodologies.</td></tr>
<tr><td>4</td><td colspan="2">apply the concept of support vector machines in real life problems.</td></tr>
<tr><td colspan="3">Course Content:</td></tr>
<tr><td>Unit-I</td><td>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.</td><td>11 Hours Theory +
8 Hours Lab</td></tr>
<tr><td>Unit-II</td><td>Review of Probability Concepts, Least Square Approximation and Minimum Normed Solution, Linear and Multiple Regression, Logistic Regression, Python Implementation.</td><td>11 Hours Theory +
7 Hours Lab</td></tr>
<tr><td>Unit-III</td><td>Introduction to Optimization, Convex sets and convex functions, properties of convex functions, Various Optimization algorithms: Gradient Descent and others, Python Implementation of Optimization.</td><td>11 Hours Theory +
8 Hours Lab</td></tr>
<tr><td>Unit-IV</td><td>Discrete and continuous distribution functions, joint probability and covariance, Separating Hyperplanes, Primal and Dual Support Vector Machines, Kernels and Python Implementation.</td><td>12 Hours Theory +
7 Hours Lab</td></tr>
</table>

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. Cheney W., 2001, *Analysis for Applied Mathematics*, New York: Springer Science+Business Medias.
2. Axler S., 2015, *Linear Algebra Done Right (3rd 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 (2nd Ed.)*, Singapore: World Scientific Publishing.

Reference Books:

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

E-resources:

1. https://archive.nptel.ac.in/courses/111/107/111107137/

LEVEL-6

Semester-V (Integrated M.Sc. B.Ed)							
S. No.	**Course Code**	**Course Title**	**Type of Course (C/E)**	**L**	**T**	**P**	**Credits**
1	EDU601	School Internship-I (6 Weeks)		0	0	6	6
2	EDU602	School Internship & Teaching Practice-II and Case Study and Community Survey Research (14 weeks)		0	0	12	12
3	EDU603	Action Research in Schools		0	0	4	4
4		One course from Education Department					2
Total				**0**	**0**	**22**	**24**

Semester-VI (Integrated M.Sc. B.Ed)							
S. No.	**Course Code**	**Course Title**	**Type of Course (C/E)**	**L**	**T**	**P**	**Credits**
1	MAT681	Major Project Dissertation in Mathematics	AECC	0	0	16	16
2		Elective Paper (Subjective)	DE	3	1	0	4
3		Elective Paper	GE	3	1	0	4
4		UHV**	Audit Course	3	1	0	4
Total				**9**	**3**	**16**	**24**

LEVEL-6 (DE) (Electives)				
S. No.	**Course Code**	**Course Title**	**Credit**	**Remarks**
1	MAT631	ADVANCE REAL ANALYSIS	4	
2	MAT632	ADVANCED NUMERICAL METHODS	4	
3	MAT633	COMPLEX DYNAMICS	4	
4	MAT634	Number Theory	4	
5	MAT635	NONLINEAR DYNAMICS AND CONTROLS	4	

Course Code: MAT631 Course Title: ADVANCED REAL 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:		
1.	Basic knowledge of Mathematical Analysis	
Course Objectives:		
1.	The course covers advanced metric space properties	
2	The course covers advanced Riemann integrability	
3	The course covers Cesaro"s Method of Summability and Fourier Series	

Course Outcomes: Students will be able to		
1.	define the advanced properties in metric space	
2.	find the Riemann integrals using Lebesgue's criterion	
3.	find the bounded variations	
4.	classify the Cesaro"s Method of Summability and Fourier Series.	
Course Content:		
Unit-I	Metric spaces revisited; Baire Category theorem, completion of Metric spaces, Banach contraction principle and some of its applications. Compactness, Total boundedness, characterization of compactness for arbitrary Metric spaces; Arzella-Ascoli theorem, Stone Weierstrass theorem.	15 Hours
Unit-II	Integrations : Lebesgue"s criterion of Riemann integrability over a bounded closed interval [a, b] and its consequence, length of a rectifiable curve in a plane, Riemann-Stieltjes integral over [a, b] and its properties.	15 Hours
Unit-III	Integrators of bounded variation, Integration by parts, Stieltjes integral as a Riemann integral, Step function as integrator, Riesz theorem.	15 Hours
Unit-IV	Cesaro"s Method of Summability and Fourier Series: Cesaro"s method of summability of order 1 and order 2, Some specific examples, Regularity of Cesaro"s method, Definition of Fourier series and some examples, Dirichlet"s Kernel, Fejer"s Kernel, Fejer"s theorem, Dini"s and Jordan"s tests for point wise convergence of Fourier series.	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. Bruckner, A. M., Bruckner J., Thomson B., 1997, *Real Analysis*, Prentice-Hall, N.Y.
2. Goldberg, R. R., 1970, *Methods of Real Analysis*, Oxford-IBH, New Delhi.
3. Natanson, I. P.,1955, *Theory of Functions of a Real Variable*, Vol-I, F.Ungar, N.Y.
4. Hewitt, E., Stromberg, K.,1965, *Real and Abstract Analysis*, John-Willey, N.Y.

Reference Books:

1. Randolph J. F.,1968, *Basic Real and Abstract Analysis*. Academic Press, N.Y.
2. Jain P. K., Ahmad K., 1996, *Metric Spaces*, Narosa Publishing House.
3. Tolstov G., 1962, *Fourier Series*, Dover Publication, N.Y.

E-resources:

https://archive.nptel.ac.in/noc/courses/noc21/SEM2/noc21-ma63

Course-Code: MAT632
Course Title: ADVANCED NUMERICAL METHODS

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:

1.	Basic knowledge of numerical analysis

Course Objectives:

1.	The course covers advanced methods for solving the system of equations,
2	The course covers advanced methods to solve eigenvalue problems, numerically.
3	The course covers advanced methods to solve IVP and BVP, numerically.

Course Outcomes: Students will be able to

1.	find the zeros of nonlinear equations

2.	find the solution of system of equations	
3.	find the solutions of BVP governed by ODE, numerically	
4.	find the solutions of IVP and BVP governed by PDE, numerically.	
Course Content:		
Unit-I	Numerical solution of algebraic and transcendental equations: Introduction- iteration method, Newton-Raphson method, Graeffe‟s root square method, acceleration of convergence. Numerical Solution of systems of nonlinear equations: iteration method, Newton-Raphson method.	15 Hours
Unit-II	Linear Systems of equations: Introduction- Gauss elimination method, LU decomposition, Solution of tridiagonal system, Ill-conditioned linear systems and method for Ill-conditioned matrix. EigenValue problem: Power method, Jacobi Method, Householder method.	15 Hours
Unit-III	Introduction- finite difference formulas. Boundary value problem: Introduction, BVP governed by second order ordinary differential equations, Finite difference method, shooting method, cubic splines method.	15 Hours
Unit-IV	IVP and BVP in partial differential equations: classification of linear second order partial differential equations, Finite difference methods for Laplace and Poisson equations - Jacobi method, Gauss-Seidel method and ADI (alternating direction implicit) method , Finite difference method for heat conduction equation - Bender- Schmidt recurrence relation, Crank-Nicolson formula, and Jacobi Iteration formula, Finite difference method for wave equation.	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. Atkinson K. E., 1989, *An Introduction to Numerical Analysis (2nd Ed.)*, Wiley-India.		

2. Sastry S. S., 2012, *Introductory Methods of Numerical Analysis (5th Ed.)*, Eastern Economy Edition. 3. Jain M. K., Iyengar S. R. K., Jain R. K., 2012, *Numerical Methods for Scientific and Engineering Computation (6th Ed.)*, New Age International Publishers.
Reference Books:
1. Buchaman J. I., Turner P. R., 1992, *Numerical Methods and Analysis,* McGraw-Hill.
E-resources:
https://archive.nptel.ac.in/courses/111/107/111107105/

Course Code: MAT633 **Course Title: COMPLEX DYNAMICS**		
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		
1.	Complex analysis	
Course Objectives:		
1.	To teach students bilinear transformation of complex functions	
2.	To teach students Fatou sets and Julia sets	
3.	To teach students the Euler characteristic, Riemann Hurwitz formula for covering maps	
Course Outcomes: Students will be able to		
1.	classify the bilinear transformation of complex functions	

2.	explain Fatou sets and Julia sets	
3.	explain the Euler characteristic, Riemann Hurwitz formula for covering maps.	
Course Content:		
Unit-I	Iteration of a Mobius transformation, attracting, repelling and indifferent fixed points. Iterations of R(z) = z2, z2+c, z + . The extended complex plane, chordal metric, spherical metric, rational maps, Lipschitz condition, conjugacy classes of rational maps, valency of a function, fixed points, Critical points, Riemann Hurwitz relation.	15 Hours
Unit-II	Equicontinuous functions, normality sets , Fatou sets and Julia sets, completely invariant sets, Normal families and equicontinuity, Properties of Julia sets, exceptional points Backward orbit, minimal property of Julia sets.	15 Hours
Unit-III	Julia sets of commuting rational functions, structure of Fatou set, Topology of the Sphere, Completely invariant components of the Fatou set.	15 Hours
Unit-IV	The Euler characteristic, Riemann Hurwitz formula for covering maps, maps between components of the Fatou sets, the number of components of Fatou sets, components of Julia sets.	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. Beardon, A.F. 1991, *Iteration of rational functions*, Springer Verlag , New York.
2. Carleson, L., Gamelin, T. W. 1993, *Complex dynamics*, Springer Verlag.
3. Morosawa, S., Nishimura, Y.,Taniguchi, M., Ueda, T., 2000, *Holomorphic dynamics*, Cambridge University Press.

Reference Books:

1. Hua, H.X., Yang, C. C., 1998, *Dynamics of transcendental functions*, Gordan and Breach Science Pub.
E-resources:
https://archive.nptel.ac.in/courses/111/106/111106141

Course-Code: MAT634 **Course Title: 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: The student should have knowledge of		
1.	Elementary Number Theory	
Course Objectives:		
1	To teach the students approximation of real numbers	
2	To teach the students the Diophantine equations	
3	To teach the students the arithmetic functions	
4	To teach the students Chebychev's theorems	
Course Outcomes: Students will be able to learn		
1.	the concepts of continued fractions	
2	the Waring's problem	
3	the Fibonacci series	

4	the Prime number theorem	
Course Content:		
Unit-I	Jacobi’s Symbol, Kronecker Symbol, Approximation of real number, Farey Sequence, Approximation by rational numbers, Continued fractions	15 Hours
Unit-II	Diophantine equation ax^2+by^2+cz^2=0, sum of three squares, Pell’s equation, Fundamental solutions, General (Diophantine) equation of second degree, Waring’s problem	15 Hours
Unit-III	Review of arithmetic functions, Character modulo k, Principal character, Additive arithmetic functions, Linear recurrence, Fibonacci series, Bonnet formula	15 Hours
Unit-IV	Bertrand’s postulate, Chebychev’s theorems, The function □(x), Von Mangoldt function, Merten’s theorems, Prime number theorem (statement only)	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. Redmond D.., 1996, *Number Theory An Introduction,* Marcel Dekker, New York		
2. Shockley J. E., 1967,. *Introduction to Number Theory*, Holt, Rinehart and Winston Inc., New York.		
Reference Books:		
1. Nathanson M. B., 2000, *Elementary Methods in Number Theory,* Springer, New York		
E-resources:		

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

Course-Code: MAT 635 **Course Title: NONLINEAR SYSTEMS & CONTROLS**		
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 and Calculus
Course Objectives:	
1.	To introduce control theory followed by dynamical system theory
2.	To teach different concepts in dynamical system theory
3.	To teach Lyapunov functions and Poincare-Bendixon's theorem
4.	To introduce two dimensional systems and associated bifurcations
5.	To discuss different topics in control theory
Course Outcomes: Students will be able to learn	
1.	different topics in dynamical systems and control theory
2.	stability theory associated with dynamical systems
3.	Lyapunov stability-I and Lyapunov stability-II.
4.	several important aspects related to control systems

5.	different applications of control theory in computing, communications, and sensing technologies that present unprecedented opportunities to impact the economic and scientific development of a particular nation and the world.	
Course Content:		
Unit-I	Formulation of physical systems, Existence and Uniqueness theorems, Linear systems, Solution of linear systems, Fundamental matrix, autonomous systems, solution of non-homogeneous systems, Fundamental matrices for Non-autonomous systems, solution of non-homogeneous systems.	15 Hours
Unit-II	Stability of systems: equilibrium points, stability of linear autonomous systems, Stability of linear systems, Stability of weakly non-linear systems, Linearization, Properties of phase portrait, Properties of Orbits, Phase portrait: Types of critical points, Phase portrait of linear differential equations, Poincare Bandixon's theorem, Limit cycle, Lyapunov stability-I, Lyapunov stability-II.	15 Hours
Unit-III	Introduction of control systems, Controllability of autonomous systems, Controllability of non-autonomous systems, Observability, Results on controllability and observability, Companion form, Feedback Control, State Observer, Stabilizability, Introduction to discrete systems, Lyapunov stability-I, Lyapunov stability-II, Lyapunov stability-III.	15 Hours
Unit-IV	Optimal Control, Optimal Controls for Discrete systems, Controllability of discrete systems, Observability of discrete systems-I, Stability for discrete systems, Relation between continuous and discrete systems-II.	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. Barun M. 2011, *Differential Equations and Their Applications*, Springer		

2. Barnett S., 1990, *Introduction to Mathematical Control Theory*, Oxford University Press.
3. Naidu R.D.S., 2010, *Optimal Control Systems*, CRC Press.
4. Lakshmikantham, V., Raghvendra, V., 2005, *Text Book of Ordinary Differential Equations*, Tata McGraw Hill.
5. Gopal, M., 1994, *Modern Control Systems*, John Wiley and Sons.
Reference Books:
1. Simmons G.F., 203, *Ordinary Differential Equations*, Tata McGraw Hill
2. Deo, S.G., Lakshminkantahm, V,., Raghbendra, V., 2020, *Text Book of of Ordinary Differential Equations*.
E-resources:
https://onlinecourses.nptel.ac.in/noc20_ma46/preview