PERIYAR UNIVERSITY

Re-accredited with ‘A’ grade by the NAAC

PERIYAR PALKALAI NAGAR

SALEM - 11

M.Phil. Mathematics

(SEMESTER PATTERN)

(Under Choice Based Credit System)

(For University Department & Affiliated Colleges)

REGULATIONS AND SYLLABUS

(For candidates admitted from 2018-2019 onwards)

PERIYAR UNIVERSITY, SALEM –11

M.Phil., Mathematics - CHOICE BASED CREDIT SYSTEM (CBCS)

REGULATIONS AND SYLLABUS

(For the candidates admitted from 2018-2019)

1. PROGRAMME OBJECTIVES

The objectives of this M.Phil programme is to

- Motivate the students for critical thinking to pursue research in mathematics
- Impart knowledge in advanced concepts of pure and applied mathematics
- Acquire specific knowledge in the emerging research areas of mathematics
- Train the students with latest teaching and research methodologies
- Educate the students to write research articles/technical reports in mathematics
- To prepare students to become an independent researcher in mathematics

2. PROGRAMME OUTCOME

At the time of graduation, students will be able to

PO4	Do independent research with a strong background in mathematics
PO2	Identify research problems in the relevant area of mathematics
PO3	Apply the acquired mathematical techniques to solve existing research problems
PO4	Prepare research articles in mathematics
PO5	Obtain career in the field of teaching and research
PO6	Interact with the leading experts in the subject of his interest.

3. DURATION OF THE COURSE

The duration of the M.Phil. Programme shall be one year consisting of two semesters under Choice Based Credit System.

4. ELIGIBILITY FOR ADMISSION

A Master degree in Mathematics of Periyar University or any other university recognized by the Syndicate as equivalent thereto, provided that those who have qualified for the Master's degree prior to 1st January 1991 must have secured a minimum of 50 percent of marks and those who have qualified for the Master's degree on or after 1st January 1991 must have secured a minimum of 55 percent of marks. For SC / ST candidates who have qualified on or after 1st January 1991 a concession of 5 percent of marks shall be given in the minimum eligibility marks.

5. DISTRIBUTION OF CREDIT POINTS

The minimum credit requirement for one year M.Phil, programme shall be 24 Credits. The break-up of credits for the programme is as follows:

PART – I

- Core Course : 4 credits
- Core Course : 4 credits
- Specialization Course (Elective) : 4 credits

PART – II

- Dissertation : 8 credits
- Viva Voce : 4 credits

6. COURSE OF STUDY:

The courses of study for the M.Phil. Degree shall be in Mathematics (under Choice Based Credit System) with internal assessment according to syllabi prescribed from time to time. The **Internal Assessment** is distributed to **Tests, Seminar, Assignment** and **Attendance** as **10**, **05, 05** and **05** marks, respectively.

There are three courses under Part-I for Semester I and Dissertation & Viva Voce under Part-II for Semester II. The Third Course in the first semester shall be specialization related to the dissertation. The student in consultation with the research supervisor must select any one of the thirteen titles as specialization course.

Total marks : **500**

For each paper : **100** (Internal 25 Marks + External 75 Marks)

Dissertation : **200** (Internal Valuation 75 + External Valuation 75 and Joint Viva Voce 25 + 25 Marks]

7. BLOOM'S TAXONOMY

Provides a taxonomy of cognitive levels for learning objectives

Create →	**K6**
Evaluate →	**K5**
Analyze →	**K4**
Apply →	**K3**
Understand →	**K2**
Recall →	**K1**

ACTION VERBS FOR LEARNING OBJECTIVES

K1	**Recall – Remember previously learned material** cite, label, name, reproduce, define, list, quote, pronounce, identify, match recite, state
K2	**Understand- Grasp meaning** alter, explain, rephrase, substitute, convert, give example, restate, translate, describe, illustrate, interpret, paraphrase
K3	**Apply- Use learned material in new and concrete situations** apply, relate, solve, classify, predict compute, prepare
K4	**Analyze- break down into component parts to understand structure** ascertain, diagnose, distinguish, infer, associate, examine, differentiate, reduce, discriminate, dissect, determine
K5	**Evaluate- judge the value of material for a given purpose** appraise, conclude, critique, judge assess, contrast, deduce, weigh compare, criticize, evaluate
K6	**Create- combine parts together to form a new whole** combine, devise, compile, expand, plan, compose, extend, synthesize, conceive, modify generalize, revise, integrate, design, invent, rearrange, develop

8. STRUCTURE OF THE PROGRAMME

Course Code	Title of the Course	Core/Elective	Credits			
			L	T	P	C
I SEMESTER (Part-I)						
18URMAT0C01	Research Methodology	Core	4	1	0	4
18URMAT0C02	Algebra and Design Theory	Core	4	1	0	4
*18URMAT0E__	Specialization Course	Elective	4	1	0	4
II SEMESTER (Part-II)						
18URMAT0D01	Dissertation	Core	-	-	-	8
	Viva Voce	Core	-	-	-	4

*18URMAT0E__ - Guide Paper

- L – Lecture, T – Tutorial, P – Practical, C – Credits

SPECIALIZATION COURSE WILL BE ANY ONE OF THE FOLLOWING:

S.NO	COURSE CODE	TITLE OF THE SPECIALIZATION COURSE
1.	18URMAT0E01	Commutative Algebra
2.	18URMAT0E02	Non Commutative Algebra
3.	18URMAT0E03	Advanced Topology
4.	18URMAT0E04	Advanced Topics in Graph Theory
5.	18URMAT0E05	Geometric Function Theory
6.	18URMAT0E06	Functional Equations
7.	18URMAT0E07	Mathematical Modelling
8.	18URMAT0E08	Ordinary Differential and Difference Equations
9.	18URMAT0E09	Fractional Differential Equations
10.	18URMAT0E10	Theory of Partial Differential Equations
11.	18URMAT0E11	Advanced Topics in Fluid Dynamics
12.	18URMAT0E12	Fuzzy Sets: Theory and Applications
13.	18URMAT0E13	Optimization Techniques

9. SCHEME OF EXAMINATION

Part-I Written Examination:

For the purpose of uniformity, particularly for interdepartmental transfer of credits, there shall be a uniform pattern of examination to be adopted by all the teachers offering courses. There shall be three tests, one seminar and one assignment for internal evaluation and End semester examination during each semester.

The distribution of marks for internal evaluation and End Semester Examination shall be 25 marks and 75 marks, respectively. Further, distribution of internal marks shall be 10 marks for test, 5 marks for seminar, 5 marks for assignment and 5 marks for attendance, respectively. The average of the highest two test marks out of the three internal tests should be taken for Internal Assessment.

Part-II – Dissertation:

The exact title of the dissertation shall be intimated within one month after the registration of the Programme. Candidates shall submit the dissertation to the university through the supervisor and Head of the Department at the end of the year from the commencement of the programme which shall be valued by internal examiner (supervisor) and **one external examiner** appointed by the university from a panel of **four** names sent by the supervisor through the Head of the Department at the time of submitting the dissertation.

The examiners who value the dissertation shall report the merit of candidates as "**Highly Commended**" (75% and above) or "**Commended**" (50% and above and below 75%) or **"Not Commended"** (below 50%).

If one examiner commends the dissertation and the other examiner, does not commend, the dissertation will be referred to the third examiner and the third valuation shall be final.

Submission or resubmission of the dissertation will be allowed twice a year subject to the University rules.

10. QUESTION PAPER PATTERN:

Time: 3 Hours **Maximum Marks:** 75

Part – A (10 X 2 = 20 Marks)

Answer **ALL** Questions

(Two questions from each unit)

Part – B (5 X 5 = 25 Marks)

Answer **ALL** Questions

(Two questions from each unit with internal choice)

Part – C (3 X 10 = 30 Marks)

Answer any **THREE** questions out of **FIVE** questions

(One question from each unit)

11. DISSERTATION:

(a) Topic:

The topic of the dissertation shall be assigned to the candidate within one month (based on paper III) after registration and a copy of the same should be submitted to the university for approval.

(b) Number of copies of dissertation:

The students should prepare two copies of dissertation and submit the same to the University for the Evaluation.

Format to be followed:

The format of the dissertation to be submitted by the students is given below:

Format for the preparation of project work:

(a) Title page
(b) Bonafide Certificate
(c) Acknowledgement
(d) Table of contents

CONTENTS

Chapter No.	Title	Page No.
1.	Introduction	
2.	Review of Literature	
3.	Summary	
4.	Results	
5.	References	

Format of the Title Page

TITLE OF THE DISSERTATION

Dissertation Submitted in partial fulfilment of the requirement for the award of Degree of Master of Philosophy in **MATHEMATICS** to the Periyar University, Periyar Palkalai Nagar, Salem – 636 011.

By

Student's Name :

Register Number :

Department/College :

Month and Year :

Format of the Certificate

CERTIFICATE

This is to certify that the dissertation entitled ...(Title)....submitted by ……(Candidate Name)……. to the Periyar University,Periyar Palkalai Nagar, Salem in partial fulfilment of the requirement for the award of Degree of Master of Philosophy in **Mathematics** is a bonafide record of work carried out by the candidate during .... in the Department and that no part of the dissertation has been submitted for the award of any Degree / Diploma / Associateship / Fellowship or other similar titles that the dissertation represents independent work on part of the candidate under my guidance.

Date:

Place: Signature of the Guide

Signature of the Head of the Department

12. PASSING MINIMUM:

A candidate shall be declared to have passed Part-I of the examination if he/she secures not less than 50% of the marks in each course.

A candidate shall be declared to have passed Part-II of the examination if his/her dissertation is atleast commended.

A candidate who has passed all the examinations under both parts and earned a minimum of 24 credits shall be considered to have passed the M.Phil programme.

13. RESTRICTION IN NUMBER OF CHANCES:

No candidate shall be permitted to reappear for the written examination in any paper for more than two occasions or to resubmit a Dissertation more than once. Candidates shall have to qualify for the degree passing all the written papers and dissertation within a period of two years from the date of joining the course.

14. COMMENCEMENT OF THIS REGULATION:

These regulation and syllabi shall take effect from the academic year 2018 – 2019 that is, for those admitted to the Programme during the academic year 2018 – 2019 and thereafter.

SEMESTER I (PART - I)

18URMAT0C01	RESEARCH METHODOLOGY	L	T	P	C
		4	1	0	4

OBJECTIVE:

The objective of this course is improve the technical writing skill and to study some advanced topics in Analysis, Differential Equations and Dynamical Systems.

Unit-I: Technical Writing

Basic Elements – Identification of the author and his writing - Chapters and sections –Numbering of elements.

Unit-II: Topological Vector Spaces

Introduction – Separation properties – Linear mappings – Finite-dimensional spaces – Metrization – Boundedness and continuity – Seminorms and local convexity.

UNIT III: Completeness

Quotient spaces – Examples – Baire category – The Banach-Steinhaus theorem – The open mapping theorem – The closed graph theorem – Bilinear mappings.

Unit IV: Linear Systems

Uncoupled Linear Systems - Exponentials of Operators – The Fundamental Theorem for Linear Systems – Linear Systems in R^{2}.

Unit V: Linear and Nonlinear Systems

Stability Theory – Nonhomogeneous Linear Systems – The Fundamental Existence-Uniqueness Theorems. Dependence on Initial Conditions and Parameters.

TEXT BOOKS:

1. **B.N. Basu,** *"Technical Writing",* PHI, Pvt., ltd., New Delhi, 2007.
2. **W.Rudin,** *"Functional Analysis",* 2nd Edition, Tata McGraw-Hill, New Delhi, 2006.
3. **L. Perko,** *"Differential Equations and Dynamical Systems"*, Springer-Verlag, New York, 2001.

UNIT	Chapter(s)/Book	Sections / Pages
I	4, 5, 6, 8 of [1]	4.1 – 4.5, 5.1 – 5.4
II	1 of [2]	3 – 30
III	1, 2 of [2]	30 – 55
IV	1 of [3]	1.1, 1.3, 1.4, 1.5, 1.9
V	1 & 2 of [3]	1.9, 1,10, 2.2, 2.3

REFERENCE BOOKS:

1. **J. Anderson, B. H. Durston, M. Poole**, *"Thesis and Assignment Writing"*, John Wiley & Sons, 1989.
2. **D. H. McBurney**, *"Research Methods"*, Thomson Asia Pvt., Ltd., 2002.
3. **A. Browder**, *"Introduction to Function Algebras"*, Mathematics Lecture Notes Series, W.A.Benjamin, New York, 1969.
4. **J. L. Kelley** and I. Namioka, *"Linear Topological Spaces"*, D. Van Nostrand Company, Princeton, New Jersey, 1963.
5. **G. Kothe**, *"Topological Vector Spaces"*, Springer-Verlag, New York, vol.1, 1969; vol.2, 1979.
6. **S. G. Deo, V. Lakshmikantham and V. Raghavendra,** *"Textbook of Ordinary Differential Equations"*, Tata McGraw-Hill, New Delhi, 1997.
7. **Earl A. Coddington and N. Levinson,** *"Theory of Ordinary Differential Equations",* Tata McGraw Hill, New Delhi, 1987.

COURSE OUTCOME: At the end of the course, students will be able to

CO	Statements	Knowledge level
CO1	Identify and explain the basic elements of a thesis or a paper and to prepare a thesis or a paper for a journal.	**K1, K2, K3**
CO2	Define what a topological vector space is, to classify the types of topological vector spaces and to analyze the metrizability of a topological vector space.	**K1, K3, K4**
CO3	Define Quotient spaces, Completeness, to understand the concepts of Equicontinuity and Bilinear Mappings, and to relate the continuity on F-Spaces.	**K1, K2, K3**
CO4	Define a linear system and to solve the linear system of ordinary differential equations using the Fundamental Theorem for Linear Systems.	**K1, K3**
CO5	Describe the invariant sets and limiting behavior of the dynamical system, to solve the nonhomogeneous linear system of differential equations and to examine the dependence of the solution of the initial value problem.	**K2, K3, K4**

MAPPING WITH PROGRAMME OUTCOME(S):

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	L	M	L	S	L	S
CO2	S	S	S	S	M	S
CO3	M	S	M	S	S	S
CO4	S	S	S	S	M	M
CO5	M	S	S	M	M	M

S – Strong, **M –** Medium, **L -** Low

18URMAT0C02	ALGEBRA AND DESIGN THEORY	L	T	P	C
		4	1	0	4

OBJECTIVE: The objective of this course is to

- Study functorial properties of Hom and Tensor product.
- Introduce the concept of categories and functors.
- Study basic properties of projective, injective and flat modules.
- Introduce blockdesigns, resolvability and Latin squares.
- Introduce the concept of orthogonal Latin squares.

Unit I: Modules

Modules – free modules – exact sequences – homomorphisms – tensor product of modules – direct and inverse limits – pull back and push out.

Unit II: Categories and Functors

Categories – functors – equivalent categories - the functors Hom and Tensor.

Unit III: Projective and Injective Modules

Projective Modules – projective basis theorem - Injective Modules – Bear's Criterion – divisible modules - an embedding theorem.

Unit IV: Designs

Block designs – resolvability- Latin squares-pair wise balanced designs-systems of distinct representatives – finite fields – exercises.

Unit V: Orthogonal Latin Squares

Early results – orthogonal arrays – using pair wise balanced designs – the collapse of the Euler conjecture – transversal designs – transversal designs and orthogonal arrays – group divisible designs – exercises.

TEXT BOOKS:

1. **L.R.Vermani**, Elementary Approach to Homological Algebra, Chapman and Hall / CRC Monographs and Surveys in Pure and Applied Mathematics, Volume 130, CRC Press LLC, Florida, 2003.
2. **Ian Anderson**, *"Combinatorial Designs and Tournaments"*, Clarendon Press, Oxford, 1998.

UNIT	Chapter/Book	Section
I	I of [1]	1.1 to 1.7
II	II of [1]	2.1 to 2.3
III	III of [1]	3.1 to 3.4
IV	I of [2]	1.1 to 1.7
V	IV of [2]	4.1 to 4.8

REFERENCE BOOKS:

1. **T.Y. Lam**, *"Lectures on Modules and Rings"*, GTM Vol.189, Springer-Verlag, New York., Inc., 1999.
2. **F.W. Anderson and K.R. Fuller**, *"Rings and Categories of Modules"*, GTM Vol.13, Springar-Verlag, New York, Inc., 1992.
3. **L.H. Rowen**, *"Ring Theory"*, Academic Press, Inc., Sam Diego, CA.
3. **Yury J.Ionin and Mohan S, Shrikande**, "*Combinatorics of Symmetric Designs"*, Cambridge University Press, 2006
4. **Charles C. Lindner, C.A. Rodger**, *"Design Theory",* CRC Press, 2009.
5. **W.D Wallis**, *"Introduction to Combinatorial Designs"*, 2nd Edition, Chapman & Hall/ CRC, 2007.

COURSE OUTCOME: At the end of the course, students will be able to

CO	Statements	Knowledge level
CO1	Understand some basic results on modules and define pull back of a diagram and push out of a diagram in any abelian category.	**K1, K2**
CO2	Understand the concept of categories and functors	**K2, K3, K4**
CO3	Know the basic properties of projective, injective and flat modules.	**K4, K5**
CO4	Know how new design can be obtained from old.	**K3, K5**
CO5	Construct traversal designs and find the existence of pair wise balanced designs.	**K4, K6**

MAPPING WITH PROGRAMME OUTCOME(S):

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	L	M	L	S	L	S
CO2	S	S	S	S	M	S
CO3	M	S	M	S	S	S
CO4	S	S	S	S	M	M
CO5	M	S	S	M	M	M

S – Strong, **M –** Medium, **L -** Low

Specialization Course (Guide Paper) will be any one of the following:

18URMAT0E01	COMMUTATIVE ALGEBRA	L	T	P	C
		4	1	0	4

OBJECTIVE: The objective of this course is to

- Introduce homological methods in commutative algebra.
- Introduce localizations and give some applications.
- Study the basic properties of Notherian and Artinian rings.
- Introduce integral extensions and know results such as the going up and going down theorems, normalization theorem and the finiteness of integral closure.
- Study some basic results on completion such as Artin Rees Lemma, Krull's intersection theorem and Hensel's lemma.

UNIT I: Modules

Free modules – Direct sum of sub modules – Projective modules – Shanuel's Lemma – Tensor products – Flat modules – Faithfully flat modules.

UNIT II: Localisation

Ideals – Chinese remainder theorem – Extended and contracted ideals local rings – Nakayama Lemma – Localisation – Applications.

UNIT III: Noetherian Rings

Noetherian modules – Hilber's Basis theorem – Primary decomposition – first and second uniqness theorems – Artinian modules – structure of artinian rings – length of a module.

UNIT IV: Integral Extensions

Integral elements – integral extensions – goingup theorem – integrally closed domains – goindown theorem – finiteness of integral closure – Noether's Normalisation theorem – Valuation rings.

UNIT V: Integral Domain and completions

Discrete valuation rings – Dedekind domain – ramification formula – feltered rings and modules –completion – I-adic filtration – Krull's Intersection theorem – associated graded rings – Hensel's lemma.

TEXT BOOK:

1. **N.S. Gopala Krishnan**, Commutative Algebra, University Press, Hyderabad, india, 2016.

REFERENCE BOOKS:

1. **M.F. Atiyah** and **I.G. Macdonald**, Introduction to Commutative Algebra, Westview Press, Kolkata, India, 2007.
2. **N. Bourbaki**, Commutative Algebra, Chapter 1-7, Springer, 1985.
3. **I. Kaplansky**, Commutative Rings, Allyn and Abcon, Boston, 1970.
4. **H. Masumura**, Commutative Ring Theory, Cambridge Studies in Mathematics Vol.8, Cambridge University Press, Cambridge, 1985.
5. **M. Reid**, Undergraduate Commutative Algebra, LMS Student Texts, Vol. 29, Cambridge University Press, Cambridge, 1997.

COURSE OUTCOME: At the end of the course, students will be able to

CO	Statements	Knowledge level
CO1	Know projective modules which play the role of a vector space while studying linear algebra over a bigger field.	**K1, K2**
CO2	Understand the localization operation which is defined also for a module is to be well behaved with respect to quotients, tensor products and exact sequences.	**K2, K3**
CO3	Understand the concept of length which generalizes the concept of dimension of a vector space.	**K3, K5**
CO4	Know about the integral extensions which are well behaved with respect to extension and contraction of prime and maximal ideals.	**K4, K5**
CO5	Understand the generalized concept of valuation which is used to develop the concept of order of contact of two algebraic varieties along generalized branches.	**K5, K6**

MAPPING WITH PROGRAMME OUTCOME(S):

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	L	L	L	M	M	M
CO2	L	M	L	M	M	M
CO3	L	M	L	L	M	L
CO4	L	L	L	L	M	L
CO5	L	M	M	L	M	M

S – Strong, **M –** Medium, **L -** Low

****

18URMAT0E02	NON COMMUTATIVE ALGEBRA	L	T	P	C
		4	1	0	4

OBJECTIVE: The objective of this course is to

- Introduce the subject of the structure theory of associative rings and related structures.
- Give a very simple and clear approach to both classical and new results.
- Study the Jacobson radicals and its properties.
- Give the main applications of the fundamental theorem for finitely generated modules over principal ideal domains.
- Introduce the important notion of Goldie rings, local and semilocal rings.

UNIT I: Decompositions of Rings:

Modules and homomorphisms – classical isomorphism theorems – direct sums and products – finitely generated and free modules – two sided Peirce decomposition of a ring – the Wedderburn – Artin theorem – lattices, Boolean algebras and rings - finitely decomposable rings.

UNIT II: Artinian and Noetherian Rings:

Artinian and Noetherian modules and rings - the Jordan-Holder theorem – the Hilbert basis theorem – the radical of a module and a ring – the radical of Artinian rings – a criterion for a ring to be Artinian or Noetherian - Semiprimary rings.

UNIT III: Integral Domains

Principal ideal domains – factorial rings – Euclidean domains – Rings of fractions and quotient fields – Polynomial rings over fractional rings –Smith normal form over a PID – finitely generated modules over a PID – the Frobenius theorem.

UNIT IV: Dedekind Domains

Integral closure – Dedekind domains – hereditary domains – discrete valuation rings – finitely generated modules over Dedekind domains – Puüfier rings.

UNIT III: Goldie rings and Semiperfect rings

The Ore condition – classical rings of fractions – Prime and semiprime rings – Goldie rings – Goldie's theorem -Local and semilocal rings – noncommutative discrete valuation rings – lifting idempotent – semiperfect rings.

TEXT BOOK:

1. **M. Hazewinkel, N. Gubareni** and **V.V. Kirichenko, "***Algebras, Rings and Modules", Volume I*, Springer International Edition, New Delhi, 2011.

REFERENCE BOOKS:

1. **T.Y. Lam**, *"Lectures on Modules and Rings*", Graduate Texts in Mathematics, Vol. 189, Springer-Verlag, Berlin-Heidelberg, New York, 1999.
2. **J. Lambek,** *"Lectures on Rings and Modules*", 3rd Edition, AMS Chelsea Publishing, AMS, Providence, Rhode Island, 2009.
3. **D.S. Passman,** *"A Course in Ring Theory"*, AMS Chelsea Publishing, AMS, Providence, Rhode Island, 2004.
4. **P.E. Bland**, *"Rings and their Modules*", Walter de GmbH Co.KG, Berlin New York, 2011.
5. **J.C. Mc Connel** and **J.C. Robson**, *"Noncommutative Noetherian Rings*", Graduate Studies in Mathematics, Vol.30, AMS, Providence, 2001.

COURSE OUTCOME: At the end of the course, students will be able to

CO	Statements	Knowledge level
CO1	Learn non commutative algebra from the beginning to research level.	**K1, K2**
CO2	Know any decomposition of a module into a direct sum of sub modules has a close connection with idempotent of the ring.	**K2, K3**
CO3	Understand the theory of divisibility in some commutative domains factorization.	**K2, K4**
CO4	Know the main properties of Dedekind domains and Prüfer rings and describe finitely generated modules over Dedekind domains.	**K4, K5**
CO5	Know which rings have classical rings of fractions that are semisimple.	**K4, K5**

MAPPING WITH PROGRAMME OUTCOME(S):

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	M	S	M	S	S	M
CO2	M	M	M	S	S	M
CO3	L	M	M	M	M	M
CO4	S	S	S	S	S	M
CO5	L	L	L	L	M	L

S – Strong, **M –** Medium, **L -** Low

****

18URMAT0E03	ADVANCED TOPOLOGY	L	T	P	C
		4	1	0	4

OBJECTIVE: The objective of this course is to

- Study the factorial relation of fundamental group to covering space.
- Develop some machinery this will enable us to compute the fundamental group of a large class of spaces.
- Construct the Stone-Čech Compactification of a completely regular space.
- See how paracompactness generalizes compactness and to construct Peano space-filling curve.
- Study another formulation of compactness for metric space, one that involves the notion of completeness.

UNIT I:

Fundamental Group and covering spaces: Homotopy, Fundamental Group and Covering Spaces.

(Chapter 3 (Sections 3.1, 3.2 and 3.3) from [**1**])

UNIT II:

Simplical Complexes: Geometry of simplical complexes, Barycentric subdivisions, Simplical approximation theorem.

(Chapter 4 (Sections 4.1, 4.2 and 4.3) from [**1**])

UNIT III:

The Tychonoff Theorem: The Tychonoff theorem, The Stone-Čech Compactification. Metrization theorems and Para compactness: Local Finiteness, The Nagata – Smirnov Metrization theorem.

(Chapter 5 (Sections 37, 38), Chapter 6 (Sections 39, 40) from [**2**])

UNIT IV:

Para Compactness, The Smirnov Metrization theorem. Complete Metric spaces and Function spaces: Complete metric spaces, A space-filling curve.

(Chapter 6 (Sections 41, 42), Chapter 7 (Sections 43, 44) from [**2**])

UNIT V:

Compactness in Metric spaces, Pointwise and compact convergence, Ascoli's theorem.

(Chapter 7 (Sections 45, 46 and 47) from [**2**])

TEXT BOOKS:

1. **M. Singer** and **J. A. Thorpe**, "Lecture Notes on Elementary Topology and Geometry", Springer – Verlag, New York, 1967. (Units I & II)
2. **James R. Munkres**. , "Topology", Pearson Education Limited, 2009. (Units – III to V)

REFERENCE BOOKS:

1. **Bert Mendelson**, Introduction to Topology, 3rd Edition, Dover publications, 1990.
2. **T.W. Gavnelin** and **R.E. Green**, Introduction to Topology, 2nd Edition, Dover Publications, 1997.
3. **G.E. Bredon**, Topology and Geometry, GTM Vol. 139, Springer-Verlag, 1993.
4. **J. Milnor**, Topology from the Differential Viewpoint, Revised Edition, Princeton University press, 1997.
5. **A.R. Kosinsk**, Differential Manifolds, Dover publications, 2007.

COURSE OUTCOME: At the end of the course, students will be able to

CO	Statements	Knowledge level
CO1	Describe fundamental group and covering space of a (Hausdorff) topological space.	**K1, K2**
CO2	Compute the fundamental group of a large class of spaces.	**K2, K3**
CO3	Examine under what conditions does a metrizable space have a metrizable compactification.	**K4**
CO4	Evaluate a partition of unity on an arbitrary paracompact Hausdorff space.	**K5**
CO5	Generalize the Ascoli's theorem.	**K6**

MAPPING WITH PROGRAMME OUTCOME(S):

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	L	L	L	M	M	M
CO2	M	M	M	M	M	M
CO3	L	L	L	L	L	S
CO4	L	L	M	M	M	M
CO5	L	L	L	M	M	S

S – Strong, **M –** Medium, **L -** Low

****

18URMAT0E04	ADVANCED TOPICS IN GRAPH THEORY	L	T	P	C
		4	1	0	4

OBJECTIVE: The objective of this course is to

- Provide wide exposure to various current research topics in graph theory.
- Impart basics and important properties on each topic in the course.
- Motivate the students towards Research in the field of graph theory by imparting applications involved in the topics concerned.

UNIT I:

Perfect graphs.

UNIT II:

Other classes of perfect graphs.

UNIT III:

Labeling of graphs.

UNIT IV:

Factorizations and decompositions.

UNIT V:

Domination in graphs.

TEXT BOOKS:

1. **D.B. West**, Introduction to Graph Theory, Prentice Hall Publication Ltd, 2002.
   Unit – I & II – Chapter 8.1 (Imperfect graphs excluded)
2. **G. Chartrand** and **L. Lesniak**, Graphs and Digraphs, Chapen & Hall / CRC press, 1996.
   UNIT III – Chapter 9; Section 3
   UNIT IV – Chapter 9; Section 2
   UNIT V – Chapter 10; Section 1 and 2

REFERENCE BOOKS:

1. **R. Balakrishnan** and **K. Ranganathan**, A TREATMENT AS IN of Graph Theory, Springer, 2000.
2. **A. Gibbons**, Algorithmic Graph Theory, Cambridge University Press, Cambridge, 1989.

3. **R.J. Wilson** and **J.J. Watkins**, Graphs: An Introducing Approach, John Wiley and sons, New York, 1989.
4. **K.R. Parthasarathy**, Basic Graph Theory, Tata Mc – Graw Hill Publishing Company New Delhi, 1994.

COURSE OUTCOME: At the end of the course, students will be able to

CO	Statements	Knowledge level
CO1	Clarify /identify the classes of graphs which are perfect / imperfect after applying related basic properties and the class of forbidden subgraphs.	**K1, K2, K3 K4**
CO2	Solve some exercise problems /open problem in the area of graph labeling by applying the known ideas in this area.	**K1, K2, K3**
CO3	Know various important results on decomposition of graphs and the necessary and sufficient conditions for the existence of required decomposition even by applying labeling techniques studied earlier.	**K2, K3, K4**
CO4	Know various parameters of domination and the relation between them. Further by applying the known properties, one may able to attack the existing open problems like Vizing's conjecture and some other in product graphs.	**K1, K3, K5**
CO5	Have a domain knowledge of knowing various potential research areas in the field of graph theory. Attack open problem by combining more than one topic studied in this course.	**K3, K4, K5**

MAPPING WITH PROGRAMME OUTCOME(S):

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	L	L	M	S	S
CO2	L	M	L	S	M	L
CO3	M	S	S	M	S	S
CO4	L	M	M	M	S	S
CO5	S	S	M	S	M	S

S – Strong, **M –** Medium, **L -** Low

****

18URMAT0E05	GEOMETRIC FUNCTION THEORY	L	T	P	C
		4	1	0	4

OBJECTIVE: The objective of this course is to

- Provide a strong foundation on the geometric behaviors of analytic univalent functions.
- Understand the conformal mapping properties and its various class of functions.
- Introduce subordination technique to unifies those classes.
- Create interest among students to take a research career in the field of GFT.

UNIT I: Elementary Theory of Univalent Functions

Basic Principles – Local mapping properties – Normal families – Extremal problems – The Riemann mapping theorem – Analytic continuation – The area theorem-growth and distortion theorem-coefficients estimates – convex and starlike functions – close-to-convex functions –Exercises.

(Section 1.1 – 1.6; 2.1 – 2.6 from **[1]**)

UNIT II: Some Theorems on Power Series

Coefficients for the Area theorem – Coefficients for the inverse of a function – Transformation of the range from the unit disk to the right half-plane – problems.

(Chapter 3 from **[1]**)

UNIT III: Subordination

Basic principles – coefficient inequalities – sharpened forms of the Schwarz lemma – Majorization – univalent subordination functions – Exercises.

(Section 6.1 – 6.5 from **[1]**)

UNIT IV: Convex and Starlike Functions

Convexity and starlikeness on a curve - functions univalent in the unit disk – Ford's theorem - Alexander's theorem -Sharp bounds for the coefficients – Two radius problems - Integral representations - The Schwarz – Christoffel transformation. Univalent functions with real coefficients.

(Chapter 8 from **[2]**)

UNIT V: Typically – Real Valued Functions

The region of values at a point - Functions that are convex in one direction - functions with positive real part and real coefficients.

(Section 2.8 from **[1]**; Chapter 10 from **[2]**)

TEXT BOOKS:

1. **P. L. Duren**, Univalent Functions, Springer-Verlag, New York, 1984.
2. **A. W. Goodman**, Univalent Functions, Vol - I & II, Mariner Publication company, Florida, 1984.

REFERENCE BOOKS:

1. **Graham, G. Kohr**, Geometric Function Theory in One and Higher Dimensions, Marcel Dekker Inc., New York-Basel, 2003.
2. **Ch. Pommerenke**, Univalent Functions, Vanderhoeck and Ruprecht, Gottingen,1975.

COURSE OUTCOMES: At the end of the course, students will be able to

CO	Statements	Knowledge level
CO1	Promote the analyzing skill.	**K1, K2**
CO2	Understand elementary theory in conformal mapping.	**K1, K2**
CO3	Solve research problems in GFT by suitable approach.	**K2, K3**
CO4	Apply Complex Analysis tools to solve problems in GFT.	**K2, K3**
CO5	Classify behaviors of functions through its geometric properties.	**K2, K4**

MAPPING WITH PROGRAMME OUTCOME(S):

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	M	S	M	M	M
CO2	M	M	M	S	M	L
CO3	M	M	M	M	L	L
CO4	S	M	M	M	M	M
CO5	M	M	M	M	L	L

S – Strong, **M –** Medium, **L -** Low

******

18URMAT0E06	FUNCTIONAL EQUATIONS	L	T	P	C
		4	1	0	4

OBJECTIVE: The objective of this course is to

- Introduce the additive Cauchy, Jensen and Paxider's functional equations and determine their solutions.
- Study biadditive functions, quadratic functions and the quadratic functional equations.
- Present some important results concerning these trigonometric functional equations and some other related functional equations.
- Study the stability of the positive additive functional equations and the stability of homomorphisms and derivations in proper CQ* - algebras associated with functional inequalities.

UNIT I: Additive Cauchy Functional Equations

Introduction – Functional Equations – Solution of Additive Cauchy Functional Equation – Discontinuous Solution of Additive Cauchy Equation – Other Criteria for Linearity – Additive Functions on the Complex plane – Jensen and Pexider's Functional Equations.
(Chapter 1-Scetions: 1.1 – 1.6; Chapter 7-Sections: 7.1-7.4 and Chapter 8-Sections: 8.1-8.4 from **[1]**)

UNIT II: Quadratic Functional Equation and its Stability

Introduction – Biadditive Functions – Continuous Solution of Quadratic Functional Equations – A Representation of Quadratic Functions – Pexiderization of Quadratic Equation – Stability of Quadratic Equation – Stability of Generalized Quadratic Equation – d'Alembert Functional Equations and Hosszu Functional Equation. (Chapter 9 - Sections: 9.1-9.5, Chapter 10 – Sections 10.1 – 10.4, Chapter 13 – Sections: 13.1 – 13.3 and Chapter 21-Sections: 21.1 -21.4 from **[1]**)

UNIT III: Remaining Cauchy Functional Equations

Introduction – Solution of Exponential Cauchy Equation – Solution of the Logarithmic Cauchy Equation – Solution of the Multiplicative Cauchy Equation.
(Chapter 2-Sections: 2.1-2.4 from **[1]**)

UNIT IV: Trigonometric Functional Equations

Introduction – Solution of a Cosine-Sine Functional Equation – Solution of a Sine – Cosine Functional Equation - Solution of a Sine Functional Equation – Solution of a Sine Functional Inequality – An Elementary Functional Equation.

(Chapter 11: Sections: 11.1-11.6 from **[1]**)

UNIT V: Banach Algebras – Hyers –Ulam Stability

Stability of the Positive – Additive Functional Equations: The Fixed Point Method – Stability of the Positive – Additive Functional Equations: The Direct Method - *-Homomorphism in JC*-Algebras – Stability of *-Homomorphism in JC*-Algebras – Stability of C-Linear Mappings in Banach Spaces – Stability of Homomorphism in Proper CQ*-Algebras – Stability of Derivations in Proper CQ*-Algebras – Functional Equations and Their Applications.

(Chapter 3-Sections: 3.10-3.11; Chapter 4- Sections: 4.1 from **[1]**) and

(Chapter 4: Sections: 4.1 -4.2 from **[2]**)

TEXT BOOKS:

1. **Prasanna K. Sahoo** and **Palaniappan Kannappan**, Introduction to Functional Equations, Taylor & Francis Group, London, 2011.
2. **Yeol Je Cho, Choonkil Park, Themistocles M. Rassias,** and **Reza Saadati**, Stability of Functional Equations in Banach Algebras, Springer –Verlag, New York, 2015.

REFERENCE BOOKS:

1. **J. Aczel**, Lectures on Functional Equations and their Applications, Academic Press, New York, 1966.
2. **E. Castilo** and **M.R. Ruiz-Cobo**, Functional Equations and Modelling in Science and Engineering, Marcel Dekker, Inc., 1992.
3. **Marek kuczma**, An Introduction to the theory of Functional Equations and Inequalities: Cauchy's Equation and Jensen's Inequality, Birkhauser, 2009.
4. **S. Czerwik**, Functional Equations and Inequalities in Several Variables, World Scientific, Singapore, 2002.
5. **D.H. Hyers, G. Issac** and **Th. M. Rassias**, Stability of Functional Equations in Several Variables, Birkhauser, Basel, 1998.

COURSE OUTCOMES: At the end of the course, students will be able to

CO	Statements	Knowledge level
CO1	Give continuous solution of the Jensen functional equation.	**K2, K3**
CO2	Examine the solution of the d'Alembert Functional Equation and Hosszu Functional Equation.	**K3, K4**

CO3	Determine all the functions that satisfy three Cauchy functional equations.	**K3, K4**
CO4	Find the general solution of the trigonometric functional equations.	**K4, K5**
CO5	Analyze the stability of the positive additive functional equations and approximate the homomorphisms in Proper CQ*-Algebras and derivations on proper CQ* - algebras.	**K4, K5**

MAPPING WITH PROGRAMME OUTCOME(S):

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	M	M	M	L	S	L
CO2	M	M	M	L	M	L
CO3	L	L	M	L	M	L
CO4	M	L	M	L	M	L
CO5	S	M	S	M	M	M

S – Strong, **M –** Medium, **L -** Low

****

18URMAT0E07	**MATHEMATICAL MODELLING**	L	T	P	C
		4	1	0	4

OBJECTIVE:

Population models are used to determine maximum harvest for agriculturists, to understand the dynamics of biological invasions, and for environmental conservation. Population models are also used to understand the spread of parasites, viruses, and disease. The aim of this course is know to how mathematical modelling can be used in different areas of biology. Also, it analyses the dynamical behaviors and Turing instability of reaction diffusion equations in biology.

UNIT I: Continuous Population Models

Continuous Growth Models - Insect Outbreak Model: Spruce Budworm - Delay Models - Linear Analysis of Delay Population Models: Periodic Solutions.

Reaction Diffusion – Chemotaxis: Simple Random Walk and Derivation of the Diffusion Equation - Reaction Diffusion Equations – Chemotaxis.

UNIT II: Models for Interacting Populations

Predator–Prey Models: Lotka–Volterra Systems - Complexity and Stability - Realistic Predator–Prey Models - Analysis of a Predator–Prey Model with Limit Cycle Periodic Behaviour: Parameter Domains of Stability - Competition Models: Competitive Exclusion Principle - Mutualism or Symbiosis - General Models and Cautionary Remarks - Threshold Phenomena.

UNIT III: Reaction Kinetics

Enzyme Kinetics: Basic Enzyme Reaction - Transient Time Estimates and Nondimensionalisation - Michaelis–Menten Quasi-Steady State Analysis - Suicide Substrate Kinetics - Cooperative Phenomena - Autocatalysis, Activation and Inhibition - Multiple Steady States, Mushrooms and Isolas.

UNIT IV: Dynamics of Infectious Diseases

Historical Aside on Epidemics-Simple Epidemic Models and Practical Applications-Modelling Venereal Diseases - Multi-Group Model for Gonorrhea and Its Control - AIDS: Modelling the Transmission Dynamics of the Human Immunodeficiency Virus (HIV) - HIV: Modelling Combination Drug Therapy - Delay Model for HIV Infection with Drug Therapy - Modelling the Population Dynamics of Acquired Immunity to Parasite Infection.

UNIT V: Spatial Pattern Formation with Reaction Diffusion Systems

Role of Pattern in Biology - Reaction Diffusion (Turing) Mechanisms - General Conditions for Diffusion-Driven Instability: Linear Stability Analysis and Evolution of Spatial Pattern - Detailed Analysis of Pattern Initiation in a Reaction Diffusion Mechanism - Dispersion Relation, Turing Space, Scale and Geometry Effects in Pattern Formation Models - Mode Selection and the Dispersion Relation - Pattern Generation with Single-Species Models: Spatial Heterogeneity with the Spruce Budworm Model - Spatial Patterns in Scalar Population Interaction Diffusion Equations with Convection: Ecological Control Strategies - Nonexistence of Spatial Patterns in Reaction Diffusion Systems: General and Particular Results.

TEXT BOOKS:

1. **J.D. Murray, "**Mathematical Biology I: An Introduction", Springer-Verlag, New York, 2002.
2. **J.D. Murray, "**Mathematical Biology II: Spatial Models and Biomedical Applications", Springer-Verlag, New York, 2003.

REFERENCE BOOKS:

1. **A. D. Bazykin,** "Nonlinear Dynamics of Interacting Populations", World Scientific, 1998.
2. **N. Britton,** "Essential Mathematical Biology", Springer Science & Business Media, 2012.
3. **J.N.Kapur,** "Mathematical Models in Biology And Medicine", Affiliated East–West, New Delhi, 1985.

COURSE OUTCOMES: At the end of the course, students will be able to

CO	Statement	Knowledge Level
CO1	Know basic concepts of Continuous time models, Growth models, Logistic model, Delay models. Reaction Diffusion Equations – Chemotaxis.	**K1**
CO2	Understand the concepts of Lotka-Volterra Prey-Predator model and study the stability and dynamical properties.	**K1,K2**
CO3	Drive the Enzyme kinetics reaction with Michaelis–Menten and autocatalysis, activation and inhibition.	**K1,K4**
CO4	Develop the epidemic and SIS diseases, SIR Epidemics, SIR Endemics and its behavior. Also develop the transmission dynamics of the Human Immunodeficiency Virus (HIV) model.	**K1,K3**
CO5	Apply the concepts of Pattern (Turing instability) Mechanisms into reaction diffusion equations in population dynamics with general and particular results.	**K1,K3**

MAPPING WITH PROGRAMME OUTCOME(S):

CO \ PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	L	L	L	L	S	S
CO2	M	L	L	M	S	S
CO3	L	L	L	M	S	S
CO4	S	M	L	M	S	S
CO5	S	S	S	S	S	S

S – Strong, **M –** Medium, **L -** Low

****

18URMAT0E08	ORDINARY DIFFERENTIAL AND DIFFERENCE EQUATIONS	L	T	P	C
		4	1	0	4

OBJECTIVE: The objective of the course is to

- Study comparison theorems for second order ordinary equations.
- Study different kinds of oscillation criteria and asymptotic behavior of ordinary and neutral differential equations.
- Study linear difference equations of higher order and system of difference equations with applications.

UNIT I: Sturm-Type Theorems for Second Order Ordinary Equations

Comparison Theorems for Self - Adjoint Equations - Additional Results of Leighton - Extension to General Second Order Equations - Comparison Theorems for Singular Equations - Comparison Theorems for Eigen functions.

(Chapter 1: Sections 1 - 5 of [1])

UNIT II: Oscillation and Non-oscillation Theorem for Second Order Ordinary Equation

The Oscillation Criteria of Hille and Nehari - Conditionally Oscillatory Equations - Nehari's Comparsion Theorems - The Hille-Winter Comparision Theorem - Hille Necessary and Sufficient Conditions for Nonoscillatory Equations -Leighton's Oscillation Criteria - Potter's Oscillation Criteria - Hille's Kneser-Type Oscillation Criteria - Nonoscillation Theorems of Hartman and Wintner - Nonoscillation criteria for Hille's Equation.

(Chapter 2: Sections 1 – 9 and 11 of [1])

UNIT III: Oscillations of Neutral Differential Equations

Oscillations and asymptotic behaviour of scalar neutral delay differential equations - Oscillations of scalar neutral equations with mixed arguments - Necessary and sufficient conditions for the oscillation of systems of neutral equations - Oscillations of scalar neutral equations with variable coefficients - Differential inequalities and comparison theorems - Linearized oscillations for neutral equations - Existence of positive solutions - Oscillations in neutral delay logistic differential equations - Oscillations in non-autonomous equations with several delays -Oscillations in a system of neutral equations.

(Chapter 6: Sections 6.1 – 6.10 of [2])

UNIT IV: Linear Difference Equations of Higher Order

Difference Calculus – General Theory of Linear Difference Equations – Linear Homogeneous Equations with Constant Coefficients – Linear Non homogeneous Equations: Method of Undetermined Coefficients – Limiting Behavior of Solutions – Nonlinear Equations Transformable to Linear Equations - Applications.

(Chapter 2: Sections 2.1 – 2.7 of [3])

UNIT V: Systems of Difference Equations

Autonomous Systems – The Basic Theory – The Jordan Form: Autonomous Systems Revisited – Applications.

(Chapter 3: Sections 3.1 – 3.5 of [3])

TEXT BOOKS:

1. **C. A. Swanson**, Comparison and Oscillation Theory of Linear Differential Equations, *Academic Press, New York and London*, 1968.
2. **I. Gyori** and **G. Ladas**, Oscillation Theory of Delay Differential Equations with Applications, *Clarendon Press, Oxford*, 1991.
3. **Saber Elaydi**, An Introduction to Difference Equations, 2nd edition, Trinity University, *San Antonio, Texas, 1995*.

REFERENCE BOOKS:

1. **K. Gopalsamy** and **Kluwer**, Stability and Oscillations in Delay Differential Equation of Population Dynamics, *Academic Publishers*, 1992.
2. **S. H. Saker**, Oscillation theory of delay differential and difference equations, VDM Verlag Dr.Muller Aktiengesellschaft and Co, *USA*, 2010.
3. **K.S. Miller**, Linear Difference Equations, New York, 1968.
4. **W.G. Kelley** and **A.C. Peterson**, Difference Equations, An Introduction with Applications, Academic Press, New York, 1991.

COURSE OUTCOME: At the end of the course, students will be able to

CO	Statements	Knowledge level
CO1	State comparison theorems for different kinds of second order ordinary equations and to illustrate them by suitable examples.	**K1, K2**
CO2	State and apply various oscillation and nonoscillation criteria for investigating the zeros of solutions of second order ordinary equations.	**K1, K3**
CO3	Identify neutral delay differential equations and to determine the oscillation and asymptotic behavior of various types of neutral delay differential equations.	**K1, K4**

CO4	Define basic properties of difference operator, to solve linear difference equations and to examine the stability and oscillatory behavior of second-order difference equations.	**K1, K3, K4**
CO5	Recall Cayley–Hamilton theorem, to apply Putzer algorithm and to solve the system of linear difference equations.	**K1, K3**

MAPPING WITH PROGRAMME OUTCOME(S):

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	M	S	M	S	S	S
CO2	S	S	M	S	S	S
CO3	S	S	M	S	S	S
CO4	S	S	M	S	S	S
CO5	S	S	M	S	S	S

S – Strong, **M –** Medium, **L -** Low

****

		L	T	P	C
18URMAT0E09	**FRACTIONAL DIFFERENTIAL EQUATIONS**	4	1	0	4

OBJECTIVE: The objective of the course is to

- Introduce various kinds of fractional derivatives.
- Study the properties of fractional derivatives.
- Study the Existence and uniqueness results of fractional differential equations.

UNIT I: Grunwald-Letnikov Fractional Derivatives

Unification of integer-order derivatives and integrals – Integrals of arbitrary order – Derivatives of arbitrary order – Fractional derivative of (t – a)^β - Composition with integer- order derivatives – Composition with fractional derivatives.

Unit-II: Riemann – Liouville Fractional Derivatives

Unification of integer-order derivatives and integrals – Integrals of arbitrary order – Derivatives of arbitrary order – Fractional derivative of (t – a)^β - Composition with integer- order derivatives – Composition with fractional derivatives – Link to the Grunwald – Letnikov Approach.

Unit-III: Properties of Fractional Derivatives

Linearity – The Leibniz rule for fractional derivatives – Fractional derivative of a composite function – Riemann–Liouville fractional differentiation of an integral depending on a parameter – Behaviour near the lower terminal - Behaviour far from the lower terminal.

Unit-IV: Some other Approaches and Laplace Transforms of Fractional Derivatives

Caputo's fractional derivative – Generalized functions approach - Sequential fractional derivatives – Left and right fractional derivatives – Basic facts on the Laplace transform - Laplace transform of the Riemann–Liouville fractional derivative - Laplace transform of the Caputo derivative - Laplace transform of the Grunwald – Letnikov fractional derivative - Laplace transform of the Miller-Ross sequential fractional derivative.

Unit-V: Existence and Uniqueness Theorems

Linear fractional differential equations - Fractional differential equations of a general form - Existence and uniqueness theorem as a method of solution – Dependence of a solution on initial conditions.

TEXT BOOK:

1. **I. Podlubny**, Fractional Differential Equations, Academic press, London, 1999.

REFERENCE BOOKS:

1. **K.S. Miller and B.Ross**, An introduction to the Fractional Calculus and Fractional Differential Equations, John Wiley & Sons, New York, 1993.
2. **A. A. Kilbas, H. M. Srivastava** and **J. J. Trujillo**, Theory and Applications of Fractional Differential Equations, Elsevier, Amsterdam, 2006.

COURSE OUTCOME: At the end of the course, students will be able to

CO	Statements	Knowledge level
CO1	Explain how the integer order derivatives and integrals are generalized and to identify the properties of Grunwald-Letnikov Fractional Derivatives.	**K1, K2**
CO2	Define the Riemann – Liouville Fractional Derivative and to relate the Riemann – Liouville and the Grunwald-Letnikov approaches to differentiation of arbitrary real order.	**K1, K3**

CO3	State and Apply the properties of fractional derivatives.	**K1, K3**
CO4	Understand the link between Riemann – Liouville and the Caputo approaches, and to determine the Laplace Transforms of all kinds of fractional derivatives.	**K2, K4**
CO5	Apply the Existence and Uniqueness theorem as a method of solution of fractional differential equations and to examine the dependence of a solution on initial conditions.	**K3, K4**

MAPPING WITH PROGRAMME OUTCOME(S):

CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	S	S	M	S	S	S
CO2	S	S	M	S	S	S
CO3	S	S	M	S	S	S
CO4	S	S	M	S	S	S
CO5	S	S	M	S	S	S

S – Strong, **M –** Medium, **L -** Low

****

18URMAT0E10	**THEORY OF PARTIAL DIFFERENTIAL EQUATIONS**	L	T	P	C
		4	1	0	4

OBJECTIVE: The objective of this course is to

- Provide a strong foundation on the fundamental theory of partial differential equations (PDEs) in particular Laplace, heat and wave equations.
- Make understand some of the important mathematical methods and tools to obtain solutions to PDEs.
- Introduce variational methods to solve PDEs using functional analysis tools.
- Create interest among students to take a research career in the field of PDEs.

UNIT I: Linear Partial Differential Equations

Laplace equation: Fundamental solution – Mean-value formulas – Properties of harmonic functions – Green's functions - Heat equations: Fundamental solution – Mean-value formula – Properties of solutions.

(Section 2.2 - 2.2.1 – 2.2.4 only, 2.3 – 2.3.1 – 2.3.3 from [1])

UNIT II: Other Ways to Represent Solutions

Separation of variables – Similarity solutions – Transform methods.

(Sections 4.1 – 4.3 only from [1])

UNIV III: Distributions

Preliminary ideas - Test Functions and Mollifiers – Distributions – Calculus – Fourier Transforms.

(Sections 7.1 – 7.4, 7.6 from [2])

UNIT IV: Sobolev Spaces

An abstract construction - Approximations by Smooth Functions and Extensions – Traces.

(Sections 7.7, 7.8, 7.9 only from [2])

Unit V: Variational Formulation of Elliptic Problems

Elliptic equations – Poisson problem – Diffusion, Drift and Reaction – Variational formulation of Poisson's problem – Dirichlet problem - Neumann, Robin and mixed problems – Regularity.

(Sections 8.1, 8.2, 8.3, 8.4 – 8.4.1, 8.4.2, 8.6 only from [2])

TEXT BOOKS:

1. **L. C. Evans,** Partial Differential Equations, Graduate studies in Mathematics, Volume 19, American Mathematical Society, 2009.
2. **S. Salsa,** Partial Differential Equations in Action: From Modelling to Theory, Springer, Milan, 2008.

REFERENCE BOOKS:

1. **R.A. Adams** and **J.F.Fournier**, Sobolev Spaces, Academic Press, New York, Second Edition, 2003.
2. **H. Brezis**, Functional Analysis, Sobolev Spaces and Partial Differential Equation, Springer, 2011.
3. **S. Kesavan**, Topics in Functional Analysis and Applications, New Age International, New Delhi, 2015.
4. **R.C.McOwen**, Partial Differential Equations: Methods and Applications, Second Edition, Pearson Education, New Delhi, 2005.

COURSE OUTCOMES: At the end of the course, students will be able to

CO	Statements	Knowledge level
CO1	Understand mathematical questions and research problems in PDEs.	**K1, K2**

CO2	Obtain solutions to PDEs through existing methods	**K1, K2**
CO3	Apply functional analysis tools to solve problems in partial differential equations (PDEs).	**K2, K3**
CO4	Classify classical and weak solutions of PDEs.	**K2, K4**
CO5	Make an attempt to solve research problems in PDEs by incorporating suitable mathematical assumptions.	**K2, K5**

MAPPING WITH PROGRAMME OUTCOME(S):

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	M	M	L	M	M	L
CO2	S	S	S	M	M	S
CO3	L	S	L	S	S	S
CO4	L	M	S	S	S	S
CO5	S	M	S	M	M	S

S – Strong, **M –** Medium, **L -** Low

******

		L	T	P	C
18URMAT0E11	**ADVANCED TOPICS IN FLUID DYNAMICS**	4	1	0	4

OBJECTIVE:

The objective of the course is to acquire the knowledge of fluid dynamics and also the analyze the fluid flow problems in the diverse real life applications.

UNIT I:

Some features of viscous flows: Real and ideal fluids – Viscosity - Reynolds number – Laminar and turbulent flows – Asymptotic behavior at large Reynolds number. Boundary layer theory: Boundary layer concepts – Laminar boundary layer on a flat plate – Turbulent boundary layer on a flat plate – Fully developed turbulent flow in a pipe.

UNIT II:

Field Equations for flows of Newtonian field : Continuity equation – Momentum equation - Navier Stokes equation – Energy equation – Equation of motion for arbitrary co- ordinate systems – Exact solution of Navier stokes equation – Steady plane flows : Couette – Poiseuille flow – Flow past a circular cylinder – Steady axisymmetric flows – Circular Pipe flow - Flow between two concentric rotating cylinders.

UNIT III:

Thermal boundary layers in laminar flow: Derivation of the energy equation – Temperature increase through adiabatic compression - Stagnation temperature – Theory of similarity in heat transfer - Exact solutions for the problem of temperature distribution in a viscous flow - Boundary layer simplifications.

UNIT IV:

Magnetohydrodynamics: Electrodynamics of moving media – The electromagnetic effects and the magnetic Reynolds number - Alfven's theorem – The magnetic energy - The mechanical equations - Basic equations for the incompressible MHD - Steady Laminar motion - Hartmann flow.

UNIT V:

Magnetohydrodynamic waves - waves in an infinite fluid of infinite electrical conductivity -Alfven waves – Magnetohydrodynamic waves in a compressible fluid - Magneto acoustic waves- Slow and Fast waves - Stability - Physical concepts – Linear Pinch-Kink - Sausage and Flute types of instability - Method of small oscillations – Jeans criterion for gravitational stability.

TEXT BOOKS:

1. **H. Schlichting**, and **K. Gersten**, Boundary - Layer Theory, Springer-Verlag, New York, 2003, Relevant topics from chapter 1,2,3,5 and 12.
2. **V. C. A. Ferraro** and **C. Plumpton**, An Introduction to Magneto Fluid Dynamics, Oxford: Clarendon Press, 1966, Relevant topics from Chapters 1,2,3 and 5.

REFERENCE BOOKS:

1. **P. A. Davidson**, An Introduction to Magneto hydrodynamics, Cambridge University Press, Cambridge, 2001.
2. **P. K. Kundu**, I. M. Cohen, Fluid Mechanics, Academic Press, London, 2002.

COURSE OUTCOMES: At the end of the course, students will be able to

CO	Statements	Knowledge level
C01	Establish an understanding of the fundamental concepts of fluid and its properties.	**K1**

C02	Understand the principles of governing equation of motion and its behaviour in static and dynamics region.	**K2, K4**
C03	Acquire the knowledge on two dimensional flow and also understand the various types flow pattern.	**K3**
C04	Get idea about nonlinear equation and analyze the approximate solution in boundary layer flow and also in different flow region.	**K4, K6**
C05	Analyze fluid flow problems with the application of the momentum and energy equations.	**K3, K5**

MAPPING WITH PROGRAMME OUTCOME(S):

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	S	L	M	M	M
CO2	M	M	S	S	M	L
CO3	L	L	M	S	S	M
CO4	L	L	S	M	S	S
CO5	L	L	S	M	S	S

S – Strong, **M –** Medium, **L -** Low

****

18URMAT0E12	**FUZZY SETS: THEORY AND APPLICATIONS**	L	T	P	C
		4	1	0	4

OBJECTIVE:

The objective of the course is to inculcate the ideas of fuzzy and intuitionistic fuzzy sets with respect to the operations, measures, graphs and patterns with applications to the real time problems.

UNIT I:

CRISP SETS AND FUZZY SETS: Introduction –Crisp Sets: An Overview-The Notion of Fuzzy Sets - Classical Logic: An Overview –Fuzzy Logic. OPERATIONS ON FUZZY SETS: General Discussion –Fuzzy Complement-Fuzzy Union –Fuzzy Intersection – Combinations of Operations – General Aggregation Operations. FUZZY MEASURES: Belief and Plausibility measures- Probability measures – possibility and Necessity measures.

UNIT II:

FUZZY SYSTEMS: General Discussion – Fuzzy Controllers: An Overview – Fuzzy Controllers: An Example – Fuzzy Systems and Neural Networks – Fuzzy Automata – Fuzzy Dynamic Systems. PATTERN RECOGNITION: Introduction – Fuzzy clustering-Fuzzy pattern Recognition - Fuzzy Image Processing. APPLICATIONS: General Discussion - Natural,life, and Social Sciences-Engineering –Medicine-Management and Decision Making - Computer Science-Systems Science - Other Applications.

UNIT III:

FUZZY GRAPHS: Introduction – Operations on fuzzy Graphs – Cartesian Product and Composition – Union and Join paths and Connectivity- Bridges and Cut Vertices- Forests and trees- Trees and cycles- A Characterization of Fuzzy Trees – Fuzzy Cut Sets- Fuzzy Chords- Fuzzy Cotrees - Fuzzy Line Graphs-Fuzzy Interral Graphs- Fuzzy Intersection Graphs-The Fulkerson and Gross Characterization-The Gilmore and Hoffman Characterization.

UNIT IV:

INTUITIONISTIC FUZZY SETS: Definition - operations and Relations-Properties - Intuitionistic Fuzzy sets of a Certain Level - Necessity and possibility Operators – Topological Operators- Geometrical Interpretations.

UNIT V:

INTUITIONISTIC FUZZY RELATIONS: Cartesian Products over IFSS – Index Matrix-Basic Definition and properties - Other Definitions and properties - Intuitionistic Fuzzy Index Matrices- Intuitionistic Fuzzy Relations- Intuitionistic Fuzzy Graphs – Example- Experts who order Alternatives –Measurement tools that Evaluate Alternatives- Some Ways of Determining Membership and Non-membership Functions.

TEXT BOOKS:

1. **George J. Klir** and **Bo Yuan**, Fuzzy sets and fuzzy logic: Theory and Applications Prentice Hall of India Private Limited. New Delhi, 2008. (for Units I & II)
2. **John N. Mordeson** and **Premchand S. Nair**, Fuzzy Graphs and Fuzzy Hypergraphs, Physica- Verlag Heidelberg,2000. (for Unit III)
3. **Krassimir T Atanassov**, On Intuitionistic Fuzzy Sets Theory, Springer - Verlag, Heidelberg, 1999. (for Units IV & V)

REFERENCE BOOKS:

1. **A.I. Ban**, Intuitionistic Fuzzy Measures: Theory and Applications, Nova Science Publishers, New York, 2006.
2. **J.J. Buckl**ey, AND **E. Eslami**, An Introduction to Fuzzy Logic and Fuzzy Sets, Physica- verlag, Heidelberg, 2002.

COURSE OUTCOMES: At the end of the course, students will be able to

CO	Statements	Knowledge level
CO1	Define a fuzzy set and distinguish between the crisp set and fuzzy set with respect to the operations and measures.	**K1**
CO2	Draw the fuzzy pattern using Clustering in image processing and aware of the real time application of fuzzy logic.	**K2, K4**
CO3	Characterize fuzzy graphs, fuzzy trees and fuzzy chords to develop models in traffic network.	**K6**
CO4	Define intuitionistic fuzzy subsets and the operations among them with the geometrical interpretations.	**K1, K3**
CO5	Define intuitionistic fuzzy index matrix using relations and identify the measurement tools that evaluate alternatives.	**K3, K5**

MAPPING WITH PROGRAMME OUTCOME(S):

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	L	L	L	M	M
CO2	L	S	S	L	L	S
CO3	S	L	M	M	S	L
CO4	S	L	L	L	M	M
CO5	S	M	S	M	S	S

S – Strong, **M –** Medium, **L -** Low

****

18URMAT0E13	OPTIMIZATION TECHNNIQUES	L	T	P	C
		4	1	0	4

OBJECTIVE: The objective of this course is to

- Enrich the knowledge of students with advanced techniques of both linear and nonlinear programming problem along with real life applications.

- Explain the concept of decision theory, games, inventory and queuing models and its applications.
- Make the learners aware of the importance of optimizations in real scenarios.

UNIT I: Dynamic Programming

Elements of the DP Model: The Capital Budgeting – More on the Definition of , the state-Examples of DP models and computations - Problem of Dimensionality in Dynamic programming - Solution of Linear programs by Dynamic programming.

UNIT II: Decision Theory, Games and Inventory Model

Decisions under Risk - Decision Trees – Decisions Under Uncertainty - Game Theory - The ABC Inventory System - Generalized Inventory Models – Deterministic Models – Just-in-Time (JIT) manufacturing system.

UNIT III: Stochastic Process

Introduction – Classification – Stationary Process – Time Average – Ergodic Process – Markov Process and Markov Chain – Poisson Process – Renewal Process.

UNIT IV: Queuing Models

Role of Poisson and Exponential Distribution – Processes of Birth and Processes of Death - Queues with Combined Arrival and Departures - Non-Poisson Queues - Queues with Priorities for Service – Queueing Network.

UNIT V: Nonlinear Programming

Unconstrained Extremal Problems – Constrained Extremal Problems - Nonlinear Programming Algorithm - Unconstrained Nonlinear Algorithms - Constrained Nonlinear Algorithms.

TEXT BOOKS:

1. **H. A. Taha**, Operations Research -An Introduction, Fifth Edition, Prentice Hall of India (P) Limited, New Delhi, 1996.
2. **J. Medhi**, Stochastic Processes**,** Second edition, New York, Wiley.

REFERENCE BOOKS:

1. **D. Ravindran, T. Phillips**, and **J. J. Solberg**, Operations Research: Principles and Practice, Second Edition, John Wiley & Sons (Asia), New Delhi, 2006.
2. **S. S. Rao**, Engineering Optimization, Third Edition, New Age International (p) Ltd, New Delhi, 1996.

COURSE OUTCOME(S): At the end of the course, students will be able to

CO	Statements	Knowledge level
CO1	Understand different types of decision-making environments and suitable approaches.	**K1, K2**
CO2	Characterize the queueing models to analyze real world systems.	**K3,K4**
CO3	Classify different types of stochastic process.	**K2,K3**
CO4	Apply dynamic programming to optimize multi stage decision problems.	**K2, K3**
CO5	Choose the research problems in optimization techniques.	**K4,K5**

MAPPING WITH PROGRAMME OUTCOME(S):

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	S	L	M	L	M	M
CO2	S	M	M	L	M	M
CO3	M	S	L	L	M	M
CO4	M	M	M	L	M	M
CO5	M	L	S	M	S	M

S – Strong, **M –** Medium, **L -** Low

SEMESTER II (PART - II)

18URMAT0D01	**DISSERTATION**	***Dissertation:*** 8 Credits ***Viva Voce:*** 4 Credits

****