Appendix - VI (D)

Cochin University of Science and Technology

Department of Mathematics

Five Year Integrated MSc Major in Mathematics

Syllabus approved by the

Board of Studies of Physical and Mathematical Sciences

(2024 admission onwards)

Integrated MSc Mathematics Scheme (2024 Admission onwards)

Semester	Details of courses offered in each semester						
	Major 4 credits	**Minor** 4 credits	**MDC** 3 credits	**AEC** 3 credits	**SEC** 3 credits	**VAC** 3 credits	**Total credits**
I	1	2	1	2*			21
II	1	2	1	2*			21
III	1	2	1			2*	21
IV	4				1	1*	22
V	5				1		23
VI	5**				1		23
		Internship***					2
Total credits/courses	68 (17) DSC 60 (15) DSE 8 (2-3)	24 (6)	9 (3)	12 (4)	9 (3)	9 (3)	133

*Courses offered by the Center for Integrated Studies, CUSAT

** One course with 4 credits, maybe replaced with one/two online courses to acquire 4 credits

***Not counted as a course

Exit with BSc in Mathematics (Total credits = 133)

VII	5 Courses + online course (2 credits)						22
VIII	2 Courses + online (2 credits) + Project (12 credits) Or 4 Major Courses + Mini project (4 credits) + online(2credits)						22
Total credits/courses	Hon. (Research): 112 (26 + Project) Hon. : 112 (28 + Mini Project)	24 (6)	9 (3)	12 (4)	9 (3)	9 (3)	177
Exit with BSc (Honours with Research) in Mathematics (Total credits = 177) Exit with BSc (Honours) in Mathematics (Total credits = 177)							
IX	5 Courses + online (2 credit**)						20-24
X	5* courses + online (2 credit**)						20-24
Total credits	156	24 (6)	9 (3)	12 (4)	9 (3)	9 (3)	221
* A project of 4 credits or 8 credits may be done to replace elective course/s of equivalent credit in the X semester ** Instead of taking two online courses worth 2 credits each, a student can opt for one online course worth 4 credits in the ninth/tenth semester. In such cases, the credits earned in that semester will be 24, and in the other semester, they will be 20. Exit with MSc in Mathematics (Total credits = 221)							

MDC: Multi-Disciplinary Courses
AEC: Ability Enhancement Courses
SEC: Skill enhancement Courses
VAC: Value Added Courses

Details of Courses Offered from Department of Mathematics

for students doing 5-year Integrated MSc

DSC – Department Specific Core, DSE – Department Specific Elective

MDC – Multidisciplinary Course, SEC – Skill Enhancement Course

SEMESTER: 1

Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10101	Calculus 1	100	DSE (For everyone)	4	4-0-0	50	50	100
MAT 10102	Basic Analysis 1	100	DSC (Only for Major in Mathematics)	4	3-0-2	50	50	100
MAT 10103	Mathematical Methods 1	100	DSE (Offered as Minor / MDC alone)	3	3-0-0	50	50	100

SEMESTER: 2

Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10201	Calculus 2	100	DSC (Major/Minor)	4	4-0-0	50	50	100
MAT 10202	Basic Analysis 2	100	DSC (Major)	4	3-0-2	50	50	100
MAT 10203	Mathematical Methods 2	100	DSE (Offered as Minor / MDC alone)	3	3-0-0	50	50	100

SEMESTER: 3

Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10301	Calculus 3	200	DSC (Major/Minor)	4	4-0-0	50	50	100
MAT 10302	Matrix Theory 1	200	DSC (Major)	4	3-0-2	50	50	100
MAT 10303	Matrix Theory and Graph Theory	200	MDC	3	3-0-0	50	50	100

SEMESTER: 4								
Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10401	Basic Group Theory	200	DSC	4	3-0-2	50	50	100
MAT 10402	Matrix Theory II	200	DSC	4	3-0-2	50	50	100
MAT 10403	Elementary Complex Analysis	200	DSC	4	3-0-2	50	50	100
MAT 10404	Basics in Python Programming	200	DSC	4	3-0-2	50	50	100
MAT 10405	Skill Enhancement Course	200	SEC	3	3-0-0	50	50	100

SEMESTER: 5								
Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10501	Real Analysis I	300	DSC	4	3-0-2	50	50	100
MAT 10502	Complex Analysis	300	DSC	4	3-0-2	50	50	100
MAT 10503	Group Theory	300	DSC	4	3-0-2	50	50	100
MAT 10504	Linear Algebra and Geometry	300	DSC	4	3-0-2	50	50	100
MAT 10505	Skill Enhancement Course	300	SEC	3	3-0-0	50	50	100
MAT 1050x	Elective I	300	DSE	4	3-0-2	50	50	100

SEMESTER: 6								
Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10601	Real Analysis II	300	DSC	4	3-0-2	50	50	100
MAT 10602	Ring Theory	300	DSC	4	3-0-2	50	50	100
MAT 10603	Ordinary Differential Equations	300	DSC	4	3-0-2	50	50	100
MAT 1060x	Elective I	300	DSE	4	3-0-2	50	50	100
MAT 1060x	Elective II	300	DSE	4	3-0-2	50	50	100
	Skill Enhancement Course	300	SEC	3	3-0-0	50	50	100
Internship (Not counted as a course)				2				

LIST OF ELECTIVE COURSES OFFERED IN V AND VI SEMESTERS:-

MAT 10505 / MAT 10605: Discrete Mathematics

MAT 10506 / MAT 10606: Linear Programming

MAT 10507 / MAT 10607: Elements of Applied Mathematics

MAT 10508 / MAT 10608: Introduction to Optimization Techniques

MAT 10509 / MAT 10609: Metric Topology

MAT 10510 / MAT 10610: Fuzzy Mathematics

MAT 10511 / MAT 10611: Introduction to Optimization in Machine Learning

MAT 10512 / MAT 10612: Elementary Number Theory

A student can exit, if he/she prefers, at this stage with BSc in Mathematics degree with a total credit of 133

SEMESTER: 7								
Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10701	Linear Algebra	400	DSC	4	3-0-2	50	50	100
MAT 10702	Measure and Integration	400	DSC	4	3-0-2	50	50	100
MAT 10703	Groups and Rings	400	DSC	4	3-0-2	50	50	100
MAT 10704	Topology I	400	DSC	4	3-0-2	50	50	100
MAT 1070x	Elective I	400	DSE	4	3-0-2	50	50	100
	Online Course			2				

SEMESTER: 8								
Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10801	Field Theory	400	DSC	4	3-0-2	50	50	100
MAT 10802	Functional Analysis	400	DSC	4	3-0-2	50	50	100
MAT 10803	Complex Analysis	400	DSC / DSE	4	3-0-2	50	50	100
MAT 10804	Functions of Several Variables and Geometry	400	DSC	4	3-0-2	50	50	100
MAT 10805	Minor Project	400	DSC	4			100	100
	Online Course			2				

Students who wish to exit with BSc Honors can opt out elective to do a minor project. Students who wish to exit with a BSc Honors with research must do a research project of 12 credits, for additional credits, or can opt out a maximum of 2 core papers offered in 8th semester. The eligibility to opt for research project and the papers that can be omitted shall be decided by the student in consultation with the project supervisor and with the approval of the department council.

SEMESTER 9								
Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 10901	Operator Theory	500	DSC	4	3-0-2	50	50	100
MAT 10902	Ordinary Differential Equations and Integral Equations	500	DSC	4	3-0-2	50	50	100
MAT 10903	Elective I	500	DSE	4	3-0-2	50	50	100
MAT 109xx	Elective II	500	DSE	4	3-0-2	50	50	100
XXX 109xx	Elective III	500	DSE	4	3-0-2	50	50	100
	Online Course*			2/4				

SEMESTER 10								
Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
MAT 11001	Partial Differential Equations and Variational Problems	500	DSC	4	3-0-2	50	50	100
MAT 11002	Probability Theory	500	DSC	4	3-0-2	50	50	100
MAT 110xx	Elective I	500	DSE	4	3-0-2	50	50	100
MAT 110xx	Elective II	500	DSE	4	3-0-2	50	50	100
MAT 110xx	Elective III	500	DSE	4	3-0-2	50	50	100
	Online Course*			2/4				

*****A student can do either two online courses of two credits each or one online course of 4 credits in either semester 9 or 10.

Project (6 months – 4 credits / 1 year – 8 credits) can be taken instead of elective courses in semester 9 / 10

LIST OF ELECTIVE COURSES OFFERED IN VARIOUS SEMESTERS:-

MAT 10705 : Real Analysis I
MAT 10905 : Topics in Applied Mathematics (Inter-departmental elective)
MAT 10906/ MAT 11006 : Advanced Linear Algebra
MAT 10907/ MAT 11007 : Discrete Framelets
MAT 10908/ MAT 11008 : Harmonic Analysis
MAT 10909/ MAT 11009 : Integral Transforms
MAT 10910/ MAT 11010 : Functions Of Several Variables
MAT 10911/ MAT 11011 : Advanced Spectral Theory
MAT 10912/ MAT 11012 : Banach Algebras And Spectral Theory
MAT 10913/ MAT 11013 : Number Theory
MAT 10914/ MAT 11014 : Representation Theory Of Finite Groups
MAT 10915/ MAT 11015 : Algebraic Topology
MAT 10916/ MAT 11016 : Differential Geometry
MAT 10917/ MAT 11017: Algebraic Graph Theory
MAT 10918/ MAT 11018 : Wavelets
MAT 10919/ MAT 11019 : Advanced Optimization Methods and Machine Learning
MAT 10920/ MAT 11020 : Commutative Algebra
MAT 10921/ MAT 11021 : Graph Theory
MAT 10922/ MAT 11022 : C*-Algebra and Representation Theory
MAT 10923/ MAT 11023 : Reproducing Kernel Hilbert Spaces
MAT 10924/ MAT 11024 : Topology II
MAT 10925/ MAT 11025 : Computational Mathematics Laboratory

Cochin University of Science and Technology
Department of Mathematics

Mathematics Elective Papers

(Semester: 1, 2 and 3)

Departmental / Inderdepartmental Elective

(Offered as a Minor for all students)

Semester I
24-803-0101 - Calculus I

Number of credits: 4
Number of hours per week: 4 hrs
Total No. of Hours: 72 hours

Objective: This course introduces the basic concepts from calculus that are required both in the applied and pure branches of science.

Course Outcome (CO): After completing the course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Evaluate the limit of a function and to do differentiation and integration	Evaluate
CO2	Apply the concepts in calculus to solve problems	Apply
CO3	Understand the basic concepts of calculus.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3	1		
CO3	3			

Prerequisites : Set theory, Operations on sets, functions, The set of natural numbers, Set of integers, Set of rational numbers, Set of real numbers and the set of Complex numbers.

Text books:

1. George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry.* Pearson Education India; 9th edition, (2010).

References:

1. Anton, Bivens and Davis, John: *Calculus single variable* 10th edition, Wiley and sons, Inc. (2012).
2. Tom M. Apostol: *Calculus, Vol I* (Second Edition), Wiley Student Edition, (2006).
3. N. Piskunov, M.I.R. Publisher, *Differential and Integral Calculus*, (Vol: I), (1977).
4. A Course in Calculus and Real Analysis, Ghorpade Sudhir, Limaye Balmohan V., Springer International Edition, (2006).

Syllabus

Module 1: Real Numbers and the Real Line, Coordinates, Lines, and Increments, Functions, Shifting Graphs, Trigonometric Functions, Rates of Change and Limits, Rules for Finding Limits, Target Values and Formal Definitions of Limits, Extensions of the Limit Concept, Continuity and Tangent Lines.
(Sections: Preliminaries 1, 2, 3, 4, 5, 1.1, 1.2, 1.3, 1.4, 1.5 and 1.6 of Text book 1).

Module 2: The Derivative of a Function, Differentiation Rules, Derivatives of Trigonometric Functions, The Chain Rule, Implicit Differentiation and Rational Exponents.
(Sections 2.1, 2.2, 2.4, 2.5 and 2.6 of Text book 1).

Module 3: Extreme Values of Functions, The Mean Value Theorem, The First Derivative Test for Local Extreme Values, Graphing with y' and y''.
(Sections 3.1, 3.2, 3.3 and 3.4 of Text book 1).

Module 4: Indefinite Integrals, Differential Equations, Integration by Substitution-Running the Chain Rule Backward, Riemann Sums and Definite Integrals, Properties, Area, and the Mean Value Theorem, The Fundamental Theorem, Substitution in Definite Integrals.
(Section 4.1, 4.2, 4.3, 4.5, 4.6, 4.7 and 4.8 of Text book 1).

Semester II
24-803-0201 - Calculus II

Number of credits: 4
Number of hours per week: 4 hrs
Total number of Hours: 72 hours

Objective: This course introduces the basic concepts from calculus that are required both in the applied and pure branches of science.

Course Outcome (CO): After completing the course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Evaluate the limit of a function using various rules	Evaluate
CO2	Apply the concepts in calculus to solve problems	Apply
CO3	Understand the basic concepts of sequences and series.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3	1		
CO3	3			

Prerequisites : This course is a continuation of Calculus I course offered in Semester I

Text books:

1. George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry.* Pearson Education India; 9th edition, (2010).

References:

1. Anton, Bivens and Davis, John: *Calculus single variable* 10th edition, Wiley and sons, Inc. (2012).
2. Tom M. Apostol: *Calculus, Vol I* (Second Edition), Wiley Student Edition, (2006).
3. N. Piskunov, M.I.R. Publisher, *Differential and Integral Calculus*, (Vol: I), (1977).
4. A Course in Calculus and Real Analysis, Ghorpade Sudhir, Limaye Balmohan V., Springer International Edition, (2006).

Syllabus

Module 1: Areas Between Curves, Finding Volumes by Slicing, Volumes of Solids of Revolution, Lengths of Plane Curves.
(Sections: 5.1, 5.2, 5.3 and 5.5 of Text book 1).

Module 2: L Hopital's Rule, Basic Integration Formulas, Integration by Parts, Partial Fraction, Improper Integrals.
(Sections: 6.6, 7.1, 7.2. 7.3 and 7.6 of Text book 1).

Module 3: Limits of Sequences of Numbers, Theorems for Calculating Limits of Sequences.
(Sections: 8.1 and 8.2 of Text book 1).

Module 4: Infinite series, The integral test for series of non negative terms, Comparison tests for series of non negative terms, Ratio and root test for series of non negative terms, Alternating Series, Absolute and Conditional Convergence. (Sections 8.3, 8.4, 8.5, 8.6 and 8.7 of text book 1).

Semester III
24-803-0301 - Calculus III

Number of credits: 4
Number of hours per week: 4 hrs
Total number of Hours: 72 hours

Objective: This course introduces the advanced concepts of calculus that are required both in the applied and pure branches of science.

Course Outcome (CO): After completing the course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Evaluate the limit of a function and to do differentiation and integration	Evaluate
CO2	Apply the concepts in calculus to solve problems	Apply
CO3	Understand the basic concepts of calculus.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3	1		
CO3	3			

Prerequisites : This is a continuation course of Calculus II offered in Semester II.

Text books:

1. George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry.* Pearson Education India; 9th edition, (2010).

References:

1. Anton, Bivens and Davis, John: *Calculus single variable* 10th edition, Wiley and sons, Inc. (2012).
2. Tom M. Apostol: *Calculus, Vol I* (Second Edition), Wiley Student Edition, (2006).
3. N. Piskunov, M.I.R. Publisher, *Differential and Integral Calculus*, (Vol: I), (1977).
4. A Course in Calculus and Real Analysis, Ghorpade Sudhir, Limaye Balmohan V., Springer International Edition, (2006).

Syllabus

Module 1: Conic Sections and Quadratic Equations, Classification of Conic Section by Eccentricity, Quadratic Equation and Rotations, Parametrization of Plane Curves, Calculus with Parametrized Curves, Polar coordinates, Cylindrical and Spherical coordinates, Vector valued functions and space curves, Arc length and the unit tangent vector, Curvature, torsion and the TNB frame.
(Sections 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, and 10.7 of the text book 1).

Module 2: Functions of several variables, Limits and continuity, Partial derivatives, Differentiability.
(Sections 12.1, 12.2, 12.3 and 12.4 of the text book 1).

Module 3: Linearization and Differentials, The chain rule, Partial derivatives with constrained variables, Directional derivatives, Gradient and tangent planes, Extreme values and saddle points, Lagrange multipliers, Taylor's formula.
(Sections 12.5, 12.6, 12.7, 12.8, 12.9 and 12.10 of the text book 1).

Module 4: Double integrals, Areas, Double integral in polar form, Triple integrals in Rectangular coordinates, Masses, moments in three dimension.
(Sections 13.1, 13.2, 13.3, 13.4 and 13.5 of the text book).

Cochin University of Science and Technology
Department of Mathematics

Mathematics Elective Papers

(Semester: 1, 2 and 3)

Interdepartmental Multidisciplinary Course

(Offered for students not taking Mathematics as major. Can be counted towards minor or multidisciplinary)

Semester I
24-803-0103 - Mathematical Methods I

Number of credits: 3
Number of hours per week: 3 hrs
Total No. of Hours: 54 hours

Objective: This course introduces basic Complex analysis and Differential equations techniques which are important tools in all branches of science.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Understand basic differential equations and know how to solve them.	Understand
CO2	Evaluate complex integrals and higher order complex derivatives	Evaluate

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3	1		

Prerequisites: Basic theory, formulas and techniques of differential and integral calculus of one variable.

Text book:

1. Advanced Engineering Mathematics, Erwin Kreyszig, 8th Edition. John Wiley and Sons, Inc., New York, (1999).

Reference books:

1. Calculus, Vol I (Second Edition), Tom M. Apostol, Wiley Student Edition, (2006).
2. Calculus and Analytic Geometry (Ninth Edition), George.B.Thomas and Ross.L.Finney, Pearson Education, Inc, (2006)
3. Complex variables and Applications (5th Edition) , J. W. Brown, R.V. Churchill, McGrawHill Higher Education, (1990).
4. Complex Analysis (3rd edition), L.V. Ahlfors, McGrawHill Book Company, (1979).

Syllabus

Module 1: Basic concepts and ideas, Geometric meaning, Exact equations, Linear differential equations, Applications Homogeneous Linear differential equations of second order.
(Chapter 1, Section 2.1 of Text book 1).

Module 2: Homogeneous Linear differential equations of second order with constant coefficients, Euler Cauchy equations, Existence and uniqueness theory, Wronskian, Non homogeneous

equations, Solutions by undetermined coefficients and by variation of parameters.
(Sections 2.2-2.3, Sections 2.6-2.10 of Text book 1).

Module 3: Complex Numbers, Polar form, Analytic Function, Cauchy-Riemann Equations, Elementary Functions, logarithm. Complex Integration, Cauchy's Integral Theorem and Integral Formula (without proof), Higher Derivatives (without proof).
(Section 12.1-12.4, 12.6-12.8, 13.1-13.4 of Text Book 1).

Semester II
24-803-0203 - Mathematical Methods II

Number of credits: 3
Number of hours per week: 3 hrs
Total No. of Hours: 54 hours

Objective: This course introduces Laplace Transform and Fourier series which are important tools in all branches of science. Also, Numerical Methods in General, Numerical Methods in Linear Algebra and Numerical Methods for Differential Equations are introduced. This course also introduces the abstract concept of Groups which is useful in all branches of science.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know Laplace Transform and Fourier series and their applications to various branches.	Remember
CO2	Apply numerical techniques for interpolation, integration and differentiation	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	
CO2	3			

Prerequisites: Basic theory, formulas and techniques of differential and integral calculus of one variable.

Text books:

1. Advanced Engineering Mathematics, Erwin Kreyszig, 8th Edition. John Wiley and Sons, Inc., New York, (1999).

Reference books:

1. Calculus, Vol I (Second Edition), Tom M. Apostol, Wiley Student Edition, (2006).
2. Calculus and Analytic Geometry (Ninth Edition), George.B.Thomas and Ross.L.Finney, Pearson Education, Inc, (2006)
3. Complex variables and Applications (5th Edition) , J. W. Brown, R.V. Churchill, McGrawHill Higher Education, (1990).
4. Complex Analysis (3rd edition), L.V. Ahlfors, McGrawHill Book Company, (1979).
5. Joseph A. Gallian: *Contemporary Abstract Algebra*, Eight Edition, University of Minnesota Duluth, 2017.

Syllabus

Module 1: Power Series, Power series representation of Analytic functions,Taylor series and Maclaurin series, Practical methods for power series. Laplace Transform, Transforms of Derivatives and integrals, Second Shifting theorem.
(Section 14.2-14.5, 5.1-5.3 of Text Book 1).

Module 2: Periodic functions, Fourier Series, Functions of any period, Half-Range Expansion, Fourier Series (Contd.): Complex Fourier Series, Forced Oscillations, Fourier Transform. (Section 10.1-10.10 of Text Book 1).

Module 3: Introduction, Solution of Equations by Iteration, Interpolation, Spline Interpolation, Numeric Integration and Differentiation, Linear Systems: Gauss Elimination (Section 17.1-17.5 of the Text Book)

Semester III
24-803-0303 - Matrix Theory and Graph Theory

Number of credits: 3
Number of hours per week: 3 hrs
Total No. of Hours: 54 hours

Objective: This course introduces the basic concepts from linear algebra and Graph Theory that are required both in the applied and pure branches of science.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know the fundamental concepts of linear algebra and graph theory.	Remember
CO2	Apply the basic results in linear algebra and graph theory for problem-solving.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3	2	1	

Text books:

1 Advanced Engineering Mathematics, Erwin Kreyszig, 10th Edition. John Wiley and Sons, Inc., New York, (2011).

2 John Clark Derek Allen Holton - A first look at graph theory, Allied Publishers, 1991.

Reference books:

1 S. Kumaresan: *Linear Algebra: A Geometric Approach*, PHI Learning, 2009.

2 Howard Anton and Chris Rorres: *Elementary Linear Algebra* with Supplemental Applications, 11th Edition, John Wiley, 2015.

3 R Balakrishnan and K Ranganathan: *A Text Book of Graph Theory*, Springer.

Syllabus

Module 1: Matrices, Vectors: Addition and Scalar Multiplication, Matrix Multiplication, Linear Systems of Equations, Gauss Elimination, Linear Independence, Rank of a Matrix, Vector Space, Solutions of Linear Systems: Existence, Uniquenes.
(Sections 7.1-7.5 of Text book 1).

Module 2: Determinants, Cramer' s Rule, Inverse of a Matrix, Gauss–Jordan Elimination, The Matrix Eigenvalue Problem, Determining Eigenvalues and Eigenvectors, Some Applications of Eigenvalue Problems, Symmetric, Skew-Symmetric, and Orthogonal Matrices.
(Sections 7.7, 7.8, 8.1 - 8.3 of Text book 1).

Module 3: An introduction to graph: Definition of a Graph, More definitions, Vertex Degrees, Sub graphs, Paths and cycles, the matrix representation of graphs. Trees. Definitions and Simple properties, Bridges, Spanning trees, Cut vertices and Connectivity, Euler's Tours, the Chinese postman problem, Hamiltonian graphs, The travelling salesman problem.
(Sections 1.1 - 1.7, 2.1 - 2.3, 2.6, 3.1 - 3.4 of Text book 2)

Cochin University of Science and Technology
Department of Mathematics

Mathematics Core Papers

(Semester: 1 - 6)

Core papers

(Offered for students opting Mathematics as Major or Minor)

Semester I
24-803-0102 - Basic Analysis I

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the structure of Natural Numbers. This course is planned to introduce the notions real number system, Convergence of sequence and series.

Learning Outcomes: After completing the course students will be able to

No.	Course Outcome	Cognitive level
CO1	Know basics of calculus and important notions on the set of real numbers.	Remember
CO2	Understand sequence of real numbers and evaluate their convergence.	Understand
CO3	Apply limit theorems and series convergence tests.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

UNIT 1: Introduction to Natural numbers and Rational Numbers, The set of all Real numbers, Completeness axiom (Sections 1, 2, 3 and 4)

UNIT 2: Extended real number system.Limit of sequence (Sections 5, 6, 7 and 8)

UNIT 3: Limit theorems, Monotone Sequences and Cauchy Sequences (Sections 9, and 10)

UNIT 4: Subsequences, Limsup's and Liminf's, Series (Sections 11, 12 and 14)

UNIT 5: Alternating Series and Integral Tests, Continuous functions, Properties of continuous functions (Sections 15, 17 and 18)

Text Book: Kenneth A. Ross Elementary Analysis: The Theory of Calculus, Second Edition, Springer-Verlag (2013).

References:-

1. Terence Tao, Analysis I and II, Third Edition, Springer 2016.

2. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, Fourth Edition, Wiley India Edition (2011).

3. N.L Carothers, Real Analysis, Wiley 2000.

4. Halsey L. Royden, Real Analysis, Prentice Hall, Upper Saddle River, NJ, (1988).

5. Tom M. Apostol, Mathematical Analysis, Addison-Wesley, Reading, MA, (1974).

6. A. K. Sharma, Real Analysis, Discovery publishing house Pvt. Lts., New Delhi, (2008).

7. D Somasundaram and B. Choudhary, A first course in mathematical analysis, Narosa, Oxford, London,(1996).

8. S Kumaresan, Topology of Metric Space, Alpha Science international Ltd, Harrow, UK, (2005)

Semester II
24-803-0202 - Basic Analysis II

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the notion of continuous functions. This course is planned to introduce the notions continuity, Convergence of sequence and series of functions and some metric space notions.

Learning Outcomes: After the completion of the course the students will be able to

No.	Course Outcome	Cognitive level
CO1	Understand the notions of limit, continuity and uniform continuity of functions.	Understand
CO2	Understand power series, their convergence, integration and differentiation.	Understand
CO3	Know basic properties and results of derivatives.	Remember
CO4	Know the basics of Riemann integration.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			

UNIT 1: Uniform Continuity, Limit of functions, Power Series (Sections 19, 20 and 23)

UNIT 2: Uniform Convergence, More on Uniform Convergence, Differentiation and Integration of Power Series (Sections 24, 25 and 26)

UNIT 3: Basic Properties of the Derivative, The Mean Value Theorem (Sections 28 and 29)

UNIT 4: L'Hospital's Rule, Taylor's Theorem (Sections 30 and 31)

UNIT 5: The Riemann Integral, Properties of the Riemann Integral, Fundamental Theorem of Calculus (Sections 32, 33 and 34)

Text Book: Kenneth A. Ross Elementary Analysis: The Theory of Calculus, Second Edition, Springer-Verlag (2013).

References:-

1. Terence Tao, Analysis I and II, Third Edition, Springer 2016.

2. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, Fourth Edition, Wiley India Edition (2011).

3. N.L Carothers, Real Analysis, Wiley 2000.

4. Halsey L. Royden, Real Analysis, Prentice Hall, Upper Saddle River, NJ, (1988).

5. Tom M. Apostol, Mathematical Analysis, Addison-Wesley, Reading, MA, (1974).

6. A. K. Sharma, Real Analysis, Discovery publishing house Pvt. Lts., New Delhi, (2008).

7. D Somasundaram and B. Choudhary, A first course in mathematical analysis, Narosa, Oxford, London,(1996).

8. S Kumaresan, Topology of Metric Space, Alpha Science international Ltd, Harrow, UK, (2005)

Semester III
24-803-0302 - Matrix Theory I

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces the basic concepts from linear algebra that are required in all branches of science.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Understand the fundamental concepts and applications of linear algebra.	Understand
CO2	Know how to use the computer software MATLAB.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1		
CO2	3	2	1	2

Text books:

1 Ron Larson: *Elementary Linear Algebra*, 8th Edition, Cengage Learning, 2016.

Reference books:

1 S. Kumaresan: *Linear Algebra: A Geometric Approach*, PHI Learning, 2009.

2 Howard Anton and Chris Rorres: *Elementary Linear Algebra* with Supplemental Applications, 11th Edition, John Wiley, 2015.

3 Michael Artin: *Algebra*, Pearson Prentice Hall, . Linear Algebra: A First Course with Applications

Syllabus

Module 1: Introduction to Systems of Linear Equations, Gaussian Elimination and Gauss-Jordan Elimination, Applications of Systems of Linear Equations, Computational Aspects using computer software MATLAB.
(Sections 1.1 - 1.3 of Text book 1).

Module 2: Operations with Matrices, Properties of Matrix Operations, The Inverse of a Matrix, Elementary Matrices, Computational Aspects using computer software MATLAB.
(Sections 2.1 - 2.4 of Text book 1).

Module 3: Markov Chains, More Applications of Matrix Operations, The Determinant of a Matrix, Determinants and Elementary Operations, Computational Aspects using computer software MATLAB.
(Sections 2.5,2.6, 3.1, 3.2 of Text book 1)

Module 4: Properties of Determinants, Applications of Determinants, Vectors in R^n, Vector Spaces, Subspaces of Vector Spaces, Computational Aspects using computer software MATLAB.
(Sections 3.3, 3.4, 4.1 to 4.3 of Text book 1).

Module 5: Spanning Sets and Linear Independence, Basis and Dimension, Rank of a Matrix and Systems of Linear Equations, Computational Aspects using computer software MATLAB. (Sections 4.4 to 4.6 of Text book 1).

Semester IV
24-803-0401 - Basic Group Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces the basic concepts from algebra that are required in all branches of science.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Understand the fundamental concepts and applications of algebra.	Understand
CO2	Know how to use the computer algebra system GAP.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1	1	
CO2	3	1		2

Text books:

1 Joseph A. Gallian: *Contemporary Abstract Algebra*, Eight Edition, University of Minnesota Duluth, year.

Reference books:

1 M. Artin: *Algebra*, Pearson Prentice Hall, 2007.

2 J.B. Fraleigh: *A first Course in Abstract Algebra*, Seventh Edition, Pearson, 2014.

3 M.A. Amstrong: *Groups and Symmetry*, Springer, 1997.

4 I.N. Herstein: *Topics in Algebra*, Wiley, 2006.

Syllabus

Module 1: Introduction to Groups: Symmetries of a Square, The Dihedral Groups; **Groups:** Definition and Examples of Groups, Elementary Properties of Groups, Exercises using Computer Algebra System GAP. (PART 2 Chapters 1, 2 of Text book 1).

Module 2: Finite Groups; Subgroups: Subgroup Tests, Examples of Subgroups, Exercises using Computer Algebra System GAP.
(PART 2 Chapter 3 of Text book 1).

Module 3: Cyclic Groups: Properties of Cyclic Groups, Classification of Subgroups of Cyclic Groups, Exercises using Computer Algebra System GAP.
(PART 2 Chapter 4 of Text book 1)

Module 4: Permutation Groups: Cycle Notation, Properties of Permutations, Exercises using Computer Algebra System GAP.
(PART 2 Chapter 5 of Text book 1)

Module 5: Isomorphisms Definition and Examples, Cayley's Theorem, Properties of Isomorphisms, Automorphisms, Exercises using Computer Algebra System GAP.
(PART 2 Chapter 6 of Text book 1)

Semester IV
24-803-0402 - Matrix Theory II

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course serves as a second course in linear algebra as a continuation of the Matrix Theory I course.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Understand in depth fundamental concepts and applications of linear algebra.	Understand
CO2	Know in detail the computer software MATLAB.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1	1	
CO2	3	2	1	2

Text books:

1 Ron Larson: *Elementary Linear Algebra*, 8th Edition, Cengage Learning, 2016.

Syllabus

Module 1: Review of Vector space, Applications of Vector Spaces, Inner Product Spaces, Computational Aspects using computer software MATLAB.
(Sections 4.7 - 4.8, 5.1-5.2 of Text book 1).

Module 2: 5.3 Orthonormal Bases, Gram-Schmidt Process, Mathematical Models and Least Squares Analysis, Applications of Inner Product Spaces, Computational Aspects using computer software MATLAB.
(Sections 5.3 - 5.5 of Text book 1).

Module 3: 6.1 Introduction to Linear Transformations, The Kernel and Range of a Linear Transformation, Matrices for Linear Transformations, Computational Aspects using computer software MATLAB.
(Sections 6.1-6.3 of Text book 1)

Module 4: Transition Matrices and Similarity, Applications of Linear Transformations Eigenvalues and Eigenvectors, Computational Aspects using computer software MATLAB.
(Sections 6.4, 6.5 and 7.1 of Text book 1).

Module 5: Diagonalization, Symmetric Matrices and Orthogonal Diagonalization, Applications of Eigenvalues and Eigenvectors, Computational Aspects using computer software MATLAB.
(Sections 7.2 to 7.4 of Text book 1).

References:-

1. Arindama Singh: *Introduction to Matrix Theory*, Springer, 2021.

2. Kenneth Hoffman and Ray Kunze *Linear Algebra*, Second Edition, PHI (1975).

3. M. Artin, Algebra, Prentice-Hall, (1991)

4. Howard Anton and Chris Rorres: *Elementary Linear Algebra* with Supplemental Applications, 11th Edition, John Wiley, 2015.

5. S.Kumaresan, *Linear Algebra: A Geometric Approach*, Fist Edition PHI Learning (2009).

6. Sheldon Axler, *Linear Algebra Done Right*, Second Edition, Springer, (1997).

Semester IV
24-803-0403 - Elementary Complex Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces the concepts and results from complex variable theory that are required for further study of advanced mathematics.

Outcome: After completing the course, students will be able to

No.	Course Outcome	Cognitive level
CO1	Understand the fundamental notions of complex functions and their mappings.	Understand
CO2	Evaluate the continuity and differentiability of complex functions.	Evaluate
CO3	Know Analytic functions with examples.	Understand
CO4	Evaluate definite integrals of functions and contour integrals.	Evaluate

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3	1		
CO3	3			
CO4	3	1		

Prerequisites Basic familiarity with formulas and techniques of differential and integral calculus

Text books:

1 J. W. Brown and R. V. Churchill, Complex Variables and Applications (8th Edition), Mcgraw-Hill,(2009).

Reference books:

1 L. V. Ahlfors, Complex Analysis, Mcgraw-Hill, 1980.

2 J. B. Conway, Functions of One Complex Variable (2nd Edition), Springer-Verlag, 1978.

3 R. Greene and S. G. Krantz, Function Theory of One Complex Variable, 3rd Edition, GSM, Vol. 40, AMS, 2006

4 T. W. Gamelin, Complex Analysis, Springer-Verlag, 2001.

5 S. Ponnusamy and H. Silverman, Complex Variables with Applications, Birkhauser Boston, 2006.

Syllabus

Module 1. Sums and products, Basic Algebraic Properties, Further Properties, Vectors and Moduli, Complex conjugates, Exponential Form, Products and Power in Exponential Form, Argument of Products and Quotients, Roots of Complex Numbers, Examples, Regions in the Complex plane. (Sections 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11 of the text book 1).

Module 2. Functions of Complex Variable, Mappings, Mappings by the Exponential Function, Limits, Theorems of Limits, Limits Involving the Point at Infinity. (Sections 12, 13, 14, 15, 16 and 17 of the Text book 1).

Module 3. Continuity, Derivatives and Differentiation Formulas. Cauchy-Riemann Equations, Sufficient Conditions for Differentiability, Polar Coordinates. (Sections 18, 19, 20, 21, 22 and 23 of the text book 1).

Module 4. Analytic Functions, Examples and Harmonic Functions. The Exponential Function, The Logarithmic Function, Some Identities Involving Logarithms, Complex Exponents, Trigonometric Functions Hyperbolic Functions. (Sections 24, 25, 26, 29, 30, 32, 33, 34 and 35 of the text book 1).

Module 5. Derivatives of Functions w(t), Definite Integrals of Functions w(t), Contours, Contour Integrals, Some Examples. Upper Bounds for Moduli of Contour Integrals, Antiderivatives and Cauchy–Goursat Theorem. (Sections 33, 37, 38, 39, 40, 41 43, 44, and 46 of the text book 1).

Semester IV
24-803-0404 - Basics in Python Programming

Number of credits: 3
Number of hours per week: 4 hrs
Total number of Hours: 72 hours

Objective: This course introduces the basics in python programming that are required in all branches of science.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know the fundamentals in python programming	Remember
CO2	Apply Python programs in other branches of study.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	2
CO2	3	3	1	3

Text books:

1 Kaswan, K. S., Dhatterwal, J. S. and Balamurugan, B. (2023). Python for Beginners. CRC Press.

2 Fuhrer, C., Solem, J. E., Verdier, O. (2021). Scientific Computing with Python: High-performance scientific computing with NumPy, SciPy, and pandas. Packt Publishing Ltd.

Reference books:

1 Langtangen, H. P. (2016). A primer on scientific programming with Python. Springer-Verlag Berlin Heidelberg.

2 Charles Dierbach, "Introduction to Computer Science Using Python: A Computational Problem-Solving Focus", Wiley, 2013.

3 Kenneth A Lambert., Fundamentals of Python : First Programs, 2/e, Cengage Publishing,2016

4 Mark Lutz, 'Learning Python', 5th Edition, O'Reilly Media, Inc.

Syllabus

Module 1: Introduction- Python Software setup, Datatypes, Sequence types, special types, Operators and Operands, Input and Output Functions, Flow control statements
(Sections 1.6, 2, 3.1, 4.3-4.6, 5.1, 5.3, 5.4 of Text 1).

Module 2: Functions, Lambda, Modules, List Comprehensions, Object Oriented Programming
(Sections 6.1 - 6.8, 7.1 - 7.8, 11.1 - 11.6 of Text 1).

Module 3: Encapsulation, Inheritance, Error and Exception Handling, Numpy
(Sections 11.8- 11.9 of Text 1 & Sections 12.1 - 12.3, 14.1- 14.2 of Text 2)

Module 4: Python for Scientific Computing- Linear Algebra Arrays, Understanding SciPy, Solving Linear System in Python, Building Least square Models and application on Prediction Problems
(Sections 4.1- 4.9 of Text 2).

Module 5: Data Analysis with Pandas, Working with Matplotlib
(Sections 6.1- 6.3, 10.2 - 10.4 Text 2).

Semester V
24-803-0501 - Real Analysis I

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course aims to provide the fundamentals of mathematical analysis such as axiomati introduction to the real number system, convergence of sequences and series, notion of continuous functions on metric spaces motivated from the real number system.

Outcome: After completing the course the student will be able to

No.	Course Outcome	Cognitive level
CO1	Know basics of Real Number system and its properties.	Remember
CO2	Understand sequences and series and evaluate their convergence and limits.	Understand
CO3	Understand continuity and uniform continuity of functions.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Text book:

1 R.G. Bartle and D.N. Sherbert, *Introduction to Real Analysis*, Thired Edition, John Wiley & Sons (2000).

Reference books:

1 G.B folland : *A Guide to Advanced Real Analysis* Mathematical Association of America Publishing.

2 Elias M. Stein, Rami Shakarchi: *REAL ANALYSIS Measure Theory, Integration, and Hilbert Spaces* Princeton University press.

3 Kenneth A. Ross *Elementary Analysis The Theory of Calculus* Springer-Verlag, New York, 2013.

4 Andrew M. Bruckner, Judith B. Bruckner, Brian S. Thomson *Real analysis* Prentice-Hall, 2001.

5 Sterling K. Berberian *Fundamentals of Real Analysis* Springer-Verlag, New York 1999.

6 Walter Rudin: *Principles of Mathematical Analysis*, third edition, McGrawHill Publishing (1964).

Syllabus

Module 1. Sets and Functions, Mathematicle Induction, Finte and Infinite Sets, The Algebraic and Order Properties of $\mathbb{R}$, Absolute Value and Real Line and The completeness Property of $\mathbb{R}$. (Sections 1.1, 1.2, 1.3, 2.1, 2.2 and 2.3 of Text book 1).

Module 2. Applications of the Supremum Property, Intervals, Open and Closed Sets in $\mathbb{R}$, Compact Sets, Continuous Functions and Metric Spaces. (Sections 2.4, 2.5, 11.1, 11.2, 11.3 and 11.4 of Text book 1).

Module 3. Sequences and Their Limits, Limit Theorems, Monotone Sequences, Subsequences and the Bolzano-Weierstrass Theorem, The Cauchy Criterion and Properly Divergent Sequences. (Sections 3.1, 3.2, 3.3, 3.4, 3.5, 3.6 of Text book 1).

Module 4. Introduction to Series, Limits of Functions, Limits Theorems and Some Extensions of Limit Concept. (Sections 3.7, 4.1, 4.2 and 4.3 of Text book 1).

Module 5. Continuous Functions, Combinations of Continuous Functions, Continuous Functions on Intervals, Uniform Continuity, Continuity and Gauges, Monotone and Inverse functions. (Sections 5.1, 5.2, 5.3, 5.4, 5.5 and 5.6 of Text book 1).

Semester V
24-803-0502 - Complex Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces the concepts and results from complex variable theory athat is required for further study of advanced mathematics.

Outcome: After completing the course, students will be able to

No.	Course Outcome	Cognitive level
CO1	Know basic theorems of complex integration.	Remember
CO2	Understand power series and their convergence.	Understand
CO3	Comprehend the idea of singular points with examples.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Prerequisites: Basic familiarity with formulas, techniques of differential and integral calculus, Natural Numbers and Integers.
Text books:

1 J. W. Brown and R. V. Churchill, Complex Variables and Applications (8th Edition), Mcgraw-Hill,(2009).

Reference books:

1 L. V. Ahlfors, Complex Analysis, Mcgraw-Hill, 1980.

2 J. B. Conway, Functions of One Complex Variable (2nd Edition), Springer-Verlag, 1978.

3 R. Greene and S. G. Krantz, Function Theory of One Complex Variable, 3rd Edition, GSM, Vol. 40, AMS, 2006.

4 T. W. Gamelin, Complex Analysis, Springer-Verlag, 2001.

5 S. Ponnusamy and H. Silverman, Complex Variables with Applications, Birkhauser Boston, 2006.

Syllabus

Module 1. Cauchy Integral Formula, An Extension of the Cauchy Integral Formula, Some Consequences of the Extension, Liouville's Theorem and the Fundamental Theorem of Algebra, Maximum Modulus Principle. (Sections 50, 51, 52, 53 and 54 of the text book 1).

Module 2. Convergence of Sequences, Convergence of Series, Taylor Series, Examples, Laurent Series, Examples. (Sections 55, 56, 57, 59, 60 and 62 of Text book 1).

Module 3. Absolute and Uniform Convergence of Power Series, Continuity of Sums of Power Series, Integration and Differentiation of Power Series, Uniqueness of Series Representations, Multiplication and Division of Power Series, Isolated Singular Points and Residues Cauchy's Residue Theorem, Residue at Infinity. (Sections:63, 64, 65, 66, 67, 68, 69 and 71, of Text book 1).

Module 4. The Three Types of Isolated Singular Points, Residues at Poles, Examples, Zeros of Analytic Functions, Zeros and Poles, Behavior of Functions Near Isolated Singular Points.(Sections: 72, 73, 74, 75, 76 and 77 of Text book 1).

Module 5. Argument Principle, Rouche's Theorem, Linear Transformations, Transformation $w = \frac{1}{z}$, Mapping of $\frac{1}{z}$, Linear fractional transformations, Mapping of the upper half plane. (Sections: 86, 87, 90, 91, 92, 93 and 95 of Text book 1).

Semester V
24-803-0503 - Group Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: The course is devoted to some of the basic concepts and results of Group Theory. This course aims to introduce students to some more sophisticated concepts and results of group theory as an essential part of general mathematical culture and as a basis for further study of more advanced mathematics.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know the fundamental concepts of Group theory.	Remember
CO2	Understand basic results and techniques from the theory of finite groups.	Understand
CO3	Comprehend the symmetries in the Euclidean plane.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3	1		

Text books:

1 J.B. Fraleigh: *A first Course in Abstract Algebra*, Seventh Edition, Pearson, 2014.

2 Michael Artin: Algebra, Prentice-Hall India, New Delhi, 2007.

Reference books:

1 M.A. Amstrong: *Groups and Symmetry*, Springer, 1997.

2 Joseph A. Gallian: *Contemporary Abstract Algebra*, Eight Edition, University of Minnesota Duluth, 2017.

3 I.N. Herstein: *Topics in Algebra*, Wiley, 2006.

Syllabus

Module 1: Review of group theory: Groups, Subgroups, Cyclic groups.
(Sections 4, 5, 6 of Text Book 1).

Module 2: Generating sets and Cayley digraphs, Groups of Permutations, Orbits, Cycles, Alternating Groups.
(Sections 7, 8, 9 of Text Book 1).

Module 3: Cosets and the Theorem of Lagrange, Direct Products and Finitely Generated Abelian Groups.
(Sections 10, 11, 13 of Text Book 1).

Module 4: Homomorphisms, Factor Groups, Factor-Group Computations and Simple Groups. (Sections 14,15 of Text Book 1).

Module 5: Symmetry: Symmetry of plane figures, The group of motions of the Plane, Finite group of motions.
(Sections 5.1-5.3 of Text Book 2).

Semester V
24-803-0504 - Linear Algebra and Geometry

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces the basic concepts from linear algebra and Group Theory that are required both in the applied and pure branches of science.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know basics of linear transformations, orthogonality and hyperplanes.	Remember
CO2	Understand diagonalization and classification of quadrics.	Understand
CO3	Evaluate multiple integrals.	Evaluate
CO4	Apply Stoke's theorem and Green's theorem for integration.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3	1		
CO4	3	1		

Text books:

1. S.Kumaresan, *Linear Algebra: A Geometric Approach*, First Edition PHI Learning (2009).
2. George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry.* Pearson Education India; 9th edition, (2010).

Reference books:

1. Sheldon Axler: *Linear Algebra Done Right*, 3rd edition. Undergraduate Texts in Mathematics, Springer, Cham, 2015.
2. Howard Anton and Chris Rorres: *Elementary Linear Algebra* with Supplemental Applications, 11th Edition, John Wiley, 2015.
3. Michael Artin: *Algebra*, Prentice Hall, Inc., Englewood Cliffs, NJ, 1991.
4. Gilbert Strang: *Introduction to Linear Algebra*, 4th Edition, Wellesley Cambridge Press; 2009.

Syllabus

UNIT 1: Lines and Quotient spaces, Geometric ideas, Some special linear transformations (Chapter 3, Sections 4.5 - 4.6 of Text book 1).

UNIT 2: Orthogonality, Geometricapplications, Orthonormal basis, Hyperplanes, Reflections (Sections 5.2 - 5.9 of Text book 1)

UNIT 3: Diagonalization, Classification of quadrics (Chapter 7, 8 of Text book 1)

Module 4: Triple integral in cylindrical and spherical coordinates, Substitution in Multiple integrals, Line integral, Vector fields, work, circulation and flux, Path independence, Potential functions and conservative fields. (Sections 13.6, 13.7, 14.1, 14.2 and 14.3 of the text book 2).

Module 5: Green's theorem in the plane, Surface area Surface integral, parametrized surface, Stoke's theorem and Divergence theorem. (Sections 14.4, 14.5, 14.6, 14.7 and 14.8 of the text book 2).

Semester VI
24-803-0601 - Real Analysis II

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course aims to provide the fundamentals of mathematical analysis: notion of differentiability, The Riemann Integral, sequences and series of functions, uniformconvergence, and the interchange of limit operations and an invitation to the calculus of several real variables.

Outcome: After the completion of this course, student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand basic concepts and theorems of derivatives.	Understand
CO2	Understand Riemann integration.	Understand
CO3	Evaluate convergence and absolute convergence.	Evaluate
CO4	Know basic properties of generalized Riemann integral and Lebesgue integral.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3	1		
CO4	3			

Text book:

1 R.G. Bartle and D.N. Sherbert, *Introduction to Real Analysis*, Thired Edition, John Wiley & Sons (2000).

Reference books:

1 G.B folland : *A Guide to Advanced Real Analysis* Mathematical Association of America Publishing.

2 Elias M. Stein, Rami Shakarchi: *REAL ANALYSIS Measure Theory, Integration, and Hilbert Spaces* Princeton University press.

3 Kenneth A. Ross *Elementary Analysis The Theory of Calculus* Springer-Verlag, New York, 2013.

4 Andrew M. Bruckner, Judith B. Bruckner, Brian S. Thomson *Real analysis* Prentice-Hall, 2001.

5 Sterling K. Berberian *Fundamentals of Real Analysis* Springer-Verlag, New York 1999.

6 Walter Rudin: *Principles of Mathematical Analysis*, third edition, McGrawHill Publishing (1964).

Syllabus

Module 1. The Derivatie, The Mean Value Theorem , L'Hospital Rules and Taylors Theorem. (Sections 6.1, 6.2, 6.3 and 6.4 of Text book 1).

Module 2. The Riemann Integral, Riemann Integrable Functions, The Fundamental Theorem and Approximate Integration. (Sections 7.1, 7.2, 7.3 and 7.4 of Text book 1).

Module 3. Pointwise and Uniform Convergence, Interchange of Limits, The Exponential and Logarithmic Functions and Trigonometric Functions. (Sections 8.1, 8.2, 8.3 and 8.4 of Text book 1).

Module 4. Absolute Convergence, Test for Absolute Convergence, Test for Nonabsolute Convergence and Series of Functions. (Sections 9.1, 9.2, 9.3 and 9.4 of Text book 1).

Module 5. Definition and main properties of Generalized Riemann Integral, Improper and Lebesuge Integrals, Infinite Intervals. (Sections 10.1, 10.2 and 10.3 of Text book 1).

Semester VI
24-803-0602 - Ring Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course aims to introduce students to the basic concepts of ring theory.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know fundamental concepts of Rings and Fields with examples.	Remember
CO2	Understand rings of polynomial and factorization of polynomials over a field.	Understand
CO3	Know Homomorphisms and factor rings.	Remember
CO4	Understand prime and maximal ideals.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			

Text books:

1 J.B. Fraleigh: *A first Course in Abstract Algebra*, Seventh Edition, Pearson, 2014.

Reference books:

1 Michael Artin: Algebra, Prentice-Hall India, New Delhi, 2007.

2 Joseph A. Gallian: *Contemporary Abstract Algebra*, Eight Edition, University of Minnesota Duluth, 2017.

3 I.N. Herstein: *Topics in Algebra*, Wiley, 2006.

Syllabus

Module 1: Rings and Fields: Definitions and Basic Properties, Homomorphisms and Isomorphisms, Fields; Integral Domains: Divisors of zero and cancellation, Integral Domain, The Characteristic of a Ring.
(Section 18, 19 of Text Book 1).

Module 2: Fermat's and Euler's Theorems: Fermat's Theorem, Euler's Generalization, Application to Congruence Equations; The Field of Quotients of an Integral Domain: The Construction, Uniqueness.
(Section 20, 21 of Text Book 1).

Module 3: Rings of Polynomials: Polynomials in an Indeterminate, The Evaluation Homomorphisms, Factorization of polynomials over a field: The Division Algorithm in $F[x]$, Irreducible Polynomials, Unique Factorization in $F[x]$.
(Section 22, 23 of Text Book 1).

Module 4: Homomorphisms and Factor Rings: Homomorphisms, Properties of Homomorphisms, Factor Rings, Fundamental Homomorphism Theorem.
(Section 26 of Text Book 1).

Module 5: Prime and Maximal Ideals: Maximal Ideals, Prime Ideals, Prime Fields, Ideal Structure in $F[x]$, Application to Unique Factorization in $F[x]$.
(Section 26, 27 of Text Book 1).

Semester VI
24-803-0603 - Ordinary Differential Equations

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the review of Ordinary differential equations. Course aims to build an understanding of the classical models in terms of ordinary differential equations and pave the foundations for the study of Integral equations.

Learning Outcomes: After the completion of the course the students will be able to

No.	Course Outcome	Cognitive level
CO1	Understand solving techniques of first order differential equations.	Understand
CO2	Know basics notions of second order linear and partial differential equations.	Remember
CO3	Understand the ideas of initial value problems and analyse the existence and uniqueness of their solution.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	2		
CO2	3			
CO3	3	1		1

UNIT 1: A brief introduction, Physical and other models, Review of basics; Uniform convergence, Fixed Point Theorem, Some points in Linear Algebra (Chapter 1, 2 of the Text book)
UNIT 2: First Order Equations, Exact Differential Equations (Chapter 3, Sections 3.1,3.2.)
UNIT 3: Second Order Linear Equations, PDE and ODE (Chapter 3, Sections 3.3-3.6.)
UNIT 4: General Theory of Initial Value Problems; Well-posed problems, Uniqueness Theorem (Chapter 4, Sections 4.1-4.2.)
UNIT 5: Existence and Uniqueness Theorems, Continuous dependance of solution on initial data and dynamics (Chapter 4, Sections 4.3-4.8.)
Text Book:

1. A. K. Nandakumaran; P. S. Datti; Raju K. George, *Ordinary Differential Equations; Principles and Applications*, Cambridge University Press, IISc Series 2017.

References:-

1. Peter J. Collins, *Differential and Integral Equations*, Oxford University Press,(2006).
2. Carmen Chicone, *Ordinary Differential Equations with Applications*, Springer (2006).
3. George F. Simmons, *Differential Equations with Applications and Historical Notes*, Tata McGraw-Hill, Third Editon 2003.
4. Michael D. Greenberg, *Ordinary Differential Equations*, Wiley (2012).
5. Michael E. Taylor, *Introduction to Differential Equations*, AMS (2011).
6. Vladimir I. Arnol'd, *Ordinary Differential Equations*, Springer (1992).
7. Earl A. Coddington, *An Introduction to Ordinary Differential Equations*, Dover Publications, New york, (1961).

Cochin University of Science and Technology
Department of Mathematics

Mathematics – Elective Papers

(Semester: 5 and 6)

Departmental Elective

(Offered for students opting Mathematics as Major or Minor)

Semester V or VI: 24-803-0505 / 24-803-0605 - Discrete Mathematics

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours
Objective: This course gives a thorough introduction to Discrete Mathematics with rigorous mathematics and serves as the basis for further studies in this area.

Outcome: After completing the course, the student will be able to

No.	Course Outcome	Cognitive level
CO1	Know basic terminologies and ideas of graph theory.	Remember
CO2	Know important ideas of counting and notions of lattices and ordered sets.	Remember
CO3	Understand the fundamental concepts of Boolean algebra.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			1

Text books:

1. John Clark Derek Allen Holton - A first look at graph theory, Allied Publishers, 1991.
2. Seymour Lipschutz - Discrete Mathematics, Tata McGraw Hill, 1997.

Module 1: Introduction to Graph Theory
Graph Theory. An introduction to graph. Definition of a Graph, More definitions, Vertex Degrees, Sub graphs, Paths and cycles, the matrix representation of graphs.
Text 1: Chapter 1 (Sections 1.1, 1.3 to 1.7)

Module 2: Trees and connectivity
Trees. Definitions and Simple properties, Bridges, Spanning trees. Cut vertices and Connectivity. Euler's Tours, the Chinese postman problem. Hamiltonian graphs and the travelling salesman problem.
Text 1: Chapter 2 (Sections 2.1, 2.2, 2.3, 2.6); Chapter 3 (Sections 3.1 (algorithm deleted), 3.2 (algorithm deleted), 3.3, and 3.4 (algorithm deleted))

Module 3: Counting
Counting, Basic counting principles, Permutations, Combinations, Pigeon-hole principle, Inclusion-exclusion principle, Ordered-unordered partitions.
Text 2: Chapter 6 (Sections 6.1-6.8)

Module 4: Language, Grammars and Machine - Lattices and Ordered Sets
Languages, Grammars, Machines languages, Regular languages, Finite state automata, Finite state machines, ordered sets, Lattices distributive lattices.
Text 2: Chapters 13 and 14 (Sections 13.1-13.7; 14.1-14.11)

Module 5: Boolean Algebra

Boolean algebra, Representation theorem, Minimal boolean expressions, Logic gates, boolean functions.

Text 2: Chapter 15 (Sections 15.1-15.11)

Semester V or VI: 24-803-0506 / 24-803-0606 - Linear Programming

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: Linear Programming is perhaps the most recognized and widely used optimization tool in the world today. It has its origins in planning and operations models from World War II through the seminal work of George Dantzig and his development of the simplex method. In this course, the student will learn how to model real world problems as linear programs, and will learn various methods to solve them.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know solution techniques of LP problems geometrically and more effectively using Simplex algorithm.	Remember
CO2	Understand duality theory, a theory that establishes relationships between linear programming problems of maximization and minimization.	Understand
CO3	Know how to solve transportation and assignment problems.	Apply
CO4	Know how to determine the shortest path, critical path and maximal flow in a network.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	2		1
CO2	3			
CO3	3	2	2	2
CO4	3	2	2	1

Pre-Requisite : Elementary Linear Algebra and basic Calculus.

Text books:

1. K.V. Mital; C. Mohan: Optimization methods in operations, Research and systems analysis (3rd Edn.), New age international (P) Ltd., 1996.

References:-

1. A. Ravindran, D.T. Philips and J.J. Solberg: Operations Research-Principles and Practices (2nd Edn.); John Wiley & Sons, 2000

2. G. Hadley: Linear Programming; Addison-Wesley Pub Co Reading, 1975.

3. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall of India, 2000.

4. H.S. Kasana and K.D. Kumar: Introductory Operations Research-Theory and Applications, Springer-Verlag, 2003.

5. James K. Strayer: Linear Programming and Its Applications,Under graduate Texts in Mathematics Springer (1989), Springer-Verlag, 2003.

6. R. Panneerselvam: Operations Research, PHI, New Delhi (Fifth printing), 2004.

Module 1: Mathematical Preliminaries
Euclidean Space, Linear Algebraic functions, Convex Sets. (Chapter 1 (1.1-1.19) of the text).

Module 2: : Linear Programming
Introduction – Degeneracy. (Chapter 3 (3.1-3.14) of the text).

Module 3: Linear Programming (continued)
Simplex multipliers – Dual simplex method. (Chapter 3 (3.15-3.20) of the text).

Module 4:
Transportation and Assignment problems. (Chapter 4 (4.1 – 4.15) of the text).

Module 5:
Flow and potential in networks. (Chapter 5 (5.1 – 5.9) of the text).

Semester V or VI: 24-803-0507 / 24-803-0607: Elements of Applied Mathematics

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the structure of $\mathbb{C}^n$ and it is planned to introduce the Discrete Fourier Transformation in a Linear algebraic perpsective. Towards the end Differece calculus and solution of Linear and Non Linear difference equations will be discussed.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know the necessary tools in applied mathematics in a signal processing perspective.	Apply
CO2	Understand the theory revolving signal processing based around transforms.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3		1	
CO2	3			

Pre-Requisite : Review of sections 1.1, 1.2, 1.3 of the text 1.

Text Book:

1. Michael W. Frazier, An Introduction to Wavelets Through Linear Algebra, Springer-Verlag New York, (1999).

2. Walter G. Kelley & Allan C. Peterson Difference Equations An Introduction with Applications, Second Edition, Academic Press 2001.

References:-

1. Stephane Mallat, *A Wavelet Tour Of Signal Processing*, Academic Press (1999).

2. Don Hong, Jianzhong Wang, Robert Gardner, *Real Analysis with an Introduction to Wavelets*, Elsevier Academic Press (2005).

3. Ronald. E.Mickens, Difference Equations: Theory, Applications and Advanced Topics, Third Edition, Chapman and Hall, 2015.

UNIT 1: Diagonalization of Linear Transformations and Matrices, Inner products, Orthonormal Bases and Unitary Matrices. (Chapter 1, Sections 1.5, 1.6 of the text 1.)

UNIT 2: The Discrete Fourier Transform, Translation-Invariant Linear Transformations (Chapter 2, Sections 2.1, 2.2 of the text 1.)

UNIT 3: The Fast Fourier Transform, Introduction, The Difference Operator, Summation, Generating Functions and Approximate summation. (Section 2.3 of text 1, Chapters 1, 2 of the text 2.)

UNIT 4: Linear Difference Equations, First Order Equations, General Results for Linear Equations, Solving Linear Equations, Applications. (Chapter 3, Sections 3.1, 3.2, 3.3, 3.4 of the text 2.)

UNIT 5: Equations with Variable Coefficients, Nonlinear Equations That Can Be Linearized, The z-Transform. (Chapter 3 sections 3.5, 3.6, 3.7 of text 1.)

Semester V or VI: 24-803-0508 / 24-803-0608: Introduction to Optimization Techniques

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: The objective of this course is to introduce different classes of optimization problems following some classical methods to solve them. Starting with methods to solve Linear Programming problem, different direct and indirect methods to solve Non-linear Programming problems are also discussed in this course. This course also includes solution methods for constrained and unconstrained optimization problems.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Evaluate the optimization problems and classify them based on objective function and constraints.	Evaluate
CO2	Apply the knowledge of different optimization methods to solve an optimization problem efficiently.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3		1	
CO2	3	2	2	2

Pre-Requisite : Calculus and Linear Algebra.

Text books:

1. "Engineering Optimization: Theory and Practice" by Singiresu S. Rao (Fourth Edition).

References:-

1. "Optimization for Engineering Design Algorithms and Examples" by Kalyanmoy Deb.

Module 1: Introduction to Optimization
Introduction, Statement of an Optimization Problem, Classification of Optimization Problems. (Sec 1.1,1.4,1.5).

Module 2: : Classical Optimization Techniques
Single-Variable Optimization, Multivariable Optimization with No Constraints, Multivariable Optimization with Equality Constraints, Multivariable Optimization with Inequality Constraints, Convex Programming Problem. (Sec 2.1-2.6).

Module 3: Linear Programming
Standard Form of a Linear Programming Problem, Simplex Algorithm, Duality in Linear Programming, Transportation Problem, Karmarkar's Interior Method, Quadratic Programming. (Sec 3.3, 3.8, 3.9, 4.3, 4.6, 4.7, 4.8).

Module 4: Nonlinear Programming: Unconstrained Optimization Techniques
Random Search Methods, Grid Search Method, Univariate Method, Pattern Directions, Powell's Method, Steepest Descent (Cauchy) Method, Conjugate Gradient (Fletcher–Reeves) Method,

Newton's Method, Marquardt Method, Quasi-Newton Methods, DFP Method, BFGS Method. (Sec 6.2-6.6, 6.8-6.15).

Module 5: Nonlinear Programming: Constrained Optimization Techniques
Random Search Methods, Complex Method, Sequential Linear Programming, Basic Approach in the Methods of Feasible Directions, Zoutendijk's Method of Feasible Directions, Rosen's Gradient Projection Method, Sequential Quadratic Programming, Penalty Function Method, Convex Programming. Problem. (Sec 7.9-7.8, 7.10-7.15).

Semester V or VI: 24-803-0509 / 24-803-0609: Metric Topology

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: The aim is to give a very streamlined development of a course in metric space topology emphasizing only the most useful concepts, concrete spaces and geometric ideas. To encourage the geometric thinking. In this course there are large number of examples which allow us to draw pictures and develop our intuition and draw conclusions, generate ideas for proofs. To this end, this course boasts of a lot of pictures. A secondary aim is to treat this as a preparatory ground for a general topology course and arm the reader with a repertory of examples.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know fundamental ideas revolving around limit and continuity.	Remember
CO2	Understand the notions of compactness and connectedness with examples.	Understand
CO3	Know in depth, completeness property and spaces that serve as examples.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Prerequisites: Introductory course in real analysis.
Text books:

1 S. Kumaresan, *Topology of Metric Spaces*, Alpha Science International Ltd, 2005.

Reference books:

1 G.B. Folland : *A Guide to Advanced Real Analysis* Mathematical Association of America Publishing.

2 Andrew M. Bruckner, Judith B. Bruckner, Brian S. Thomson *Real analysis* Prentice-Hall, 2001.

3 Sterling K. Berberian *Fundamentals of Real Analysis* Springer-Verlag, New York 1999.

4 Walter Rudin: *Principles of Mathematical Analysis*, third edition, McGrawHill Publishing (1964).

Syllabus

Module 1: Review of Definition and Examples of Open Balls and Open Sets, Convergent Sequences, Limit and Cluster Points, Cauchy Sequences and Completeness, Bounded Sets, Dense Sets, Basis and Boundary of a Set. (Chapter 2 of Text book 1).

Module 2: Continuous Functions, Equivalent Definitions of Continuity, Topological Property, Uniform Continuity, Limit of a Function, Open and closed maps. (Chapter 3 of Text book 1).

Module 3: Compact Spaces and their Properties, Continuous Functions on Compact Spaces, Characterization of Compact Metric Spaces and Arzela-Ascoli Theorem. (Chapter 4 of Text book 1).

Module 4: Connected Spaces, Path Connected spaces. (Chapter 5 of Text book 1).

Module 5: Examples of Complete Metric Spaces, Completion of a Metric Space, Baire Category Theorem and Banach's Contraction Principle. (Chapter 6 of Text book 1).

Semester V or VI: 24-803-0510 / 24-803-0610: Fuzzy Mathematics

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course gives a thorough introduction to Fuzzy Mathematics with an extension to how crisp concepts can be fuzzified through introducing the concept of Fuzzy Graphs.

Outcome: After the completion of the course the student will be able to

No.	Course Outcome	Cognitive level
CO1	Know the fundamental concepts of fuzzy sets and fuzzy arithmetic.	Remember
CO2	Understand the idea of fuzzy logic.	Understand
CO3	Know fuzzy graphs and their basic properties.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Text books:

1 George J. Klir and BoYuan, Fuzzy Sets and Fuzzy Logic Theory and Applications, Prentice Hall of India Private Limited New Delhi, 2000.

2 Sunil Mathew, John N Mordeson, Davender S Malik, Fuzzy Graph Theory, Springer, 2018.

Reference books:

1 Klir, G. J and T. Folger, Fuzzy Sets, Uncertainty and Information, Prentice Hall of India Private Limited New Delhi, 1988.

2 H.J Zimmermann, Fuzzy Set Theory- and its Applications, Allied Publishers, 1996.

3 Dubois, D and H. Prade , Fuzzy Sets and System: Theory and Applications, Academic Press, New York, 1988.

4 Abraham Kandel, Fuzzy Mathematical Techniques with Applications, Addison Wesley Publishing Company 1986.

Syllabus

Module 1: Crisp sets to Fuzzy sets

Introduction , Crisp Sets: An Overview ,Fuzzy Sets: Basic Types ,Fuzzy Sets: Basic concepts. Additional properties ofalpha cuts, Representation of fuzzy sets.
(Chapter 1: 1.1, 1.2, 1.3 and 1.4 and Chapter 2: 2.1 , 2.2 of Text 1).

Module 2: Operations on Fuzzy Sets
Types of Operations, Fuzzy complements, Fuzzy intersections: t-norms, Fuzzy Union, t-conorms, Combinations of operations.
(Theorems 3.7, 3.8,3.11,3.13, 3.16 and 3.18 statement only)
(Chapter 3: 3.1, 3.2, 3.3, 3.4, 3.5 of Text 1).

Module 3: Fuzzy Arithmetic
Compact Fuzzy numbers, Arithmetic operations on Intervals, Arithmetic operations on Fuzzy numbers. (Exclude the proof of Theorem 4.2), Fuzzy equations.
(Chapter 4: 4.1, 4.3, 4.4 and 4.6 of Text 1).

Module 4: Fuzzy Logic
Classical Logic: An Overview, Multivalued Logics, Fuzzy propositions, Fuzzy quantifiers, Linguistic Hedges, Inference from Conditional Fuzzy propositions.
(Chapter 8: 8.1, 8.2, 8.3, 8.4, 8.5 and 8.6 only of Text 1).

Module 5: Fuzzy Graphs
Fuzzy Graphs: Definitions and Basic Properties, Connectivity in Fuzzy Graphs, Forests and Trees, Fuzzy Cut Sets.
(Chapter 2: 2.1, 2.2, 2.3, 2.4 of Text 2).

Semester V or VI: 24-803-0511 / 24-803-0611: Introduction to Optimization in Machine Learning

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course introduces relevant aspects of linear algebra and how these concepts are related to optimization in machine learning.

Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Apply Linear Algebra in Machine learning	Apply
CO2	Understand how the concepts of linear algebra are related to optimization methods used in machine learning.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	2		2
CO2	3	2	2	1

Text books:

1 Aggarwal, C. C., Aggarwal, L. F., & Lagerstrom-Fife. (2020). Linear algebra and optimization for machine learning (Vol. 156). Springer International Publishing.

Reference books:

1 Boyd, S., Boyd, S. P., & Vandenberghe, L. (2004). Convex optimization. Cambridge university press.

2 Noble, B., & Daniel, J. W. (1977). Applied linear algebra (Vol. 477). Englewood Cliffs, NJ: Prentice-Hall

3 Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep learning. MIT press

4 Strang, G. (2019). Linear algebra and learning from data (Vol. 4). Cambridge: Wellesley-Cambridge Press.

5 Strang, G. (2016). Introduction to Linear Algebra (5th Edition). Wellesley Publishers (India), ISBN : 978-09802327-7-6.

Syllabus

Module 1: Introduction to Optimization, Scalars, Vectors and Matrices, Matrix Multiplication on Decomposible Operator, Matrix Factorization.
(Sections 1.1- 1.3, 1.4.1 of Text 1).

Module 2: Basic Problems in Machine Learning- Clustering, classification and Regression Modelling, Outlier Detection, Optimization for Machine Learning
(Sections 1.4-1.5 of Text 1).

Module 3: Geometry of Matrix Multiplication, Vector Spaces and their Geometry, Basis, Rank of a Matrix, Effect of Matrix Operations on Rank, Generating Orthogonal Basis sets
(Sections 2.1- 2.3, 2.6-2.7 of Text 1)

Module 4: An Optimization- centric view of Linear Systems, Determinants, Diagonalizable transformations and Eigenvectors, Fast Matrix Operations in Machine Learning, Diagonalizable matrices in Machine Learning
(Sections 2.8, 3.2-3.3, 3.4.1- 3.4.2 of Text 1).

Module 5: Symmetric Matrices in Quadratic Optimization, Variable Separation for Optimization, Numerical Algorithms for Finding Eigen vectors, Basics of Optimization
(Sections 3.4.3- 3.4.5, 3.5, 4.2 of Text 1).

Semester V or VI: 24-803-0512 / 24-803-0612: Elementary Number Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: Number theory is one of the oldest and most mysterious parts of mathematics. This course will give an introduction to the area of Number Theory.

Outcome: After completing the course, students will be equipped to

No.	Course Outcome	Cognitive level
CO1	Know fundamental principles of Number Theory	Remember
CO2	Know the concepts of convergence and theorems related to it.	Remember
CO3	Know quadratic reciprocity and quadratic convergence with composite moduli.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Prerequisites: Basic familiarity with formulas, techniques of differential and integral calculus, Natural Numbers and Integers.
Text books:

1 D. M. Burton, Elementary Number Theory, 7th Ed., McGraw Hill, 2017.

Reference books:

1 I. Niven, S. Zuckerman and H. L. Montgomery, An Introduction to the Theory of Numbers, 5th Ed., Wiley-India, 1991.

2 K. H. Rosen, Elementary Number Theory and its Applications, Pearson, 2015.

3 G. A. Jones and J. M. Jones, Elementary Number Theory, Springer-Verlag (1998).

Syllabus

Module 1. Mathematical Induction, The Binomial Theorem, Early Number theory, The Division Algorithm, The Greatest Common Divisor, The Euclidean Algorithm, The Diophantine Equation. (Chapter 1 and 2 of Text book 1).

Module 2. The Fundamental Theorem of Arithmetic, The Sieve of Eratosthenes, The Goldbach Conjecture. (Chapter 3 of Text book 1).

Module 3. Carl Friedrich Gauss, Basic Properties of Congruence, Binary and Decimal Representations of Integers, Linear Congruence and the Chinese Remainder Theorem. (Chapter 4 of Text book 1).

Module 4. Pierre de Fermat, Fermat's Little Theorem, Pesudoprimes, Wilson's Theorem, The Fermat-Kraitchik Factorization Method. (Chapter 5 of Text book 1).

Module 5. Euler's Criterion, The Legendre symbols and Its Properties, Quadratic Reciprocity, Quadratic Congruence with Composite Moduli. (Chapter 9 of Text book 1).

Cochin University of Science and Technology
Department of Mathematics

Mathematics – Core Papers

(Semester: 7 - 10)

Departmental Core

(Offered for students opting Mathematics as Major)

Semester VII
24-803-0701 - Linear Algebra

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the notion of vector spaces. Finite-dimensional vector spaces and maps between them preserving the structure are objects of study. The dual of a vector space also forms a major part of the study, especially with the study of the adjoint map. Studying the important multi-linear maps, like the Determinant map, form an important part of the course. Finally, the important primary decompositions of the vector space concerning a linear transformation is studied. This also helps to understand the extra symmetry in the representation of the matrices.

Learning Outcomes: After the completion of this course, the student should be able to

No.	**Course Outcome**	**Cognitive level**
CO1	Understand the notions of vector spaces, linear transformations, coordinates and the representation of transformation by matrices.	Understand
CO2	Know the dual space of a vector space and adjoint of a linear map that acts between the dual spaces.	Remember
CO3	Understand the important generalizations of linear maps to more than one variable especially the Determinant map and its important properties.	Understand
CO4	Comprehend ideas on the advanced topics like annihilating polynomials, simultaneous triangulation, diagonalization and direct sum decomposition.	Analyze
CO5	Know primary decompositions associated with subspaces or with respect to a given operator.	Remember

CO - PSO Mapping Table:

CO/PSO	**PSO1**	**PSO2**	**PSO3**	**PSO4**
CO1	3			
CO2	3			
CO3	3			
CO4	3			
CO5	3			

UNIT 1: Review of system of linear equations and their solution set, Vector spaces, Subspaces, Bases and dimensions, Coordinates, Summary of row equivalence, Linear Transformations, The Algebra of Linear transformations, Isomorphism, Representation of Transformations by matrices.

UNIT 2: Linear functionals, The double Dual, The Transpose of a Linear Transformation, Inner product spaces, Linear functionals and Adjoints. (Sections 3.1, 3.2, 3.3 and Sections 8.1, 8.2, 8.3 from Hoffman and Kunze)

UNIT 3: Bilinear forms, Symmetric forms: Orthogonality, The geometry associated to a positive form, Hermitian forms (Chapter 7 Sections 1, 2, 3, 4 from Artin), Determinants-Commutative rings, Determinant functions, Permutations and the Uniqueness of determinants. (Sections 5.1, 5.2, 5.3 from Hoffman and Kunze)

UNIT 4: Characteristic Values, Annihilating polynomials, Invariant subspaces, Simultaneous Triangulation, Simultaneous Diagonalization, Direct-Sum Decompositions, Invariant Direct

Sums, The Primary Decomposition Theorem. (Chapter 6 of Hoffman and Kunze)
UNIT 5: The Rational and Jordan Forms- Cyclic Subspaces and Annihilators, Cyclic Decompositions and the Rational Form, The Jordan Form. (Sections 7.1, 7.2, 7.3 from Hoffman and Kunze)
Text Books:

1. Kenneth Hoffman and Ray Kunze *Linear Algebra*, Second Edition, PHI (1975).

2. M. Artin, Algebra, Prentice-Hall, (1991)

References:-

1. M. Artin, *Algebra*, Prentice-Hall, (1991).

2. Serge Lang, *Introduction to Linear Algebra*, Second Editon, Springer (1997).

3. K.T Leung, *Linear Algebra and Geometry*, Hong Kong University Press, (1974).

4. S.Kumaresan, *Linear Algebra: A Geometric Approach*, Fist Edition PHI Learning (2009).

5. Sheldon Axler, *Linear Algebra Done Right*, Second Edition, Springer, (1997).

6. Richard Kaye and Robert Wilson, *Linear Algebra*, Oxford University Press, (1998).

Semester VII
24-803-0702 - Measure and Integration

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: One of the objectives of measure theory is to make platform for developing tools for a new method of integration of functions that are not Riemann integrable. Apart from studying the Lebesgue measure and integration, this course introduces the concept of general measure spaces and the integration in this setting also.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Comprehend Lebesgue measure and general measure spaces.	Understand
CO2	Evaluate integrals of measurable functions.	Evaluate
CO3	Understand the basics of Lp spaces.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3	1		
CO3	3	1		

Pre-requisites: Familiarity with complex numbers and basic calculus, Geometric ideas of school level.
UNIT 1: The Axiom of Choice, Zorn's Lemma, Lebesgue Outer measure, Measurable sets and Lebesgue measure, Non measurable sets (Chapter 2 and relevant sections of Preliminaries of the text)
UNIT 2: Lebesgue measurable functions: Litlewood's Three Principles, The Riemann Integral, The Lebesgue Integral (Chapters 3 and 4 of the text, upto section 4.3)
UNIT 3: The General Lebesgue Integral, Continuity of Integration, Convergence in Measure, Characterizations of Riemann and Lebesgue integrability, Differentiation of monotone functions, Lebesgue's theorem, Functions of bounded variations: Jordan's Theorem (avoid proofs of Vitali Covering lemma and Lebesgue's theorem). (Section 4.4-4.5, 5.2-5.3 and 6.1-6.3 of the text)
UNIT 4: Differentiation of an integral, Absolute continuity, Convex Functions, The L^p spaces, Minkowski and Hölder inequalities, (Section 6.4-6.6 and 7.1-7.2 of the text)
UNIT 5: Completeness of L^p spaces, Approximation and Separability, The Riesz Representation for the Dual of L^p spaces (Section 7.3-7.4 and 8.1 of the text)

Text Book: H L Royden, P. M. Fitzpatrick, Real Analysis, Fourth Edition (2009), PHI

References:-

1. I K Rana, An Introduction to Measure and Integration, Narosa Publishing Company.
2. P R Halmos, Measure Theory, GTM , Springer Verlag.
3. T.W. Gamelin, Complex Analysis, Springer.
4. R.G. Bartle, The elements of Integration (1966) John Wiley & Sons, Delhi,(2006)

5. K B. Athreya and S N Lahiri:,Measure theory, Hindustan Book Agency, New Delhi.
6. Thamban Nair, Measure and Integration: A First Course, CRC Press, 2019.
7. Terence Tao: An Introduction to Measure Theory,Graduate Studies in Mathematics,Vol 126 AMS.
8. S. Kesavan Measure and Integration, Hindustan Book Agency, Springer (TRIM 77).

Semester VII
24-803-0703 - Groups and Rings

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the basic algebraic structure Group, and studies various aspects of groups. It also covers another mathematical structure Rings and various types of rings.
Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know the definition of a group, order of a finite group and order of an element.	Remember
CO2	Comprehend different types of subgroups such as normal subgroups, cyclic subgroups, and understand the structure of these subgroups.	Remember
CO3	Understand the concepts of permutation groups, factor groups and group homomorphisms.	Understand
CO4	Know basics of advanced topics such as Sylow's theorem and apply those results.	Understand
CO5	Understand other mathematical structures such as rings and various classes of rings, their sub structures like ideals, and their homomorphisms.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			
CO5	3			

UNIT 1: Introduction to Groups: Basic Axioms and Examples, Dihedral Groups, Symmetric Groups, Matrix Groups, The Quaternion Group, Homomorphisms and Isomorphisms, Group Actions; Subgroups: Definitions and Examples, Centralizers and Normalizers, Stabilizers and Kernels. Subgroups: Cyclic groups, Groups generated by subsets of a Group, The Lattice of Subgroups of a Group.(Chapter 1 and Chapter 2 of Textbook)
UNIT 2: Quotient Groups and Homomorphisms: Quotient Groups, homomorphisms, Langange's Theorem, The Isomorphism Theorems, Composition Series and Holder Program, Transpositions and Alternating Group, Group Actions: Group actions and permutation representations, Cayley's Theorem. (Chapter 3 of Textbook sections 3.1-3.5 and Chapter 4 of Textbook sections 4.1, 4.2)
UNIT 3: Group Actions: Groups acting on themselves by conjugation-The Class Equation, Orbits, Counting Lemma, Automorphisms, Sylow Theorems, Applications of Sylow's theorems, Simplicity of A_n. (Chapter 4 of Textbook sections 4.3-4.6)
UNIT 4: Rings: Basic Definitions and Examples, Examples: Polynomial Rings, Matrix Rings, and Group Rings, Ring Homomorphisms an Quotient Rings, Properties of Ideals. (Chapter 7 of Textbook sections 7.1 - 7.4)
UNIT 5: Factorization in domains: Euclidean Domains, Principal Ideal Domains (P.I.D.s), Unique Factorization Domain (Chapter 8 of Textbook 1 sections 8.1, 8.2, 8.3)

Text Books:

1. Abstract Algebra - D.S. Dummit and R.M. Foote, 3rd Edition, Publisher: Wiley.

References:-

1. A First Course in Abstract Algebra - J.B. Fraleigh, 7th Edition, Publisher - Pearson
2. Algebra - M. Artin, Second Edition, Publisher - Pearson
3. Contemporary Abstract Algebra - J. A. Gallian, 4th Edition, Publisher - Narosa
4. Topics in Algebra - I.N. Herstein, Second Edition, Publisher - Wiley Student Edition.
5. Rings and Modules - C. Musili, Second revised edition, Narosa Publishing House.

Semester VII
24-803-0704 - Topology I

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: Topology is essentially the study of surfaces in which normally non geometric properties are studied. This course introduces the basic concepts of topology and standard properties such as compactness connectedness, separation axioms.
Learning Outcomes: On completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know basic topological spaces	Remember
CO2	Understand topological properties	Understand
CO3	Understand the connection of topology with other branches of Mathematics	Understand
CO4	Apply topological properties to prove theorems.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			1
CO4	3			

Pre-requisites: Basic ideas of Set Theory, Basic concepts of Real Analysis and Metric Spaces.
UNIT 1: Topological Spaces: Logical warm up, Motivation for topology, Definition of topological spaces, examples, Bases and Sub bases, Subspaces. (Chapter 3 & 4 of Text 1)
UNIT 2: Basic Concepts: Closed sets and Closure, Neighbourhoods, Interior and Accumulation Points, Continuity and Related Concepts, Making functions continuous and Quotient Spaces (Chapter 5 of Text 1)
UNIT 3: Spaces with special properties: Smallness conditions on a space, Connectedness, Locally connectedness and paths. (Chapter 6 of Text 1)
UNIT 4: Separation axioms: Hierarchy of separation axioms, Compactness and separation axioms, Urysohn's characterization of normality, Tietze extension Theorem. (Chapter 7 of Text 1)
UNIT 5: Product and Coproducts: The Cartesian product of family of sets, product topology, productive properties, Embedding Lemma, Embedding theorem and Urysohn's Metrization Theorem. (Relevant sections of Chapter 8 & 9 of Text 1)

Text Book: K.D. Joshi: Introduction to General Topology (Revised Edn.), New Age International (P) Ltd., New Delhi, Revised printing in 1984.

References:-

1. G.F. Simmons: Introduction to Topology and Modern Analysis; McGraw-Hill International Student Edn.; 1963

2. J. Dugundji: Topology; Prentice Hall of India; 1975

3. J. R. Munkers; Topology (Second Edition) PHI, 2009.

4. M. Gemignani: Elementary Topology; Addison Wesley Pub Co Reading Mass; 1971

5. M.A. Armstrong: Basic Topology; Springer- Verlag New York; 1983

6. M.G. Murdeshwar: General Topology (2nd Edn.); Wiley Eastern Ltd; 1990

7. S. Willard: General Topology; Addison Wesley Pub Co., Reading Mass; 1976

8. John Gilbert Hocking and Gail S. Young, Topology (Revised Edition), Dover Publications, (1988).

Semester VIII
24-803-0801 - Field Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the advanced topics in Group theory. It also covers other mathematical structures Modules and Fields.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know the advanced concepts of group theory such as direct products and semi-direct products.	Remember
CO2	Understand the groups of small orders so as to classify them using the advanced concepts such as semi-direct products and direct products.	Understand
CO3	Comprehend the concept of algebraic structures called modules and various types of modules.	Remember
CO4	Apply the ideas of Field theory for problem-solving.	Apply
CO5	Apply group-theoretic information to deduce results about fields and polynomials.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3	1		
CO5	3			

UNIT 1: Direct product of Abelian Groups: Direct products, Fundamental theorem of finitely generated abelian groups, Groups of small order, Recognizing direct products, p-groups, Nilpotent groups and Solvable groups. (Chapter 5 of Textbook 1 sections 5.1-5.4, Chapter 6 of Textbook 1 section 6.1)
UNIT 2: Polynomial Rings: Definitions and Basic Properties, Polynomial Rings over Fields I, Polynomial Rings that are Unique Factorization Domains, Irreducibility Criteria, Polynomial Rings over Fields II. (Chapter 9 of TextBook 1 sections 9.1, 9.2,9.3 , 9.4, 9.5)
UNIT 3: Fields: Basic Theory of Field Extensions, Algebraic Extensions, Classical Straightedge and compass constructions, Splitting Fields and Algebraic Closures. (Chapter 13 son Textbook 1 sections 13.1, 13.2, 13.3, 13.4)
UNIT 4: Fields: Separable and Inseparable Extensions, Cyclotomic Polynomials and Extensions, Galois theory: Basic Definitions, The Fundamental Theorem of Galois Theory, Finite Fields. (Chapter 13 sections 13.5, 13.6 of Textbook 1 and Chapter 14 sections 14.1, 14.2, 14.3 of Textbook 1)
UNIT 5: Galois theory: Composite Extensions and Simple Extensions, Cyclotomic Extensions and Abelian Extensions over Q, Galois groups of polynomials, Solvable and Radical Extensions: Insolubility of the Quintic. (Chapter 14 sections 14.4-14.7 of Textbook 1)
Text Books:

1. Abstract Algebra - D.S. Dummit and R.M. Foote, 3rd Edition, Publisher: Wiley.

References:-

1. A First Course in Abstract Algebra - J.B. Fraleigh, 7th Edition, Publisher - Pearson
2. Algebra - M. Artin, Second Edition, Publisher - Pearson
3. Contemporary Abstract Algebra - J. A. Gallian, 4th Edition, Publisher - Narosa Publishing
4. Topics in Algebra - I.N. Herstein, Second Edition, Publisher - Wiley Student Edition
5. Rings and Modules - C. Musili, Second revised edition, Narosa Publishing House.
6. Galois Theory - J. Rotman, Second Edition, Springer International Edition.

Semester VIII
24-803-0802 - Functional Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This is the first part of the series of 2 courses taught in the second and third semester on Functional Analysis. In the first part, we cover important structures used in analysis like Banach spaces, Hilbert spaces and operators acting on them. The foundation results are discussed in this part.
Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand the concepts of Banach spaces, Hilbert spaces and their examples.	Understand
CO2	Understand the action of operators in Normed spaces and Innerproduct spaces.	Understand
CO3	Know the basics of duals and transpose of a space.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Pre-requisites:

1. A first course in linear algebra
2. Basic real analysis and topology

UNIT 1: Review of Linear Spaces and Linear Maps, Metric Spaces and Continuous Functions, Lebesgue Measure and integration on R. (Chapter I, Section 2, 3, and 4; excluding the proofs of 2.1, 2.3, 3.4, 3.5, 3.9 and 3.10).
UNIT 2: Normed Spaces, Continuity of Linear Maps, Hahn-Banach Theorems (Chapter II, Section 5, 6, 7; upto Theorem 7.11).
UNIT 3: Banach Spaces., Uniform Boundedness Principle, Closed Graph and Open Mapping Theorem, Bounded Inverse Theorem. (Chapter III, Section 8, 9 upto Theorem 9.4, Section 10).
UNIT 4: Bounded Inverse Theorem, Inner Product Spaces, Orthonormal Sets. (Chapter III: Section 11, Chapter VI: Section 21, 22)
UNIT 5: Duals and Transpose. Duals of $L^p([a, b])$ and $C([a, b])$. (Chapter IV, Section 13, 14; upto Theorem 14.5).
Text Book: Balmohan V. Limaye, *Functional Analysis*, Revised Second Edition, New Age International Publishers, 1996 (Reprint 2013)

References:-

1. Courant, R. and D. Hilbert, Methods of Mathematical Physics, vol. I, Interscience, Newyork (1953).
2. Dunford N. and T. Schwartz, Linear Operators, Part I, Interscience, Newyork (1958).
3. E. Kreyzig, Introduction to Function Analysis with Applications, Addison – Wesley.

4. Rudin W., Real and Complex Analysis, 3rd edition, McGraw-Hill, Newyork (1986).

5. Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, Newyork (1991).

6. Reed, M. and B. Simon, Methods of Mathematical Physics, vol. II, Academic Press, Newyork (1975).

7. Rajendra Bhatia, Notes on Functional Analysis, Texts and Readings in Mathematics, Hindusthan Book Agency, New Delhi(2009).

8. G. F. Simmons, Introduction to Topology and Modern Analysi,s TMH.

9. M. Thamban Nair, Functional Analysis; A first course, PHI Learning Pvt. Ltd (2001).

Semester VIII
24-803-0803 - Complex Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the review of complex functions which will be followed by the Classical theory of analytic functions. This will involve some of the classical theorems in the subject such as Cauchy's integral formula and its' general forms.
Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand Conformal mapping and Linear transformations.	Understand
CO2	Know Analytic functions and some classical results in this regard.	Remember
CO3	Apply basic results like residue theorems to evaluate complex integrals.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3	2		

Pre-requisites: Familiarity with complex numbers and basic calculus, Geometric ideas of school level.
UNIT 1: The field of complex numbers, The complex plane, Polar representations and roots of complex numbers, Lines and half planes in complex plane, The extended plane and its spherical representations, Power series, Analytic functions and Analytic functions as mapping and Mobius transformations. [Chapter - I (Sections - 2,3,4,5,6), Chapter - III (Sections - 1,2,3)]
UNIT 2: Riemann-Stieltjes integrals, Power series representation of analytic functions, Zeros of an analytic function and The index of a closed curve [Chapter - IV (Sections - 1,2,3,4)].
UNIT 3: Cauchy's Theorem and Integral Formula, The homotopic version of Cauchy's Theorem and simple connectivity, Counting zeros; the Open Mapping Theorem and Goursat's Theorem [Chapter - IV (Sections - 5,6,7,8)].
UNIT 4: Classification of singularities, Residues and The Argument Principle [Chapter - V (Sections - 1,2,3)].
UNIT 5: The Maximum Principle, Schwarz's Lemma, Convex functions and Hadamard's Three Circles Theorem and Phragmen-Lindelof Theorem [Chapter - VI (Sections - 1,2,3,4)].

Text Book: J.B. Conway, Functions of One Complex Variable (2^{nd} Edition), Springer 1973.

References:-

1. L.V. Ahlfors, Complex Analysis (Third Edition) Mc-Graw Hill International (1979)
2. Milnor, Dynamics in One Complex Variable (3rd ed.), Princeton U. Press.
3. T.W. Gamelin, Complex Analysis, Springer
4. H. A. Priestley: Introduction to Complex Analysis, Oxford University Press.
5. J.H. Mathews and R.W. Howell: Complex Analysis for Mathematics and Engineering, Jones & Bartlett Learning.

Semester VIII
24-803-0804 - Functions of Several Variables and Geometry

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective:

- In the first module, the students will be introduced to inner product theory and multivariable functions in Euclidean spaces and the notion of differentiation in several variables.
- In the second module we go deeper in the theory of multivariable differentiation and see their application in the inverse function theorem, implicit function theorem and the maxima-minima theory.
- In the third module we apply the notions of multi-variable differentiation and associated local properties to regular curves and surfaces.
- Differentiable manifolds are introduced in the fourth module. Examples and differentiable maps between differentiable manifolds are studied along with their associated tangent planes are studied.
- In the fifth module the notions of geometry are introduced. The Riemannian metric structure on a differentiable manifold is introduced for conceptual clarity. The fundamental forms on regular surfaces are also introduced.

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

No.	Course Outcome	Cognitive level
CO1	Understand continuity and differentiability of functions of several variables and their applications.	Understand
CO2	Apply these concepts to regular curves and surfaces in Euclidean spaces.	Apply
CO3	Know the idea of tangent planes to regular surfaces and differentiable manifolds with examples.	Remember
CO4	Understand the concept of orientation of vector fields on such manifolds.	Understand
CO5	Know the Riemannian structure on a differentiable manifold which makes the study of geometry on regular surfaces in R^3 more clear conceptually.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			
CO5	3			1

Pre-requisites:

1. Basic real analysis and Linear Algebra

UNIT 1: Norm and inner product, subsets of Euclidean spaces, functions and continuity, (Differentiation in several variables) Basic definitions, basic theorems, partial derivatives, derivatives. (Sections 1.11, 8.1, 8.2, 8.4, 8.6, 8.7, 8.8, 8.10, 8.11, 8.12, 8.13, 8.15, 8.16, 8.18, 8.19, 8.20, 8.21, 8.23 of textbook 1)
UNIT 2: Inverse functions, Implicit functions (Sections 13.2, 13.3, 13.4 of textbook 2, Sections 9.6, 9.7 of textbook 1), Maximima, Minima and Saddle points, Second order Taylor formula for scalar fields, nature of a stationary point determined by the eigenvalues of the Hessian matrix, Second-derivative test for extrema of functions of two variables. (Sections 9.9, 9.10, 9.11, 9.12 of Textbook 1)
UNIT 3: Regular curves, The local theory of curves parametrised by arc length, The local canonical form, Regular surfaces, Change of parameters, The tangent plane.(Sections 1.3, 1.5, 1.6, 2.2, 2.3, 2.4 of textbook 3)
UNIT 4: Introduction to differentiable manifolds, tangent space of differentiable manifolds, Immersions and embeddings, other examples, Orientation, vector fields, brackets, topology of manifolds. (Chapter 0 of textbook 4)
UNIT 5: Introduction to Riemannian metrics, Riemannian metrics (Chapter 1 of textbook 4), The first fundamental form (Area), Orientation of Surfaces. (Sections 2.5, 2.6 of textbook 3)

Text Books:-

1. Michael Spivak: *Calculus on Manifolds A modern approach to classical theorems of advanced calculus*, Addison-Wesley Publishing house, 1965.

2. Manfredo P. Do Carmo: *Differential geometry of curves and surfaces*, Dover Publications, Second edition, 2016.

3. Manfredo P. Do Carmo: *Riemannian Geometry*, Birkhauser, 1993.

References:-

1. Andrew Pressley: Elementary Differential Geometry, Springer, 2000.

2. Theodore Shifrin: Differential Geometry: A first course in curves and surfaces, 2016.

Semester IX
24-803-0901 - Operator Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This is the second part of the series of 2 courses taught in the second and third semester on Functional Analysis. In the second part, we focus on compact operators on Banach spaces, Hilbert spaces and their spectral properties.
Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know the basic notions of spectral theory.	Remember
CO2	Understand the idea of compact self-adjoint operators.	Understand
CO3	Analyse spectrum of operators	Analyze
CO4	Evaluate problems using operators for approximate solutions.	Evaluate

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3	1		

Pre-requisites:

1. A first course in functional analysis
2. Basic real analysis and topology

UNIT 1: Spectrum of a Bounded Operator, Weak and Weak* Convergence, Reflexivity. (Chapter III, Section 12, Chapter IV, Section 15, upto Theorem 15.5, Chapter IV: Section 16 excluding the proof of Theorem 16.5).
UNIT 2: Compact Linear Maps, Spectrum of a Compact Linear Map. (Chapter V, Section 17, 18).
UNIT 3: Fredholm Alternative, Approximate Solutions, Normal, Unitary and Self-Adjoint Operators (Chapter V, Section 19, 20, upto Theorem 20.4, Chapter VII: Section 26).
UNIT 4: Approximation and Optimization, Projection and Riesz Representation Theorems. Bounded Operators and Adjoints. (Chapter VI: Section 23, 24, 25)
UNIT 5: Spectrum and Numerical Range, Compact Self-adjoint Operators, Sturm-Liouville Problems. (Chapter VII, Section 28, Appendix C).

Text Book: Balmohan V. Limaye, *Functional Analysis*, Revised Second Edition, New Age International Publishers, 1996 (Reprint 2013)

References:-

1. Courant, R. and D. Hilbert, Methods of Mathematical Physics, vol. I, Interscience, Newyork (1953).
2. Dunford N. and T. Schwartz, Linear Operators, Part I, Interscience, Newyork (1958).
3. E. Kreyzig, Introduction to Function Analysis with Applications, Addison – Wesley.

4. Rudin W., Real and Complex Analysis, 3rd edition, McGraw-Hill, Newyork (1986).
5. Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, Newyork (1991).
6. Reed, M. and B. Simon, Methods of Mathematical Physics, vol. II, Academic Press, Newyork (1975).
7. Rajendra Bhatia, Notes on Functional Analysis, Texts and Readings in Mathematics, Hindusthan Book Agency, New Delhi(2009).
8. G. F. Simmons, Introduction to Topology and Modern Analysi,s TMH.
9. M. Thamban Nair, Functional Analysis; A first course, PHI Learning Pvt. Ltd (2001).

Semester IX
24-803-0902 - Ordinary Differential Equations & Integral Equations

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the review of Ordinary differential equations. Course aims to build an understanding of the classical models in terms of ordinary differential equations and pave the foundations for the study of Integral equations.

Learning Outcomes: At the end of teh course, students will be able to

No.	Course Outcome	Cognitive level
CO1	Compare solutions of first order differential equations using Separation and Comparison theorems.	Analyze
CO2	Know basics of Legendre Polynomials and Bessel polynomials along with their important properties.	Remember
CO3	Analyse critical points and stability of linear systems.	Analyze
CO4	Understand integral equations and method of successive approximations.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3	2	1	
CO4	3	2		

UNIT 1: Oscillations and the Sturm Separation Theorem, The Sturm Comparison Theorem, Series solutions of First order equations, Second order Linear Equations, Gauss's Hyper Geometric Equation. (Chapter 4, Section 24, 25. Chapter 5, sections 27, 28, 29, 30, 31.)
UNIT 2: Legendre Polynomials, Properties of Legendre Polynomials, Bessel Polynomials, Properties of Bessel Polynomials. (Chapter 8, sections 44, 45, 46, 47.)
UNIT 3: Systems, Nonlinear equations: Autonomous systems, The Phase Plane and its Phenomena, Types of Critical points. Stability, Critical points and Stability for Linear Systems. (Review Chapter 10, Chapter 11, Sections 58, 59,60)
UNIT 4: Method of successive approximations, Picard's Theorem, Integral Equations with separable kernels, Fredholm Integral Equations, Method of successive approximations. (Chapter 13, sections 68, 69 of text 1, Chapter 2 and 3 of the text 2.)
UNIT 5: The Fredholm Method of Solution, Fredholm's Theorems, Applications to Ordinary Differential Equations. (Chapters 4, 5 of the text 2)
Text Books:

1. George F. Simmons, *Differential Equations with Applications and Historical Notes*, Tata McGraw-Hill, Third Editon 2003.

2. Ram P. Kanwal, *Linear Integral Equations*, Second Edition, Springer Science+Business Media, LLC, (1997).

References:-

1. Peter J. Collins, *Differential and Integral Equations*, Oxford University Press,(2006).

2. Carmen Chicone, *Ordinary Differential Equations with Applications*, Springer (2006).

3. Linear Integral Equations

4. Michael D. Greenberg, *Ordinary Differential Equations*, Wiley (2012).

5. Michael E. Taylor, *Introduction to Differential Equations*, AMS (2011).

6. Vladimir I. Arnol'd, *Ordinary Differential Equations*, Springer (1992).

7. Earl A. Coddington, *An Introduction to Ordinary Differential Equations*, Dover Publications, New york, (1961).

Semester X
24-803-1001 - Partial Differential Equations and Variational Calculus

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with simple models of Partial differential equations which will be followed by the analytic and algebraic study of PDEs. This will involve some of the classical models in the subject: diffusion equations and wave equations. Towards the end of the course students will get an idea of variational calculus.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know the concepts of classical models of diffusion and wave phenomena	Remember
CO2	Understand the terminology and concepts of partial differential equations	Understand
CO3	Apply solution techniques of PDE's for problem-solving.	Apply
CO4	Know basics of variational problems and solution techniques.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1		
CO2	3	1		
CO3	3	2	1	
CO4	3	1		

UNIT 1: Classification of First-Order Equations, Construction of a First-Order Equation, Geometrical Interpretation of a First-Order Equation, Method of Characteristics and General Solutions, Canonical Forms of First-Order Linear Equations, Method of Separation of Variables (Chapter 2 of Text 1).
UNIT 2: The Vibrating String, The Vibrating Membrane, Waves in an Elastic Medium, Conduction of Heat in Solids, Second-Order Equations in Two Independent Variables, Canonical Forms, Equations with Constant Coefficients, The Cauchy Problem, Charpit's method. (Chapter 3, sections 3.2-3.5, Chapter 4 of Text 1, Sections 5.1-5.4.).
UNIT 3: Eigenvalue Problems and Special Functions, Sturm–Liouville Systems, Eigenfunction Expansions, Completeness and Parseval's Equality, Bessel's Equation and Bessel's Function (Sections 8.1-8.6 of the Text 1).
UNIT 4: Variation and its properties, Euler equation, Functionals involving higher order derivatives, Functionals involving partial derivatives, Variational problems with movable boundaries. (Chapter 1, 2 of text 2).
UNIT 5: Sufficiency condition for an extremum, Variational problems with constrained extrema, isoperimetric problems, Direct methods, Euler's method of finite differences, Ritz method. (Chapter 3, 4, 5 of text 2).

Text 1. Tyn Myint-U, Lokenath Debnath *Linear Partial Differential Equations for scientists and Engineers*, Fourth Edition, Birkhauser (2007).

Text 2. Lev D. Elsgolc, *Calculus of Variations*, Dover publications, Inc. (2007.)

References:-

1. Walter A. Strauss, *Partial Differential Equations an Introduction*, John Wiley, (1992).

2. Ravi P. Agarwal, Donal O'Regan, *Ordinary and Partial Differential Equations With Special Functions, Fourier Series, and Boundary Value Problems*, Springer-Verlag (2009).

3. Fritz. John, *Partial Differential Equations*, Fourth Edition, Springer (2009).

4. G. Evans, I. Blackedge and P.Yardley, *Analytic Methods for Partial Differential Equations*, Springer (1999).

5. Ian N. Sneddon, *Elements of Partial Differential Equations*, McGraw Hill (1983).

Semester X
24-803-1002 - Probability Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the introduction to probability theory following different probability distributions. The connection between probability theory and measures are also discussed in this course. This will involve some of the classical theorems in the subject such as central limit theorem and law of large numbers.
Learning Outcomes: After the completion of this course, the student should be able to

No.	**Course Outcome**	**Cognitive level**
CO1	Know fundamental concepts of probability theory and classical results.	Remember
CO2	Apply basic ideas of probability theory for problem solving.	Apply
CO3	Comprehend probability spaces and different kinds of convergence associated with it.	Evaluate

CO - PSO Mapping Table:

CO/PSO	**PSO1**	**PSO2**	**PSO3**	**PSO4**
CO1	3			
CO2	3	2	2	1
CO3	3			

Pre-requisites:

1. A first course in measure theory.
2. Basic real analysis and topology.

UNIT 1: Recalling Probability: Sample Space, events and probability, Independence and conditioning, Discrete random variables, The branching process, Borel's strong law of large numbers (Chapter 1)
UNIT 2: Integration: Measurability and measure, The Lebesgue integral, The other big theorems (Chapter 2)
UNIT 3: Probability and Expectation: From integral to expectation, Gaussian vectors, Conditional expectation (Chapter 3)
UNIT 4: Convergences Almost-sure convergences, Two other types of convergence, Zero-one laws (Chapter 4, section 4.1-4.3)
UNIT 5: Convergence continued: Convergence in distribution and in variation, Central Limit Theorem, The hierarchy of convergences (Chapter 4, section 4.4-4.6)

Text. Pierre Bremaud, Probability Theory and Stochastic Processes, Springer 2020.

References:-

1. S.R. Athreya, V.S. Sunder: Measure and Probability, University Press (India) Pvt. Ltd. (2008).
2. Sidney I Resnick: A Probability Path, Birkhauser 2005 Edition
3. A.K. Basu: Probability Theory, Prentice Hall, India, 2002.
4. W. Feller: An Introduction to Probability Theory and Its Applications.

Cochin University of Science and Technology
Department of Mathematics

Mathematics – Elective Papers

(Semester: 7, 8, 9 and 10)

Departmental / Interdepartmental Elective

(Offered for students opting Mathematics as Major. Students from other disciplines can also opt.)

Semester VII
24-803-0705 - Real Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the structure of Real Numbers. This course is planned to introduce the notions Metric Spaces, Continuity, Uniform continuity, Differentiation, Riemann-Steiltjes integration, Fundamental theorem of Calculus, Convergence of sequence of functions, Uniform convergence, Stone-Weierstrass Theorem and Power series.

Learning Outcomes: After the completion of this course, the student should able to

No.	Course Outcome	Cognitive level
CO1	Know basics of calculus and other important notions on the set of real numbers	Remember
CO2	Understand in detail metric spaces, continuity, uniform continuity and differentiation	Understand
CO3	Apply the ideas of Riemann-Steiltjes integration and fundamental theorem of calculus for problem-solving	Apply
CO4	Analyse the convergence of sequence of functions	Analyze
CO5	Know uniform convergence, Stone-Weierstrass Theorem and basics of power series	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3	1		
CO4	3			
CO5	3			

UNIT 1: Metric Spaces; Definition and examples, open and closed sets in metric space, compactness, Connectedness, Continuity, Uniform continuity, discontinuity.(Chapter 2 and 4)
UNIT 2: Derivative: Derivatives and continuity, L' Hospital Rules, Mean-Value theorem, Derivatives of vector-valued functions.(Chapter 5)
UNIT 3: The Riemann-Steiltjes integrals, Fundamental theorem of Calculus, Differentiation under integral signs, integration under vector valued function, rectifiable curves. (Chapter 6)
UNIT 4: Sequences and series of functions: Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation. (Chapter 7, sections upto 7.18)
UNIT 5: Equicontinuous families of functions, Stone-Weierstrass Theorem, Power series. (Chapter 7; sections upto 7.18-7.33, Chapter 8; sections up to 8.5)

Text Book: Walter Rudin, Principles of Mathematical analysis, 3rd edition, McGraw-Hill Higher Education (1976).

References:-

1. Terence Tao, Analysis I and II, Third Edition, Springer 2016.

2. N.L Carothers, Real Analysis, Wiley 2000.

3. Halsey L. Royden, Real Analysis, Prentice Hall, Upper Saddle River, NJ, (1988).

4. Tom M. Apostol, Mathematical Analysis, Addison-Wesley, Reading, MA, (1974).

5. A. K. Sharma, Real Analysis, Discovery publishing house Pvt. Lts., New Delhi, (2008).

6. D Somasundaram and B. Choudhary, A first course in mathematical analysis, Narosa, Oxford, London,(1996).

7. S Kumaresan, Topology of Metric Space, Alpha Science international Ltd, Harrow, UK, (2005)

8. K. A. Ross, Elementary Analysis; Theory of Calculus, Springer-Verlag,(2013).

Semester IX
24-803-0905 : Topics in Applied Mathematics
(Inter-departmental elective. Not for students opting Mathematics)

Number of credits: 3
Number of hours per week: 4 hrs
Total No. of Hours: 72 hours

Objective: To learn important Mathematical Tools applicable in Science and Technology.

Learning Outcomes: After the completion of this course, the student should able to

No.	Course Outcome	Cognitive level
CO1	Understand the necessary mathematical tools that are used in science and technology	Understand
CO2	Understand popular transforms of Laplace and Fourier and their applications to various fields	Understand
CO3	Comprehend common mathematical models like vibating string, Heat conduction and their solutions using transforms.	Apply
CO4	Know necessary machinery in complex function theory	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3		1	
CO2	3	2		
CO3	3	2		
CO4	3	1		

UNIT 1: Second order Linear ODEs, Homogeneous Linear ODEs of Second Order, Homogeneous Linear ODEs with Constant Coefficients, Euler-Cauchy Equations.
UNIT 2: Laplace Transform, Linearity, First Shifting Theorem (s-Shifting), Transforms of Derivatives and Integrals ODEs, Unit Step Function (Heaviside Function), Second Shifting Theorem (t-Shifting)
UNIT 3: Fourier Series, Arbitrary Period, Even and Odd Functions, Half-Range Expansions, Forced Oscillations, Fourier Integral, Fourier Cosine and Sine Transforms, Fourier Transform.
UNIT 4: Basic Concepts of PDEs, Modeling: Vibrating String, Wave Equation, Modeling: Heat Flow from a Body in Space, Heat Equation
UNIT 5: Complex Numbers: Preliminary requirements, limits, Continuity, Cauchy-Reimann equations, Complex Integration, Line Integral in the complex plane, Cauchy's Integral Theorem, Cauchy's Integral formula, Derivatives of Analytic functions, Laurent Series, Singularities and zeros, Residue Integration method, Residue Integration of real Integrals.

Text Book: Advanced Engineering Mathematics, Erwin Kreyszig, 10^{th} edition, JOHN WILEY & SONS, INC.2011. (Chapter 2, Section 2.1-2.3, and 2.5, Chapter 6, Section 6.1-6.4, Chapter 11, Section 11.1-11.3, 11.7,11.8, Chapter 12, Section 12.1-12.6, Chapter 14, Section 14.1-14.4, Chapter 16, Section 16.1-16.4.)

References:-

1. Advanced Engineering Mathematics, C.Ray Wylie, Louis. C. Barrett, 6th edition, McGraw Hill Publishing, 1998.

2. Advanced Engineering Mathematics, K.A Stroud, 5th edition, Palgrave Macmillain, 2003.

3. Advanced Engineering Mathematics, Michael Greenberg, 2nd edition, Prentice Hall, 1998.
4. Advanced Engineering Mathematics, Dennis. G.Zill, Warren S.Wright, 4th edition, 2011.

Semester IX or X
24-803-0906/ 24-803-1006 : Advanced Linear Algebra

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the review of linear algebra, which will be followed by the factorisation and triangulation theorems. This will also discuss canonical forms and eigenvalue inequalities and inclusions for hermitian matrices. Some important results in linear algebra are discussed here which are not done in the core courses on this subject. This will benefit students wants to pursue research in the areas like Functional Analysis, Spectral theory, Stochastic models, Numerical linear algebra, etc.
Learning Outcomes: After the completion of this course, the students will be able to

No.	Course Outcome	Cognitive level
CO1	Understand the advanced concepts of linear algebra and matrix analysis.	Understand
CO2	Know the skills to deal with advanced techniques in estimating eigenvalues, singular values, etc.	Apply
CO3	Know basics of Eigenvalue perturbation theorems	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Pre-requisites:

1. A basic course in linear algebra and matrix theory.
2. Normed spaces and basic analysis.

UNIT 1: Review of Linear Algebra: Eigenvalues, Algebraic and geometric multiplicity, Special types of matrices, Change of basis, etc.
UNIT 2: Unitary matrices and QR factorization, Unitary similarity, Triangulation theorems and consequences, Singular Value Decomposition (SVD).
UNIT 3: Jordan canonical form and its consequences, minimal polynomial, Triangular factorization.
UNIT 4: Hermitian matrices, Eigenvalue inequalities, diagonalization.
UNIT 5: Matrix norms, Condition numbers, Gersgorin discs, Eigenvalue perturbation theorems.

Text Book: Roger A Horn, Charles R Johnson, Matrix Analysis, Second Edn., Cambridge University Press, 2013.

References:-

1. M. Artin, Algebra, Prentice-Hall, (1991).
2. Serge Lang, Introduction to Linear Algebra, Second Edition, Springer (1997).
3. K.T Leung, Linear Algebra and Geometry, Hong Kong University Press, (1974).
4. Kenneth Hoff man and Ray Kunze Linear Algebra, Second Edition, PHI (1975)
5. Sheldon Axler, Linear Algebra Done Right, Second Edition, Springer, (1997).

Semester IX or X
24-803-0907/ 24-803-1007: Discrete Framelets

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: Course is aimed to introduce the basic tools for applications using Discrete Framelets. Students will get knowlege in analysing signals and images using finite filters. This course will pave the necessary foundations to study numerical solutions of partial differential equations and some insights into computer aided geometric design.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand the subject in a signal processing perspective with the help of finite filters	Understand
CO2	Know filter-bank theory for signal analysis	Apply
CO3	Understand the multilevel framelet decomposition of signals in bounded intervals.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1		
CO2	3	2	1	
CO3	3	2	1	

UNIT 1: Discrete Framelet Transform, Perfect reconstruction of discrete framelet transforms, One-Level Standard Discrete Framelet Transforms, Perfect Reconstruction of Discrete Framelet Transforms, Some Examples of Wavelet or Framelet Filter Banks. (Section 1.1 of text.)
UNIT 2: Sparsity of Discrete Framelet transforms, Convolution and Transition Operators on Polynomial Spaces, Subdivision Operator on Polynomial Spaces, Linear-Phase Moments and Symmetry Property of Filters, An Example. (Section 1.2 of text.)
UNIT 3: Multilevel Discrete Framelet Transforms and Stability, Multilevel Discrete Framelet Transforms, Stability of Multilevel Discrete Framelet Transforms, Discrete Affine Systems in $\ell^2(\mathbb{Z})$, Nonstationary and Undecimated Discrete Framelet Transforms (Section 1.3 of text.)
UNIT 4: Oblique extension principle, OEP-Based Tight Framelet Filter Banks, OEP-Based Filter Banks with One Pair of High-Pass Filters, OEP-Based Multilevel Discrete Framelet Transforms. (Section 1.4 of text.)
UNIT 5: Discrete Framelet Transforms for signals on bounded Intervals, Boundary Effect in a Standard Discrete Framelet Transform, Discrete Framelet Transforms Using Periodic Extension, Discrete Framelet Transforms Using Symmetric Extension, Symmetric Extension for Filter Banks Without Symmetry, Discrete Framelet Transforms Implemented in the Frequency Domain. (Section 1.5 and 1.6 of text.)

Text. Bin Han, Framelets and Wavelets Algorithms, Analysis and Applications, Birkhauser 2017.

References:-

1. Ole Christensen, Frames and Bases An Introductory Course, Birkhauser, 2008.
2. Ole Christensen, Frames and Riesz Bases, Birkhauser, 2008.

3. Christopher Heil, A Basis Theory Primer, Citeseer, 1998.

4. Yves Meyer, Wavelets and Operators, CUP, England, 1992.

5. Ingrid Daubechies, Ten Lectures on Wavelets, SIAM, Philadelphia, 1992.

Semester IX or X
24-803-0908/ 24-803-1008 : Harmonic Analysis

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the review of Measure theory. This course is planned to introduce the basics of Topolgical groups and measure and Intergration on Locally compact groups.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know basics of Modular functions and convolutions.	Remember
CO2	Understand the fundamental ideas of representations	Understand
CO3	Comprehend the formulation of Measure and integration on Locally compact groups and representations of Compact groups.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			1

UNIT 1: Topological groups, Haar Measure, Modular Functions, Convolutions (Sections 2.1, 2.2, 2.3, 2.4, 2.5)
UNIT 2: Homogeneous spaces, Unitary Representations, Representation of a group and its group algebra (Sections 2.6, 2.7, 2.8, 3.1, 3.2)
UNIT 3: Functions of positive type, The Dual group, The Fourier transform, The Pontrjagin Duality theorem (Sections 3.3, 3.4, 4.1, 4.2, 4.3)
UNIT 4: Representations of Locally Compact Abelian Groups, Closed ideals, Spectral synthesis, Bohr Compactification(Sections 4.4, 4.5, 4.6, 4.7, 4.8)
UNIT 5: Representations of Compact Groups, The Peter-Weyl Theorem, Fourier Analysis on Compact Groups. (Sections 5.1, 5.2, 5.3, 5.4, 5.5)
Text Book: Folland, G.B., *A Course in Abstract Harmonic Analysis*, CRC Press, (1995).

References:-

1. Hewitt, E and Ross K., *Abstract Harmonic Analysis* Vol.1 Springer (1979).

2. Gaal, S.A., *Linear Analysis and Representation Theory*, Dover (2010).

3. Asim O. Barut and Ryszard Raczka, *Theory of Group Representations*, second revised edition, Polish scientific publishers (1980).

4. Groenchenig, K., *Foundations of time frequency analysis*, Birkhauser Boston (2001).

Semester IX or X
24-803-0909/ 24-803-1009 : Integral Transforms

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with Fourier Transforms in detail. This course is planned to introduce the basics of Integral Transforms and its applications in various fields.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know the basic integral transforms	Remember
CO2	Understand fundamental theorems in integral transforms	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			

UNIT 1: Integral Transforms, The Fourier Integral Formulas, Fourier Transforms of generalised functions, Basic Properties of Fourier Transforms, Z-transforms (Sections 1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5 and Chapter 12)
UNIT 2: Poisson's Summation formula, The Shannon Sampling Theorem, Gibbs Phenomenon, Heisenbergs' Uncertainty Principle, Applications of Fourier Transform to ODE, Laplace Transforms and their basic properties. (Sections 2.6, 2.7, 2.8, 2.9, 2.10, 3.1, 3.2, 3.3, 3.4)
UNIT 3: Convolution Theorem and the properties of convolution, Differentiation and Integration of Laplace transforms, The Inverse Laplace Transforms, Tauberian theorems and Watson's Lemma, Applications of Laplace transforms, Evaluation of Definite Integrals, Applications of Joint Laplace and Fourier Transform. (Sections 3.5, 3.6, 3.7, 3.8, 3.9, 4.1, 4.2, 4.3, 4.6, 4.8)
UNIT 4: Finite Fourier Sine and Cosine transforms, Basic properties and Applications, Finite Lapace Transforms, Tauberian Theorems. (Chapter 10, 11)
UNIT 5: Hilbert Transform and its basic properties, Hilbert transform in the complex plane, applications of Hilbert Transform, Asymptotic expansion of One sided Hilbert Transform. (Sections 9.1, 9.2, 9.3, 9.4, 9.5, 9.6)
Text Book: Lokenath Debnath, Dambaru Bhatta *Integral Transforms and their Applications*, second edition, Taylor and Francis, (2007).

References:-

1. Frederick W. King, *Hilbert Transforms*, CRC (2009).

2. Larry C. Andrews, Bhimsen K. Shivmaoggi *Integral Transforms for Engineers*, (1999).

3. Ian N. Sneddon, *The Fourier Transforms*, Dover Publishers (1995).

4. Joel L.Schiff, *Laplace Transforms: Theory and Applications*, second revised edition, Springer (1980).

5. B.Davies, *The Integral Transforms and their applications*, Springer-Verlag (1978).

6. Ian N. Sneddon, *The Use of Integral Transforms*, McGraw-Hill (1972).

Semester IX or X
24-803-0910/ 24-803-1010 : Functions of Several Variables

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the structure of $\mathbb{R}^n$. This course is planned to introduce the Differential calculus on the finite dimensional Euclidean Space and Integration on $\mathbb{R}^n$.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know different kinds of derivatives especially directional derivative	Remember
CO2	Understand extremum problems of various kinds	Understand
CO3	Know multiple Riemann integrals and criteria for their existence	Remember
CO4	Comprehend basic theorems regarding Lebesgue integrals	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1		
CO2	3	2		
CO3	3			
CO4	3			

UNIT 1: Multivariable Differential Calculus, Directional Derivatives and continuity, Total Derivative, The Jacobian matrix, Matrix form of the chain rule, Taylor formula for functions from $\mathbb{R}^n$ to $\mathbb{R}$ (Chapter 12)
UNIT 2: Implicit Functions and Extremum problems, functions with nonzero Jacobian determinant, Inverse function theorem, Implicit funtion theorem, Extrema of real-valued functions of several variables, Extremum problems with side conditions(Chapter 13)
UNIT 3: Multiple Riemann Integrals, The measure of a bounded interval in $\mathbb{R}^n$, Riemann Integral of a bounded funtion on a compact interval in $\mathbb{R}^n$, Lebesgue criterion for the existence of a multiple Riemann integral. (Chapter 14, Sections 14.1, 14.2, 14.3, 14.4, 14.5)
UNIT 4: Jordan Measurable sets in $\mathbb{R}^n$, Multiple Integration over Jordan-measurable sets, Step functions and their integrals, Fubini's reduction thorem for the double integral of a step function. (Chapter 14, 15 Sections 14.6, 14.7, 14.8, 14.9, 14.10, 15.1,15.2,15.3,15.4, 15.5)
UNIT 5: Multiple Lebesgue Integrals, Fubini's reduction theorem for double integrals ,Tonelli-Hobson test for integrability The transformation formula for multiple integrals(Chapter 15, Sections 15.6, 15.7, 15.7, 15.8, 15.9, 15.10, 15.11, 15.12, 15.13)
Text Book: Tom M. Apostol, *Mathematical Analysis*, Second Edition, Addison-Wesley 1974.

References:-

1. Serge Lang, *Calculus Of Several Variables*, Addison-Wesley Publications, (1973).

2. C.H. Edwards Jr.,*Advanced Calculus of Several Variables*, Academic Press New York, (1973).

3. Rudin W., Real and Complex Analysis, 3rd edition, McGraw-Hill, New York (1986).

4. Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, New York (1991).

5. D Somasundaram and B. Choudhary, A first course in mathematical analysis, Narosa, Oxford, London, (1996).

6. K. A. Ross, Elementary Analysis; Theory of Calculus, Springer-Verlag, 2013.

Semester IX or X
24-803-0911/ 24-803-1011 : Advanced Spectral Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the review of Spectral Theory of Linear Operators in Normed Spaces. The idea of this course is to cover various classifications of spectrum and finally present the spectral theorem for bounded self-adjoint operators. Applications to quantum mechanics is also done.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand the use of complex analysis in spectral theory.	Understand
CO2	Know the spectral properties of operators with some properties.	Remember
CO3	Know spectral representation of some important operators.	Remember
CO4	Analyse the unbounded linear operators in quantum mechanics	Analyze

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			1

Pre-requisites:

1. Functional Analysis, Basic Analysis.
2. Linear Algebra.

UNIT 1: Review of Spectral Theory of Linear Operators in Normed Spaces; Properties of Resolventa and Spectrum, Use of Complex Analysis in Spectral Theory. (Chapter 7)
UNIT 2: Spectral Properties of Bounded Self-adjoint Operators; Positive Operators, Spectral Family. (Chapter 9, Section 9.1 to 9.7)
UNIT 3: Spectral Theorem for Bounded Self-adjoint Operators, Properties of Spectral Family. (Chapter 9, Section 9.8 to 9.11)
UNIT 4: Unbounded Linear Operators in Hilbert Spaces; Spectral Representation of Unitary Operators, Spectral Representation of Self-Adjoint Operators (Unbounded). (Chapter 10)
UNIT 5: Unbounded Linear Operators in Quantum Mechanics. (Chapter 11)

Text Book: E. Kreyzig, Introduction to Functional Analysis with Applications, Addison – Wesley.

References:-

1. Courant, R. and D. Hilbert, Methods of Mathematical Physics, vol. I, Interscience, Newyork (1953).

2. Dunford N. and T. Schwartz, Linear Operators, Part I, Interscience, Newyork (1958).

3. Rudin W., Real and Complex Analysis, 3rd edition, McGraw-Hill, Newyork (1986).

4. Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, Newyork (1991).

5. Reed, M. and B. Simon, Methods of Mathematical Physics, vol. II, Academic Press, Newyork, (1975).

6. Rajendra Bhatia, Notes on Functional Analysis, Texts and Readings in Mathematics, Hindusthan Book Agency, New Delhi (2009).

7. G. F. Simmons, Introduction to Topology and Modern Analysi,s TMH.

8. M. Thamban Nair, Functional Analysis; A first course, PHI Learning Pvt. Ltd. (2001).

Semester IX or X
24-803-0912/ 24-803-1012 : Banach Algebra and Spectral Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course introduces the notion of Banach Algebras. The theory of commutative Banach algebras are discussed in detail. Also, the spectral theory of bounded and unbounded operators on Hilbert spaces are discussed.

Learning Outcome: After completing the course, the student is expected to

No.	Course Outcome	Cognitive level
CO1	Know Banach algebras in detail	Remember
CO2	Understand the properties of commutative Banach algebras and their substructures.	Understand
CO3	Understand the spectral properties of bounded and unbounded operators with examples.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Prerequisites: A first course in Functional Analysis, Complex Analysis, Linear Algebra, Topology and Measure Theory is needed. The core courses taught in the first three semesters of the M.Sc. program will do the purpose.
UNIT 1: Banach Algebras: Introduction, Complex homomorphisms, Basic properties of Spectra, Symbolic Calculus, Invariant subspace theorem. (Chapter 10 of Text Book)
UNIT 2: Commutative Banach Algebras: Ideals and homomorphisms, Gelfand Transforms, Involutions, Positive functionals. (Chapter 11 of Text Book)
UNIT 3: Bounded Operators on a Hilbert Space: A commutativity theorem, Resolutions of the identity, The spectral theorem, Positive operators, An ergodic theorem. (Chapter 12 of Text Book)
UNIT 4: Unbounded Operators: Symmetric operators, The Cayley transform, Resolutions of the identity. (Chapter 13 of Text Book)
UNIT 5: Unbounded Operators (Contd.): The Spectral Theorem, Semigroup of Operators. (Chapter 13 of Text Book)

Text Book: Rudin, Walter. Functional Analysis. Second Edition. International Series in Pure and Applied Mathematics. McGraw-Hill, Inc., New York, 1991.

References:-

1. Takesaki, M. Theory of Operator Algebras I. Reprint of the first (1979) edition. Encyclopaedia of Mathematical Sciences, 124. Operator Algebras and Non-commutative Geometry, 5. Springer- Verlag, Berlin, 2002.

2. Arveson, William. An Invitation to C*-algebras. Graduate Texts in Mathematics, No. 39. Springer-Verlag, New York-Heidelberg, 1976.

3. Douglas, Ronald G. Banach Algebras Techniques in Operator Theory. Second Edition. Graduate Texts in Mathematics, 179. Springer-Verlag, New York, 1998.

Semester IX or X
24-803-0913/ 24-803-1013 : Number Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the review of theory of numbers which will be followed by the divisibility and prime. This will involve some of the classical theory in the subject such as congruences, the Chinese remainder theorem, quadratic reciprocity law, Arithmetic functions and diophantine equations.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know results concerning divisibility, primes and congruences	Remember
CO2	Apply the Chinese remainder theorem to solve congruence problems.	Apply
CO3	Understand quadratic reciprocity law, Arithmetic functions and diophantine equations in depth.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1		
CO2	3			
CO3	3			1

UNIT 1: Introduction to Numbers, Divisibility, Primes, [Chapter - 1 (Sections - 1.1,1.2,1.3)]
UNIT 2: Congruences, Solutions to congruences, The Chinese remainder theorem. [Chapter - 2 (Sections - 2.1,2.2,2.3)]
UNIT 3: Quadratic residues, Quadratic reciprocity, The Jacobi symbol. [Chapter - 3 (Sections - 3.1,3.2,3.3)]
UNIT 4: Greatest integer function, Arithmetic functions, The Mobius inversion formula. [Chapter - 4 (Sections 4.1, 4.2, 4.3)]
UNIT 5: The equation $ax + by = c$, Simultaneous equations, Pythagorean triangles, Assorted examples. [Chapter - 5 (Sections 5.1,5.2,5.3,5.4)]

Text Book: I. Niven, H.S. Zuckerman and H.L. Montgomery, An Introduction to the Theory of Numbers, 4th Ed., Wiley, New York, (1980).

References:-

1. W.W. Adams and L.J. Goldstein, Introduction to the Theory of Numbers, 3rd ed., Wiley Eastern, (1972).

2. A. Baker, A Concise Introduction to the Theory of Numbers, Cambridge University Press, Cambridge, (1984).

3. K. Ireland and M. Rosen, A Classical Introduction to Modern Number Theory, 2nd ed., Springer-Verlag, Berlin, (1990).

4. T.M. Apostol, An Introduction to Analytic Number Theory, Springer-Verlag, (1976).

Semester IX or X
24-803-0914/ 24-803-1014 : Representation Theory of Finite Groups

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: To introduce the facinating theory of representations to the learner. Group representation theory will be discussed in detail through FG- Modules. To discuss the irreducible representations which are the building blocks of representations in detail. Chacter of a representation is a beautiful idea which is playing a vital role in the study of representations, here we discuss the character table of a group in detrail and construct the character table which will in fact replace the group itself.

Learning Outcome: After completion of teh course, the student must be able to

No.	Course Outcome	Cognitive level
CO1	Understand in detail the idea of group representations such as permutation representation and linear representations.	Understand
CO2	Know basic theorems and concepts concerning representations.	Remember
CO3	Create the character table of some interesting class of groups.	Create

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			1

UNIT 1: Vector spaces, Modules, FG- modules, Group representations, Group algebras and homomorphisms. (Sections 1 to 7 of the text.)
UNIT 2: Maschke's theorem, Schur's lemma, Irreducibility (Sections 8 to 11 of the text.)
UNIT 3: Conjugacy classes, Character, Irreducibility, Inner product, Character table, Normal subgroups and lifted characters. (Sections 12 to 17 of the text.)
UNIT 4: Elementary charactertables, Tensor products, Restriction to subgroup, Induced modules and characters. (Sections 18 to 21 of the text.)
UNIT 5: Properties of character tables. Permutation chracters. (Sections 24 and 29 of the text.)

Text Book: Gordon James and Martin Liebeck, Representation and Characters of Groups, Cambridge University Press, Second Edition, 2001.

References:-

1. Willim Fulton, Joe Harries, Representation theory, A first course, 191 Springer Verlag, ISBN 81-8128-134-9.

2. David S Dummit, Richard M. Foot, Abstract Algebra , Third edition, John Wiley & Sons, Inc. 2004.

3. Walter Ledermann, Introduction to group characters, Second edition, Cambridge University Press, 2008. ISBN 978-0-521-33781-6.

Semester IX or X
24-803-0915/ 24-803-1015 : Algebraic Topology

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: At the end of the course the students will have the necessary introduction to the subject of Algebraic topology. The algebraic notions of the fundamental group of a space and that of homology and even cohomology theories is covered in the course. All the important topological constructions and concepts conducive for the algebraic study are also studied with enough examples.

Learning Outcomes: At the completion of the course, students will be able to

No.	Course Outcome	Cognitive level
CO1	Understand necessary topological concepts and constructions like attaching spaces, suspension, excision, homotopy and deformation retraction among others.	Understand
CO2	Know the fundamental group and classification of covering spaces.	Remember
CO3	Comprehend homology and cohomology theories, which will serve as an important application of their course in module theory	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

UNIT 1: Homotopy and homotopy type, Cell complexes, Operations on spaces, Two criteria for homotopy equivalence, the homotopy extension property. (Chapter 0 of Hatcher)
UNIT 2: Applications of Van Kampen's theorem, Covering spaces, lifting properties, Universal cover and classification of covering spaces, Deck transformations and properly discontinuous actions. (chapter 1 of Hatcher)
UNIT 3: Delta-complexes and Simplicial homology, Singular homology, Homotopy Invariance, Exact sequences and excision, Equivalence of simplicial and singular homology. (Chapter 2 of Hatcher)
UNIT 4: Cellular homology (with special emphasis on CW-complexes), Mayer-Vietoris sequences, Homology with coefficients, the formal viewpoint of homology theories (briefly) (Chapter 2 of Hatcher)
UNIT 5: The definition of cohomology groups, The Universal Coefficient theorem, computation of cohomology of spaces, Relative groups and the long exact sequence of a pair of spaces (X, A), Cup product and the Cohomology ring structure, Kunneth formula for product of spaces, Poincare duality. (Chapter 3 of Hatcher)

Text Book: Algebraic Topology, Allen Hatcher.

References:-

1. Lecture notes in Algebraic Topology, James F. Davis, Paul Kirk.

Semester IX or X
24-803-0916/ 24-803-1016 : Differential Geometry

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: The course is aimed to introduce the popular tools to perform a study of geometry with the help of calculus on an n-dimensional surface. Develop the notion of curvature of parametric surfaces with the idea of, vector fields along a parametrized curve on the surface. Towards the end of the course, students will get all the necessary foundations to study Riemannian Geometry.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand the concepts of vector fields, tangent space, surfaces and its orientations.	Understand
CO2	Comprehend the spherical image of surfaces, geodesics, Weingarten map, and curvature of surfaces.	Analyze
CO3	Understand local equivalence of surfaces and parametrized surfaces.	Understand
CO4	Understand in depth, the ideas of rigid motions, congruence and isometries.	Understand

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			

Pre-requisites: Linear Algebra, Multivariate Calculus, and Differential Equations.
UNIT 1: Graphs and level sets, Vector fields, Tangent spaces, Surfaces, Vector Fields on Surfaces; Orientation, Gauss map.
UNIT 2: Geodesics, Parallel Transport, Weingarten Map, Curvature of Plane Curves.
UNIT 3: Arc lengths, Line integrals, Curvature of surfaces
UNIT 4: Parametrized surfaces, Local equivalence of surfaces and parametrized surfaces.
UNIT 5: Differentiable manifolds, Introduction, Tangent space, Immersions and embeddings; examples, Other Examples of manifolds, Orientation, Vector fields, brackets, Topology of manifolds. (Chapter 0 of the text 2)

Texts:

1. J.A. Thorpe: Elementary Topics in Differential Geometry, Springer-Verlag [Chapters 1 -12, 14, 15, 22, 23]

2. Manfredo Perdigao do Carmo, Riemannian Geometry, Birkhauser 1993.

References:-

1. L. M. Woodward, J. Bolton, A First Course in Differential Geometry: Surfaces in Euclidean Space, Cambridge university press, 2019.

2. Edouard Goursat, A Course in Mathematical Analysis, Vol. 1, Forgotten Books, 2012.

3. Andrew Pressley, Elementary Differential Geometry, second edition, Springer 2010.

4. Dirk J. Struik, Lectures on Classical Differential Geometry, Dover publications Inc. 1988.

5. Kreyszig, Introduction to Differential Geometry and Reimannian Geometry, University of Toronto Press, 1968.

Semester IX or X
24-803-0917/ 24-803-1017 : Algebraic Graph Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course aims to introduce students to the interconnection between Algebra and Graph Theory.

Outcome: After completing the course, the student will be able to

No.	Course Outcome	Cognitive level
CO1	Know transitivity in graphs.	Remember
CO2	Understand important matrices related to graphs.	Understand
CO3	Apply graph theoretic techniques in algebra and vice-versa.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			

Prerequisites: Basic knowledge of Algebra and Graph Theory

Text books:

1 C. Godsil and G. Royle: Algebraic Graph Theory, Springer, 2001.

Reference books:

1 R. B. Bapat: Graphs and Matrices, Springer, 2014.

2 N. Biggs: Algebraic Graph Theory (2nd edn.), Cambridge, 1993.

Syllabus

Module 1: Review of Graphs: Graphs, Subgraphs, Automorphisms, Homomorphisms, Circulant Graphs, Johnson Graphs, Line Graphs, Planar Graphs
(Section 1.1 - 1.8 of Text Book 1).

Module 2: Review of Groups: Permutation Groups, Counting, Asymmetric Graphs, Orbits on Paths, Primitivity, Connectivity
(Section 2.1 - 2.6 of Text Book 1).

Module 3: Transitive Graphs: Vertex transitive graphs, Edge transitive graphs, Edge connectivity, Vertex connectivity, Matchings
(Section 3.1 - 3.5 of Text Book 1).

Module 4: Matrix Theory: Adjacency matrix, Incidence matrix, Incidence matrix of oriented graphs, Symmetric matrices
(Section 8.1 - 8.4 of Text Book 1).

Module 5: Strongly Regular Graphs: Parameters, Eigen values, Some characterizations, Latin square graphs
(Section 26, 27 of Text Book 1).

Semester IX or X
24-803-0918/ 24-803-1018 : Wavelets

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course starts with the structure of $\mathbb{C}^n$. This course is planned to introduce the Wavelets as an extension to the idea of Fourier's method in Linear algebraic perpsective.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know Multi-resolution analysis and its applications	Remember
CO2	Apply ideas of wavelets in the space of periodic functions, non-periodic functions square integrable functions on the real line.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1		
CO2	3	1		1

UNIT 1: The Discrete Fourier Transform, Translation-Invariant Linear Transformations, First Stage Construction of Wavelets on $\mathbb{Z}_N$ (Chapter 2, Chapter 3, Sections 2.1, 2.2, 3.1)
UNIT 2: Construction of Wavelets on $\mathbb{Z}_N$: Iteration step, Examples and Applications, $l^2(\mathbb{Z})$ (Chapter 3, Sections 3.2, 3.3, Chapter 4, Section 4.1)
UNIT 3: Complete Orthonormal Sets in Hilbert Spaces, $L^2([-\pi,\pi))$ and Fourier Series, The Fourier Transform and Convolution on $l^2(\mathbb{Z})$ (Chapter 4, Sections 4.2, 4.3, 4.4, 4.5)
UNIT 4: First-Stage Wavelets on $\mathbb{Z}$, The Iteration step for Wavelets on $\mathbb{Z}$, Implementation and Examples. (Chapter 4, Sections 4.6, 4.7, Chapter 5, Section 5.1,)
UNIT 5: $L^2(\mathbb{R})$ and approximate Identities, The Fourier Transform on $\mathbb{R}$, Multiresolution Analysis and Wavelets, Construction of MRA (Chapter 5, Sections 5.2, 5.3, 5.4)

Text Book: Michael W. Frazier, An Introduction to Wavelets Through Linear Algebra, Springer-Verlag New York, (1999).

References:

1. Charles K. Chui, *An Introduction to Wavelets*, Academic (1992).
2. Ingrid Daubechies, *Ten Lectures on Wavelets*, SIAM, (1992).
3. K.R Unni, *Wavelets, Frames and Wavelet Bases in L^P Lecture notes*, Bhopal (1997).
4. Stephane Mallat, *A Wavelet Tour Of Signal Processing*, Academic Press (1999).
5. Don Hong, Jianzhong Wang, Robert Gardner, *Real Analysis with an Introduction to Wavelets*, Elsevier Academic Press (2005).
6. Yves Meyer, *Wavelets and Operators*, Cambridge University Press (1992).
7. John. J Beneditto, Michael W. Frazier *Wavelets-Mathematics and Applications*, CRC, (1994).
8. Eugenio Hernandez, Guido L. Weiss, *First course on wavelets*, CRC, (1996).

Semester IX or X
24-803-0919/ 24-803-1019 : Advanced Optimization Methods and Machine Learning

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course provides a detailed theoretical background on optimization in machine learning with a knowledge on python implementation.

Outcome: After completing the course, students will be able to

No.	Course Outcome	Cognitive level
CO1	Create mathematical models in Machine learning	Create
CO2	Apply Deep Learning to develop algorithms for Python implementation.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	1
CO2	3	3	2	2

Text books:

1 Aggarwal, C. C., Aggarwal, L. F., & Lagerstrom-Fife. (2020). Linear algebra and optimization for machine learning (Vol. 156). Springer International Publishing.

Reference books:

1 Boyd, S., Boyd, S. P., & Vandenberghe, L. (2004). Convex optimization. Cambridge university press.

2 Noble, B., & Daniel, J. W. (1977). Applied linear algebra (Vol. 477). Englewood Cliffs, NJ: Prentice-Hall

3 Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep learning. MIT press

4 Strang, G. (2019). Linear algebra and learning from data (Vol. 4). Cambridge: Wellesley-Cambridge Press.

5 Strang, G. (2016). Introduction to Linear Algebra (5th Edition). Wellesley Publishers (India), ISBN : 978-09802327-7-6.

Syllabus

Module 1: The Basics of Optimization, Convex Objective Functions, Properties of Optimization in Machine Learning, Computing Derivatives with respect to Vectors, Stochastic Gradient Descent, Use of Bias
(Sections 4.2, 4.3, 4.5, 4.6, 4.7.2, 4.7.3 of Text 1).

Module 2: Challenges in Gradient Based Optimization, Momentum Based Learning, Ada-Grad, Newton Method, Newton Method for Linear Regression, Newton Method- Challenges

and Solution
(Sections 5.2, 5.3.1, 5.3.2, 5.4, 5.5.1,5.6 of Text 1).

Module 3: Singular Value Decomposition- Introduction, SVD- A linear Algebra Perspective, SVD- An Optimization Perspective
(Sections 7.1 - 7.3 of Text 1)

Module 4: Applications of SVD- Dimensionality Reduction, Noise Removal, Moore- Penrose Pseudoinverse, Feature preprocessing, Outlier Detection, Feature Engineering, Numerical Algorithms for SVD, Python Implementation of SVD.
(Sections 7.4 - 7.5 of Text 1).

Module 5: Basics of Computational Graphs, Neural Networks as Directed Computational Graphs, Back-propagation in Neural Networks, Python Implementation of Feed Forward Back-Propagation Neural Network.
(Sections 11.1 - 11.2, 11.4 of Text 1).

Semester IX or X
24-803-0920/ 24-803-1020 : Commutative Algebra

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course is an advanced course in algebra. This course discusses the theory of commutative rings. These rings are of fundamental significance in Mathematics because of its applications to other topics such as algebraic number theory, algebraic geometry and many other advanced topics in mathematics.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand the basic definitions concerning different classes of commutative rings, elements in commutative rings, and ideals in commutative rings.	Understand
CO2	Know the theory of modules, including the tensor product of modules and algebras, and localisation.	Remember
CO3	Know the theory of primary decomposition of ideals in a commutative rings.	Remember
CO4	Know the theory of integral dependance and integral extensions.	Remember
CO5	Know the definition and examples of Noetherian and Artinian rings.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			
CO5	3			

UNIT 1: Rings and ideals: review of ideals in quotient rings; prime and maximal ideals, prime ideals under quotient, existence of maximal ideals; operations on ideals (sum, product, quotient and radical); Chinese Remainder theorem; nilradical and Jacobson radical; extension and contraction of ideals under ring homomorphisms; prime avoidance.
UNIT 2: Free modules; Projective Modules; Tensor Product of Modules and Algebras; Flat, Faithfully Flat and Finitely Presented Modules; Shanuels Lemma.
UNIT 3: Localisation and local rings, universal property of localisation, extended and contracted ideals and prime ideals under localisation, localisation and quotients, exactness property.
UNIT 4: Nagata's criterion for UFD and applications; equivalence of PID and one-dimensional UFD. Associated Primes and Primary Decomposition.
UNIT 5: Integral dependence, Going-up theorem, Integral Extensions: integral closure, Going-down theorem, Valuation rings, Chain Conditions. Definition and examples of Noetherian rings and Artinian rings.

Text Book: M.F. Atiyah and I.G. Macdonald, Introduction to commutative algebra, Addison-Wesley (1969).

References:

1. R.Y. Sharp: Steps in commutative algebra, LMS Student Texts (19), Cambridge Univ. Press (1995).

2. D. Eisenbud: Commutative algebra with a view toward algebraic geometry GTM (150), Springer-Verlag (1995).

3. H. Matsumura: Commutative ring theory, Cambridge Studies in Advanced Mathematics No. 8, Cambridge University Press (1980).

4. N.S. Gopalakrishnan: Commutative Algebra (Second Edition), Universities Press (2016).

5. Miles Reid: Undergraduate Commutative Algebra , Cambridge University Press (1995).

Semester IX or X
24-803-0921/ 24-803-1021 : Graph Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: The course introduce the concept of automorphism of simple graphs, graph operators, graph parameters and some interesting graph classes

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Understand the basic concepts of graph theory	Understand
CO2	Know with clarity, graph operators, graph parameters and graph classes.	Remember
CO3	Create graph models of real-life problems.	Create
CO4	Apply graph theoretic tools to solve problems.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3	2		3
CO4	3	2		2

UNIT 1: Basic Concepts, Degree of Vertices, Automorphism of a Simple Graph, Line Graphs, Operation on Graphs, Directed Graphs, Tournaments (Chapter 1: Sec. 1.1 - 1.12, Chapter 2: Sec. 2.1 - 2.3)
UNIT 2: Connectivity, Vertex Cuts and Edge Cuts, Connectivity and Edge Connectivity, Blocks, Trees, Definition, Characterization, Centers, Cayley's Formula, Applications (Chapter 3:Sec.3.1 – 3.4 (Theorem 3.4.3 omitted), Chapter 4: Sec. 4.1 - 4.5, 4.7)
UNIT 3: Independent sets, Vertex coverings, Edge Independent sets, Matchings, Factors, Matching in Bipartile Graphs, Eulerian Graphs, Hamiltonian Graphs, Hamilton Cycles in Line Graphs, 2-Factorable Graphs (Chapter 5: Sec. 5.1 - 5.5, Chapter 6: Sec. 6.1 - 6.3, 6.5 - 6.6)
UNIT 4: Graph Colorings, Critical Graphs, Brook's Theorem, Triangle Free Graphs, Edge Colorings, Chromatic Polynomials, Perfect Graphs, Triangulated Graphs, Interval Graphs (Chapter 7: Sec. 7.1 - 7.2, 7.3, 7.3.1, 7.5 – 7.6, 7.9, Chapter 9: Sec. 9.1 – 9.4)
UNIT 5: Planar and nonplanar graphs, Euler's Formula, Dual, Four Color Theorem and Five Color Theorem, Kuratowski's Theorem (without proof), Hamilton Plane graphs, Domination, Bounds, Independent Domination and Irredundance (Chapter8: Sec. 8.1 – 8.8, Chapter 10: Sec.10.1 – 10.3. 10.5)
Text Book: R. Balakrishnan, K. Ranganathan: A Text book of Graph Theory (Second Edition), Springer 2012.
References:-

1. D. B. West: Introduction to Graph Theory, 2nd ed. Prentice Hall, New Jersey (2011)
2. F. Harary: Graph Theory, Addison – Wesley Publishing Company, Inc. (1969).
3. M. C. Golumbic: Algorithmic Graph Theory and Perfect Graphs, Academic Press, New York (1980)
4. Teresa W. Haynes, S. T. Hedetneimi, P. J. Slater: Fundamentals of Domination in Graphs, Marcel Dekker, New York (1998)

Semester IX or X
24-803-0922/ 24-803-1022 : C^*-Algebra and Representation Theory

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: This course aims to provide the fundamentals of C^*-algebras, Von Neumann algebras and their representation theory.

Outcome: After this course student will able to

No.	Course Outcome	Cognitive level
CO1	Comprehend recent research articles by own reading.	Analyze
CO2	Understand the basic ideas in the representation theory of C^*-algebras.	Understand
CO3	Analyse problems in representation theory of C^*-algebras to come up with solutions.	Analyze

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			1
CO2	3			
CO3	3	1		2

Text book:

1. Murphy, Gerard J. C^*-algebras and operator theory. Academic Press, Inc., Boston, MA, 1990.

Reference books:

1. Arveson, William. An invitation to C^*-algebras. Graduate Texts in Mathematics, No. 39. Springer-Verlag, New York-Heidelberg, 1976.

2. Sunder, V. S. Functional analysis. Spectral theory. Birkhäuser Advanced Texts: Basler Lehrbücher. [Birkhäuser Advanced Texts: Basel Textbooks] Birkhäuser Verlag, Basel, 1997.

3. Conway, John B. A course in functional analysis. Second edition. Graduate Texts in Mathematics, 96. Springer-Verlag, New York, 1990.

4. Davidson, Kenneth R. C^*-algebras by example. Fields Institute Monographs, 6. American Mathematical Society, Providence, RI, 1996.

5. Douglas, Ronald G. Banach algebra techniques in operator theory. Second edition. Graduate Texts in Mathematics, 179. Springer-Verlag, New York, 1998.

SYLLABUS

Module 1: C^*-Algebras and Hilbert Space Operators: C^*-Algebras, Positive Elements of C^*-Algebras, Operators and Sesquilinear Forms, Compact Hilbert Space Operators and The Spectral Theorem. (Chapter - 2 of Text Book - 1).

Module 2: Ideals and Positive Functionals: Ideals in C^*-Algebras, Hereditary C^*-Subalgebras , Positive Linear Functionals, The Gelfand-Naimark Representation and Toeplitz Operators. (Chapter - 3 of Text Book - 1).

Module 3: Von Neumann Algebras: The Double Commutant Theorem, The Weak and Ultraweak Topologies, The Kaplansky Density Theorem and Abelian Von Neumann Algebras. (Chapter - 4 of Text Book - 1).

Module 4: Representations of C^*-Algebras: Irreducible Representations and Pure States, The Transitivity Theorem, Left Ideals of C^*-Algebras, Primitive Ideals, Extensions and Restrictions of Representations, Liminal and Postliminal C^*-Algebras. (Chapter - 5 of Text Book - 1).

Module 5: Direct Limits and Tensor Products: Direct Limits of C^*-Algebras, Uniformly Hyperfinite Algebras, Tensor Products of C^*-Algebras, Minimality of the Spatial C^*-Norm and Nuclear C^*-Algebras and Short Exact Sequences. (Chapter - 6 of Text Book - 1).

Semester IX or X
24-803-0923/ 24-803-1023 : Reproducing Kernel Hilbert Spaces

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 hours

Objective: Reproducing kernel Hilbert spaces have developed into an important tool in many areas, especially statistics and machine learning, and they play a valuable role in complex analysis, probability, group representation theory, and the theory of integral operators. This course aims to provide an introduction to the theory of reproducing kernel Hilbert spaces.

Outcome: After this course student will be able to

No.	Course Outcome	Cognitive level
CO1	Understand recent research articles in the theory of reproducing kernel Hilbert spaces.	Understand
CO2	Analyse problems in reproducing kernel Hilbert spaces and attempt solutions.	Analyze

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3	1		2
CO2	3	1		2

Text book:

1. Paulsen, Vern I.; Raghupathi, Mrinal. An introduction to the theory of reproducing kernel Hilbert spaces. Cambridge Studies in Advanced Mathematics, 152. Cambridge University Press, Cambridge, 2016.

Reference books:

1. Jim Agler and John E. McCarthy, Pick interpolation and Hilbert function spaces, Graduate Studies in Mathematics, vol. 44, American Mathematical Society, Providence, Rhode Island, 2002.

2. N. Aronszajn, Theory of reproducing kernels, Trans. Amer. Math. Soc. 68 (1950), 337–404.

3. Ronald G. Douglas and Vern I. Paulsen, Hilbert modules over function algebras, Pitman Research Notes in Mathematics, vol. 217, Longman Scientific, 1989.

4. John B. Conway, A course in functional analysis, 2nd ed., Graduate Texts in Mathematics, vol. 96, Springer-Verlag, New York, 1990.

5. Donald Sarason, Complex function theory, American Mathematical Society, Providence, Rhode Island, 2007.

SYLLABUS

Module 1: Introduction: Definition of reproducing kernel Hilbert spaces (RKHS), Basic examples, Examples from analysis, Function theoretic examples. (Chapter - 1 of Text Book - 1).

Module 2: Fundamental results: Hilbert space structure, Characterization of reproducing kernels, The Reconstruction Problem. (Chapter - 2 of Text Book - 1).
Module 3: Interpolation and approximation: Interpolation in an RKHS, Strictly positive kernels, Best least squares approximants, The elements of H(K). (Chapter - 3 of Text Book - 1).
Module 4: Cholesky and Schur: Cholesky factorization, Schur products and the Schur decomposition, Tensor products of Hilbert spaces, Kernels arising from polynomials and power series. (Chapter - 4 of Text Book - 1).
Module 5: Operations on kernels: Complexification, Differences and sums, Finite-dimensional RKHSs, Pull-backs, restrictions and composition operators Composition operators, Products of kernels and tensor products of spaces, Push-outs of RKHS, Multipliers of a RKHS. (Chapter - 5 of Text Book - 1).

Semester IX or X
24-803-0924 / 24-803-1024 - Topology II

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: With this course, the students will have a sound introductory knowledge of the topics in Algebraic topology. The first module is important to understand the topology of non-metric spaces. From second module onwards the student is gradually introduced to the important category of topological spaces and subsequently the algebraic machinery like simplicity homology and fundamental groups for their study. The course ends with a rigorous understanding of covering spaces.

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

No.	Course Outcome	Cognitive level
CO1	Know nets and filters, the generalisation of sequences for topologies that are no more defined by a metric.	Remember
CO2	Understand the important geometric objects like complexes and Polyhedra and different identification spaces whose topology is studied.	Understand
CO3	Comprehend the definition of simplicial homology groups and apply them to compute the homology groups for certain important spaces.	Analyze
CO4	Understand the fundamental group and the Van Kampen theorem with examples.	Understand
CO5	Know covering spaces and their properties along with their classification.	Remember

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			
CO2	3			
CO3	3			
CO4	3			
CO5	3			

UNIT 1: Nets and Filters: Definition and convergence of Nets, Topolgy and convergence of Nets, Filters and their convergence, Ultra filters (Tychnoff's theorem) (Relevant Sections from text 1)
UNIT 2: Geometric Complexes and Polyhedra: Introduction. Examples, Geometric Complexes and Polyhedra, Orientation of geometric complexes. **Simplicial Homology Groups:** Chains, cycles, Boundaries and homology groups, Examples of homology groups, The structure of homology groups, (Sections 1.1 to 1.4, Sections 2.1 to 2.3 from text 2)
UNIT 3: Simplicial Homology Groups (Contd.): The Euler Poincare's Theorem, Pseudomanifolds and the homology groups of S_n. **Simplicial Approximation:** Introduction, Simplicial approximation, Induced homomorphisms on the Homology groups, The Brouwer fixed point theorem and related results (Sections 2.4, 2.5, and Sections 3.1 to 3.4 from text 2)
UNIT 4: The Fundamental Group: Introduction, Homotopic Paths and the Fundamental Group, The Covering Homotopy Property for S1, Examples of Fundamental Groups. (Sections 4.1 to 4.4 from text 2)

UNIT 5: Covering Spaces: The Definition and Some Examples, Basic Properties of Covering Spaces, Classification of Covering Spaces, Universal Covering Spaces, Applications (Sections 5.1 to 5.5 of text 2)

Text Books:

1. K.D. Joshi: Introduction to General Topology (Revised Edn.),New Age International(P) Ltd., New Delhi, 1983.
2. F.H. Croom: Basic Concepts of Algebraic Topology, Springer, 1978

References:-

1. Allen Hatcher: Algebraic Topology, Cambridge University Press, 2002
2. C.T.C. Wall: A Geometric Introduction to Topology, Addison-Wesley Pub. Co. Reading Mass, 1972
3. Eilenberg S, Steenrod N.: Foundations of Algebraic Topology, Princeton Univ. Press, 1952.
4. J. R. Munkers: Elements Of Algebraic Topology, Perseus Books, Reading Mass, 1993, CRC, 2018.
5. J. R. Munkers: Topology (Second Edition) PHI, 2009.
6. Massey W.S.: Algebraic Topology : An Introduction, Springer Verlag NY, 1977
7. S.T. Hu: Homology Theory, Holden-Day, 1965

Semester IX or X
24-803-0925 or 24-803-1025 - Computational Mathematics Laboratory

Number of credits: 4
Number of hours per week: 5 hrs
Total number of Hours: 90 hours

Objective: This course starts with the review of Numerical methods for differentiation and integration, and simple models of Partial differential equations. This course is planned to introduce the basics of mathematical documention setting using LaTeX. Introduction of programming using Python for solving Mathematical problems arising in various fields, that are covered in the Msc curriculum.

Learning Outcomes: After the completion of this course, the student should be able to

No.	Course Outcome	Cognitive level
CO1	Know how to prepare mathematical documnets in LATEX and Python.	Remember
CO2	Understand Python programming techniques.	Understand
CO3	Apply programming ideas to solve mathematical problems.	Apply

CO - PSO Mapping Table:

CO/PSO	PSO1	PSO2	PSO3	PSO4
CO1	3			1
CO2	3	2	1	
CO3	3	3	2	1

UNIT 1: Introduction to LaTeX Documentation setting, Standard document classes, Bibtex, standard environments, Macros, Table of contents, Bibliography styles, tables, Pstricks, Multiline math displays (Texts 1, 2)
UNIT 2: Introduction to programming with Python, Fundamentals, Data types, Functions, Pointers and string handling, Class, File handling, Programming Excercises from Linear Algebra, Number Theory, Numerical Approximations, Differential Equations. (Texts 3, 4, 5 , 6)
UNIT 3: Matplotlib, Numpy, and Scipy Exercises. (Texts 7, 3)
UNIT 4: Introduction to SageMath, Symbolic Calculus, Linear Algebra using SageMath, SageTex Package, Graphics, Combinatorics, Graph Theory (Text 8).
UNIT 5: Coding Theory using SageMath, Standard Rings and Fields (Text 8)

References:-

1. George *Grätzer*, *Math into LaTeX an Introduction to LaTeX and AMS-LaTeX*, Birkhauser Boston, (1996).

2. Donald. E. Knuth, *Computers & Type setting*, Addison-Wesley, (1986).

3. Hans Petter Langtangen, *A Primer on Scientific Programming with Python*, Third Edition, Springer (2012).

4. John M. Zelle, *Python Programming: An Introduction to Computer Science*, (2002).

5. Steven Lott, *Functional Python Programming*, Packt Publishing Ltd, (2015).

6. Jody. S. Ginther Start here: Python programming made simple for the Beginner.

7. John Hunter, Darren Dale, Eric Firing, Michael Droettboom, *Matplotlib Release 1.4.3*.

8. William Stein, *SAGE Reference Manual Release 2007.10.29*.

NB: A Lab Report type-setted in LaTeX by the student has to be submitted at the end of the semester.