File Ref.No.Ac.A3/General/2023

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

(Abstract)

Department of Mathematics - Modifications in the programme curriculum of M.Sc. Mathematics consequent to the introduction of mandatory MOOC courses - Resolution of the Academic Council - Communicated - Orders issued.

ACADEMIC A SECTION

No.CUSAT/AC(A).A3/4655/2024 Dated,KOCHI-22,31.10.2024

Read:-1. Item No.II (34) (3) of the minutes of the meeting of the Academic Council held on 07.09.2024

2. Notification No: Ac.A3/Faculty of Science/2023 dated 19.02.2024

ORDER

The Academic Council meeting held on 07.09.2024, vide item referred above, considered along with the recommendations of it's standing committee and resolved to approve modifications in the programme curriculum of M.Sc. Mathematics, consequent to the introduction of mandatory MOOC programmes, with effect from 2024 admission onwards.

The modified curriculum is appended.

Orders are, therefore, issued accordingly.

Dr. Arun A U *
Registrar

To:

1. The Dean, Faculty of Science
2. The Chairperson, BoS in Mathematics
3. The Head, Department of Mathematics
4. All AR/DR Examination wing - with a request to forward to concerned sections
5. The Director, IQAC/ DoA
6. CIRM/Conference Sections
7. PS To VC/PVC;PA To Registrar/CE.

* This is a computer generated document. Hence no signature is required.

Cochin University of Science and Technology

Department of Mathematics

MSc in Mathematics

(2024 admission onwards)

DEPARTMENT OF MATHEMATICS

M.Sc. MATHEMATICS (Course Structure)

SEMESTER: 1

Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
24-314-0101	Linear Algebra	400	DSC	4	3-0-2	50	50	100
24-314-0102	Real Analysis	400	DSC	4	3-0-2	50	50	100
24-314-0103	Measure and Integration	400	DSC	4	3-0-2	50	50	100
24-314-0104	Groups and Rings	400	DSC	4	3-0-2	50	50	100
24-314-0105	Topology I	400	DSC	4	3-0-2	50	50	100

SEMESTER: 2

Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
24-314-0201	Field Theory	400	DSC	4	3-0-2	50	50	100
24-314-0202	Functional Analysis	400	DSC	4	3-0-2	50	50	100
24-314-0203	Complex Analysis	400	DSC	4	3-0-2	50	50	100
24-314-0204	Functions of Several Variables and Geometry	400	DSC	4	3-0-2	50	50	100
24-314-0205	Computational Mathematics Laboratory	400	DSC	4	3-0-2	50	50	100

SEMESTER 3

Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
24-314-0301	Operator Theory	500	DSC	4	3-0-2	50	50	100
24-314-0302	Ordinary Differential Equations and Integral Equations	500	DSC	4	3-0-2	50	50	100
24-314-03xx	Elective I	500	DSE	4	3-0-2	50	50	100
24-314-03xx	Elective II	500	DSE	4	3-0-2	50	50	100
xx-xxx-03xx	Elective III	500	IDE	4	3-0-2	50	50	100
24-314-03xx	MOOC	500	DSE	Min. 2	--	--	100	100

SEMESTER 4								
Course Code	Course Name	Level	Course Type	Credits	L-T-P	CE	ESE	Total Marks
24-314-0401	Partial Differential Equations and Variational Calculus	500	DSC	4	3-0-2	50	50	100
24-314-0402	Probability Theory	500	DSC	4	3-0-2	50	50	100
24-314-04xx	Elective I	500	DSE	4	3-0-2	50	50	100
24-314-04xx	Elective II	500	DSE	4	3-0-2	50	50	100
24-314-04xx	Elective III	500	DSE	4	3-0-2	50	50	100
Project (6 months – 4 credits / 1 year – 8 credits) can be taken instead of elective courses								

LIST OF ELECTIVE COURSES OFFERED IN VARIOUS SEMESTERS:-

24-314-0305 : Topics in Applied Mathematics (Inter-departmental elective)
24-314-0306/ 24-314-0406: Advanced Linear Algebra
24-314-0307/ 24-314-0407 : Discrete Framelets
24-314-0308/ 24-314-0408 : Harmonic Analysis
24-314-0309/ 24-314-0409 : Integral Transforms
24-314-0310/ 24-314-0410 : Functions Of Several Variables
24-314-0311/ 24-314-0411 : Advanced Spectral Theory
24-314-0312/ 24-314-0412 : Banach Algebras And Spectral Theory
24-314-0313/ 24-314-0413 : Number Theory
24-314-0314/ 24-314-0414 : Representation Theory Of Finite Groups
24-314-0315/ 24-314-0415 : Algebraic Topology
24-314-0316/ 24-314-0416 : Differential Geometry
24-314-0317/ 24-314-0417: Algebraic Graph Theory
24-314-0318/ 24-314-0418 : Wavelets
24-314-0319/ 24-314-0419 : Advanced Optimization Methods and Machine Learning
24-314-0320/ 24-314-0420 : Commutative Algebra
24-314-0321/ 24-314-0421 : Graph Theory
24-314-0322/ 24-314-0422 : C*-Algebra and Representation Theory
24-314-0323/ 24-314-0423 : Reproducing Kernel Hilbert Spaces
24-314-0324/ 24-314-0424 : Topology II
24-314-0325 : MOOC 1
24-314-0326 : MOOC 2
24-314-0327 : MOOC 3
24-314-0328 : MOOC 4, etc

Semester I
24-314-0101 - 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 I
24-314-0102 - 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 I
24-314-0103 - 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 I
24-314-0104 - 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 I
24-314-0105 - 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 II
24-314-0201 - 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 II
24-314-0202 - 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 II
24-314-0203 - 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 II

24-314-0204 - 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 II
24-314-0205 - 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.

Semester III
24-314-0301 - 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 III
24-314-0302 - 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 IV
24-314-0401 - 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 IV
24-314-0402 - 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: 3 and 4)

Departmental / Interdepartmental Elective

Semester III
24-314-0305 : Topics in Applied Mathematics
(Inter-departmental elective.)

Number of credits: 4
Number of hours per week: 5 hrs
Total No. of Hours: 90 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 III or IV
24-314-0306/ 24-314-0406 : 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 III or IV
24-314-0307/ 24-314-0407: 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 III or IV
24-314-0308/ 24-314-0408 : 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 III or IV
24-314-0309/ 24-314-0409 : 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 III or IV
24-314-0310/ 24-314-0410 : 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 III or IV
24-314-0311/ 24-314-0411 : 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 III or IV
24-314-0312/ 24-314-0412 : 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 III or IV
24-314-0313/ 24-314-0413 : 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 III or IV
24-314-0314/ 24-314-0414 : 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 III or IV
24-314-0315/ 24-314-0415 : 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 III or IV
24-314-0316/ 24-314-0416 : 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 III or IV
24-314-0317/ 24-314-0417 : 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 III or IV
24-314-0318/ 24-314-0418 : 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 III or IV
24-314-0319/ 24-314-0419 : 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, AdaGrad, 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 III or IV
24-314-0320/ 24-314-0420 : 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 III or IV
24-314-0321/ 24-314-0421 : 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 III or IV
24-314-0322/ 24-314-0422 : 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 III or IV
24-314-0323/ 24-314-0423 : 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 III or IV
24-314-0324 / 24-314-0424 - 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