Centre for Basic Sciences
(CBS)

COURSE STRUCTURE
SCHEME OF EXAMINATION
&
SYLLABUS
of
M.Sc. (Mathematics)
(Five - Year Integrated Course)
UNDER
FACULTY OF SCIENCE
Approved by Board of Studies in Mathematics
Effective from July 2024 onward

Center for Basic Sciences,
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Contents

Title of the Program: M.Sc. Mathematics (Five-Year Integrated Course)

Program Objective

To impart fundamental and computational knowledge of mathematics to students to develop world-class academician, researcher and mathematics teachers who can understand their responsibilities in solving social and ethical issues with a scientific approach for the betterment of society.

General Pattern of the Program

Courses offered during the first year (Semesters I to II) are meant as basic and introductory courses in Biology, Chemistry, Mathematics, Physics and Environmental Science. These are common and mandatory for all students. These courses are intended to give a flavor of the various approaches and analyses and to prepare the students for advanced courses in later years of study. In addition, there will be Interdisciplinary Courses for computational skills using mathematical methods. Students are also given training to develop skills in Communication, Creative Hindi & Scientific Writing and History of Science through courses in Humanities. In the second year (Semester - III), students have the freedom to choose their stream (Biology, Chemistry, Mathematics, Physics) for masters program on the bases of their interest. Courses offered in the first two years would help them make an informed judgment to determine their real interest and aptitude for a given subject. One of the important features that the CBS has adopted is semester-long projects called Lab Training / Theory projects, which are given the same weightage as a regular course. By availing this, a student can work in an experimental lab or take up a theory project every semester. This is meant to help the student get trained in research methodology, which will form a good basis for the 9^{th} semester project work in the fifth year. The subjects/courses are described further with their credit points. Few courses are common to different streams.

Program Outcomes:
Upon successful completion of the Master of Science in Mathematics program, students will be able to:

PO-1	**Knowledge:** Demonstrate a deep understanding of advanced mathematical concepts, theories, and techniques in various subfields of Mathematics.
PO-2	**Critical Thinking and Reasoning:** Exhibit advanced critical thinking skills by analyzing and evaluating mathematical arguments, theories, and proofs, and by making reasoned judgments about mathematical concepts and their implications.
PO-3	**Problem Solving:** Formulate abstract mathematical problems and derive solutions using rigorous logical reasoning. Demonstrate mastery in constructing mathematical proofs and justifications.
PO-4	**Advanced Analytical and Computational Skills:** Possess advanced skills in mathematical analysis and computation, including proficiency in using mathematical software, programming languages, and computational tools for numerical simulations and data analysis.
PO-5	**Effective Communication:** Communicate complex mathematical ideas and results effectively to both technical and non-technical audiences, through written reports, presentations, and teaching.
PO-6	**Social/ Interdisciplinary Interaction:** Integrate mathematical concepts and techniques into interdisciplinary contexts, collaborating effectively with professionals from other fields to address complex problems.
PO-7	**Self-directed and Life-long Learning:** Recognize the importance of ongoing professional development and lifelong learning in the rapidly evolving field of mathematics, and will exhibit the ability to continue learning independently or in formal educational settings.
PO-8	**Effective Citizenship:** Leadership and Innovation: Lead and innovate in various mathematical contexts, contributing to advancements in the field and applying mathematical insights to emerging challenges.
PO-9	**Ethics:** Demonstrate ethical and responsible conduct in mathematical research, teaching, and collaboration, adhering to professional standards and best practices.
PO-10	**Further Education or Employment:** Engage for further academic pursuits, including Ph.D. programs in mathematics or related fields. Get employment in academia, research institutions, industry, government, and other sectors.
PO-11	**Global Perspective:** Recognize the global nature of mathematical research and its impact, appreciating diverse cultural perspectives in mathematical practices.

PROGRAMME SPECIFIC OUTCOMES (PSOs): At the end of the programme students will be able to:

PSO1	Understand the nature of abstract mathematics and explore the concepts in further details.
PSO2	Apply the knowledge of mathematical concepts in interdisciplinary fields and draw the inferences by finding appropriate solutions.
PSO3	Pursue research in challenging areas of pure/applied mathematics.
PSO4	Employ confidently the knowledge of mathematical software and tools for treating the complex mathematical problems and scientific investigations.
PSO5	Effectively communicate and explore ideas of mathematics for propagation of knowledge and popularization of mathematics in society.
PSO6	Qualify national level tests like NET/GATE etc.

Course Structure of
M.Sc. (Mathematics)
(Five-Year Integrated Course)

Effective from July, 2024

- Minimum total credits for integrated M.Sc. degree is 240.
- Semesters I to VIII will carry 25 credits each.
- Semesters IX and X will carry 20 credits each.

Abbreviation: B: Biology, C: Chemistry, M: Mathematics, P: Physics, G: General, H: Humanities, BL: Biology Laboratory, CL: Chemistry Laboratory, PL: Physics Laboratory, GL: General Laboratory, ML: Mathematics Laboratory; ME: Mathematics Elective, MPr: Mathematics Project

First Year

Integrated M.Sc., Semester - I

Subject Code	Subject	Contact Hours/ Week [Theory + Tutorial]	Credit
B101	Biology - I	[2+1]	3
C101	Chemistry - I	[2+1]	3
M101/MB101	Mathematics - I	[2+1]	3
P101	Physics- I	[2+1]	3
G101	Computer Basics	[2+1]	3
H101	Communication Skills	[2+0]	2
		Contact Hours/ Week Laboratory	
BL101	Biology Laboratory-I	[4]	2
CL101	Chemistry Laboratory-I	[4]	2
PL101	Physics Laboratory-I	[4]	2
GL101	Computer Laboratory	[4]	2
	(25 of 240 credits)	**Total:**	25
Additional Papers		**Contact Hours/ Week [Theory + Tutorial]**	
ES101	Environmental Studies	[2+0]	2

Integrated M.Sc., Semester - II

Subject Code	Subject	Contact Hours/ Week [Theory + Tutorial]	Credit
B201	Biology - II	[2+1]	3
C201	Chemistry - II	[2+1]	3
M201/MB201	Mathematics - II	[2+1]	3
P201	Physics- II	[2+1]	3
G201	Electronics and Instrumentation	[2+1]	3
		Contact Hours/ Week Laboratory	
BL201	Biology Laboratory-II	[4]	2
CL201	Chemistry Laboratory-II	[4]	2
PL201	Physics Laboratory-II	[4]	2
GL201	Electronics Laboratory	[4]	2
H201	Communication Skills Lab	[4]	2
	(50 of 240 credits)	**Total:**	25
Additional Papers			
ES201	Environmental Studies	[2]	2

Second Year

Integrated M.Sc. Mathematics, Semester - III

Subject Code	Subject	Contact Hours/ Week [Theory + Tutorial]	Credit
M301	Mathematical Foundations	[3+1]	4
M302	Analysis - I	[3+1]	4
M303	Algebra - I	[3+1]	4
M304	Elementary Number Theory	[3+1]	4
M305	Computational Mathematics-I	[3+1]	4
H301	Creative Hindi	[2+0]	2
H302	History and Philosophy of Science	[2+0]	2
		Contact Hours/ Week Laboratory	
GL301	Computational Mathematics Laboratory-I	[2]	1
	(75 of 240 credits)	**Total:**	25

***H302 is Indian Knowledge System (IKS) Course.**

Integrated M.Sc. Mathematics, Semester - IV

Subject Code	Subject	Contact Hours/ Week [Theory + Tutorial]	Credit
M401	Analysis-II	[3+1]	4
M402	Algebra - II	[3+1]	4
M403	Introduction to Differential Equations	[3+1]	4
M404	Topology-I	[3+1]	4
G401	Statistical Techniques and Applications	[3+1]	4
		Contact Hours/ Week Laboratory	
GL401	Computational Laboratory and Numerical Methods	[4]	2
GL402	Statistical Techniques Laboratory	[2]	1
H401	Communication Skills Lab-II	[4]	2
	(100 of 240 credits)	**Total:**	25

Third Year

Integrated M.Sc. Mathematics, Semester - V

Subject Code	Subject	Contact Hours/ Week [Theory + Tutorial]	Credit
M501	Analysis-III	[3+1]	4
M502	Algebra - III	[3+1]	4
M503	Topology - II	[3+1]	4
M504	Probability Theory	[3+1]	4
PM501	Numerical Analysis	[3+1]	4
H501	Scientific Writing in Hindi	[2+0]	2
		Contact Hours/ Week Laboratory	
PML501	Numerical Methods Laboratory	[6]	3
	(125 of 240 credits)	**Total:**	25
Value Added Course		**Contact Hours/ Week Laboratory**	
SEL501	English Language for Competence Skills	[4]	2

Integrated M.Sc. Mathematics, Semester - VI

Subject Code	Subject	Contact Hours/ Week [Theory + Tutorial]	Credit
M601	Analysis-IV	[3+1]	4
M602	Algebra - IV	[3+1]	4
M603	Partial Differential Equations	[3+1]	4
M604	Ordinary Differential Equations	[3+1]	4
M605	Numerical Analysis of Partial Differential Equations	[3+1]	4
H601	Ethics of Science and IPR	[2]	2
H602	Scientific Writing in English	[2]	2
		Contact Hours/ Week Laboratory	
ML601	Computational Mathematics Laboratory-III	[2]	1
	(150 of 240 credits)	**Total:**	25
Value Added Course		**Contact Hours/ Week Laboratory**	
SEL601	Pratiyogi Parikshaon ke liye Hindi Bhasha	[4]	2

Fourth Year

Integrated M.Sc. Mathematics, Semester - VII

Subject Code	Subject	Contact Hours/ Week [Theory + Tutorial]	Credit
M701	Functional Analysis	[3+1]	4
M702	Discrete Mathematics	[3+1]	4
M703	Introduction to Mathematical Modelling	[3+1]	4
M704	Operations Research	[3+1]	4
M705	Stochastic Analysis	[3+1]	4
Project		Contact Hours/ Week	
MPr701	Reading Project	[10]	5
	(175 of 240 credits)	**Total:**	25
Value Added Course		**Contact Hours/ Week Laboratory**	
SEL701	Linux Operating System	[4]	2

Integrated M.Sc. Mathematics, Semester - VIII

Subject Code	Subject	Contact Hours/ Week [Theory + Tutorial]	Credit
M801	Graph Theory	[3+1]	4
M802	Advanced Discrete Mathematics	[3+1]	4
M803	Nonlinear Dynamics and Chaos	[3+1]	4
M804	Mathematical Biology	[3+1]	4
M805	Computational Mathematics III	[3+1]	4
Project		Contact Hours/ Week	
MPr801	Project	[10]	5
	(200 of 240 credits)	**Total:**	25
Value Added Course		**Contact Hours/ Week Laboratory**	
SEPML801	LaTeX and XFig - typesetting software	[4]	2

Fifth Year

Integrated M.Sc. Mathematics, Semester - IX

Subject Code	Subject	Contact Hours/ Week [Theory + Tutorial]	Credit
MPr901	Project		20
	(220 of 240 credits)	Total:	20

Integrated M.Sc. Mathematics, Semester - X

Subject Code*	Subject	Contact Hours/ Week [Theory + Tutorial]	Credit
ME1001	Elective-I	[4+1]	5
ME1002	Elective-II	[4+1]	5
ME1003	Elective-III	[4+1]	5
ME1004	Elective-IV	[4+1]	5
	(240 of 240 credits)	Total:	20

*Four subjects will be offered according to the availability of the instructors and minimum number of students taking a course. The chosen four subject will have subjects codes ME1001, ME1002, ME1003 and ME1004.

Integrated M.Sc. Mathematics, Semester - X: Electives

Elective No	Subject
ME01	Dynamical Systems Using Matlab
ME02	Commutative Algebra
ME03	Financial Mathematics
ME04	Nonlinear Analysis
ME05	Differential Topology
ME06	Introduction to Cryptography
ME07	Introduction to Nonlinear Optimization
ME08	Complex Network
ME09	Representation Theory of Finite Groups
ME10	Algebraic Number Theory
ME11	Algebraic Topology
ME12	Differential Geometry & Applications
ME13	Fuzzy Set Theory & Its Applications
ME14	Wavelets
ME15	Mathematical Methods
ME16	Fourier Analysis

Note:

1. In place of Elective Course Student can choose paper(s) from MOOC Courses (Swayam Portal) subject to the following conditions:
    - The chosen paper will be other than the papers offered in the current course structure.
    - The paper will be PG level with a minimum of 12 weeks' duration.
    - The list of courses on SWAYAM keeps changing, the departmental committee will finalize the list of MOOC courses for each semester.
    - The paper(s) may be chosen from Swayam Portal on the recommendation of Head of the Department.
2. The candidates who have joined the PG Programme in School of Studies (University Teaching Department), shall undergo Generic Elective Courses (only qualifying in nature) offered by other departments/SoS in Semester II and Semester III.

3. The candidates who have joined the PG Programme in School of Studies (University Teaching Department), shall undergo Skill Enhancement Course/Value Added Course (only qualifying in nature) in Semester I and Semester II.

Skill Enhancement/ Value Added Courses

Candidates enrolled in the 5-Year Integrated M.Sc. in Mathematics program at the Center for Basic Sciences must complete Skill Enhancement/Value Added Courses, which are qualifying in nature.

Semester	Course Code	Course Title	Course Type (T/P)	Hrs/ Week	Credits	Marks		
						CIA	ESE	Total
V	SEL501	English Language for Competence Skills	P	4	2	60	40	100
VI	SEL601	Pratiyogi Parikshao ke liye Hindi Bhasha	P	4	2	60	40	100
VII	SEL701	Linux Operating System	P	4	2	60	40	100
VIII	SEPML801	LaTeX & XFig - typesetting software	P	4	2	60	40	100

Indian Knowledge System Course

Candidates enrolled in the 5-Year Integrated M.Sc. Program at the Center for Basic Sciences are required to complete the Indian Knowledge System course, a core component of the curriculum.

Semester	Course Code	Course Title	Course Type (T/P)	Hrs/ Week	Credits	Marks		
						CIA	ESE	Total
III	H302	History and Philosophy of Science	T	[2+0]	2	60	40	100

Programme Articulation Matrix:

Following matrix depicts the correlation between all the courses of the programme and Programme Outcomes

Course Code	**POs**											**PSOs**					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
M101	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MB101	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
G101	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
GL101	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
M201	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MB201	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
M301	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
M302	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
M303	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
M304	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
M305	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
GL301	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
M401	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
M402	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
M403	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
M404	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
G401	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓

Course Code	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
GL401	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
GL402	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
M501	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
M502	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
M503	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
M504	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
PM501	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
PML501	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗	✓	✓	✓	✓	✓	✓
M601	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
M602	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
M603	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
M604	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
M605	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
ML601	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
M701	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
M702	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
M703	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
M704	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
M705	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
M801	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
M802	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
M803	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
M804	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
M805	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
ME01	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
ME02	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
ME03	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
ME04	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
ME05	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
ME06	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
ME07	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
ME08	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
ME09	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
ME10	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
ME11	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
ME12	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
ME13	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
ME14	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
ME15	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
ME16	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
No of courses mapping PO/PSO	57	57	57	26	57	57	57	57	16	56	57	57	57	57	57	57	33
SEL501	✓	✗	✗	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗
SEL01	✓	✗	✗	✗	✓	✓	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗
SEL701	✓	✓	✓	✓	✓	✗	✗	✗	✗	✓	✗	✗	✓	✓	✓	✗	✗
SEPML801	✓	✓	✓	✓	✓	✗	✗	✗	✗	✓	✗	✗	✓	✓	✓	✗	✗

Scheme of Examination
M.Sc. (Mathematics)

First Year

Integrated M.Sc. Semester - I

Subject Code	Subject	Internal Marks		External Marks		Total Marks	Credit
		Max	Min	Max	Min	Max	
B101	Biology - I	60	24	40	16	100	3
C101	Chemistry - I	60	24	40	16	100	3
M101/MB101	Mathematics - I	60	24	40	16	100	3
P101	Introductory Physics- I	60	24	40	16	100	3
G101	Computer Basics	60	24	40	16	100	3
H101	Communication Skills	60	24	40	16	100	2
Practical							
BL101	Biology Laboratory-I	60	24	40	16	100	2
CL101	Chemistry Laboratory-I	60	24	40	16	100	2
PL101	Physics Laboratory-I	60	24	40	16	100	2
GL101	Computer Laboratory	60	24	40	16	100	2
Additional Papers							
ES101	Environmental Studies	60	24	40	16	100	2

Integrated M.Sc. Semester - II

Subject Code	Subject	Internal Marks		External Marks		Total Marks	Credit
		Max	Min	Max	Min	Max	
B201	Biology - II	60	24	40	16	100	3
C201	Chemistry - II	60	24	40	16	100	3
M201/MB201	Mathematics - II	60	24	40	16	100	3
P201	Physics- II	60	24	40	16	100	3
G201	Electronics and Instrumentation	60	24	40	16	100	3
Practical							
BL201	Biology Laboratory-II	60	24	40	16	100	2
CL201	Chemistry Laboratory-II	60	24	40	16	100	2
PL201	Physics Laboratory-II	60	24	40	16	100	2
GL201	Electronics Laboratory	60	24	40	16	100	2
H201	Communication Skills Lab	60	24	40	16	100	2
Additional Papers							
ES201	Environmental Studies	60	24	40	16	100	2

Second Year

Integrated M.Sc. Mathematics, Semester - III

Subject Code	Subject	Internal Marks		External Marks		Total Marks	Credit
		Max	Min	Max	Min	Max	
M301	Mathematical Foundations	60	24	40	16	100	4
M302	Analysis - I	60	24	40	16	100	4
M303	Algebra - I	60	24	40	16	100	4
M304	Elementary Number Theory	60	24	40	16	100	4
M305	Computational Mathematics-I	60	24	40	16	100	4
H301	Creative Hindi	60	24	40	16	100	2
H302	History and Philosophy of Science	60	24	40	16	100	2
Practical							
GL301	Computational Mathematics Laboratory-I	60	24	40	16	100	1

Integrated M.Sc. Mathematics, Semester - IV

Subject Code	Subject	Internal Marks		External Marks		Total Marks	Credit
		Max	Min	Max	Min	Max	
M401	Analysis-II	60	24	40	16	100	4
M402	Algebra - II	60	24	40	16	100	4
M403	Introduction to Differential Equations	60	24	40	16	100	4
M404	Topology-I	60	24	40	16	100	4
G401	Statistical Techniques and Applications	60	24	40	16	100	4
Practical							
GL401	Computational Laboratory and Numerical Methods	60	24	40	16	100	2
GL401	Statistical Techniques Laboratory	60	24	40	16	100	1
H401	Communication Skills Lab-II	60	24	40	16	100	2

Third Year

Integrated M.Sc. Mathematics, Semester - V

Subject Code	Subject	Internal Marks		External Marks		Total Marks	Credit
		Max	Min	Max	Min	Max	
M501	Analysis-III	60	24	40	16	100	4
M502	Algebra - III	60	24	40	16	100	4
M503	Topology - II	60	24	40	16	100	4
M504	Probability Theory	60	24	40	16	100	4
PM501	Numerical Analysis	60	24	40	16	100	4
H501	Scientific Writing in Hindi	60	24	40	16	100	2
Practical							
PML501	Numerical Methods Laboratory	60	24	40	16	100	3
Value Added Course							
SEL501	English Language for Competence Skills	60	24	40	16	100	2

Integrated M.Sc. Mathematics, Semester - VI

Subject Code	Subject	Internal Marks		External Marks		Total Marks	Credit
		Max	Min	Max	Min	Max	
M601	Analysis-IV	60	24	40	16	100	5
M602	Algebra - IV	60	24	40	16	100	5
M603	Partial Differential Equations	60	24	40	16	100	4
M604	Ordinary Differential Equations	60	24	40	16	100	4
M605	Numerical Analysis of Partial Differential Equations	60	24	40	16	100	4
H601	Ethics of Science and IPR	60	24	40	16	100	2
H602	Scientific Writing in English	60	24	40	16	100	2
Practical							
ML601	Computational Mathematics Laboratory-III	60	24	40	16	100	3
Value Added Course							
SEL601	Pratiyogi Parikshaon ke liye Hindi Bhasha	60	24	40	16	100	2

Fourth Year

Integrated M.Sc. Mathematics, Semester - VII

Subject Code	Subject	Internal Marks		External Marks		Total Marks	Credit
		Max	Min	Max	Min	Max	
M701	Functional Analysis	60	24	40	16	100	4
M702	Discrete Mathematics	60	24	40	16	100	4
M703	Introduction to Mathematical Modelling	60	24	40	16	100	4
M704	Operations Research	60	24	40	16	100	4
M705	Stochastic Analysis	60	24	40	16	100	4
Project							
MPr701	Reading Project	60	24	40	16	100	5
Value Added Course							
SEL701	Linux Operating System	60	24	40	16	100	2

Integrated M.Sc. Mathematics, Semester - VIII

Subject Code	Subject	Internal Marks		External Marks		Total Marks	Credit
		Max	Min	Max	Min	Max	
M801	Graph Theory	60	24	40	16	100	4
M802	Advanced Discrete Mathematics	60	24	40	16	100	4
M803	Nonlinear Dynamics and Chaos	60	24	40	16	100	4
M804	Mathematical Biology	60	24	40	16	100	4
M805	Computational Mathematics III	60	24	40	16	100	4
Project							
MPr801	Project	60	24	40	16	100	5
Value Added Course							
SEPML801	LaTeX and XFig - typesetting software	60	24	40	16	100	2

Fifth Year

Integrated M.Sc. Mathematics, Semester - IX

Subject Code	Subject	Project Report/ Dissertation		Seminar Based on Project		Viva-Voce Based on Project Report and Seminar		Total Marks Max	Credit
		Max	Min	Max	Min	Max	Min		
MPr901	Project	150	60	150	60	100	40	400	20

Integrated M.Sc. Mathematics, Semester - X

Subject Code*	Subject	Internal Marks		External Marks		Total Marks	Credit
		Max	Min	Max	Min	Max	
ME1001	Elective-I	60	24	40	16	100	5
ME1002	Elective-II	60	24	40	16	100	5
ME1003	Elective-III	60	24	40	16	100	5
ME1004	Elective-IV	60	24	40	16	100	5

***Elective subjects will be offered according to the availability of instructors and minimum number of interested students taking a course from the list of elective subjects in the syllabus. The chosen four subjects will have codes ME1001, ME1002, ME1003 and ME1004.**

Syllabus of Integrated M.Sc. (Mathematics)

1 Semester-I

1.1 M101: Mathematics-I

Learning Objective (LO): The aim of this course is to develop a robust understanding of foundational mathematics, including number systems, proofs, sets, sequences, and series, to analyze and evaluate mathematical problems and establish a strong base for advanced studies.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the basic concepts of number systems, their algebraic properties, and the completeness property of real numbers.	U
2	Illustrate and employ various mathematical proof techniques, including conjunction, disjunction, and negation of statements.	Ap
3	Explore sets, relations, and functions, and understand their properties, including De Morgan's laws, equivalence relations, and inverse functions.	An
4	Comprehend and analyze sequences, their convergence, limit theorems, and Cauchy sequences.	An
5	Analyze infinite series and evaluate their convergence using different tests such as geometric series and comparison tests.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	3	2	1	2	2	1	3	2	3	3	1	1	2	3
CO2	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	3
CO3	3	3	3	3	2	1	3	2	1	3	2	3	3	2	2	1	3
CO4	3	3	3	3	2	1	3	3	-	3	2	3	3	3	2	1	3
CO5	3	3	3	3	2	1	3	2	1	3	2	3	3	2	2	2	3

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	**Introduction of Number Systems:** Natural Numbers, Algebraic Properties, Mathematical Induction. Real Numbers, Order Properties and Completeness Property of $\mathbb{R}$, Intervals on $\mathbb{R}$, Infinity, Infinite Sets and Cardinality.	8	1
II	**Reading and Writing Mathematics:** Illustration of mathematical proofs via examples, Illustration of Conjunction, Disjunction, Negation of Statements and Conditional Statements via examples. Techniques of mathematical proofs.	8	2
III	**Functions and Relations:** Sets, De Morgan's Laws, Relations, Cartesian Products, Functions and Graphical Representation, Injective and Surjective functions, Composition and Inverse of Functions, Level Sets, Equivalence Relations and Equivalence Classes. **Limits:** Limits of Functions, Boundedness, Squeeze Theorem, Limits at Infinity.	10	3
IV	**Sequences:** Sequences, Convergence, Limit theorems, Divergence, Cauchy Sequences.	10	4
V	**Infinite Series:** Convergence and Divergence of Series, Geometric Series, Tests for Convergence.	9	5

Textbooks & References

[1] Subhash Chandra Malik and Savita Arora. *Mathematical analysis.* New Age International, 2012.

[2] Ajit Kumar, S Kumaresan, and Bhaba Kumar Sarma. *A Foundation Course in Mathematics.* Alpha Science International Limited, 2018.

[3] Donald R Sherbert and Robert G Bartle. *An Introduction to Real Analysis.* John Wiley & Sons, Inc., 2014.

[4] D'Angelo John Philip and Douglas Brent West. *Mathematical thinking: problem-solving and proofs.* Prentice-Hall, 1997.

[5] James R Munkres. *Elements of algebraic topology.* CRC press, 2018.

1.2 MB101: Remedial Mathematics-I

Learning Objective (LO): The aim of this course is to build foundational skills in trigonometry, vector operations, and basic mathematical techniques to solve practical problems and strengthen the understanding required for advanced mathematical applications.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand and apply trigonometric identities and vector operations, including dot and cross products, for solving mathematical problems.	Ap
2	Analyze different types of numbers and their properties, and use mathematical induction, divisibility, and congruences in problem-solving.	An
3	Evaluate the convergence of series using various convergence tests, and apply Taylor's series and power series for approximations.	E
4	Comprehend the concept of limits and continuity, and analyze continuous and uniformly continuous functions.	An
5	Understand and differentiate various types of functions, apply rules of differentiation, and explore the applications of the Mean Value Theorem and L'Hospital's Rule.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	3	3	3	1	1	1	1	-	1	-	3	1	2	1	2	3
CO2	3	2	3	2	2	1	2	1	-	2	1	3	2	1	2	2	3
CO3	2	3	2	3	2	1	2	1	-	2	-	3	1	1	2	2	3
CO4	3	3	3	3	2	1	2	2	1	3	1	3	3	1	1	1	3
CO5	3	3	3	3	2	1	1	2	-	2	2	3	3	2	2	2	3

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	**Trigonometry and Vectors:** Polar coordinates, relations between different trigonometric functions, periodicity, graphical representation, fundamental identities, addition formulae, multiple angles, factorization formulae. Scalars and vectors, norm of a vector, dot product, projections, cross product. **Sets and Functions:** Sets, Functions, Inequalities, graphical representation.	9	1
II	**Numbers:** Numbers of Different Types ($\mathbf{N}, \mathbf{Z}, \mathbf{R}, \mathbf{R} \backslash \mathbf{Q}$). Algebraic Properties, Factorial notation, Mathematical Induction, Division Algorithm, Divisibility, Prime Numbers, Fundamental Theorem of Arithmetic, Order Properties and Completeness Property of $\mathbf{R}$, concept of congruences.	8	2
III	**Series:** AP, GP and HP and inequalities of the mean, Sum of a series, Sigma notation, Convergence, Limit Theorems, Divergence Tests for Convergence (Absolute Convergence and Non-absolute Convergence), Series of Functions, Taylor's Series, Power Series.	9	3
IV	**Limits and Continuity:** Limits of functions, Boundedness, Squeeze Theorem. Graphical idea of monotonic function and Continuity, Continuous Functions, Continuous Functions on Intervals, Uniform Continuity.	10	4
V	**Derivatives and Differentiation:** Definition and Graphical Representation of Derivatives, Differentiability and Continuity, Chain Rule, Product and quotient rules, Higher Derivatives. Derivatives of Exponential, Logarithmic, Trigonometric and Inverse Trigonometric functions, derivatives of inverse functions, derivatives of Power Series. Mean Value Theorem, Derivatives and Extrema, L'Hospital's Rule.	9	5

Textbooks & References

[1] Ajit Kumar, S Kumaresan, and Bhaba Kumar Sarma. *A Foundation Course in Mathematics.* Alpha Science International Limited, 2018.

[2] Donald R Sherbert and Robert G Bartle. *An Introduction to Real Analysis.* John Wiley & Sons, Inc., 2014.

[3] Maurice D Weir, George Brinton Thomas, Joel Hass, and Frank R Giordano. *Thomas' calculus.* Pearson Education, 2018.

[4] James Stewart. *Single variable calculus: Concepts and contexts.* Cengage Learning, 2018.

[5] Gilbert Strang and Edwin Herman. *Calculus.* OpenStax Houston, Texas, 2016.

[6] TM Apostol. *Mathematical Analysis.* Pearson Education, Inc, 2004.

1.3 G101: Computer Basics (Programming in C)

Learning Objective (LO): The aim of this course is to introduce students to computer programming through C, emphasizing fundamental concepts such as program design, control flow, data handling, and basic algorithms. The course equips students with the ability to write, debug, and optimize simple programs, building a strong base for future computing studies.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand and demonstrate the basic structure of a C program, data representation, and simple input/output statements.	U
2	Apply control structures such as if-else, loops, and switch statements effectively in C programming.	Ap
3	Understand and manipulate arrays, string handling, and functions including recursive functions for solving problems.	U
4	Analyze the use of structures and unions to create and operate on complex data structures in C.	An
5	Evaluate and implement pointer concepts to manage memory effectively and pass data between functions in C.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
CO	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	2	2	2	3	2	1	3	2	1	3	2	2	3	2	1	2	-
CO2	2	3	3	3	2	1	2	2	1	3	2	1	2	1	2	1	-
CO3	2	3	3	3	2	1	2	1	1	2	2	2	3	2	1	1	-
CO4	2	3	3	3	2	1	3	2	1	2	2	1	2	1	1	1	-
CO5	1	3	2	3	2	1	2	3	1	2	2	1	2	1	1	1	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Introduction to C programming structure and C compiler. Data representation: Simple data types like real integer, character etc. Program, statements and Header Files. Simple Input Output statements in C. Running simple C programs, Data Types. Operators and Expressions.	10	1
II	Control Structure: If statement, If-else statement. Compound Statement. Loops: For - loop. While - loop. Do-While loop, Break and exit statements, Switch statement, Continue statement, Goto statement.	7	2
III	Array. Types of Array, String Handling. Functions: Function main, Functions accepting more than one parameter, User defined and library functions. Concept associatively with functions, function parameter, Return value, recursion function.	8	3
IV	Structure and Union, Declaring and using Structure, Structure initialization, Structure within Structure, Operations on Structures, Array of Structure. Array within Structure, Structure and Functions, Union, Scope of Union, Difference between Structure and Union.	10	4
V	Pointers Definition and use of pointer, address operator, pointer variable, referencing pointer, void pointers, pointer arithmetic, pointer to pointer, pointer and arrays, passing arrays to functions, pointer and functions, accessing array inside functions. pointers and two dimensional arrays, array of pointers. pointers constants, pointer and strings.	10	5

Textbooks & References

[1] Venu Gopal. *Mastering C.* McGraw-Hill Education (India) Pvt Limited, 2006.

[2] V Rajaraman and Neeharika Adabala. *Fundamentals of computers.* PHI Learning Pvt. Ltd., 2014.

[3] Yashvant Kanethkar. *Let Us, C.* BPB publications, 2018.

1.4 GL101: Programming in C

Learning Objective (LO): The aim of this course is to provide students with a solid foundation in the C programming language, covering topics such as program structure, data representation, input/output, control structures, arrays, and functions. Students will develop skills to write efficient, error-free code and apply problem-solving techniques to practical programming challenges.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand and demonstrate the basic structure of a C program, data representation, and simple input/output statements.	U
2	Apply control structures such as if-else, loops, and switch statements effectively in C programming.	Ap
3	Understand and manipulate arrays, string handling, and functions including recursive functions for solving problems.	U
4	Analyze the use of structures and unions to create and operate on complex data structures in C.	An
5	Evaluate and implement pointer concepts to manage memory effectively and pass data between functions in C.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	3	2	1	3	2	1	3	2	3	3	2	1	2	-
CO2	3	3	3	3	2	1	2	2	-	3	2	3	3	2	2	1	-
CO3	3	3	3	3	2	1	2	1	1	2	2	2	3	2	1	1	-
CO4	3	3	3	2	2	1	3	2	-	2	2	3	2	3	1	1	-
CO5	3	3	2	2	2	1	2	3	-	2	2	3	2	3	1	1	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Contents: Practical of programming in C are based on syllabus of G-101.

Textbooks & References

[1] Venu Gopal. *Mastering C.* McGraw-Hill Education (India) Pvt Limited, 2006.

[2] V Rajaraman and Neeharika Adabala. *Fundamentals of computers.* PHI Learning Pvt. Ltd., 2014.

[3] Yashvant Kanethkar. *Let Us, C.* BPB publications, 2018.

2 Semester-II

2.1 M201: Mathematics-II

Learning Objective (LO): The aim of this course is to provide students with a deeper understanding of advanced mathematical concepts, including continuity, differentiation, and integration, along with their applications in solving real-world problems. Students will enhance their problem-solving skills and analytical thinking through various mathematical techniques and methods.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand and demonstrate the concepts of continuity, differentiation, and their applications, including graphical representation and composition of continuous functions.	U
2	Apply the principles of maxima and minima, and analyze convex and concave functions using sufficient conditions.	Ap
3	Understand and apply the concepts of Riemann integration, including the Fundamental Theorem of Calculus, and calculate lengths and volumes of plane curves and solids of revolution.	Ap
4	Comprehend and analyze the continuity and differentiability of scalar fields, applying partial derivatives and gradient concepts to identify maxima, minima, and saddle points.	An
5	Understand and apply properties of complex numbers, including de Moivre's theorem and logarithmic and exponential functions, in solving algebraic and trigonometric problems.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	3	3	1	2	1	2	2	1	3	2	3	3	1	1	2	3
CO2	3	3	3	3	2	1	3	2	1	3	2	3	3	2	2	1	3
CO3	3	3	3	3	2	1	3	2	1	3	2	3	3	2	2	1	3
CO4	3	3	3	3	2	1	3	3	1	3	2	3	3	3	2	1	3
CO5	3	3	3	3	2	1	3	2	1	3	2	3	3	2	2	2	3

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	**Continuity:** Continuous Functions, Graphical Representation, Composition and Inverse of Continuous Functions, Continuous Functions on Intervals. **Differentiation:** Definition and Graphical Representation of Derivatives, Differentiability and Continuity, Chain Rule, Higher Derivatives. Mean Value Theorems, Derivatives and Extrema, L'Hospital's Rule, Taylor's Theorem and Applications.	10	1
II	Maxima and Minima: Sufficient conditions for a function to be increasing/decreasing, Sufficient conditions for a local extremum, Absolute minimum/maximum, Convex/concave functions.	8	2
III	**Integration:** Riemann Integral and its Properties, Statement of Fundamental Theorem of Calculus. Applications of Integration: Arc length of a plane curve, Arc length of a plane curve in parametric form, Area of a surface of revolution, Volume of a solid of revolution by slicing, by the washer method and by the shell method.	8	3
IV	Limit and Continuity of Scalar Fields: Spaces $\mathbb{R}^2$ and $\mathbb{R}^3$, Scalar fields, level curves and contour lines, Limit of a scalar field, Continuity of a scalar field, Properties of continuous scalar fields. Differentiation of Scalar Fields: Partial derivatives, Differentiability, Chain rules, Implicit differentiation, Directional derivatives, Gradient of a scalar field, Tangent plane and normal to a surface, Higher order partial derivatives, Maxima and minima, Saddle points, Second derivative test for maxima/minima/saddle points.	10	4
V	**Complex Numbers:** Complex Numbers, Statement of Fundamental Theorem of Algebra, Polar Coordinates, Euler's and de Moivre's Formulae, Formulae for Sine and Cosine, Powers and roots of complex numbers, The exponential and trigonometric functions, Hyperbolic functions, Logarithms, Complex roots and powers, Inverse trigonometric and hyperbolic functions.	9	5

Textbooks & References

[1] Mary L Boas. *Mathematical methods in the physical sciences.* John Wiley & Sons, 2006.

[2] Peter D Lax and Maria Shea Terrell. *Calculus with applications.* Springer, 2020.

[3] Kenneth A Ross. *Elementary Analysis.* Springer, 2013.

[4] Maurice D Weir, George Brinton Thomas, Joel Hass, and Frank R Giordano. *Thomas' calculus.* Pearson Education, 2018.

[5] James Stewart. *Single variable calculus: Concepts and contexts.* Cengage Learning, 2018.

[6] Gilbert Strang and Edwin Herman. *Calculus.* OpenStax Houston, Texas, 2016.

2.2 MB201: Remedial Mathematics-II

Learning Objective (LO): The aim of this course is to provide students with a deeper understanding of advanced mathematical concepts, including continuity, differentiation, and integration, along with their applications in solving real-world problems. Students will enhance their problem-solving skills and analytical thinking through various mathematical techniques and methods.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand and apply the concept of integrals, including definite and indefinite integrals, and their applications in finding path lengths, areas, and volumes.	Ap
2	Analyze complex numbers and their algebraic properties, visualize them on the complex plane, and understand Euler's formula and its consequences.	An
3	Solve systems of linear equations using matrices, determinants, and Gauss elimination, and understand the properties of matrices and their inverses.	Ap
4	Apply concepts of permutations, combinations, and introductory probability theory to solve problems involving conditional probability and distributions.	Ap
5	Use frequency tables and calculate measures of central tendency and variation to interpret basic statistical data.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	1	2	1	2	2	-	3	2	3	3	1	1	2	3
CO2	3	3	3	1	2	1	3	2	-	3	2	3	3	2	2	1	3
CO3	3	3	3	1	2	1	3	2	-	3	2	3	3	2	2	1	1
CO4	3	3	3	1	2	1	3	3	-	3	2	3	3	3	2	1	1
CO5	3	3	3	1	2	1	3	2	-	3	2	3	3	2	2	2	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	**Integration:** Notion of an integral, integral as limit of sums, anti-derivatives, area under a curve, Fundamental theorem of calculus, definite integrals, indefinite integrals, Rules of integration: integration by parts, integration by substitution, Properties of definite integrals, Application of integrals (path lengths, areas, volumes, etc.).	10	1
II	**Complex Numbers:** real and imaginary parts, the complex plane, complex algebra (complex conjugate, absolute value, complex equations, graphs, physical applications). Consequences of Euler's formula.	8	2
III	**Matrices and Linear Equations:** System of linear equations, notion of a matrix, determinant. Row and column operations, Gauss Elimination, Simple properties of matrices and their inverses.	11	3
IV	**Combinatorics and Probability:** Permutations and combinations, Binomial theorem for integral and non-integral powers, Pascal's triangle, Introductory probability theory, Conditional probability, Binomial probability distribution.	9	4
V	**Basic Statistics:** frequency tables, measure of central tendencies (mean, median, mode), measure of variation (standard deviation etc).	7	5

Textbooks & References

[1] TM Apostol. *Mathematical Analysis.* Pearson Education, Inc. 2004.

[2] Saminathan Ponnusamy. *Foundations of mathematical analysis.* Springer Science & Business Media, 2011.

[3] Roger J Barlow. *Statistics: a guide to the use of statistical methods in the physical sciences.* John Wiley & Sons, 1993.

[4] SC Gupta and VK Kapoor. *Fundamentals of mathematical statistics.* Sultan Chand & Sons, 2020.

3 Semester-III

3.1 M301: Mathematical Foundation

Learning Objective (LO): The aim of this course is to introduce students to the mathematical foundations essential for computer science, including logic, set theory, and combinatorics. Students will develop the ability to apply mathematical reasoning and techniques to solve problems and analyze computational processes.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand and apply the fundamental concepts of logic, including quantifiers, negations, set operations, and De-Morgan's laws.	U
2	Analyze and establish relations and mappings, such as injective, surjective, and bijective maps, and understand the connection between inverse images and set-theoretic operations.	An
3	Comprehend the distinctions between finite and infinite sets, including countably infinite and uncountable sets, and prove properties related to these sets.	U
4	Apply the principles of partially ordered sets and demonstrate understanding through examples and the use of Zorn's Lemma.	Ap
5	Understand and prove the equivalences between Peano's axioms, the Well-Ordering Principle, Mathematical Induction, and Zorn's Lemma.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	1	2	1	2	2	1	2	2	2	3	1	1	2	2
CO2	3	3	3	1	2	1	3	2	-	3	2	3	3	2	2	1	2
CO3	3	3	3	1	2	1	3	2	-	2	2	2	3	2	2	1	2
CO4	3	3	3	-	2	1	3	3	1	3	2	3	3	3	2	1	2
CO5	3	3	3	1	2	1	3	2	-	3	2	2	3	2	2	2	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	**Logic**: Quantifiers, negations, examples of various mathematical and non-mathematical statements. Exercises and examples. **Set Theory**: Definitions. subsets, unions, intersections, complements, symmetric difference, De-Morgan's laws for arbitrary collection of sets. Power set of a set.	10	1
II	**Relations and maps**: Cartesian product of two sets. Relations between two sets. Examples of relations. Definition of a map, injective, surjective and bijective maps. A map is invertible if and only if it is bijective. Inverse image of a set with respect to a map. Relation between inverse images and set theoretic operations. Equivalence relations (with lots of examples). Schroeder-Bernstein theorem.	15	2
III	**Finite and Infinite sets**: Finite sets, maps between finite sets, proof that number of elements in a finite set is well defined. Definition of a countable set (inclusive of a finite set). Countably infinite and uncountable sets. Examples. Proof that every infinite set has a proper, countably infinite subset. Uncountability of P(N).	15	3
IV	**Partially Ordered Sets**: Concept of partial order, total order, examples. Chains, Zorn's Lemma.	10	4
V	Peano's Axioms. Well-Ordering Principle. Weak and Strong Principles of Mathematical Induction. Transfinite Induction. Axiom of Choice, product of an arbitrary family of sets. Equivalence of Axiom of Choice, Zorn's Lemma and Well-ordering principle.	10	5

Textbooks & References

[1] Ajit Kumar, S Kumaresan, and Bhaba Kumar Sarma. *A Foundation Course in Mathematics.* Alpha Science International Limited, 2018.

[2] Pêter Komjáth and Vilmos Totik. *Problems and theorems in classical set theory.* Springer Science & Business Media, 2006.

[3] Stephen Abbott. *Understanding analysis.* Springer, 2001.

[4] Daniel J Velleman. *How to prove it: A structured approach.* Cambridge University Press, 2019.

[5] Daniel Cunningham. *A logical introduction to proof.* Springer Science & Business Media, 2012.

[6] Daniel W Cunningham. *Set Theory: A First Course.* Cambridge University Press, 2016.

[7] R. Lal. *Algebra 1: Groups, Rings, Fields and Arithmetic.* Infosys Science Foundation Series. Springer Singapore, 2017.

3.2 M302: Analysis I

Learning Objective (LO): The aim of this course is to provide students with a rigorous understanding of real analysis, including the construction of the real number system, sequences, limits, and continuity. Students will learn to analyze and prove fundamental properties of functions and develop precise mathematical reasoning and problem-solving skills.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the construction of the real number system and properties such as completeness. the Archimedean property, and the uniqueness of positive n^{th} roots.	U
2	Analyze and apply the concepts of sequences, subsequences, and Cauchy sequences. including convergence criteria and the Sandwich theorem.	An
3	Comprehend the convergence of infinite series, differentiate between absolute and conditional convergence, and apply various convergence tests.	U
4	Understand and demonstrate the continuity of functions, properties of continuous functions on intervals, and the concept of uniform continuity with examples.	Ap
5	Apply the principles of differentiability, including proofs of Rolle's theorem, the Mean Value Theorem, and Taylor's theorem with higher derivatives.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	1	2	1	2	2	1	3	2	3	3	1	1	2	3
CO2	3	3	3	1	2	1	3	2	1	3	2	3	3	2	2	1	3
CO3	3	3	3	2	2	1	3	2	1	3	2	3	3	2	2	1	3
CO4	3	3	3	2	2	1	3	3	1	3	2	3	3	3	2	1	3
CO5	3	3	3	1	2	1	3	2	1	3	2	3	3	2	2	2	3

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	**Real Number System:** Real number system: Construction via Cauchy sequences. Concept of a field, ordered field, examples of ordered fields, supremum, infimum. Order completeness of **R**, **Q** is not order complete. Absolute values. Archimedean property of **R**. **C** as a field, and the fact that **C** cannot be made into an ordered field. Deneness of **Q** in **R**. Every positive real number has a unique positive n^{th} root.	12	1
II	**Sequences:** Sequences, limit of a sequence, basic properties. Bounded sequences, monotone sequences, convergence of a monotone sequence. Sandwich theorem and its applications. Cauchy's first limit theorem, Cauchy's second limit theorem. **Subsequences and Cauchy sequences:** Every sequence of real numbers has a monotone subsequence. Definition of a Cauchy sequence. Cauchy completeness of $\mathbb{R}$, $\mathbb{Q}$ is not Cauchy complete.	14	2
III	**Infinite Series:** Basic notions on the convergence of infinite series. Absolute and conditional convergence. Comparison test, ratio test, root test, alternating series test, Dirichlet's test, Statement of Riemann's rearrangement theorem, Cauchy product of two series. Power series, radius of convergence.	12	3
IV	**Continuous functions:** Continuity, sequential and neighbourhood definitions, basic properties such as sums and products of continuous functions are continuous. Intermediate Value Theorem, Continuous functions on closed and bounded intervals, Monotone continuous functions, inverse functions, Uniform Continuity, examples and counter-examples.	11	4
V	**Differentiable functions:** Definition: as a function infinitesimally approximal by a linear map, equivalence with Newton's ratio definition, basic properties. One-sided derivatives, The O; o and notations with illustrative examples. Chain rule with complete proof (using above definition). Local monotonicity, relation between the sign of f' and local monotonicity. Proofs of Rolle's theorem and the Cauchy-Lagrange Mean value theorem. L'Hospital's rule and applications. Higher derivatives and Taylor's theorem, estimation of the remainder in Taylor's theorem, Convex functions.	11	5

Textbooks & References

[1] Ajit Kumar and Somaskandan Kumaresan. *A basic course in real analysis.* CRC press, 2014.

[2] Stephen Abbott. *Understanding analysis.* Springer, 2001.

[3] Terence Tao. Analysis ii, texts and readings in mathematics, 2015.

[4] T. Tao. *Analysis I: Third Edition.* Texts and Readings in Mathematics. Springer Singapore, 2016.

[5] W.R. Wade. *Introduction to Analysis: Pearson New International Edition.* Pearson Education, Limited, 2013.

[6] Saminathan Ponnusamy. *Foundations of mathematical analysis.* Springer Science & Business Media, 2011.

[7] Steven G Krantz. *A guide to real variables.* American Mathematical Soc., 2014.

[8] Miklós Laczkovich and Vera T Sós. *Real Analysis: Foundations and Functions of One Variable.* Springer, 2015.

[9] Sadhan Kumar Mapa. *Introduction to Real Analysis.* Sarat Book Distributors, 2014.

3.3 M303 : Algebra - I

Learning Objective (LO): The aim of this course is to introduce students to the foundational concepts of algebra, including groups, rings, and fields. Students will learn to analyze and apply algebraic structures to solve problems, develop abstract reasoning, and understand the symmetries in mathematical systems.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand and explain the definition of a group and its various examples, including matrices, permutation groups, and groups of symmetry.	U
2	Apply Lagrange's theorem to explore subgroups, cosets, and properties related to the order of elements in finite and infinite groups.	Ap
3	Analyze group homomorphisms, kernels, images, and use the fundamental theorem of group homomorphisms in solving group-related problems.	An
4	Comprehend and apply Cayley's theorem and understand the concept of conjugacy classes and the center of a group, leading to the application of Sylow theorems.	Ap
5	Understand the concept of rings, including ideals, homomorphisms, polynomial rings, and their properties such as units and integral domains.	U

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	1	2	1	2	2	1	3	2	3	3	1	1	2	3
CO2	3	3	3	1	2	1	3	2	1	3	2	3	3	2	2	1	3
CO3	3	3	3	1	2	1	3	2	1	3	2	3	3	2	2	1	3
CO4	3	3	3	2	2	1	3	3	1	3	2	3	3	3	2	1	3
CO5	3	3	3	1	2	1	3	2	1	3	2	3	3	2	2	2	3

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Definition of a group, examples including matrices, permutation groups, groups of symmetry, roots of unity. Properties of a group, finite and infinite groups.	14	1
II	Subgroups and cosets, order of an element, Lagrange theorem, normal subgroups, quotient groups. Detailed look at the group S_n of permutations, cycles and transpositions, even and odd permutations, the alternating group, simplicity of A_n for n.	12	2
III	Homomorphisms, kernel, image, isomorphism, the fundamental theorem of group Homomorphisms. Abelian group, cyclic groups, subgroups and quotients of cyclic groups, finite and infinite cyclic groups.	11	3
IV	Cayleys theorem on representing a group as a permutation group. Conjugacy classes, centre, class equation, centre of a p-group. Sylow theorems.	12	4
V	Definition of a ring, examples including congruence classes modulo n, ideals and Homomorphisms, quotient rings, polynomial ring in one variable over a ring, units, fields, nonzero divisors, integral domains. Rings of fractions, field of fractions of an integral domain.	11	5

Textbooks & References

[1] Serge Lang. *Algebra*. Springer Science & Business Media, 2012.

[2] Nathan Jacobson. *Basic Algebra II*. Freeman, New York, 1989.

[3] David S Dummit and Richard M Foote. *Abstract Algebra*. John Wiley and Sons, Inc, 2004.

[4] Michael Artin. *Algebra*. Pearson College Division, 1991.

3.4 M304: Elementary Number Theory

Learning Objective (LO): The aim of this course is to provide students with a comprehensive understanding of elementary number theory, including divisibility, congruences, prime numbers, and number-theoretic functions. Students will enhance their problem-solving skills and develop a foundation for exploring advanced topics in mathematics and cryptography.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand and apply the concepts of divisibility in integers, Euclidean algorithm, greatest common divisor, and least common multiple.	Ap
2	Analyze and use congruences, Wilson's theorem, Fermat's little theorem, and the Chinese remainder theorem to solve number theory problems.	An
3	Apply Euler's criterion, Gauss' lemma, and quadratic reciprocity to identify quadratic residues and calculate symbols in modular arithmetic.	Ap
4	Comprehend and explore properties of Legendre symbols and their applications in proving important theorems like Fermat's two square theorem and Lagrange's four square theorem.	U
5	Solve Diophantine equations and explore the properties of Pythagorean triples and Bachet's equation.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	1	2	1	2	2	1	3	2	3	3	1	1	2	1
CO2	3	3	3	2	2	1	3	2	1	3	2	3	3	2	2	1	1
CO3	3	3	3	1	2	1	3	2	1	3	2	3	3	2	2	1	1
CO4	3	3	3	1	2	1	3	3	1	3	2	3	3	3	2	1	1
CO5	3	3	3	2	2	1	3	2	1	3	2	3	3	2	2	2	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Fundamental theorem of arithmetic, divisibility in integers. Prime numbers and infinitude of primes. Infinitude of primes of special types. Special primes like Fermat primes, Mersenne primes, Lucas primes etc. Euclidean algorithm, greatest common divisor, least common multiple.	13	1
II	Equivalence relations and the notion of congruences. Wilson's theorem and Fermat's little theorem. Chinese remainder theorem. Continued fractions and their applications. Primitive roots, Euler's Phi function. Sum of divisors and number of divisors, Mobius inversion.	11	2
III	Quadratic residues and non-residues with examples. Euler's Criterion, Gauss' Lemma. Quadratic reciprocity and applications. Applications of quadratic reciprocity to calculation of symbols.	11	3
IV	Legendre symbol: Definition and basic properties. Fermat's two square theorem, Lagrange's four square theorem.	12	4
V	Pythagorean triples. Diophantine equations and Bachet's equation. The duplication formula.	13	5

Textbooks & References

[1] David Burton. *Elementary Number Theory*. McGraw Hill, 2010.

[2] Kenneth H Rosen. *Elementary number theory and its applications*, volume 1. Pearson/Addison Wesley, 2005.

[3] Ivan Niven, Herbert S Zuckerman, and Hugh L Montgomery. *An introduction to the theory of numbers*. John Wiley & Sons, 1991.

3.5 M305 : Computational Mathematics-I

Learning Objective (LO): The aim of this course is to introduce students to computational mathematics using tools like Mathematica, focusing on programming fundamentals, mathematical expressions, and data structures. Students will develop computational thinking, enhance their problem-solving abilities, and apply mathematical concepts to practical and theoretical problems using computational approaches.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the core structure of programming in Mathematica, including constants, strings, lists, and mathematical expressions.	U
2	Apply the principles of functional programming in Mathematica, including user-defined functions, recursive and iterative methods, and flow control.	Ap
3	Create and manipulate two-dimensional and three-dimensional graphical representations of mathematical functions.	C
4	Explore and solve problems in basic linear algebra and calculus using built-in functions and tools in Mathematica.	An
5	Develop programs in Mathematica to find numerical solutions to linear and non-linear equations.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
CO	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	1	2	1	2	2	1	3	2	3	3	1	1	2	1
CO2	3	3	3	1	2	1	3	2	1	3	2	3	3	2	2	1	1
CO3	3	3	3	1	2	1	3	2	1	3	2	3	3	2	2	1	1
CO4	3	3	3	1	2	1	3	3	1	3	2	3	3	3	2	1	1
CO5	3	3	3	1	2	1	3	2	1	3	2	3	3	2	2	2	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	**Core language and structure:** Introduction to programming, Notation and conversion, Mathematica basic concept, constants, strings, lists, Mathematical expressions.	11	1
II	**Functional programming:** Built-in Functions, user-defined functions, Operation on functions, Recursive functions, Iterative functions, Loops and Flow-control.	12	2
III	**Two-Dimensional Graphics:** Plotting functions of single variable, Three-Dimensional Graphics – Plotting functions of two variables, other graphics command, Algebra and trigonometry.	13	3
IV	Basic Linear Algebra and Calculus using Mathematica.	12	4
V	Numerical Solutions of Linear and Non-linear equations using Mathematica. Developing Programs for each of these methods.	12	5

Textbooks & References

[1] Eugene Don. *Schaum's outline of Mathematica.* McGraw-Hill Professional, 2000.

[2] Kenneth M Shiskowski and Karl Frinkle. *Principles of Linear Algebra with Mathematica.* John Wiley & Sons, 2013.

[3] Selwyn L Hollis. *CalcLabs with Mathematica: Multivariable Calculus.* Thomson Learning, 1998.

[4] Selwyn L Hollis. *Multivariable Calculus.* Brooks/Cole Publishing Company, 2002.

3.6 GL301 : Computational Mathematics-I

Learning Objective (LO): The aim of this course is to provide students with a solid foundation in computational mathematics using tools like Mathematica. The course emphasizes programming structures, mathematical expressions, and problem-solving techniques, equipping students to tackle both theoretical and applied mathematical challenges through computational methods.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the core structure of programming in Mathematica, including constants, strings, lists, and mathematical expressions.	U
2	Apply the principles of functional programming in Mathematica, including user-defined functions, recursive and iterative methods, and flow control.	Ap
3	Create and manipulate two-dimensional and three-dimensional graphical representations of mathematical functions.	C
4	Explore and solve problems in basic linear algebra and calculus using built-in functions and tools in Mathematica.	An
5	Develop programs in Mathematica to find numerical solutions to linear and non-linear equations.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	3	2	1	2	2	1	3	2	3	3	1	1	2	-
CO2	3	3	3	3	2	1	3	2	1	3	2	3	3	2	2	1	-
CO3	3	3	3	3	2	1	3	2	1	3	2	3	3	2	2	1	-
CO4	3	3	3	3	2	1	3	3	1	3	2	3	3	3	2	1	-
CO5	3	3	3	3	2	1	3	2	1	3	2	3	3	2	2	2	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Contents: Practical of computational mathematics laboratory using Mathematica based on syllabus of M305.

Textbooks & References

[1] Eugene Don. *Schaum's outline of Mathematica.* McGraw-Hill Professional, 2000.

[2] Kenneth M Shiskowski and Karl Frinkle. *Principles of Linear Algebra with Mathematica.* John Wiley & Sons, 2013.

[3] Selwyn L Hollis. *CalcLabs with Mathematica: Multivariable Calculus.* Thomson Learning, 1998.

[4] Selwyn L Hollis. *Multivariable Calculus.* Brooks/Cole Publishing Company, 2002.

3.7 CB301: Essential Mathematics for Chemistry & Biology

Learning Objective (LO): The aim of this course is to introduce students to the essential mathematical techniques required in chemistry and biology, including differential equations, linear algebra, and calculus. Students will develop the ability to model and analyze biological and chemical systems mathematically, enhancing their problem-solving and analytical skills.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand and solve first-order differential equations using methods such as linear equations, separable equations, and exact equations with integrating factors.	U
2	Analyze second-order differential equations and apply reduction of order techniques for homogeneous equations with constant coefficients.	An
3	Apply Laplace transforms and the convolution theorem to solve differential equations and systems of differential equations.	Ap
4	Understand and explore vector spaces, including the concepts of linear independence, basis, and dimension.	U
5	Analyze eigenvalue problems, including characteristic polynomials, eigenvalues, and eigenvectors of real symmetric matrices, and their properties.	An

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	1	3	2	3	3	1	1	2	2
CO2	3	3	3	-	2	1	3	2	1	3	2	3	3	2	2	1	2
CO3	3	3	3	-	2	1	3	2	1	3	2	3	3	2	2	1	2
CO4	3	3	3	-	2	1	3	3	1	3	2	3	3	3	2	1	1
CO5	3	3	3	-	2	1	3	2	1	3	2	3	3	2	2	2	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	**Topics**	**No. of Lectures**	**CO No.**
I	**First Order Differential Equations:** Linear Equations, Nonlinear Equations, Separable Equations, Exact Equations, Integrating Factors.	12	1
II	**Second Order Linear Differential Equations:** Fundamental Solutions for the Homogeneous Equation, Linear Independence, Reduction of Order, Homogeneous Equations with Constant Coefficients.	12	2
III	Laplace transforms, inverse Laplace transforms, convolution theorem, applications of Laplace transform to solve system of differential equations.	12	3
IV	**Vector Spaces:** Finite dimensional over $\mathbb{R}$ or $\mathbb{C}$, Illustrate concepts with 2- or 3-dimensional examples, Linear Independence, Basis, Dimension, Rank of a Matrix.	12	4
V	The matrix Eigenvalue problems, Secular determinants, Characteristics polynomials, Eigenvalues and Eigenvectors. Eigenvalues of real symmetric matrices; Eigenvalues and Eigenvectors, important properties and examples.	12	5

Textbooks & References

[1] MD Raisinghania. *Ordinary and partial differential equations.* S. Chand Publishing, 2013.

[2] George F Simmons. *Differential equations with applications and historical notes.* CRC Press, 2016.

[3] Marc Lipson and Seymour Lipschutz. *Schaum's Outline of Linear Algebra*. McGraw-Hill Companies, Incorporated, 2018.

[4] S Kumaresan. *Linear algebra: a geometric approach*. PHI Learning Pvt. Ltd., 2000.

4 Semester-IV

4.1 M401:Analysis II

Learning Objective (LO): The aim of this course is to provide students with an advanced understanding of analysis, focusing on Riemann integration, series of functions, and uniform convergence. Students will enhance their analytical skills and develop the ability to rigorously solve problems related to real analysis and mathematical convergence.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand and analyze the concept of Riemann integration, including upper and lower Riemann sums, and determine integrability of functions.	An
2	Evaluate improper integrals using Cauchy's condition and convergence tests, and explore elementary transcendental functions and their properties.	E
3	Apply concepts of differentiation for multiple variables, including the Jacobian, and use the Inverse and Implicit Function theorems in problem-solving.	Ap
4	Analyze critical points, maxima, minima, saddle points, and use the Lagrange multiplier method to solve optimization problems.	An
5	Understand and evaluate multiple integrals, iterated integrals, and explore integration on curves and surfaces using Green's and Stokes' theorems.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	3	3	-	2	1	2	2	1	3	2	3	2	3	2	1	2
CO2	3	3	3	-	2	1	2	2	1	3	2	3	3	2	2	1	2
CO3	3	3	3	-	2	1	2	2	1	2	2	3	2	3	2	1	2
CO4	3	3	3	-	2	1	3	2	1	2	2	3	3	3	2	1	2
CO5	3	3	3	-	2	1	3	2	1	3	2	3	3	3	2	1	2

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Riemann Integration: Definition via upper and lower Riemann sums, basic properties. Riemann integrability, continuous implies f is Riemann integrable, examples of Riemann integrable functions which are not continuous on $[a,b]$. Properties of Riemann Integration.	14	1
II	Improper integrals, power series and elementary functions: Cauchy's condition for existence of improper integrals, test for convergence. Examples: $\int \frac{\sin x}{x}dx, \int \cos x^2 dx, \int \sin x^2 dx$. Power series and basic properties, continuity of the sum, validity of term by term differentiation. Binomial theorem for arbitrary real coefficients. Elementary transcendental functions $e^x, \sin x, \cos x$ and their inverse functions, $\log x, \tan^{-1} x$, Gudermannian and other examples.	10	2
III	Linear maps from R^n to R^m, Directional derivative, partial derivative, total derivative, Jacobian, Mean value theorem and Taylor's theorem for several variables, Chain Rule. Parametrized surfaces, coordinate transformations, Inverse function theorem, Implicit function theorem, Rank theorem.	12	3
IV	Critical points, maxima and minima, saddle points, Lagrange multiplier method.	12	4
V	Multiple integrals, Riemann and Darboux integrals, Iterated integrals, Improper integrals, Change of variables. Integration on curves and surfaces, Greens theorem, Differential forms, Divergence, Stokes theorem.	12	5

Textbooks & References

[1] James J Callahan. *Advanced calculus: a geometric view*, volume 1. Springer, 2010.

[2] Terence Tao. *Analysis*. Springer, 2009.

[3] Peter D Lax and Maria Shea Terrell. *Multivariable Calculus with Applications*. Springer, 2017.

[4] Miklós Laczkovich and Vera T Sós. *Real Analysis: Series, Functions of Several Variables, and Applications*, volume 3. Springer, 2017.

[5] Stanley J Miklavcic. *An illustrative guide to multivariable and vector calculus*. Springer Nature, 2020.

[6] Walter Rudin. *Principles of mathematical analysis*. McGraw-hill New York, 1976.

[7] George Pedrick. *A first course in analysis*. Springer Science & Business Media, 1994.

4.2 M402: Algebra II (Linear Algebra)

Learning Objective (LO): The aim of this course is to introduce students to the advanced concepts of linear algebra, including vector spaces, linear transformations, eigenvalues, eigenvectors, and inner product spaces. Students will develop the skills to analyze and solve problems in linear systems, abstract algebraic structures, and real-world applications.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand and demonstrate the fundamental concepts of vector spaces, including subspaces, quotient spaces, basis, and dimension.	U
2	Analyze linear maps and their correspondence with matrices, and apply concepts of change of bases in problem-solving.	An
3	Evaluate eigenvalues, eigenvectors, and eigenspaces, and apply the Cayley-Hamilton theorem in matrix theory.	E
4	Apply concepts of inner product spaces, diagonalization, and use the Gram-Schmidt process and spectral theorem for problem-solving.	Ap
5	Analyze quadratic forms, Jordan and rational canonical forms, and solve systems of linear equations using appropriate techniques.	An

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	3	2	-	2	1	2	2	1	3	2	3	3	2	1	2	3
CO2	3	3	3	-	2	1	2	2	1	3	2	3	3	2	2	1	3
CO3	3	3	3	-	2	1	2	2	1	3	2	3	3	2	1	2	3
CO4	3	3	3	-	2	1	3	2	1	2	2	3	3	2	2	1	3
CO5	3	3	3	-	2	1	3	2	1	3	2	3	3	3	2	1	3

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	**Topics**	**No. of Lectures**	**CO No.**
I	Vector spaces over a field, subspaces, quotient spaces. Span and linear independence, basis, dimension.	15	1
II	Linear maps and their correspondence with matrices with respect to given bases, change of bases.	11	2
III	Eigen-values, eigen-vectors, eigen-spaces, characteristic polynomial, Cayley-Hamilton theorem.	11	3
IV	Bilinear forms, inner product spaces, Gram-Schmidt process, diagonalization, spectral theorem.	11	4
V	Quadratic form, Jordan and rational canonical forms. System of linear equations.	12	5

Textbooks & References

[1] Ramji Lal. *Algebra 2: Linear Algebra, Galois Theory, Representation Theory, Group Extensions and Schur Multiplier.* Springer, 2017.

[2] S Kumaresan. *Linear algebra: a geometric approach.* PHI Learning Pvt. Ltd., 2000.

[3] Marc Lipson and Seymour Lipschutz. *Schaum's Outline of Linear Algebra.* McGraw-Hill Companies, Incorporated, 2018.

[4] Serge Lang. *Linear algebra.* Springer Berlin, 1987.

[5] Kenneth Hoffman and Ray Kunze. *Linear Algebra, Prentice-Hall.* Inc., Englewood Cliffs, New Jersey, 1971.

4.3 M403 : Introduction to Differential Equations

Learning Objective (LO): The aim of this course is to provide students with a comprehensive understanding of differential equations, focusing on techniques such as Laplace transforms, series solutions, and systems of linear differential equations. Students will develop the skills to model, analyze, and solve real-world problems using differential equations.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand and apply Laplace transforms, including shifting theorems, convolution theorem, and solve systems of differential equations using Laplace transformation.	Ap
2	Analyze and solve first-order partial differential equations using Lagrange's and Charpit's methods.	An
3	Classify and solve second-order and higher partial differential equations, and explore methods to reduce complex equations.	An
4	Demonstrate knowledge of calculus of variations, including Euler's equation and variational problems with fixed boundaries.	U
5	Evaluate variational problems with moving boundaries and apply sufficient conditions for an extremum, such as Jacobi and Legendre conditions.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	3	3	-	2	1	2	2	-	3	2	3	3	3	1	2	1
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	3	1	2	1
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	3	1	2	1
CO4	3	3	3	-	2	1	2	2	-	3	2	3	3	3	1	2	1
CO5	3	3	3	-	2	1	2	2	-	3	2	3	3	3	1	2	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Laplace Transformation- Linearity of the Laplace transformation. Existence theorem for Laplace transforms. Laplace transforms of derivatives and integrals. Shifting theorems. Differentiation and integration of transforms. Convolution theorem. Solution of integral equations and systems of differential equations using the Laplace transformation.	15	1
II	Partial differential equations of the first order. Lagrange's solution, Some special types of equations which can be solved easily by methods other than the general method. Charpit's general method of solution.	11	2
III	Partial differential equations of second and higher orders, Classification of linear partial differential equations of second order, Homogeneous and non-homogeneous equations with constant coefficients, Partial differential equations reducible to equations with constant coefficients, Monge's methods.	11	3
IV	Calculus of Variations- Variational problems with fixed boundaries- Euler's equation for functionals containing first-order derivative and one independent variable, Externals, Functionals dependent on higher-order derivatives. Functionals dependent on more than one independent variable, Variational problems in parametric form, invariance of Euler's equation under coordinates transformation.	11	4
V	Variational Problems with Moving Boundaries- Functionals dependent on one and two functions, One-sided variations. Sufficient conditions for an Extremum- Jacobi and Legendre conditions, Second Variation. Variational principle of least action.	12	5

Textbooks & References

[1] AK Nandakumaran, PS Datti, and Raju K George. *Ordinary differential equations: Principles and applications.* Cambridge University Press, 2017.

[2] S.L. Ross. *Introduction to Ordinary Differential Equations.* Wiley, 1989.

[3] George F Simmons. *Differential equations with applications and historical notes.* CRC Press, 2016.

[4] MD Raisinghania. *Ordinary and partial differential equations.* S. Chand Publishing, 2013.

[5] AS Gupta. *Calculus of variations with applications.* PHI Learning Pvt. Ltd., 1996.

[6] Erwin Kreyszig. *Advanced Engineering Mathematics 9th Edition with Wiley Plus Set.* John Wiley & Sons, 2007.

4.4 M404: Topology I

Learning Objective (LO): The aim of this course is to introduce students to the fundamental concepts of topology, including metric spaces, open and closed sets, continuity, and compactness. Students will develop the skills to analyze topological properties and apply them to solve mathematical and theoretical problems.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the definition and examples of metric spaces, explore the concept of norms, and analyze metrics on different sets and spaces.	U
2	Explore the topology generated by a metric, including open and closed sets, and properties of open sets in metric spaces.	An
3	Analyze the Hausdorff property, equivalence of metrics, limit points, closures, and dense sets in metric spaces.	An
4	Apply the concept of continuous maps, including epsilon-delta definitions and properties, and explore complete metric spaces with Cauchy sequences.	Ap
5	Evaluate concepts of compactness and connectedness in metric spaces, including key theorems like Bolzano-Weierstrass, Heine-Borel, and intermediate value theorem.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	1	2	1	2	2	1	3	2	3	3	2	1	2	1
CO2	3	3	3	1	2	1	3	2	1	3	2	3	3	2	2	1	2
CO3	3	3	3	1	2	1	3	2	1	3	2	3	3	2	2	1	1
CO4	3	3	3	1	2	1	3	2	1	3	2	3	3	3	2	1	2
CO5	3	3	3	1	2	1	2	2	1	3	2	3	3	3	2	1	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	**Metric spaces:** Definition and basic examples. The discrete metric on any set. $\mathbb{R}$ and $\mathbb{R}^n$ with Euclidean metrics, Cauchy-Schwarz inequality, definition of a norm on a finite-dimensional $\mathbb{R}$-vector space and the metric defined by a norm. The set $C[0,1]$ with the metric given by $\sup\|f(t) - g(t)\|$, metric subspaces, examples.	12	1
II	**Topology generated by a metric:** Open and closed balls, open and closed sets, complement of an open (closed) set, arbitrary unions (intersections) of open (closed) sets, finite intersections (unions) of open (closed) sets, open (closed) ball is an open (closed) set, properties of open sets.	11	2
III	Hausdorff property of a metric space. Equivalence of metrics, examples, the metrics on R^2 given by $\|x_1 - y_1\| + \|x_2 - y_2\|$ (resp. $max\|x_1 - y_1\|, \|x_2 - y_2\|$ is equivalent to the Euclidean metric, the shapes of open balls under these metrics. Limit points, isolated points, interior points, closure, interior and boundary of a set, dense and nowhere dense sets.	13	3
IV	**Continuous maps:** epsilon-delta definition and characterization in terms of inverse images of open (resp. closed) sets, composite of continuous maps, point-wise sums and products of continuous maps into $\mathbb{R}$; homomorphism, isometry, an isometry is a homomorphism but not conversely, uniformly continuous maps, examples. **Complete metric spaces:** Cauchy sequences and convergent sequences, a subspace of a complete metric space is complete if and only if it is closed, Cantor intersection theorem, Baire category theorem and its applications, completion of a metric space.	14	4
V	**Compactness for metric spaces:** Bolzano-Weierstrass property, the Lebesgue number for an open covering, sequentially compact and totally bounded metric spaces, Heine-Borel theorem, compact subsets of R; a continuous map from a compact metric space is uniformly continuous. **Connectedness:** Definition, continuous image of a connected set is connected, characterization in terms of continuous maps into the discrete space $\mathbb{N}$, connected subsets of $\mathbb{R}$; intermediate value theorem as a corollary, countable (arbitrary) union of connected sets, connected components.	11	5

Textbooks & References

[1] Edward Thomas Copson. *Metric spaces.* Cambridge University Press, 1988.

[2] Robert Herman Kasriel. *Undergraduate topology.* WB Saunders Company, 1971.

[3] W.R. Wade. *Introduction to Analysis: Pearson New International Edition.* Pearson Education, Limited, 2013.

[4] George F Simmons. *Introduction to topology and modern analysis.* Tata McGraw-Hill, 1963.

[5] Wilson A Sutherland. *Introduction to metric and topological spaces.* Oxford University Press, 2009.

4.5 G401: Statistical Techniques and applications

Learning Objective (LO): The aim of this course is to equip students with the knowledge of statistical techniques, including data collection, graphical representation, probability distributions, and hypothesis testing. Students will develop the ability to apply statistical methods to analyze data and interpret results in various practical and research contexts.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand and analyze the collection, classification, and graphical representation of statistical data, and calculate measures of central tendency, dispersion, skewness, and kurtosis.	An
2	Apply probability concepts, including events, theorems, and probability distributions to solve statistical problems.	Ap
3	Analyze expected values, characteristics functions, and various probability distributions to understand their applications in statistics.	An
4	Apply Monte Carlo techniques for generating statistical distributions and use parameter inference methods to estimate parameters.	Ap
5	Evaluate hypotheses using statistical tests, including goodness-of-fit, confidence intervals, and analysis of variance, and demonstrate the use of the R program for statistical analysis.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	1	2	1	2	2	-	3	2	3	3	2	1	2	2
CO2	3	3	3	1	2	1	2	2	-	3	2	3	3	2	2	1	2
CO3	3	3	3	1	2	1	3	2	-	3	2	3	3	2	2	1	2
CO4	3	3	3	1	2	1	3	2	-	3	2	3	3	3	2	1	2
CO5	3	3	3	1	2	1	3	2	-	3	2	3	3	3	2	1	2

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	General nature and scope of statistical methods: Collection and classification of data; different types of diagrams to represent statistical data; frequency distribution and related graphs and charts. Central tendency: Its measure and their uses. Dispersion: Its measure and their uses, Moments; skewness and kurtosis. Scatter diagram.	11	1
II	Elementary idea of probability: Events and Probabilities, Assignments of probabilities to events, addition and multiplication theorems; statistical independence and conditional probability; repeated trials; mathematical expectation; Random events and variables, Probability Axioms and Theorems. Probability distributions and properties: Discrete, Continuous and Empirical distributions.	11	2
III	Expected values: Mean, Variance, Skewness, Kurtosis, Moments and Characteristics Functions. Types of probability distributions: Binomial, Poisson, Normal, Gamma, Exponential, Chi-squared, Log-Normal, Student's t, F distributions, Central Limit Theorem.	13	3
IV	Monte Carlo techniques: Methods of generating statistical distributions: Pseudorandom numbers from computers and from probability distributions, Applications. Parameter inference: Given prior discrete hypotheses and continuous parameters, Maximum likelihood method for parameter inference.	13	4
V	Hypothesis tests: Single and composite hypothesis, Goodness of fit tests, P-values, Chi-squared test, Likelihood Ratio, Kolmogorov-Smirnov test, Confidence Interval. Covariance and Correlation, Analysis of Variance and Covariance. Illustration of statistical techniques through hands-on use of computer program R.	12	5

Textbooks & References

[1] SC Gupta and VK Kapoor. *Fundamentals of mathematical statistics.* Sultan Chand & Sons, 2020.

[2] Stephen Kokoska. *Introductory Statistics: A Problem-Solving Approach.* Macmillan, 2008.

[3] Geoffrey Grimmett and David Stirzaker. *Probability and random processes.* Oxford university press, 2020.

[4] Sheldon M Ross. *Introduction to probability and statistics for engineers and scientists.* Academic press, 2020.

[5] Michael Akritas. *Probability and Statistics with R.* New York: Pearson, 2015.

[6] Dieter Rasch, Rob Verdooren, and Jürgen Pilz. *Applied Statistics: Theory and Problem Solutions with R.* John Wiley & Sons, 2019.

4.6 GL401: Computational Laboratory and Numerical Methods (Using Python)

Learning Objective (LO): The aim of this course is to provide students with hands-on experience in computational methods and numerical techniques using Python programming. Students will develop problem-solving skills, implement numerical algorithms, and apply computational tools to analyze and solve mathematical and scientific problems.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the basic concepts of Python programming, including data types, variable expressions, and flow of execution.	U
2	Apply control flow structures, loops, and functions in Python to implement algorithms using data structures like lists, tuples, and dictionaries.	Ap
3	Analyze machine representation, error propagation, stability in numerical analysis, and solve linear algebraic equations using numerical methods.	An
4	Implement basic tools for numerical analysis, including solving algebraic functions and numerical integration techniques.	Ap
5	Evaluate and solve matrix algebra problems, including eigenvalue determination and matrix inversion using iterative and direct methods.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
CO	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	3	2	1	2	2	1	3	2	3	3	2	1	2	-
CO2	3	3	3	3	2	1	2	2	1	3	2	3	3	2	2	1	-
CO3	3	3	3	3	2	1	3	2	1	3	2	3	3	2	2	1	-
CO4	3	3	3	3	2	1	3	2	1	3	2	3	3	2	2	1	-
CO5	3	3	3	3	2	1	3	2	1	3	2	3	3	2	2	1	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	**Introduction to Python:** Datatypes – Int, Float, Boolean, String, and list, Variable expressions, Statements, Precedence of operators, comments, module functions and its uses, flow of execution, parameters, and arguments.	13	1
II	**Control flow, loops:** Conditionals, Boolean values and operators, conditional (if), alternative (if-else), Chained conditional (if-elif-else), Iteration - while, for, Break, continue, functions, Arrays, List, Tuples, Dictionaries.	11	2
III	Machine representation and precision, Error and its sources, propagation and Analysis; Error in summation, Stability in numerical analysis, Linear algebraic equations, Gaussian elimination, direct Triangular Decomposition, matrix inversion. Understanding limitations of calculations due to algorithm or round-off error, Single/double precision.	14	3
IV	**Basic tools for numerical analysis in science:** Solution of algebraic functions–Fixed point method, Newton-Raphson method, Secant method. Numerical Integration – Rectangular method, trapezoidal method, Lagrange's interpolation.	10	4
V	**Matrix Algebra:** Approximate solution of a set of linear simultaneous equations by Gauss-Siedel iteration method. Exact solution by Gaussian elimination. Inversion of a matrix by Gaussian elimination. Determining all the eigenvalues of a real symmetric matrix by Householder's method of tri-diagonalization followed by QR factorization of the tri-diagonalized matrix.	12	5

Textbooks & References

[1] Chris Roffey. *Cambridge IGCSE® and O Level Computer Science Programming Book for Python.* Cambridge University Press, 2017.

[2] Bhajan Singh Grewal and Grewal. JS. *Numerical methods in Engineering and Science.* Khanna Publishers, 1996.

4.7 GL402: Statistical Techniques Laboratory

Learning Objective (LO): The aim of this course is to equip students with practical skills in statistical techniques through laboratory exercises. Students will learn data collection, classification, graphical representation, and statistical computations. The course enables learners to apply statistical methods to analyze data effectively and interpret results in practical scenarios.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand and analyze the collection, classification, and graphical representation of statistical data, and calculate measures of central tendency, dispersion, skewness, and kurtosis.	An
2	Apply probability concepts, including events, theorems, and probability distributions to solve statistical problems.	Ap
3	Analyze expected values, characteristics functions, and various probability distributions to understand their applications in statistics.	An
4	Apply Monte Carlo techniques for generating statistical distributions and use parameter inference methods to estimate parameters.	Ap
5	Evaluate hypotheses using statistical tests, including goodness-of-fit, confidence intervals, and analysis of variance, and demonstrate the use of the R program for statistical analysis.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
CO	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	3	2	1	2	2	1	3	2	3	3	2	1	2	-
CO2	3	3	3	3	2	1	2	2	1	3	2	3	3	2	2	1	-
CO3	3	3	3	3	2	1	3	2	1	3	2	3	3	2	2	1	-
CO4	3	3	3	3	2	1	3	2	1	3	2	3	3	3	2	1	-
CO5	3	3	3	3	2	1	3	2	1	3	2	3	3	3	2	1	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Contents: Practical of applied statistics using R programming language based on syllabus of G401.

Textbooks & References

[1] Chris Roffey. *Cambridge IGCSE® and O Level Computer Science Programming Book for Python.* Cambridge University Press, 2017.

[2] Bhajan Singh Grewal and Grewal. JS. *Numerical methods in Engineering and Science.* Khanna Publishers, 1996.

5 Semester-V

5.1 M501 : Analysis III (Measure Theory and Integration)

Learning Objective (LO): The aim of this course is to introduce students to advanced topics in analysis, including measure theory, Lebesgue integration, and measurable functions. Students will develop rigorous mathematical reasoning and learn to apply these concepts to solve complex problems in analysis and related fields.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the concept of sigma algebra, measure spaces, and Lebesgue outer measure, and explore measurable sets and their properties.	U
2	Analyze measurable functions and different types of convergence, and apply the Lebesgue integral to various classes of functions.	An
3	Apply convergence theorems such as the monotone convergence and dominated convergence theorems in the context of Lebesgue integration.	Ap
4	Compare and contrast the Riemann and Lebesgue integrals, and understand Riemann's theorem on functions that are continuous almost everywhere.	E
5	Evaluate product measures, Fubini's theorem, and the properties of L^p spaces, including inequalities and completeness.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO	POs											PSOs					
CO	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	1
CO2	3	3	3	-	2	1	2	2	-	3	2	3	3	2	2	1	1
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO4	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	**Topics**	**No. of Lectures**	**CO No.**
I	Sigma algebra of sets, measure spaces. Lebesgue outer measure on the real line. Measurable set in the sense of Caratheodory. Translation invariance of Lebesgue measure. Existence of a non-Lebesgue measurable set. Cantor set- uncountable set with measure zero.	15	1
II	Measurable functions, types of convergence of measurable functions. The Lebesgue integral for simple functions, nonnegative measurable functions and Lebesgue integrable function, in general.	15	2
III	Convergence theorems- monotone and dominated convergence theorems.	9	3
IV	Comparison of Riemann and Lebesgue integrals. Riemann's theorem on functions which are continuous almost everywhere.	9	4
V	The product measure and Fubini's theorem. The L^p spaces and the norm topology. Inequalities of Hölder and Minkowski. Completeness of L^p and L^∞ spaces.	12	5

Textbooks & References

[1] P.K. Jain, P.K. Jain, and V.P. Gupta. *Lebesgue Measure and Integration.* A Halsted press book. Wiley, 1986.

[2] S. Shirali. *A Concise Introduction to Measure Theory.* Springer International Publishing, 2019.

[3] C.D. Aliprantis and O. Burkinshaw. *Principles of Real Analysis.* Academic Press, 2008.

[4] I.K. Rana. *An Introduction to Measure and Integration.* Alpha Science international, 2005.

[5] J. Yeh. *Problems and Proofs in Real Analysis: Theory of Measure and Integration.* World Scientific, 2014.

[6] S.G. Krantz. *Elementary Introduction to the Lebesgue Integral.* CRC Press, 2018.

[7] HL Royden and PM Fitzpatrick. *Real analysis 4th Edition.* Printice-Hall Inc, Boston, 2010.

5.2 M502 : Algebra III (Galois Theory)

Learning Objective (LO): The aim of this course is to introduce students to advanced topics in algebra, focusing on Galois theory, field extensions, and polynomial roots. Students will develop a deeper understanding of the interplay between algebraic structures and their applications, enhancing their problem-solving and abstract reasoning skills.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the concept of prime and maximal ideals in commutative rings and their basic properties.	U
2	Analyze field extensions, characteristics of fields, and explore algebraic extensions, splitting fields, and separable extensions.	An
3	Apply the concepts of Galois Theory and understand the Fundamental Theorem of Galois Theory in finite Galois extensions.	Ap
4	Evaluate the solvability of polynomials by radicals and explore the conditions under which equations are solvable.	E
5	Explore and understand the structure and properties of extensions of finite fields.	U

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	3
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	3
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	3
CO4	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	3
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	3

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Prime and maximal ideals in a commutative ring and their elementary properties.	13	1
II	Field extensions, prime fields, characteristic of a field, algebraic field extensions, finite field extensions, splitting fields, algebraic closure, separable extensions, normal extensions.	15	2
III	Finite Galois extensions, Fundamental Theorem of Galois Theory.	10	3
IV	Solvability by radicals.	7	4
V	Extensions of finite fields.	15	5

Textbooks & References

[1] R. Lal. *Algebra 1: Groups, Rings, Fields and Arithmetic.* Infosys Science Foundation Series. Springer Singapore, 2017.

[2] R. Lal. *Algebra 2: Linear Algebra, Galois Theory, Representation theory, Group extensions and Schur Multiplier.* Infosys Science Foundation Series. Springer Nature Singapore, 2017.

[3] J.A. Gallian. *Contemporary Abstract Algebra.* Textbooks in mathematics. CRC, Taylor & Francis Group, 2020.

[4] P.B. Bhattacharya, S.K. Jain, and S.R. Nagpaul. *Basic Abstract Algebra.* Basic Abstract Algebra. Cambridge University Press, 1994.

[5] David Steven Dummit and Richard M Foote. *Abstract algebra.* Wiley Hoboken, 2004.

[6] Nathan Jacobson. *Basic algebra I.* Courier Corporation, 2012.

[7] Nathan Jacobson. *Lectures in Abstract Algebra: II. Linear Algebra.* Springer Science & Business Media, 2013.

[8] Serge Lang. *Algebra.* Springer Science & Business Media, 2012.

5.3 M503: Topology II

Learning Objective (LO): The aim of this course is to deepen students' understanding of topology by exploring general topological spaces, continuous maps, compactness, connectedness, and separation axioms. Students will enhance their ability to analyze and apply topological concepts to solve advanced mathematical problems.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the basic concepts of general topological spaces, including stronger and weaker topologies, continuous maps, and finite products of spaces.	U
2	Analyze the concept of compactness in general topological spaces and explore the relationship between compactness and Hausdorff property.	An
3	Apply separation and countability axioms, and understand Tychonoff's theorem and its implications for product spaces.	Ap
4	Explore the weak and coherent topologies induced by families of maps, and understand their applications in quotient spaces and embeddings.	An
5	Evaluate completely regular spaces, compactifications, and theorems related to normal spaces, including Urysohn's and Tietze's theorems.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
CO	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	2
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO4	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	General topological spaces, stronger and weaker topologies, continuous maps, homomorphisms, bases and subbases, finite products of topological spaces.	15	1
II	**Compactness for general topological spaces:** Finite subcoverings of open coverings and finite intersection property, continuous image of a compact set is compact, compactness and Hausdorff property.	15	2
III	Basic Separation axioms and first and second countability axioms. Examples. Products and quotients. Tychonoff's theorem. Product of connected spaces is connected.	10	3
IV	Weak topology on X induced by a family of maps $f_\alpha : X \to X_\alpha$ where each X_α is a topological space. The coherent topology on Y induced by a family of maps $g_\alpha : Y_\alpha \to Y$ are given topological spaces. Examples of quotients to illustrate the universal property such as embeddings of RP^2 and the Klein's bottle in R^4.	10	4
V	Completely regular spaces and its embeddings in a product of intervals. Compactification, Alexandroff and Stone-Cech compactifications. Normal spaces and the theorems of Urysohn and Tietze. The metrization theorem of Urysohn.	10	5

Textbooks & References

[1] Kapil D Joshi. *Introduction to general topology.* New Age International, 1983.

[2] F Simmons George. Topology and modern analysis.(1963).

[3] James Munkres. Topology james munkres, second edition. 1999.

[4] John B Conway. *A course in point set Topology.* Springer, 2014.

5.4 M504: Probability Theory

Learning Objective (LO): The aim of this course is to provide students with a rigorous understanding of probability theory, including concepts of random variables, probability distributions, expectation, and limit theorems. Students will develop the ability to apply probabilistic techniques to analyze and solve problems in various domains.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the concept of probability as a measure, probability space, conditional probability, and standard probability distributions.	U
2	Analyze sequences of random variables, convergence theorems, and apply the Borel-Cantelli lemmas and zero-one laws to study random events.	An
3	Evaluate the Central Limit Theorem, weak convergence, and characteristic functions, and understand their applications in probability theory.	E
4	Explore random walks, Markov chains, and distinguish between recurrence and transience in the context of stochastic processes.	Ap
5	Apply the concept of conditional expectation and study the properties of martingales.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	1
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO4	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Probability as a measure, Probability space, conditional probability, independence of events, Bayes formula. Random variables, distribution functions, expected value and variance. Standard Probability distributions: Binomial, Poisson and Normal distribution.	15	1
II	Borel-Cantelli lemmas, zero-one laws. Sequences of random variables, convergence theorems, Various modes of convergence. Weak law and the strong law of large numbers.	15	2
III	Central limit theorem: DeMoivre-Laplace theorem, weak convergence, characteristic functions, inversion formula, moment generating function.	10	3
IV	Random walks, Markov Chains, Recurrence and Transience.	10	4
V	Conditional Expectation, Martingales.	10	5

Textbooks & References

[1] Geoffrey Grimmett and David Stirzaker. *Probability and random processes.* Oxford university press, 2020.

[2] Marek Capinski and Tomasz Jerzy Zastawniak. *Probability through problems.* Springer Science & Business Media, 2013.

[3] Joseph K Blitzstein and Jessica Hwang. *Introduction to probability.* Crc Press Boca Raton, FL, 2015.

[4] Jeffrey S Rosenthal. *First Look At Rigorous Probability Theory, A.* World Scientific Publishing Company, 2006.

[5] Kai Lai Chung and Farid AitSahlia. *Elementary probability theory: with stochastic processes and an introduction to mathematical finance.* Springer Science & Business Media, 2006.

5.5 PM501: Numerical Analysis

Learning Objective (LO): The aim of this course is to introduce students to the principles and techniques of numerical analysis, including error analysis, interpolation, numerical differentiation, and integration. Students will develop the skills to apply numerical methods to solve mathematical problems and analyze their accuracy and efficiency.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the sources and propagation of errors in numerical analysis, and solve linear algebraic equations using Gaussian elimination and matrix inversion techniques.	U
2	Apply root-finding methods like bisection, Newton's method, and Laguerre's method, and solve matrix eigenvalue problems using methods such as Jacobi's method.	Ap
3	Analyze polynomial interpolation, least squares approximation, and the use of orthogonal polynomials for function approximation.	An
4	Evaluate numerical integration techniques, including Gaussian quadrature, and understand numerical differentiation and Monte Carlo methods.	E
5	Apply numerical methods to solve least squares problems and ordinary differential equations using techniques such as predictor-corrector and Runge-Kutta methods.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	1	2	1	2	2	-	3	2	3	3	2	1	2	1
CO2	3	3	3	1	2	1	3	2	-	3	2	3	3	2	2	1	1
CO3	3	3	3	1	2	1	3	2	-	3	2	3	3	2	2	1	1
CO4	3	3	3	1	2	1	3	2	-	3	2	3	3	2	2	1	1
CO5	3	3	3	1	2	1	3	2	-	3	2	3	3	2	2	1	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Error, its sources, propagation and analysis; Errors in summation, stability in numerical analysis. Linear algebraic equations: Gaussian elimination, direct triangular decomposition, matrix inversion.	13	1
II	Root finding: review of bisection method, Newton's method and secant method; real roots of polynomials, Laguerre's method. Matrix eigenvalue problems: Power method, eigenvalues of real symmetric matrices using Jacobi method, applications.	13	2
III	Interpolation theory: Polynomial interpolation, Newton's divided differences, forward differences, interpolation errors, cubic splines. Approximation of functions: Taylor's theorem, remainder term; Least squares approximation problem, Orthogonal polynomials.	11	3
IV	Numerical integration: review of trapezoidal and Simpson's rules, Gaussian quadrature; Error estimation. Numerical differentiation. Monte Carlo methods.	11	4
V	Least squares problems: Linear least squares, examples; Non-linear least squares. Ordinary differential equations: stability, predictor-corrector method, Runge-Kutta methods, boundary value problems, basis expansion methods, applications. Eigenvalue problems for differential equations, applications.	12	5

Textbooks & References

[1] Bhajan Singh Grewal and Grewal. JS. *Numerical methods in Engineering and Science.* Khanna Publishers, 1996.

[2] Kendall E Atkinson. *An introduction to numerical analysis.* John wiley & sons, 2008.

[3] Amos Gilat. *MATLAB: an introduction with applications.* John Wiley & Sons, 2004.

[4] Richard Hamming. *Numerical methods for scientists and engineers.* Courier Corporation, 2012.

[5] Y Vetterlillg, V Press, S Teukolsky, and B Flannery. *Numerical Recipes in C.* Cambridge University Press, 2000.

5.6 PML501: Numerical Methods Laboratory

Learning Objective (LO): The aim of this course is to provide students with practical experience in implementing numerical methods using computational tools such as MATLAB. Students will learn to solve mathematical problems, analyze data, and develop efficient algorithms for numerical computations.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand and work with Matlab, performing basic arithmetic operations, managing variables, and creating script files.	U
2	Apply concepts of arrays, plotting, and control structures, including loops and conditional statements, to solve problems in Matlab.	Ap
3	Create and manage function files in Matlab, perform polynomial operations, and implement interpolation and curve fitting techniques.	Ap
4	Solve algebraic and transcendental equations using graphical methods and numerical techniques such as Bisection, Secant, and Newton-Raphson methods.	E
5	Apply numerical methods to solve ordinary differential equations using methods like Euler's, Taylor's, and Runge-Kutta, and address boundary value and eigenvalue problems.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	3	2	1	2	2	-	3	2	3	3	2	1	2	-
CO2	3	3	3	3	2	1	2	2	-	3	2	3	3	2	2	1	-
CO3	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	-
CO5	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Starting Matlab, Matlab windows, Working in the command window, arithmetic Operations with scalars, Math Built-in function, Designing Scalar variables, Useful commands for managing variables, Script files.	13	1
II	Creating Arrays, Mathematical Operations with Arrays, Two-Dimensional Plots, Relational and logical Operators, Conditional statement, loops, Nested Loops and Nested Conditional Statements, The break and continue command.	12	2
III	Creating a function file, Structure of a function file, Local and Global variable, Polynomials - value of a polynomial, Roots of a polynomial, Addition, multiplication and Division of polynomials, Derivative of polynomials, Curve Fitting with polynomials, Interpolation.	12	3
IV	Solution of Algebraic and Transcendental Equation, Basic properties of equations, Synthetic Division of a polynomial by a linear expression, Graphics Solution of equations, Bisection Method, Secant Method, Newton Raphson Method, Mullers Method, Gauss elimination Method, Gauss Jordan Method.	12	4
V	**Numerical solution of ordinary Differential equations:** Introduction, Picard Method, Euler's Method, Taylor's Series Method, Runge Kutta Method, Boundary value problems, Eigen value problems.	11	5

Textbooks & References

[1] Bhajan Singh Grewal and Grewal. JS. *Numerical methods in Engineering and Science.* Khanna Publishers, 1996.

[2] Amos Gilat. *MATLAB: an introduction with applications.* John Wiley & Sons, 2004.

[3] Richard Hamming. *Numerical methods for scientists and engineers.* Courier Corporation, 2012.

6 Semester - VI

6.1 M601: Analysis IV (Complex Analysis)

Learning Objective (LO): The aim of this course is to provide students with a comprehensive understanding of complex analysis, including concepts of complex numbers, analytic functions, conformal mappings, and Cauchy's theorems. Students will develop the ability to solve problems in complex domains and apply theoretical knowledge to practical scenarios.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the concepts of complex numbers, Riemann sphere, and Mobius transformations and their geometric interpretations.	U
2	Apply the Cauchy-Riemann conditions to identify analytic functions, explore harmonic functions, and use power series and conformal mappings.	Ap
3	Analyze contour integrals and apply Cauchy's theorem and integral formula to simply and multiply connected domains.	An
4	Evaluate real integrals using concepts of isolated singularities, Laurent series, and the residue theorem, and understand fundamental theorems such as Morera's and Liouville's.	E
5	Explore the concepts of zeros, poles, and the argument principle, and apply Rouché's theorem in solving complex analysis problems.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	3
CO2	3	3	3	-	2	1	2	2	-	3	2	3	3	2	2	1	3
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	3
CO4	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	3
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	3

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	**Topics**	**No. of Lectures**	**CO No.**
I	Complex numbers and Riemann sphere. Mobius transformations.	10	1
II	Analytic functions. Cauchy-Riemann conditions, harmonic functions, Elementary functions, Power series, Conformal mappings.	10	2
III	Contour integrals, Cauchy theorem for simply and multiply connected domains. Cauchy integral formula, Winding number.	13	3
IV	Morera's theorem. Liouville's theorem, Fundamental theorem of Algebra. Zeros of an analytic function and Taylor's theorem. Isolated singularities and residues, Laurent series, Evaluation of real integrals.	14	4
V	Zeros and Poles, Argument principle, Rouché's theorem.	13	5

Textbooks & References

[1] Saminathan Ponnusamy and Herb Silverman. *Complex variables with applications.* Springer, 2006.

[2] D Martin and LV Ahlfors. *Complex analysis.* New York: McGraw-Hill, 1966.

[3] Bruce P Palka. *An introduction to complex function theory.* Springer Science & Business Media, 1991.

[4] Ruel Churchill and James Brown. *Complex Variables and Applications.* McGraw Hill, 2014.

[5] Endre Pap. *Complex analysis through examples and exercises.* Springer Science & Business Media, 1999.

[6] Dennis Spellman. *Schaum's Outline of Complex Variables.* McGraw-Hill, New York, 2009.

6.2 M602: Algebra IV (Rings and Modules: Some Structure Theory)

Learning Objective (LO): The aim of this course is to provide students with an in-depth understanding of the structure theory of rings and modules, including submodules, quotient modules, homomorphisms, and exact sequences. Students will develop the ability to analyze and apply algebraic structures to solve theoretical and practical problems in mathematics.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the basic concepts of modules, submodules, quotient modules, and homomorphisms, and their relationships.	U
2	Explore external and internal direct sums of modules and analyze the tensor product of modules over a commutative ring.	An
3	Understand and apply the properties of projective and injective modules in the context of commutative rings.	Ap
4	Analyze the structure of finitely generated modules over a Principal Ideal Domain (PID) and explore applications to matrices and linear maps over a field.	An
5	Explore the concepts of simple modules, modules of finite length, and understand the significance of Jordan-Holder Theorem, Schur's Lemma, and semisimple modules.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	1
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO4	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	**Topics**	**No. of Lectures**	**CO No.**
I	Modules, submodules, quotient modules, homomorphisms.	15	1
II	External and internal direct sums of modules. Tensor product of modules over a commutative ring. Functor properties of Homomorphism.	12	2
III	Definitions and elementary properties of projective and injective modules over a commutative ring.	11	3
IV	Structure of finitely generated modules over a PID. Applications to matrices and linear maps over field.	11	4
V	Simple modules over a not necessarily commutative ring, modules of finite length, Jordan-Holder Theorem, Schur's lemma. Semisimple modules.	11	5

Textbooks & References

[1] Phani Bhushan Bhattacharya, Surender Kumar Jain, and SR Nagpaul. *Basic abstract algebra.* Cambridge University Press, 1994.

[2] David Steven Dummit and Richard M Foote. *Abstract algebra*, volume 3. Wiley Hoboken, 2004.

[3] Nathan Jacobson. *Basic algebra I.* Courier Corporation, 2012.

[4] Nathan Jacobson. *Lectures in Abstract Algebra: II. Linear Algebra.* Springer Science & Business Media, 2013.

[5] Serge Lang. *Algebra.* Springer Science & Business Media, 2012.

6.3 M603 : Partial Differential Equations

Learning Objective (LO): The aim of this course is to provide students with a thorough understanding of partial differential equations, including their origins, classifications, and methods of solution. Students will develop the skills to analyze and solve mathematical models involving PDEs and apply them to various scientific and engineering problems.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the origins and generalities of partial differential equations, including the Cauchy problem, characteristics, and uniqueness theorems.	U
2	Analyze first-order quasilinear equations using the method of characteristics, and explore fully nonlinear equations, such as the Eikonal and Hamilton-Jacobi equations.	An
3	Apply detailed analysis to Laplace and Poisson equations, using Green's function and integral representations to explore properties like analyticity, mean value, and maximum principles.	Ap
4	Evaluate the Cauchy problem for the wave equation and understand its integral representation, properties of propagation, and domain of influence.	E
5	Explore the Cauchy problem for the heat equation, analyze solutions using integral representations and Fourier methods, and understand concepts like infinite propagation speed and non-uniqueness.	An

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	3
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	3
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	3
CO4	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	3
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	3

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Generalities on the origins of partial differential equations. Generalities on the Cauchy problem for a scalar linear equation of arbitrary order. The concept of characteristics. The Cauchy-Kowalevsky theorem and the Holmgren's uniqueness theorem. First order partial differential equations and their solutions.	13	1
II	Quasilinear first order scalar partial differential equations and the method of characteristics. Detailed discussion of the inviscid Burger's equation illustrating the formation of discontinuities in finite time. The fully nonlinear scalar equation and Eikonal equation. The Hamilton-Jacobi equation.	12	2
III	Detailed analysis of the Laplace and Poisson's equations. Green's function for the Laplacian and its basic properties. Integral representation of solutions and its consequences such as the analyticity of solutions. The mean value property for harmonic functions and maximum principles. Harnack inequality.	12	3
IV	The wave equation and the Cauchy problem for the wave equation. The Euler-Poisson Darboux equation and integral representation for the wave equation in dimensions two and three. Properties of solutions such as finite speed of propagation. Domain of dependence and domain of influence.	12	4
V	The Cauchy problem for the heat equation and the integral representation for the solutions of The Cauchy problem for Cauchy data satisfying suitable growth restrictions. Infinite speed of propagation of signals. Example of non-uniqueness. Fourier methods for solving initial boundary value problems.	11	5

Textbooks & References

[1] AK Nandakumaran and PS Datti. *Partial Differential Equations: Classical Theory with a Modern Touch.* Cambridge University Press, 2020.

[2] MD Raisinghania. *Ordinary and partial differential equations.* S. Chand Publishing, 2013.

[3] A Weinstein. *R. Courant and D. Hilbert, Methods of mathematical physics.* American Mathematical Society, 1954.

[4] Robert C McOwen. *Partial differential equations: methods and applications.* Pearson, 2004.

6.4 M604: Ordinary Differential Equations

Learning Objective (LO): The aim of this course is to provide students with a comprehensive understanding of ordinary differential equations, including existence and uniqueness theorems, linear and nonlinear systems, and qualitative analysis. Students will develop skills to model, analyze, and solve ODEs, applying them to various real-world problems.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the basic existence and uniqueness theorems for systems of ordinary differential equations, including the Lipschitz condition and the implications of Gronwall's lemma.	U
2	Analyze linear systems of differential equations using Wronskian properties, Abel Liouville formula, and the method of variation of parameters.	An
3	Apply techniques to solve linear systems with constant coefficients, and explore the role of matrix exponentials in inhomogeneous systems.	Ap
4	Evaluate second-order scalar differential equations, focusing on Sturm comparison and separation theorems, and understand Sturm-Liouville problems.	E
5	Study series solutions of ordinary differential equations and perform detailed analysis of Bessel and Legendre differential equations.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	3	2	-	2	1	2	2	-	3	2	3	3	2	1	2	3
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	3
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	3
CO4	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	3
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	3

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Basic existence and uniqueness of systems of ordinary differential equations satisfying the Lipschitz's condition. Examples illustrating non-uniqueness when Lipschitz or other relevant conditions are dropped. Gronwall's lemma and its applications to continuity of the solutions with respect to initial conditions. Smooth dependence on initial conditions and the variational equation. Maximal interval of existence and global solutions. Proof that if (a, b) is the maximal interval of existence and $a < 1$ then the graph of the solution must exit every compact subset of the domain on the differential equation.	15	1
II	Linear systems and fundamental systems of solutions. Wronskians and its basic properties. The Abel Liouville formula. The dimensionality of the space of solutions. Fundamental matrix. The method of variation of parameters.	10	2
III	Linear systems with constant coefficients and the structure of the solutions. Matrix exponentials and methods for computing them. Solving the in-homogeneous system.	12	3
IV	Second order scalar linear differential equations. The Sturm comparison and separation theorems and regular Sturm-Liouville problems.	12	4
V	Series solutions of ordinary differential equations and a detailed analytic study of the differential equations of Bessel and Legendre.	11	5

Textbooks & References

[1] AK Nandakumaran, PS Datti. and Raju K George. *Ordinary differential equations: Principles and applications.* Cambridge University Press, 2017.

[2] S.L. Ross. *Introduction to Ordinary Differential Equations.* Wiley, 1989.

[3] George F Simmons. *Differential equations with applications and historical notes.* CRC Press, 2016.

[4] MD Raisinghania. *Ordinary and partial differential equations.* S. Chand Publishing, 2013.

6.5 M605: Numerical Analysis of Partial Differential Equations

Learning Objective (LO): The aim of this course is to equip students with numerical techniques for solving partial differential equations. Topics include classification of PDEs, finite difference methods, and stability analysis. Students will develop the ability to implement numerical algorithms and analyze their efficiency and accuracy in solving real-world problems.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the classification of partial differential equations and analyze the properties of heat, wave, and Laplace equations.	U
2	Apply finite difference methods to solve two-dimensional Poisson equations, and perform convergence analysis in simulation contexts.	Ap
3	Explore and analyze finite volume methods for two-dimensional diffusion equations, and understand the relationship between finite volumes and finite differences.	An
4	Evaluate spectral methods based on Fourier series and Chebyshev polynomials, and understand their convergence properties.	E
5	Understand strong, weak, and variational forms of differential equations, and generalize their discretization techniques with different boundary conditions.	U

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	1
CO2	3	3	3	-	2	1	2	2	-	3	2	3	3	2	2	1	1
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO4	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO5	3	3	3	-	2	1	2	2	-	3	2	3	3	2	2	1	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	**Topics**	**No. of Lectures**	**CO No.**
I	Partial Differential Equations, Classification, Heat, Wave, Laplace Equations, Elliptical problems.	12	1
II	Finite differences for the Two-dimensional Poisson Equation, Convergence Analysis, Room Temperature Simulation using Finite Differences.	12	2
III	Finite volumes for a general Two-dimensional Diffusion Equation, Boundary conditions, Relation between Finite Volumes and Finite differences, Finite Volume method are not Consistent, Convergence Analysis.	12	3
IV	Spectral Method Based on Fourier series, Spectral Method with Discrete Fourier series, Convergence Analysis, Spectral Method Based on Chebyshev Polynomials.	12	4
V	Strong form, Weak or variation form, and Minimization, Discretization, More General Boundary conditions, Convergence Analysis, Generalization to Two – Dimensions.	12	5

Textbooks & References

[1] Martin J Gander and Felix Kwok. *Numerical analysis of partial differential equations using maple and MATLAB.* SIAM, 2018.

[2] Matthew P Coleman. *An introduction to partial differential equations with MATLAB.* CRC Press, 2016.

[3] Jichun Li and Yi-Tung Chen. *Computational partial differential equations using MATLAB®*. Crc Press, 2019.

6.6 ML601: Computational Mathematics Laboratory-III (Numerical Analysis of PDE using Matlab or Python)

Learning Objective (LO): The aim of this course is to provide students with hands-on experience in computational mathematics by solving partial differential equations using MATLAB or Python. Students will develop practical skills to implement numerical methods, analyze solutions, and understand the computational aspects of PDEs in scientific and engineering contexts.

Learning Outcomes

LO No.	Learning Outcomes	Cognitive Level (CL)
1	Use MATLAB to solve PDE.	Ap
2	Understand the Numerical Analysis of PDE using MATLAB or Python.	U
3	Apply finite element method, finite difference method to solve PDEs.	Ap
4	Apply the Spectral Method Based on Fourier series, Spectral Method with Discrete Fourier series.	Ap
5	Understand the Room Temperature Simulation using Finite Differences.	U

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	3	2	1	2	2	-	3	2	3	3	2	1	2	-
CO2	3	3	3	3	2	1	2	2	-	3	2	3	3	2	2	1	-
CO3	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	-
CO5	3	3	3	3	2	1	2	2	-	3	2	3	3	2	2	1	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Contents: Practical of numerical analysis of partial differential equations using Matlab or Python based on syllabus of M605.

Detailed Syllabus:

Unit No.	Topics	No. of Lab Hours	CO No.
I	Partial Differential Equations, Classification, Heat, Wave, Laplace Equations, Elliptical problems.	12	1
II	Finite differences for the Two-dimensional Poisson Equation, Convergence Analysis. Room Temperature Simulation using Finite Differences.	12	2
III	Finite volumes for a general Two-dimensional Diffusion Equation, Boundary conditions, Relation between Finite Volumes and Finite differences, Finite Volume method are not Consistent. Convergence Analysis.	12	3
IV	Spectral Method Based on Fourier series, Spectral Method with Discrete Fourier series, Convergence Analysis, Spectral Method Based on Chebyshev Polynomials.	12	4
V	Strong form, Weak or variation form, and Minimization, Discretization, More General Boundary conditions, Convergence Analysis, Generalization to Two – Dimensions.	12	5

Textbooks & References

[1] Martin J Gander and Felix Kwok. *Numerical analysis of partial differential equations using maple and MATLAB*. SIAM, 2018.

[2] Matthew P Coleman. *An introduction to partial differential equations with MATLAB*. CRC Press, 2016.

[3] Jichun Li and Yi-Tung Chen. *Computational partial differential equations using MATLAB®*. Crc Press, 2019.

7 Semester - VII

7.1 M701 : Functional Analysis

Learning Objective (LO): The aim of this course is to introduce students to the fundamental concepts of functional analysis, including normed linear spaces, Banach and Hilbert spaces, and important theorems such as Hahn-Banach and Banach-Steinhaus. Students will develop the skills to analyze functional spaces and apply theoretical insights to mathematical and applied problems.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the properties of normed linear spaces, Riesz lemma, and key theorems such as Heine-Borel and Hahn-Banach.	U
2	Analyze Banach spaces, subspaces, and quotient spaces, and explore principles like uniform boundedness and the open mapping theorem.	An
3	Apply the concepts of spectrum, eigenspectrum, and dual spaces, and understand the spectral radius formula and Gelfand-Mazur theorem.	Ap
4	Evaluate Hilbert spaces using Bessel inequality, Riesz-Schauder theorem, Fourier expansions, and Parseval's formula.	E
5	Understand the framework of Hilbert spaces, applying the projection theorem, Riesz representation theorem, and Hahn-Banach extension uniqueness.	U

CL: Cognitive Levels (R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	1
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO4	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Normed linear spaces. Riesz lemma. Heine-Borel theorem. Continuity of linear maps. Hahn-Banach extension and separation theorems.	14	1
II	Banach spaces. Subspaces, product spaces and quotient spaces. Standard examples of Banach spaces like l^1, L^1, etc. Uniform boundedness principle. Closed graph theorem. Open mapping theorem. Bounded inverse theorem.	12	2
III	Spectrum of a bounded operator. Eigenspectrum. Gelfand-Mazur theorem and spectral radius formula. Dual spaces. Transpose of a bounded linear map. Standard examples.	12	3
IV	Hilbert spaces. Bessel inequality, Riesz-Schauder theorem, Fourier expansion, Parseval's formula.	12	4
V	In the framework of a Hilbert space: Projection theorem. Riesz representation theorem. Uniqueness of Hahn-Banach extension.	10	5

Textbooks & References

[1] S kumaresan and D Sukumar. *Functional Analysis A first course.* Narosa, 2020.

[2] John B Conway. *A course in functional analysis.* Springer, 2019.

[3] Caspar Goffman and George Pedrick. *A first course in functional analysis.* American Mathematical Soc., 2017.

[4] E Kreyszig. Introductory functional analysis with applications, johnwiley & sons inc. *New York-Chichester-Brisbane-Toronto*, 1978.

[5] Balmohan Vishnu Limaye. *Functional analysis.* New Age International, 1996.

[6] Angus Ellis Taylor and David C Lay. *Introduction to functional analysis*, volume 1. Wiley New York, 1958.

7.2 M702: Discrete Mathematics

Learning Objective (LO): The aim of this course is to introduce students to the fundamental concepts of discrete mathematics, including combinatorics, graph theory, logic, and set theory. Students will develop problem-solving skills and learn to apply discrete structures to analyze and solve complex problems in computer science and mathematics.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand basic concepts of combinatorics, including permutations, combinations, and the Pigeonhole Principle, and their applications.	U
2	Apply principles like Inclusion-Exclusion and concepts from formal languages to analyze combinatorial and computational problems.	Ap
3	Analyze finite state machines. evaluate time complexity of algorithms. and use generating functions to represent discrete numeric functions.	An
4	Formulate and solve recurrence relations using generating functions and explore recursive algorithms in solving linear recurrence relations.	Ap
5	Understand and apply Boolean algebra concepts. such as lattices, Boolean functions. and design and implementation of digital networks and switching circuits.	U

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	1
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	**Combinatorics:** Permutations and combinations. Linear equations and their relation to distribution into boxes. Distributions with repetitions and non-repetitions. Combinatorial derivation of these formulae. Pigeonhole Principle and applications.	15	1
II	Binomial and multinomial theorems. Inclusion-Exclusion Principle and Applications. Computability and Formal Languages - Ordered Sets, Languages. Phrase Structure Grammars. Types of Grammars and Languages.	12	2
III	Finite State Machines - Equivalent Machines. Finite State Machines as Language Recognizers. Analysis of Algorithms - Time Complexity. Complexity of Problems. Discrete Numeric Functions and Generating Functions.	11	3
IV	Recurrence Relations and Recursive Algorithms - Linear Recurrence Relations with constant coefficients. Homogeneous Solutions. Particular Solution. Total Solution. Solution by the Method of Generating Functions.	11	4
V	Boolean Algebras - Lattices and Algebraic Structures. Duality, Distributive and Complemented Lattices. Boolean Lattices and Boolean Algebras, Boolean Functions and Exprcrs. Calculus. Design and Implementation of Digital Networks. Switching Circuits.	11	5

Textbooks & References

[1] Kenneth H Rosen. *Discrete mathematics and its applications*. McGraw-Hill, 2012.

[2] C Vasudev. *Graph theory with applications*. New Age International, 2006.

[3] Chung Laung Liu. *Elements of discrete mathematics*. McGraw-Hill, Inc., 1985.

[4] Richard Johnsonbaugh. *Discrete mathematics*. Pearson, 2009.

[5] Willem Conradie and Valentin Goranko. *Logic and discrete mathematics: a concise introduction*. John Wiley & Sons, 2015.

[6] Narsingh Deo. *Graph theory with applications to engineering and computer science*. Courier Dover Publications, 2017.

[7] Kapil D Joshi. *Foundations of discrete mathematics*. New Age International, 1989.

7.3 M703: Introduction to Mathematical Modelling

Learning Objective (LO): The aim of this course is to introduce students to the principles of mathematical modeling, including model formulation, analysis, and interpretation. Students will learn to apply mathematical models to represent real-world systems, analyze their behavior, and provide insights into scientific and engineering problems.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the principles, properties, and characteristics of different types of mathematical models and their limitations, focusing on dynamic models and model reduction techniques.	U
2	Apply algebraic modeling techniques to real-world problems, such as data fitting, dimensional analysis, and systems like the Global Positioning System.	Ap
3	Analyze discrete models such as Malthusian growth, economic models, and time-dependent growth, exploring periodic points, bifurcations, and chaos.	An
4	Evaluate continuous models like the Predator-Prey and Chemostat models, and explore linear and nonlinear oscillators using qualitative analysis.	E
5	Explore bifurcation theory, understand its conditions and applications, and analyze symmetry-breaking and global bifurcations in discrete and continuous systems.	An

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	-
CO2	3	3	3	-	2	1	2	2	-	3	2	3	3	2	2	1	-
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Mathematical Model, types of Mathematical models and properties, Elementary models, Models by nature of environment, Models by the Extent of generality, Principle of modeling, Solution method for models, Characteristics, Advantages and Limitations of a model, Dynamic Models. State variables and parameters, methods and challenges. Model reduction.	15	1
II	Algebraic Models: Temperature and the Chirping of a Cricket, Least Squares Fitting of Data, The Global Positioning System, Allometric Models, Dimensional Analysis.	11	2
III	Discrete Models: Malthusian Growth Model, Economic Interest Models, Time-Dependent Growth Rate, Qualitative Analysis of Discrete Models, Periodic Points and Bifurcations, Chaos.	11	3
IV	Continuous Models: Chemostat, Qualitative Analysis of Continuous Models, A Laser Beam Model, Two Species Competition Model, Predator-Prey Model, Method of Averaging, Linear and Nonlinear Oscillators, Compartmental Models.	11	4
V	Bifurcation Theory, Examples and Phase Portraits, Conditions for Bifurcations, Codimension of a Bifurcation, Codimension One Bifurcations in Discrete Systems, Codimension One Bifurcations in Continuous Systems, Global Bifurcations, Symmetry-Breaking Bifurcations.	12	5

Textbooks & References

[1] Antonio Palacios. *Mathematical Modeling: A Dynamical Systems Approach to Analyze Practical Problems in STEM Disciplines.* Springer Nature, 2022.

[2] Joel Kilty and Alex McAllister. *Mathematical Modeling and Applied Calculus.* Oxford University Press, 2018.

[3] Edward A Bender. *An introduction to mathematical modeling.* Courier Corporation, 2000.

7.4 M704: Operations Research

Learning Objective (LO): The aim of this course is to introduce students to the fundamental concepts and techniques of operations research, including linear programming, optimization methods, and decision-making models. Students will develop the ability to apply these techniques to solve complex problems in management, engineering, and other fields.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the nature, scope, and mathematical formulation of linear programming problems, and solve them using graphical and matrix methods.	U
2	Apply the simplex method, including the two-phase simplex algorithm, to solve various linear programming problems efficiently.	Ap
3	Analyze the principles of duality in the simplex method, handle unrestricted variables and problems of degeneracy, and formulate dual constraints.	An
4	Evaluate elementary queuing and inventory models, and solve steady-state solutions of Markovian queuing models like M/M/1, M/M/C, and M/G/1.	E
5	Explore game theory concepts, focusing on two-person zero-sum games, and solve game problems graphically by reducing them to linear programming problems.	Ap

CL: Cognitive Levels (R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	3	2	1	2	2	-	3	2	3	3	2	1	2	1
CO2	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	1
CO3	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	1
CO4	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	1
CO5	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Introduction, Nature and Scope of operations research. Linear Programming: Introduction, Mathematical formulation of the problem, Graphical Solution methods, Mathematical solution of linear programming problem, Slack and Surplus variables. Matrix formulation of general linear programming problems.	15	1
II	**The Simplex Method:** Simplex algorithm, Computational procedures, Artificial variables, Two-phase Simplex Method, Formulation of linear programming problems and its solution by simplex method.	12	2
III	Unrestricted variables, problems of degeneracy, Principle of duality in simplex method, Formation of dual with mixed type of constraints, Solution of primal and dual constraints.	12	3
IV	Elementary queuing and inventory models. Steady-state solutions of Markovian queuing models: M/M/1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited waiting space, M/G/1.	11	4
V	**Game Theory:** Introduction, Two persons zero sum games, The maxmin and minimax principles. Graphical Solution: Reduction of game problem to LPP.	10	5

Textbooks & References

[1] Frederick S. Hillier and Gerald J. Lieberman. *Introduction to operations research.* McGraw-Hill Higher Education, 2010.

[2] Kanti Swarup, P. K. Gupta, and Man Mohan. *Operations Research.* Sultan Chand & Sons Publishers, 1977.

[3] JK Sharma. *Operation Research: Theory and Application 4th Edition.* Macmillan Publishers india, 1997.

[4] N Paul Loomba. *Linear programming.* Tata Mcgraw hill publishing company, 1964.

[5] Hamdy A Taha. *Operation Research: An Introduction, 7th.* Prentice Hall-Pearson Education Inc., 2003.

7.5 M705 : Stochastic Analysis

Learning Objective (LO): The aim of this course is to provide students with a deep understanding of stochastic processes, including martingales, Brownian motion, and stochastic differential equations. Students will develop the ability to analyze and model random phenomena in various scientific, financial, and engineering contexts.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the concept of martingales. Brownian motion, and their properties, including the strong Markov property and stopping times.	U
2	Explore the reflection principle. hitting times. and analyze higher-dimensional Brownian motion, focusing on recurrence and transience.	Ap
3	Analyze stochastic calculus. focusing on predictable processes, continuous local martingales, and the behavior of variance and covariance processes.	An
4	Evaluate integration with respect to martingales and local martingales, and apply key results like Kunita-Watanabe inequality and Ito's formula in solving problems.	E
5	Apply the theory of stochastic differential equations, focusing on weak solutions, Girsanov's theorem, and change of measure and time techniques.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	-
CO2	3	3	3	-	2	1	2	2	-	3	2	3	3	2	2	1	-
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Preliminaries: Martingales and properties. Brownian Motion - definition and construction, Markov property, stopping times, strong Markov property, zeros of one dimensional Brownian motion.	13	1
II	Reflection principle, hitting times, higher dimensional Brownian Motion, recurrence and transience, occupation times, exit times, change of time, Levy's theorem.	12	2
III	Stochastic Calculus: Predictable processes, continuous local martingales, variance and covariance processes.	12	3
IV	Integration with respect to bounded martingales and local martingales, Kunita-Watanabe inequality, Ito's formula, stochastic integral, change of variables.	12	4
V	Stochastic differential equations, weak solutions. Change of measure, Change of time, Girsanov's theorem.	11	5

Textbooks & References

[1] Richard Durrett. *Stochastic calculus: a practical introduction.* CRC press, 2018.

[2] Ioannis Karatzas and Steven Shreve. *Brownian motion and stochastic calculus.* Springer Science & Business Media, 2012.

[3] Bernt Øksendal. *Stochastic differential equations.* Springer, 2003.

[4] J Michael Steele. *Stochastic calculus and financial applications.* Springer, 2001.

7.6 SEL701: Linux Operating System

Learning Objective (LO): The aim of this course is to familiarize students with the Linux operating system, focusing on its desktop environment, features, commands, file systems, and system administration. This course equips learners with the skills to efficiently use and manage Linux systems, fostering an understanding of open-source technologies and their practical applications in computing.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the basics of Ubuntu Linux Desktop environment and navigate through its features.	U
2	Customize the desktop environment and install software using various package managers.	Ap
3	Utilize fundamental Linux commands and manage the file system effectively.	Ap
4	Perform advanced file operations, manage processes, and understand file attributes.	An
5	Configure the Linux environment, perform basic system administration tasks, and use text processing tools.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	1	-	2	2	3	1	1	2	1	3	3	1	1	1	1
CO2	3	3	2	-	3	2	3	2	1	2	1	3	2	2	1	1	2
CO3	3	3	3	-	3	2	3	2	1	2	1	3	2	2	1	2	1
CO4	3	3	3	-	3	2	3	1	1	2	1	3	2	2	1	2	1
CO5	3	3	3	-	3	2	3	1	1	2	1	3	2	2	1	2	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Introduction to Ubuntu Linux Desktop: Ubuntu Linux Desktop latest release overview. GNOME environment and desktop navigation. The Launcher and commonly used icons: Calculator, Gedit Text Editor, Terminal. Firefox Web Browser. Videos, LibreOffice Suite components, The Home folder.	12	1
II	Desktop Customization and Software Installation: Customizing the Launcher: Removing and adding applications. System Settings and Appearance: Changing desktop themes. Workspace switcher and multiple desktops, Internet connectivity settings, Sound settings, Time and Date settings, User account management and switching. Installing software: Via Terminal, Synaptic Package Manager, Ubuntu Software Center, Configuring proxy settings and repositories, Installing applications (VLC Player, Inkscape), Performing system updates.	12	2
III	Basic Linux Commands and File System: General Purpose Utilities: echo, uname, who, passwd, date, cal. Files and Directories: pwd, ls, cat. Understanding the File System: Files, Directories, Inodes, Types of Files, Home directory and Current directory. Navigating directories (cd), Creating and removing directories (mkdir, rmdir). Working with Regular Files: cat, rm, cp, mv, cmp, wc. Basic Commands: Command interpreter and shell, Using man, apropos, whatis, –help option.	12	3
IV	Advanced File Operations and Process Management: File Attributes: chown, chmod, chgrp, Displaying files with ls -l. Understanding permissions (u+, a-w, g+w, -r). Inodes, hard links, symbolic links. Redirection and Pipes: Input, output, and error streams, Redirection operators > and », Pipes |. Working with Linux Processes: Understanding processes, Shell processes, Process spawning (parent and child processes), Process attributes (pid, ppid), Init process, User and system processes, Using ps with options.	12	4
V	Environment Variables, System Administration, and Text Processing: The Linux Environment: Environment variables vs. Local variables, set and env commands, Common environment variables (SHELL, HOME, PATH, LOGNAME, PS1, PS2), history command, using ! and , alias. Basics of System Administration: Root login (su), User management (UID, GID, useradd, usermod, userdel), Disk usage (du, df). Simple Filters: head, tail, sort, cut, paste. The grep Command: Searching file content, Using grep options (ignore case, invert match, line numbers, count), Patterns and regular expressions. The sed Command: Stream editor basics, Printing and modifying text with sed, Line and context addressing, Substituting, inserting, and deleting text.	12	5

Textbooks & References

[1] Christopher Negus. *Linux Bible*. Wiley, 10th edition edition, 2020.

[2] Richard Blum. *Linux Command Line and Shell Scripting Bible*. Wiley, 3rd edition edition, 2015.

[3] William Shotts. *The Linux Command Line: A Complete Introduction*. No Starch Press, 2012.

[4] Mark G. Sobell. *A Practical Guide to Linux Commands, Editors, and Shell Programming*. Pearson, 3rd edition edition, 2012.

[5] Ubuntu Official Documentation. Available online at `https://help.ubuntu.com/`, 2025. Accessed: 2025-01-25.

[6] Machtelt Garrels. *Introduction to Linux*. Fultus Corporation. 2010.

[7] Ellen Siever. Stephen Figgins. and Robert Love. *Linux in a Nutshell*. O'Reilly Media, 2009.

[8] Jon Emmons. *Beginning Ubuntu Linux for Novices and Professionals*. Apress. 2006.

8 Semester - VIII

8.1 M801 : Graph Theory

Learning Objective (LO): The aim of this course is to introduce students to the fundamental concepts of graph theory, including graph types, properties, connectivity, and coloring. Students will develop the ability to analyze graph structures and apply graph-theoretic techniques to solve problems in mathematics, computer science, and network analysis.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the basic definitions, types, and properties of graphs, including walks, trails, cycles, connectivity, and matrix representations.	U
2	Analyze trees, spanning trees, and network flows, applying key properties and algorithms to solve problems involving minimum spanning trees and fundamental circuits.	An
3	Explore planar graphs and graph coloring, applying techniques to detect planarity, find chromatic numbers, and explore concepts like duals and the Four Color Theorem.	Ap
4	Understand and analyze directed graphs, focusing on binary relations, connectedness, Euler digraphs, and their applications to tournaments and sequences.	U
5	Evaluate networks using graph-theoretic measures, focusing on matrix representations, connectivity, and centrality measures such as PageRank and eigenvector centrality.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	-
CO2	3	3	3	-	2	1	2	2	-	3	2	3	3	2	2	1	-
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	**Introduction to Graphs:** Definition of a graph, finite and infinite graphs, incidence of vertices and edges, types of graphs, subgraphs, walks, trails, paths, cycles, connectivity, components of a graph, Eulerian and Hamiltonian graphs, travelling salesman problem, vertex and edge connectivity, matrix representation of graphs, incidence and adjacency matrices of graphs.	13	1
II	**Trees and Fundamental Circuits:** Definition and properties of trees, rooted and binary trees, counting trees, spanning trees, weighted graphs, minimum spanning tree, fundamental circuit, cut set, separability, network flows.	13	2
III	**Planar Graphs and Graph coloring:** Planar graphs, Kuratowski's graphs, detection of planarity, Euler's formula for planar graphs, geometric and combinatorial duals of a planar graph, coloring of graphs, chromatic numbers, chromatic polynomial, chromatic partitioning, Four color theorem.	13	3
IV	**Directed Graphs:** Types of digraphs, digraphs and binary relations, directed paths and connectedness, Euler digraphs, de Brujin sequences, tournaments.	10	4
V	**Networks:** Networks and their representation, Weighted and directed networks, The adjacency, Laplacian, and incidence matrices, Degree, paths, components, Independent paths, connectivity, and cut sets. Degree centrality, eigenvector centrality, Katz centrality, PageRank.	11	5

Textbooks & References

[1] Narsingh Deo. *Graph theory with applications to engineering and computer science*. Courier Dover Publications, 2017.

[2] Md Saidur Rahman et al. *Basic graph theory*. Springer, 2017.

[3] K Erciyes. *Discrete mathematics and graph theory*. Springer, 2021.

8.2 M802 : Advanced Discrete Mathematics

Learning Objective (LO): The aim of this course is to provide students with an advanced understanding of discrete mathematics, focusing on lattices, Boolean algebras, and graph algorithms. Students will develop the ability to analyze and apply advanced discrete structures to solve complex problems in mathematics, computer science, and related fields.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the fundamental properties of lattices and Boolean algebras, including key concepts like sublattices, homomorphisms, and special lattice structures.	U
2	Apply Boolean algebra concepts in solving minimization problems and using tools like Karnaugh Maps, with applications in switching theory.	Ap
3	Explore grammars and languages, understanding different types of grammars, language derivations, and their syntax analysis methods.	An
4	Analyze the behavior of finite state machines, reduced machines, and their homomorphisms, exploring computational models.	An
5	Evaluate finite automata and their acceptors, exploring the equivalence between deterministic and non-deterministic automata, and Turing machines.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	2	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	-
CO2	2	3	2	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO3	3	2	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	2	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO5	2	3	2	-	2	1	3	2	-	3	2	3	3	2	2	1	-

"3" - Strong; "2" - Moderate: "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Lattices-Lattices as partially ordered sets. Their properties. Lattices as Algebraic Systems. Sublattices, Direct products, and Homomorphisms. Some Special Lattices e.g., Complete, Complemented and Distributive Lattices. Boolean Algebras-Boolean Algebras as Lattices. Various Boolean Identities. The Switching Algebra example. Subalgebras.	13	1
II	Direct Products and Homomorphisms. Join-Irreducible elements, Atoms and Minterms. Boolean Forms and Their Equivalence. Minterm Boolean Forms, Sum of Products Canonical Forms. Minimization of Boolean Functions. Applications of Boolean Algebra to Switching Theory (using AND, OR & NOT gates). The Karnaugh Map Method.	13	2
III	Grammars and Languages-Phrase-Structure Grammars. Rewriting Rules. Derivations. Sentential Forms. Language generated by a Grammar. Regular, Context-Free, and Context Sensitive Grammars and Languages. Regular sets, Regular Expressions. Notions of Syntax Analysis. Polish Notations. Conversion of Infix Expressions to Polish Notations. The Reverse Polish Notation.	12	3
IV	Introductory Computability Theory-Finite State Machines and their Transition Table Diagrams. Equivalence of finite State Machines. Reduced Machines. Homomorphism.	11	4
V	Finite Automata. Acceptors. Non-deterministic Finite Automata and equivalence of its power to that of Deterministic Finite Automata. Moore and Mealy Machines. Turing Machine and Partial Recursive Functions. The Pumping Lemma. Kleene's Theorem.	11	5

Textbooks & References

[1] Chung Laung Liu. *Elements of discrete mathematics*. McGraw-Hill, Inc., 1985.

[2] Jean Paul Tremblay and Rampurkar Manohar. *Discrete mathematical structures with applications to computer science*. McGraw-Hill, Inc., 1975.

[3] KLP Mishra and N Chandrasekaran. *Theory of computer science: automata, languages and computation*. PHI Learning Pvt. Ltd., 2006.

[4] Stephen A Wiitala. *Discrete mathematics: a unified approach*. McGraw-Hill, Inc., 1987.

[5] Sriraman Sridharan and Rangaswami Balakrishnan. *Foundations of Discrete Mathematics with Algorithms and Programming*. Chapman and Hall/CRC, 2018.

[6] K Erciyes. *Discrete mathematics and graph theory*. Springer, 2021.

8.3 M803 : Nonlinear Dynamics and Chaos

Learning Objective (LO): The aim of this course is to introduce students to the principles of nonlinear dynamics and chaos, including phase portraits, stability analysis, bifurcations, and chaotic systems. Students will develop the ability to analyze nonlinear systems and apply these concepts to model and understand complex dynamical behaviors in natural and engineered systems.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the fundamental concepts of dynamical systems, including phase portraits, vector fields, and linearization techniques like Jordan canonical form.	U
2	Analyze one-dimensional flows, focusing on stability, bifurcation types, and the impossibility of oscillations in linear systems.	An
3	Explore two-dimensional flows, examining classifications, phase portraits, and conservative and reversible systems with their topological consequences.	Ap
4	Evaluate limit cycles and nonlinear oscillators, applying concepts like Poincare-Bendixson theorem and understanding bifurcations, including Hopf and global bifurcations.	E
5	Understand and analyze chaotic dynamics, focusing on coupled oscillators, Poincare maps, and chaotic systems like Lorenz equations.	An

CL: Cognitive Levels (R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
CO	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	-
CO2	3	3	3	-	2	1	2	2	-	3	2	3	3	2	2	1	-
CO3	2	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	2	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO5	2	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Introduction to Dynamical Systems, history of dynamics, phase portraits, vector fields, nullclines, flows, discrete dynamical systems, 1-d maps. Fixed points, linearization of vector fields, canonical forms, generalized eigenvectors, semisimple – nilpotent decomposition, Jordan canonical form.	13	1
II	One dimensional flows: fixed points and stability, population growth model, linear stability analysis, existence and uniqueness of solution, impossibility of oscillations. Introduction to bifurcation, Saddle-Node bifurcation, Transcritical bifurcation, Pitchfork bifurcation, imperfect bifurcations and catastrophes.	13	2
III	Two dimensional flows: Linear systems, classifications of linear systems, phase plane, phase portraits, existence, uniqueness and topological consequences, fixed points and linearization. Conservative systems and reversible systems, index theory.	13	3
IV	Limit cycles, ruling out closed orbit, Poincare-Bendixson theorem, Lienard systems, Relaxation oscillations, weakly nonlinear oscillators. Bifurcations: Saddle-Node, Transcritical and Pitchfork bifurcations, Hopf bifurcations, Global bifurcations of cycles.	11	4
V	Hysteresis, coupled oscillators and quasiperiodicity, Poincare maps. Chaotic dynamics: Lorenz equations, a chaotic waterwheel, properties of the Lorenz equations.	10	5

Textbooks & References

[1] Steven H Strogatz. *Nonlinear dynamics and chaos: with applications to physics, biology, chemistry, and engineering.* CRC press, 2018.

[2] Stephen Lynch. *Dynamical systems with applications using MATLAB.* Springer, 2004.

[3] JA Rial. *Chaos: An Introduction to Dynamical Systems.* Sigma XI-The Scientific Research Society, 1997.

[4] Morris W Hirsch, Stephen Smale, and Robert L Devaney. *Differential equations, dynamical systems, and an introduction to chaos.* Academic press, 2012.

[5] Stephen Lynch. *Dynamical systems with applications using Mathematica.* Springer, 2007.

[6] Kathleen T Alligood, Tim D Sauer, James A Yorke, and David Chillingworth. *Chaos: an introduction to dynamical systems.* Philadelphia, Society for Industrial and Applied Mathematics., 1998.

8.4 M804: Mathematical Biology

Learning Objective (LO): The aim of this course is to provide students with an understanding of mathematical models in biology, including population dynamics, epidemiology, and ecological interactions. Students will learn to analyze biological systems using mathematical techniques and apply these models to predict and interpret real-world biological phenomena.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand simple single-species population models, including continuous and discrete-time models, and analyze case studies like Eutrophication and Flour Beetle Populations.	U
2	Explore and analyze continuous single-species models with delays, focusing on delayed-recruitment models and their applications in case studies like Nicholson's Blowflies.	An
3	Apply models for interacting species, such as the Lotka-Volterra and Chemostat models, and explore equilibria, limit cycles, and competition dynamics.	Ap
4	Evaluate harvesting strategies in two-species models, focusing on optimization, economic aspects, and the predator-prey system.	E
5	Explore models for populations with age and spatial structure, focusing on linear and nonlinear diffusion equations, metapopulation dynamics, and their applications.	An

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	2	1	2	-
CO2	2	3	3	-	2	1	2	2	-	3	2	3	3	2	2	1	-
CO3	3	2	2	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	2	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO5	3	3	2	-	2	1	3	2	-	3	2	3	3	2	2	1	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	**Simple Single Species Models:** Continuous Population Models, Exponential Growth, The Logistic Population Model, Harvesting in Population Models, Constant-Yield and Constant-Effort Harvesting, Eutrophication of a Lake: A Case Study. Discrete-Time Metered Models, Systems of Two Difference Equations, Oscillation in Flour Beetle Populations: A Case Study.	12	1
II	**Continuous Single-Species Population Models with Delays:** Models with Delay in Per Capita Growth Rates, Delayed-Recruitment Models, Models with Distributed Delay, Harvesting in Delayed Recruitment Models, Nicholson's Blowflies: A Case Study.	12	2
III	**Models for Interacting Species:** The Lotka–Volterra Equations, The Chemostat Model, Equilibria and Linearization, Qualitative Behavior of Solutions of Linear Systems, Periodic Solutions and Limit Cycles, Species in Competition, Kolmogorov Models, Mutualism, The Spruce Budworm: A Case Study. The Community Matrix, the Nature of Interactions Between Species, Invading Species and Coexistence.	12	3
IV	**Harvesting in Two-species Models:** Harvesting of Species in Competition, Harvesting of Predator–Prey Systems, Intermittent Harvesting of Predator–Prey Systems, Some Economic Aspects of Harvesting, Optimization of Harvesting Returns, A Nonlinear Optimization Problem, Economic Interpretation of the Maximum Principle.	12	4
V	**Models for Populations with Age and Spatial Structure:** Linear model with age structure, The Method of Characteristics, Nonlinear Continuous Models, Models with Discrete Age Groups, Some Simple Examples of Metapopulation Models, A General Metapopulation Model, A Metapopulation Model with Residence and Travel, The Diffusion Equation, Solution by Separation of Variables, Solutions in Unbounded Regions, Linear Reaction–Diffusion Equations, Nonlinear Reaction–Diffusion Equations, Diffusion in Two Dimensions.	12	5

Textbooks & References

[1] Fred Brauer, Carlos Castillo-Chavez, and Carlos Castillo-Chavez. *Mathematical models in population biology and epidemiology*. Springer, 2012.

[2] Mark Kot. *Elements of mathematical ecology*. Cambridge University Press, 2001.

[3] James D Murray. *Mathematical biology: I. An introduction. Interdisciplinary applied mathematics*. Springer, 2002.

[4] James D Murray. *Mathematical biology II: spatial models and biomedical applications*. Springer New York, 2001.

8.5 M805 : Computational Mathematics III

Learning Objective (LO): The aim of this course is to introduce students to computational tools such as SAGE software for advanced mathematical computations. Students will develop practical skills to solve complex mathematical problems, analyze data, and utilize computational approaches effectively in various scientific and engineering contexts.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the basics of SAGE software and use it as an advanced calculator for mathematical computations.	U
2	Explore and create 2D and 3D visualizations using SAGE, enhancing their understanding of geometric and graphical representations.	Ap
3	Apply SAGE to perform and visualize calculus operations for single and multi-variable functions.	Ap
4	Use SAGE to explore linear algebra concepts like row transformations, Gram-Schmidt process, and matrix factorizations, with applications to real-world problems.	Ap
5	Explore advanced mathematical topics like group theory, number theory, and combinatorics using SAGE, gaining insights into abstract mathematical structures.	An

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	3	3	2	1	2	2	-	3	2	3	3	1	1	2	-
CO2	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	-
CO3	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	3	3	3	2	1	3	3	-	3	2	3	3	3	2	1	-
CO5	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	2	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	**Topics**	**No. of Lectures**	**CO No.**
I	Introduction to SAGE, using SAGE as an advanced calculator	12	1
II	Plotting graphs of 2d and 3d objects in various forms	12	2
III	Use of SAGE to explore calculus of single and multi-variables.	12	3
IV	Use of SAGE to explore row transformations, linear transformations, Gram-Schmidt process, application of matrix diagonalization, matrix factorizations with applications to least square problems and image processing etc.	12	4
V	Use of SAGE to explore concepts in Group-Theory, Number-Theory and Combinatorics.	12	5

Textbooks & References

[1] Sang-gu lee and ajit kumar. linear algebra with sage, free online available at. `http://matrix.skku.ac.kr/2015-Album/Big-Book-LinearAlgebra-Eng-2015.pdf`.

[2] George A Anastassiou and Razvan A Mezei. *Numerical analysis using sage*. Springer, 2015.

8.6 SEPML801: LaTeX & XFig - Typesetting Software

Learning Objective (LO): The aim of this course is to introduce students to LaTeX and XFig, focusing on typesetting, document creation, and diagram generation. Students will learn to install and configure LaTeX, create structured documents, and design graphical content, enabling them to produce professional-quality reports and presentations for academic and professional purposes.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Install and configure LaTeX and its editors, and understand the basics of document creation.	U
2	Create structured documents using LaTeX, including reports, articles, and letters with proper formatting and layout.	C
3	Typeset complex mathematical expressions, equations, and matrices, and manage numbering and referencing of equations.	Ap
4	Incorporate tables, figures, and diagrams into LaTeX documents, and create presentations using Beamer.	Ap
5	Utilize advanced LaTeX features such as custom commands, environments, style files, and typeset documents in Indic languages using XeLaTeX.	C

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	1	-	2	2	3	1	1	2	1	3	3	1	1	1	1
CO2	3	3	2	-	3	2	3	2	1	2	1	3	2	2	1	1	2
CO3	3	3	3	-	3	2	3	2	1	2	1	3	2	2	1	2	1
CO4	3	3	3	-	3	2	3	1	1	2	1	3	2	2	1	2	1
CO5	3	3	3	-	3	2	3	1	1	2	1	3	2	2	1	2	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Introduction to LaTeX: Installing LaTeX and using LaTeX editors. Document classes: Report, Article, Letter. Structure of LaTeX documents: Chapters, Sections, Subsections. Generating Table of Contents, Lists of Figures and Tables. Handling compilation errors and troubleshooting.	12	1, 2
II	Document Formatting and Letter Writing: Formatting text: Fonts, Styles, Paragraphs. Creating letters: Address formatting, dates, salutations, signatures. Environments: Itemize, Enumerate for lists. Page layout: Margins, headers, footers. Including special characters and symbols.	12	2
III	Mathematical Typesetting: Inline and display math modes. Greek letters and mathematical symbols. Fractions, superscripts, subscripts. Creating equations, matrices, and aligning equations. Numbering and referencing equations. Packages: amsmath, handling errors with missing packages. Using frac, dfrac, and cases.	16	3
IV	Graphics, Tables, and Presentations: Inserting images and creating figures. Creating tables: Tabular environment, formatting tables. Using XFig for creating diagrams and importing into LaTeX. Exporting figures with special flags, handling text in figures. Creating presentations using Beamer. Cropping PDFs and tools like pdfcrop and Briss.	10	4
V	Advanced LaTeX Features: Custom commands: \newcommand, parameters, redefining commands. Custom environments: \newenvironment, parameters. Writing and importing style files. Packages: \RequirePackage, \usepackage, package management. Typesetting in Indic languages using XeLaTeX. Fonts installation and usage: Fontspec, Polyglossia. Setting default and additional languages in documents.	10	5

Textbooks & References

[1] Leslie Lamport. LaTeX—a documentation preparation system, 1985.

[2] Tobias Oetiker, Hubert Partl, Irene Hyna, and Elisabeth Schlegl. The not so short introduction to LaTeX2ε. 1999.

[3] George Grätzer. *More Math Into LaTeX*. Springer, 2016.

[4] Stefan Kottwitz. *LaTeX beginner's guide*. Packt Publishing Ltd, 2011.

[5] Helmut Kopka and Patrick W Daly. *Guide to LaTeX*. Pearson Education, 2003.

[6] XFig Development Team. Xfig user manual. `http://www.xfig.org/userman/`, n.d.

9 Semester - IX

Student has to do one-semester project from institute of repute and after completion of the project student has to submit project dissertation. The dissertation will be evaluated by both external and internal examiners.

10 Semester - X

10.1 ME01: Dynamical Systems Using Matlab

Learning Objective (LO): The aim of this course is to equip students with the knowledge and skills to model and analyze dynamical systems using MATLAB. Students will learn to utilize MATLAB for simulations, visualize system behaviors, and apply these techniques to solve complex problems in various domains of science and engineering.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the basics of MATLAB, including arithmetic operations, array handling, plotting techniques, and programming for mathematical and graphical analysis.	U
2	Explore discrete dynamical systems, focusing on stability analysis, periodic behavior, chaos, and logistic maps, including Feigenbaum numbers.	Ap
3	Analyze higher-dimensional maps, stable and unstable manifolds, Lyapunov exponents, chaotic orbits, and strange attractors, including Gaussian and Hénon Maps.	An
4	Apply differential dynamical systems concepts to visualize phase portraits, understand stability using Lyapunov functions, and explore the uniqueness of limit cycles.	Ap
5	Evaluate nonlinear dynamical systems, focusing on bifurcation, multistability, and chaotic systems like the Rössler system, Lorenz equations, and Chua's circuit.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
CO	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	3	2	1	2	2	-	3	2	3	3	1	1	2	-
CO2	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	-
CO3	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	3	3	3	2	1	3	3	-	3	2	3	3	3	2	1	-
CO5	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	2	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	**Introduction to Matlab:** Arithmetic Operations, built-in-MATH functions, scalar variables, creating arrays, built-in functions for handling arrays, mathematical operations with arrays, script files, two-dimensional plots, programming in MATLAB, polynomial, curve fitting, and interpolation, three-dimensional plots.	12	1
II	**Discrete Dynamical Systems:** One-dimensional maps, cobweb plot: graphical representation of an orbit, stability of fixed points, periodic points, the family of logistic maps, sensitive dependence on initial conditions, analysis of logistic map, Periodic Windows, Feigenbaum number, chaos in logistic map.	12	2
III	Higher-dimensional maps, sinks, sources, and saddles, nonlinear maps and the jacobian matrix, stable and unstable manifolds, lyapunov exponents, Numerical Calculation of Lyapunov Exponent, chaotic orbits. Strange Attractors, Gaussian and Hénon Maps. Julia Sets and the Mandelbrot Set.	12	3
IV	**Differential Dynamical Systems:** Differential dynamical systems, existence and uniqueness theorem, phase portraits, vector fields, nullclines, flows, fixed points, linearization of vector fields, planar systems, canonical forms, eigenvectors defining stable and unstable manifolds, phase portraits of linear systems in the plane, linearization and Hartman's theorem, limit cycles, existence and uniqueness of limit cycles in the plane, Lyapunov functions and stability.	12	4
V	Nonlinear systems and stability, bifurcations of nonlinear systems, normal forms, multistability and bistability, the Rössler system and chaos, the Lorenz equations, Chua's circuit, and the Belousov–Zhabotinski reaction.	12	5

Textbooks & References

[1] Stephen Lynch. *Dynamical systems with applications using MATLAB.* Springer, 2004.

[2] Steven H Strogatz. *Nonlinear dynamics and chaos: with applications to physics, biology, chemistry, and engineering.* CRC press, 2018.

[3] Morris W Hirsch, Stephen Smale, and Robert L Devaney. *Differential equations, dynamical systems, and an introduction to chaos.* Academic press, 2012.

[4] Stephen Lynch. *Dynamical systems with applications using Mathematica.* Springer, 2007.

[5] Kathleen T Alligood, Tim D Sauer, James A Yorke, and David Chillingworth. *Chaos: an introduction to dynamical systems.* Philadelphia. Society for Industrial and Applied Mathematics., 1998.

10.2 ME02: Commutative Algebra

Learning Objective (LO): The aim of this course is to introduce students to the principles of commutative algebra, including prime and maximal ideals, local rings, and modules. Students will develop the skills to analyze algebraic structures and apply commutative algebra to solve problems in algebraic geometry and other mathematical disciplines.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the concepts of prime and maximal ideals, Jacobson radicals, and local rings, including applications of Nakayama's lemma.	U
2	Explore the concept of fractions in rings and modules. understanding localization and its properties related to prime ideals.	Ap
3	Analyze modules of finite length. the concepts of Noetherian and Artinian modules, and perform primary decomposition and associated primes analysis.	An
4	Evaluate graded rings and modules, applying key theorems like Artin-Rees, Krull-intersection, and explore dimension theory through the Hilbert-Samuel function.	E
5	Apply integral extension concepts and theorems like Noether's normalization and Hilbert's Nullstellensatz to understand algebraic structures in local and global contexts.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	1	1	2	-
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	3	3	-	2	1	3	3	-	3	2	3	3	3	2	1	-
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	2	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	**Topics**	**No. of Lectures**	**CO No.**
I	Prime and maximal ideals in a commutative ring, nil and Jacobson radicals, Nakayama's lemma, local rings.	13	1
II	Rings and modules of fractions, correspondence between prime ideals, localization.	12	2
III	Modules of finite length, Noetherian and Artinian modules. Primary decomposition in a Noetherian module, associated primes, support of a module.	13	3
IV	Graded rings and modules. Artin-Rees, Krull-intersection, Hilbert-Samuel function of a local ring, dimension theory, principal ideal theorem.	11	4
V	Integral extensions, Noether's normalization lemma, Hilbert's Nullstellensatz (algebraic and geometric versions).	11	5

Textbooks & References

[1] W Jonsson. *Introduction to Commutative Algebra*. Cambridge University Press, 1970.

[2] David Eisenbud. *Commutative algebra: with a view toward algebraic geometry*. Springer Science & Business Media, 2013.

[3] Hideyuki Matsumura. *Commutative ring theory*. Cambridge university press, 1989.

[4] Srinivasacharya Raghavan, Balwant Singh, and Ramaiyengar Sridharan. *Homological methods in commutative algebra.* Oxford University Press, 1975.

[5] Balwant Singh. *Basic commutative algebra.* World Scientific Publishing Company, 2011.

10.3 ME03: Financial Mathematics

Learning Objective (LO): The aim of this course is to introduce students to the mathematical foundations of finance, including probability theory, stochastic processes, and financial modeling. Students will develop the ability to analyze financial systems, evaluate risks, and apply quantitative methods to solve problems in financial mathematics.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the fundamentals of probability theory and its applications in finite probability spaces in finance.	U
2	Explore financial instruments like derivatives, interest rate models, and arbitrage pricing, focusing on risk management strategies.	Ap
3	Analyze the random walk, Markov processes, and the basics of stochastic calculus in financial modeling.	An
4	Apply concepts of option pricing, portfolio optimization, and explore differential equations like the Fokker-Planck equation in financial contexts.	Ap
5	Evaluate advanced topics like the Feynman-Kac formula, exotic options, and their role in modern finance.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
CO	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	1	1	2	-
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	3	3	-	2	1	3	3	-	3	2	3	3	3	2	1	-
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	2	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Review Of probability, finite probability space.	12	1
II	Derivatives security, interest rates, other financial instruments, Arbitrage and pricing, risk less issue, yield curves, mean terms matching and immunization, interest rate models.	12	2
III	Dependent annual rates of return, random walk and Markov process, stochastic calculus.	12	3
IV	option pricing, portfolio optimization, Fokker-plank equation, distribution and green functions.	12	4
V	Feynman-kac formula options, dividends revisited. Exotic options.	12	5

Textbooks & References

[1] Richard F Bass. The basics of financial mathematics. *Department of Mathematics, University of Connecticut*, 2003.

[2] Paul Wilmott, Susan Howson, Sam Howison, Jeff Dewynne, et al. *The mathematics of financial derivatives: a student introduction.* Cambridge university press, 1995.

[3] C. Gardiner. *Stochastic Methods: A Handbook for the Natural and Social Sciences.* Springer Series in Synergetics. Springer Berlin Heidelberg, 2010.

[4] John C Hull. *Options futures and other derivatives.* Pearson Education India, 2003.

10.4 ME04: Nonlinear Analysis

Learning Objective (LO): The aim of this course is to introduce students to the concepts of nonlinear analysis, focusing on calculus in Banach spaces, fixed-point theorems, and variational methods. Students will develop analytical skills to study nonlinear systems and apply these techniques to solve problems in mathematics and applied sciences.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the concepts of calculus in Banach spaces, including continuity, derivatives, and key theorems like inverse and implicit function theorems.	U
2	Explore monotone operators, their properties, and generalizations, focusing on constructive solutions of operator equations.	Ap
3	Analyze various fixed point theorems and their applications to multi-functions and generalized contractions.	An
4	Apply monotone operator theory to solve differential and integral equations, focusing on nonlinear and generalized Hammerstein equations.	Ap
5	Evaluate the applications of fixed point theorems in Banach space geometry, game theory, and Nash equilibria, along with solving differential and integral equations.	E

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	1	1	2	-
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO3	2	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	2	3	-	2	1	3	3	-	3	2	3	3	3	2	1	-
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	2	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	**Calculus in Banach space:** Various forms of continuity, geometry in normed spaces and duality mappings, Gateaux and Frechet derivative, properties of derivatives, Taylor theorem, inverse function theorem and implicit function theorem, subdifferential of convex function.	14	1
II	**Monotone operators:** Monotone operators, Maximal monotone operators and its properties, constructive solution of operator equations, subdifferential and monotonicity, some generalization of monotone operators.	11	2
III	**Fixed point theorems:** Banach contraction principle and its generalizations, nonexpansive mappings, fixed point theorem of Brouwer and Schauder. Fixed point theorems for multi-functions, common fixed point theorems, sequence of contractions, generalized contractions and fixed points.	12	3
IV	**Applications of monotone operators theory:** Introduction, Sobolev space, differential equation, nonlinear differential equations, integral equation. Nonlinear Hammerstein integral equation, Generalized Hammerstein integral equation.	11	4
V	**Applications of fixed point theorems:** Application to Geometry of Banach Spaces, Application to System of Linear Equations, Perron–Frobenius, Fundamental Theorem of Algebra, Game Theory and Nash Equilibria, Differential equations, integral equations.	12	5

Textbooks & References

[1] Mohan C Joshi and Ramendra K Bose. *Some topics in nonlinear functional analysis.* John Wiley & Sons, 1985.

[2] Hemant Kumar Pathak. *An introduction to nonlinear analysis and fixed point theory.* Springer, 2018.

[3] Eberhard Zeidler and Peter R Wadsack. *Nonlinear Functional Analysis and Its Applications: Fixed-point Theorems.* Springer-Verlag, 1993.

[4] Rajendra Akerkar. *Nonlinear functional analysis.* Alpha Science International, Limited, 1999.

10.5 ME05: Differential Topology

Learning Objective (LO): The aim of this course is to introduce students to the principles of differential topology, focusing on differentiable functions, manifolds, and key theorems such as the implicit function theorem. Students will develop the ability to analyze topological and geometric structures using differential tools and apply these concepts to advanced mathematical problems.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the concepts of differentiable functions between spaces, implicit and inverse function theorems, and the idea of immersions and submersions.	U
2	Explore manifolds, including level sets, sub-manifolds, and tangent spaces, and understand differentiable functions between sub-manifolds.	Ap
3	Analyze differentiable functions on manifolds, applying critical points theory, Sard's theorem, Morse Lemma, and related concepts.	An
4	Evaluate the concepts of transversality, oriented intersections, and calculate the Brouwer degree and intersection numbers.	E
5	Apply integration on manifolds, focusing on Stokes' theorem, vector fields, differential forms, and de Rham theory.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	1	1	2	-
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	3	3	-	2	1	3	3	-	3	2	3	3	3	2	1	-
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	2	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Differentiable functions on R^n, Review of Differentiable functions f : R^n to R^m, implicit and inverse function theorems, immersions and Submersions, critical points, critical and regular values.	13	1
II	**Manifolds:** Level sets, sub-manifolds of R^n, immersed and embedded sub-manifolds, tangent spaces, differentiable functions between sub-manifolds of R^n, abstract differential manifolds and tangent spaces.	11	2
III	**Differentiable functions on Manifolds:** Differentiable functions $f : M \to N$, critical points, Sard's theorem, non-degenerate critical points, Morse Lemma, Manifolds with boundary, Brouwer fixed point theorem, mod 2 degree of a mapping.	12	3
IV	**Transversality:** Orientation of Manifolds, oriented intersection number, Brouwer degree, transverse intersections.	12	4
V	**Integration on Manifolds:** Vector field and Differential forms, integration of forms, Stokes' theorem, exact and closed forms, Poincaré Lemma, Introduction to de Rham theory.	12	5

Textbooks & References

[1] John Milnor and David W Weaver. *Topology from the differentiable viewpoint.* Princeton university press, 1997.

[2] Victor Guillemin and Alan Pollack. *Differential topology.* American Mathematical Soc., 2010.

[3] Morris W Hirsch. *Differential topology.* Springer Science & Business Media, 2012.

10.6 ME06: Introduction to Cryptography

Learning Objective (LO): The aim of this course is to provide students with an introduction to cryptography, including classical cryptosystems, public-key cryptography, and cryptographic protocols. Students will develop the ability to analyze and design secure communication systems and understand the mathematical foundations of cryptography.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand classical cryptosystems, including different types of ciphers and their cryptanalysis, with a focus on stream and synchronous ciphers.	U
2	Explore block ciphers, analyze DES and AES encryption standards, and study various modes of operations in block ciphers.	Ap
3	Apply Shannon's theory of perfect secrecy and analyze number generation techniques relevant to cryptography, focusing on prime number tests.	Ap
4	Evaluate public key cryptography principles and algorithms, including RSA, Rabin, and elliptic curve-based systems, with an emphasis on security analysis.	E
5	Apply and analyze cryptographic hash functions, digital signatures, and their security requirements, focusing on various signature schemes like RSA and DSA.	An

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	1	2	1	2	2	-	3	2	3	3	1	1	2	-
CO2	3	3	3	1	2	1	3	2	-	3	2	3	3	2	2	1	-
CO3	3	3	3	1	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	3	3	1	2	1	3	3	-	3	2	3	3	3	2	1	-
CO5	3	3	3	1	2	1	3	2	-	3	2	3	3	2	2	2	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	**Classical Cryptosystems:** Some Simple Cryptosystems, Monoalphabatic and Polyalphabatic cipher, The Shift Cipher, The Substitution Cipher, The Affine Cipher, The Vigenere Cipher, The Hill Cipher, The Permutation Cipher. Cryptanalysis, Some Cryptanalytic Attacks, Stream ciphers, Synchronous Stream Cipher, Linear Feedback Shift Register (LFSR), Non-Synchronous stream Cipher, Autokey Cipher.	12	1
II	**Block Ciphers:** Mode of operations in block cipher: Electronic Codebook (ECB), Ciphertext Chaining (CBC), Ciphertext FeedBack (CFB), Output FeedBack (OFB), Counter (CTR). **DES & AES:** The Data Encryption Standard (DES), Feistel Ciphers, Description of DES, Security analysis of DES. Differential & Linear Cryptanalysis of DES. Triple DES, The Advanced Encryption Standard (AES), Finite field GF(28). Description of AES, analysis of AES.	12	2
III	**Shannon's Theory of Perfect Secrecy:** Perfect Secrecy, Birthday Paradox, Vernam One Time Pad, Random Numbers, Pseudorandom Numbers. Prime Number Generation: Trial Division, Fermat Test, Carmichael Numbers, Miller Rabin Test, Random Primes.	12	3
IV	**Public Key Cryptography:** Principle of Public Key Cryptography. RSA Cryptosystem. Factoring problem. Cryptanalysis of RSA, RSA-OAEP. Rabin Cryptosystem. Security of Rabin Cryptosystem, Quadratic Residue Problem, Diffie-Hellman (DH) Key Exchange Protocol. Discrete Logarithm Problem (DLP), ElGamal Cryptosystem, ElGamal & DH. Algorithms for DLP. Elliptic Curve, Elliptic Curve Cryptosystem (ECC), Elliptic Curve Discrete Logarithm Problem (ECDLP).	12	4
V	**Cryptographic Hash Functions:** Hash and Compression Functions, Security of Hash Functions, Modification Detection Code (MDC). Message Authentication Codes (MAC), Random Oracle Model, Iterated Hash Functions. Merkle-Damgard Hash Function, MD-5, SHA-1, Other Hash Functions. **Digital Signatures:** Security Requirements for Signature Schemes, Signature and Hash Functions, RSA Signature, ElGamal Signature, Digital Signature Algorithm (DSA), ECDSA, Undeniable Signature, Blind Signature.	12	5

Textbooks & References

[1] Johannes Buchmann. *Introduction to cryptography*. Springer, 2004.

[2] Sahadeo Padhye, Rajeev A Sahu, and Vishal Saraswat. *Introduction to cryptography*. CRC Press, 2018.

[3] Douglas R Stinson. *Cryptography: theory and practice*. Chapman and Hall/CRC, 2005.

[4] Bruce Schneier. *Applied cryptography: protocols, algorithms, and source code in C*. john wiley & sons, 2007.

[5] Debdeep Mukhopadhyay and BA Forouzan. Cryptography and network security. *Noida: Tata Mcgraw Hill*, 2011.

[6] Wenbo Mao. *Modern cryptography: theory and practice*. Pearson Education India, 2003.

[7] William Stallings. *Cryptography and network security*. Pearson Education India, 2006.

10.7 ME07: Introduction to Nonlinear Optimization

Learning Objective (LO): The aim of this course is to provide students with a foundational understanding of nonlinear optimization, including mathematical preliminaries, convexity, and optimization techniques. Students will develop the ability to analyze and solve optimization problems arising in various fields of science and engineering.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the mathematical preliminaries including inner products, norms, eigenvalues, eigenvectors, and basic topological concepts.	U
2	Explore and analyze optimality conditions for unconstrained optimization problems, focusing on global and local optima, second-order conditions, and quadratic functions.	An
3	Apply least squares methods for solving overdetermined systems, perform data fitting, and understand gradient-based methods, including their convergence analysis.	Ap
4	Evaluate Newton's methods, convex sets, and their topological properties, focusing on convex hulls, cones, and extreme points.	E
5	Apply convex optimization techniques, including the gradient projection method, to solve optimization problems with convexity constraints.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	1	2	1	2	2	-	3	2	3	3	1	1	2	1
CO2	3	3	3	1	2	1	3	2	-	3	2	3	3	2	2	1	1
CO3	3	3	3	2	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	3	3	1	2	1	3	3	-	3	2	3	3	3	2	1	-
CO5	3	3	3	1	2	1	3	2	-	3	2	3	3	2	2	2	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Contents:

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Mathematical Preliminaries, the Space R^n, $R^{n\times m}$, Inner Products and Norms, Eigenvalues and Eigenvectors, Basic Topological Concepts.	11	1
II	**Optimality Conditions for Unconstrained Optimization:** Global and Local Optima, Classification of Matrices, Second Order Optimality Conditions, Global Optimality Conditions, Quadratic Functions.	12	2
III	**Least Squares:** Solution of overdetermined Systems, Data Fitting, Regularized Least Squares, Denoising, Nonlinear Least Squares. Descent Directions Methods, The Gradient Method, The Condition Number, Diagonal Scaling, The Gauss–Newton Method, The Fermat–Weber Problem, Convergence Analysis of the Gradient Method.	13	3
IV	Newton's Method, Pure Newton's Method, Damped Newton's Method, The Cholesky Factorization. Convex Sets, Algebraic Operations with Convex Sets, The Convex Hull, Convex Cones, Topological Properties of Convex Sets, Extreme Points.	13	4
V	Convex Functions, First Order Characterizations of Convex Functions, Second Order Characterization of Convex Functions, Operations Preserving Convexity, Level Sets of Convex Functions, Maxima of Convex Functions, Convexity and Inequalities, Convex Optimization, The Orthogonal Projection Operator, Optimization over a Convex Set. Stationarity in Convex Problems, The Orthogonal Projection Revisited, The Gradient Projection Method, Sparsity Constrained Problems.	11	5

Textbooks & References

[1] Amir Beck. *Introduction to nonlinear optimization: Theory, algorithms, and applications with MATLAB.* SIAM, 2014.

[2] Wenyu Sun and Ya-Xiang Yuan. *Optimization theory and methods: nonlinear programming*, volume 1. Springer Science & Business Media, 2006.

[3] Francisco J Aragón, Miguel A Goberna, Marco A López, and Margarita ML Rodríguez. *Nonlinear optimization.* Springer, 2019.

[4] HA Eiselt and Carl-Louis Sandblom. *Nonlinear optimization.* Springer, 2019.

10.8 ME08: Complex Network

Learning Objective (LO): The aim of this course is to introduce students to the principles of complex networks, including graph theory, network structures, and dynamics. Students will learn to analyze and model real-world networks in various domains, such as social, biological, and technological systems.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the fundamentals of graph theory, including directed, weighted, bipartite graphs, and the concept of complex networks.	U
2	Analyze various centrality measures in connected graphs and their importance in real-world network applications.	An
3	Explore random graphs, their degree distribution, and components, focusing on models such as Erdős–Rényi and their relevance in collaboration networks.	Ap
4	Evaluate small-world networks and apply models like Watts–Strogatz to understand clustering and network navigation.	E
5	Apply concepts of generalized random graphs, scale-free networks, and models of growing graphs to study real-world networks such as the World Wide Web.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	1	3	2	1	2	2	-	3	2	3	3	1	1	2	-
CO2	3	3	1	3	2	1	3	2	-	3	2	3	3	2	2	1	-
CO3	3	3	1	3	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	3	1	3	2	1	3	3	-	3	2	3	3	3	2	1	-
CO5	3	3	1	3	2	1	3	2	-	3	2	3	3	2	2	2	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Fundamentals of Graph Theory, Directed, Weighted and Bipartite Graphs, Trees. Complex Network, Basics, history and importance of Complex Network.	12	1
II	**Centrality Measures:** The Importance of Being Central, Connected Graphs and Irreducible Matrices, Degree and Eigenvector Centrality, Measures Based on Shortest Paths, Group Centrality.	12	2
III	**Random Graphs:** Erd"os and Rényi (ER) Models, Degree Distribution, Trees, Cycles and Complete Sub-graphs, Giant Connected Component, Scientific Collaboration Networks, Characteristic Path Length.	12	3
IV	**Small-World Networks:** Six Degrees of Separation, The Brain of a Worm, Clustering Coefficient, The Watts–Strogatz (WS) Model, Variations to the Theme. Navigating Small-World Networks.	12	4
V	**Generalised Random Graphs:** The World Wide Web, Power-Law Degree Distributions, The Configuration Model, Random Graphs with Arbitrary Degree Distribution. Scale-Free Random Graphs, Probability Generating Functions. Models of Growing Graphs, Degree Correlations.	12	5

Textbooks & References

[1] Guido Caldarelli. *Complex Networks: Principles, Methods and Applications.* Oxford University Press, 2018.

[2] Maarten Van Steen. *An introduction to Graph theory and complex networks.* Van Steen, Maarten, 2010.

[3] S Dorogovtsev. *Complex networks.* Oxford University Press Oxford, 2010.

[4] Ernesto Estrada. *The structure of complex networks: theory and applications.* Oxford University Press, 2012.

10.9 ME09: Representation Theory of Finite Groups

Learning Objective (LO): The aim of this course is to provide students with an introduction to the representation theory of finite groups, focusing on modules, characters, and representations. Students will develop the skills to analyze group actions and apply representation theory to problems in algebra and related fields.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the concepts of left and right modules, direct sums, and tensor products in ring theory.	U
2	Explore semi-simplicity of rings and modules, focusing on key theorems such as Schur's Lemma and Maschk's Theorem.	Ap
3	Analyze Wedderburn's Structure Theorem and its implications in the study of group algebra.	An
4	Evaluate representations of finite groups over a field, induced representations, and orthogonality relations of characters.	E
5	Apply representation theory concepts to special groups, including the analysis of Burnside's theorem.	Ap

CL: Cognitive Levels (R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	1	1	2	1
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO4	3	3	3	-	2	1	3	3	-	3	2	3	3	3	2	1	1
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	2	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Recollection of left and right modules, direct sums, tensor products	12	1
II	Semi-simplicity of rings and modules, Schur's lemma, Maschk's Theorem	12	2
III	Wedderburn's Structure Theorem. The group algebra.	12	3
IV	Representations of a finite group over a field, induced representations, characters, orthogonality relations	12	4
V	Representations of some special groups. Burnside's paqb theorem.	12	5

Textbooks & References

[1] Michael Artin and William F Schelter. *Graded algebras of global dimension 3.* Academic Press, 1987.

[2] Martin Burrow. *Representation theory of finite groups.* Courier Corporation, 2014.

[3] David Steven Dummit and Richard M Foote. *Abstract Algebra.* Wiley Hoboken, 2004.

[4] Nathan Jacobson. *Lectures in Abstract Algebra: II. Linear Algebra.* Springer Science & Business Media, 2013.

[5] Serge Lang. *Algebra.* Springer Science & Business Media, 2012.

[6] Jean-Pierre Serre et al. *Linear representations of finite groups.* Springer, 1977.

10.10 ME10: Algebraic Number Theory

Learning Objective (LO): The aim of this course is to introduce students to the fundamental concepts of algebraic number theory, including field extensions, polynomials, and unique factorization domains. Students will develop the ability to analyze number-theoretic problems using algebraic techniques and apply these methods to solve advanced mathematical problems.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand field extensions and various types of polynomials such as monic, minimal, and characteristic polynomials, with examples.	U
2	Analyze the concept of integral closure, with applications to rings like the ring of integers and the ring of Gaussian integers, and explore quadratic number fields.	An
3	Explore Noetherian rings, Dedekind domains, and calculate discriminants in quadratic number fields, applying concepts like norms, traces, and different.	Ap
4	Evaluate cyclotomic extensions, factorization of ideals, ramification theory, and its applications to quadratic number fields.	E
5	Apply geometric ideas and theorems such as Minkowski's theorem and Dirichlet's Unit Theorem to understand the structure of the ideal class group and discrete valuation rings.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
CO	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	1	1	2	1
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO4	3	3	3	-	2	1	3	3	-	3	2	3	3	3	2	1	1
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	2	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Field extensions and examples of field extensions of rational numbers, real numbers and complex numbers. Monic polynomials, Integral extensions, Minimal polynomial, Characteristic polynomial.	12	1
II	Integral closure and examples of rings which are integrally closed. Examples of rings which are not integrally closed. The ring of integers. The ring of Gaussian integers. Quadratic extensions and description of the ring of integers in quadratic number fields. Units in quadratic number fields and relations to continued fractions.	12	2
III	Noetherian rings, Rings of dimension one. Dedekind domains. Norms and traces. Derive formulae relating norms and traces for towers of field extensions. Discriminant and calculations of the discriminant in the special context of quadratic number fields. Different and its applications.	12	3
IV	Cyclotomic extensions and calculation of the discriminant in this case. Factorization of ideals into prime ideals and its relation to the discriminant. Ramification theory, residual degree and its relation to the degree of the extension. Ramified primes in quadratic number fields.	12	4
V	Ideal class group. Geometric ideas involving volumes. Minkowski's theorem and its application to proving finiteness of the ideal class group. Real and complex embeddings. Structure of finitely generated abelian groups. Dirichlet's Unit Theorem and the rank of the group of units. Discrete valuation rings. Local fields.	12	5

Textbooks & References

[1] Gerald J Janusz. *Algebraic number fields*. American Mathematical Soc., 1996.

[2] Jürgen Neukirch. *Algebraic number theory*. Springer Science & Business Media, 2013.

[3] Daniel A Marcus and Emanuele Sacco. *Number fields*. Springer, 1977.

10.11 ME11: Algebraic Topology

Learning Objective (LO): The aim of this course is to introduce students to the fundamental concepts of algebraic topology, including quotient spaces, topological groups, and homotopy theory. Students will develop the ability to analyze topological structures and apply algebraic methods to solve complex problems in topology and geometry.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand quotient spaces, topological groups, and the concept of connectedness, with examples like RP^n, Klein's bottle, and $SO(n, R)$.	U
2	Analyze the fundamental group, paths, and homotopies, including applications such as Brouwer's fixed point theorem and the fundamental theorem of algebra.	An
3	Explore covering spaces, their properties, and relationships with the fundamental group, including examples and criteria like Deck transformations.	Ap
4	Evaluate orbit spaces, fundamental groups of various surfaces, and their relationship to covering spaces and orientation.	E
5	Apply concepts of free groups, Seifert Van Kampen theorem, and knot theory to understand topological spaces and group structures.	Ap

CL: Cognitive Levels (R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
CO	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	2	2	2	-	2	1	2	2	-	3	2	3	3	1	1	2	-
CO2	2	1	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO3	2	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	3	3	3	-	2	1	3	3	-	3	2	3	3	3	2	1	-
CO5	2	1	3	-	2	1	3	2	-	3	2	3	3	2	2	2	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Review of quotient spaces and its universal properties. Examples on $\mathbf{RP}^n$, Klein's bottle, Mobius band. CP^n, $SO(n, R)$. Connectedness and path connectedness of spaces such as $SO(n, R)$ and other similar examples. Topological groups and their basic properties. Proof that if H is a connected subgroup such that G/H is also connected (as a topological space) then G is connected. Quaternions, S^3 and $SO(3, R)$. Connected, locally path connected space is path connected.	14	1
II	Paths and homotopies of paths. The fundamental group and its basic properties. The fundamental group of a topological group is abelian. Homotopy of maps, retraction and deformation retraction. The fundamental group of a product. The fundamental group of the circle. Brouwer's fixed point theorem. Degree of a map. Applications such as the fundamental theorem of algebra, Borsuk-Ulam theorem and the Perron Frobenius theorem.	11	2
III	Covering spaces and its basic properties. Examples such as the real line as a covering space of a circle, the double cover $\eta : \mathrm{S}^n \to \mathbf{RP}^n$, the double cover $\eta : \mathrm{S}^3 \to SO(3,R)$. Relationship to the fundamental group. Lifting criterion and Dèck transformations. Equivalence of covering spaces. Universal covering spaces. Regular coverings and its various equivalent formulations such as the transitivity of the action of the Deck group. The Galois theory of covering spaces.	12	3
IV	Orbit spaces. Fundamental group of the Klein's bottle and torus. Relation between covering spaces and Orientation of smooth manifolds. Non orientability of $\mathbf{RP}^2$ illustrated via covering spaces.	11	4
V	Free groups and its basic properties, free products with amalgamations. Concept of push outs in the context of topological spaces and groups. Seifert Van Kampen theorem and its applications. Basic notions of knot theory such as the group of a knot. Wirtinger's algorithm for calculating the Group of a knot illustrated with simple examples.	12	5

Textbooks & References

[1] Elon Lages Lima. *Fundamental groups and covering spaces.* AK Peters/CRC Press, 2003.

[2] WS Massey. *Introduction to algebraic topology.* Springer Verlag, 1967.

10.12 ME12: Differential Geometry & Applications

Learning Objective (LO): The aim of this course is to provide students with a deep understanding of differential geometry, including parametrized curves, curvature theory, and surfaces in Euclidean space. Students will develop the ability to analyze geometric structures and apply differential geometry concepts to solve problems in mathematics, physics, and engineering.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the concepts of parametrized curves and curvature theory in Euclidean space E^n, including arc-length parametrization and rigidity of curves.	U
2	Analyze Euler's theory of curves on surfaces, exploring geodesics, normal curvature, principal curvatures, and related geometric properties.	An
3	Explore Gauss' theory of curvature of surfaces, including the second fundamental form, Weingarten map, Gaussian curvature, and theorems like Theorema Egregium and Gauss-Codazzi equations.	Ap
4	Evaluate the concepts of mean curvature, minimal surfaces, geodesic coordinates, and non-orientable surfaces, focusing on the Isoperimetric Inequality and Gauss-Bonnet theorem.	E
5	Apply modern perspectives on surfaces, including tangent planes, parallel transport, affine connection, and Riemannian metrics on surfaces.	Ap

CL: Cognitive Levels (R-Remember; U-Understanding; Ap-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	2	2	2	-	2	1	2	2	-	3	2	3	3	1	1	2	-
CO2	2	2	2	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO3	3	2	2	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	2	2	2	-	2	1	3	3	-	3	2	3	3	3	2	1	-
CO5	2	2	2	-	2	1	3	2	-	3	2	3	3	2	2	2	-

"3" - Strong; "2" - Moderate: "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Curvature of curves in E^n: Parametrized Curves, Existence of Arc length parametrization, Curvature of plane curves, Frennet-Serret theory of (arc-length parametrized) curves in E^3, Curvature of (arc-length parametrized) curves in E^n, Curvature theory for parametrized curves in E^n. Significance of the sign of curvature, Rigidity of curves in E^n.	12	1
II	Euler's Theory of curves on Surfaces: Surface patches and local coordinates, Examples of surfaces in E^3, curves on a surface, tangents to the surface at a point, Vector fields along curves, Parallel vector fields, vector fields on surfaces, Normal vector fields, the First Fundamental form. Normal curvature of curves on a surface, Geodesics, geodesic Curvature, Christoffel symbols, Gauss' formula, Principal Curvatures. Euler's theorem.	12	2
III	Gauss' theory of Curvature of Surfaces: The Second Fundamental Form, Weingarten map and the Shape operator, Gaussian Curvature, Gauss' Theorema Egregium, Gauss-Codazzi equations, Computation of First/Second fundamental form, curvature etc. for surfaces of revolution and other examples.	12	3
IV	More Surface theory: Isoperimetric Inequality, Mean Curvature and Minimal Surfaces (introduction), surfaces of constant curvature, Geodesic coordinates. Notion of orientation, examples of non-orientable surfaces, Euler characteristic, statement of Gauss-Bonnet Theorem.	12	4
V	Modern perspective on surfaces, Tangent planes, Parallel transport, Affine connection, Riemannian metrics on surfaces.	12	5

Textbooks & References

[1] Andrew N Pressley. *Elementary differential geometry.* Springer Science & Business Media, 2010.

[2] John A Thorpe. *Elementary topics in differential geometry.* Springer Science & Business Media, 2012.

[3] Manfredo P Do Carmo. *Differential geometry of curves and surfaces: revised and updated second edition.* Courier Dover Publications, 2016.

[4] Richard S Millman and George D Parker. *Elements of differential geometry.* Prentice Hall, 1977.

10.13 ME13: Fuzzy Set Theory & Its Applications

Learning Objective (LO): The aim of this course is to introduce students to the principles of fuzzy set theory, including operations on fuzzy sets, membership functions, and α-level sets. Students will develop the ability to apply fuzzy logic and fuzzy set theory to solve problems in decision-making, control systems, and other applications.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the basic definitions and operations on fuzzy sets, including α-level sets, convex fuzzy sets, and t-norms/t-conorms.	U
2	Apply Zadeh's extension principle to derive images and inverse images of fuzzy sets and explore the concept of fuzzy numbers.	Ap
3	Analyze fuzzy relations, their composition, and properties, focusing on min-max composition.	An
4	Evaluate fuzzy equivalence and compatibility relations, fuzzy graphs, and similarity relations in various contexts.	E
5	Apply possibility theory concepts to compare and contrast fuzzy sets and probability theory, exploring measures like possibility and necessity.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	3	2	1	2	2	-	3	2	3	3	1	1	2	-
CO2	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	-
CO3	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	1	1
CO4	3	3	3	3	2	1	3	3	-	3	2	3	3	3	2	1	1
CO5	3	3	3	3	2	1	3	2	-	3	2	3	3	2	2	2	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	**Topics**	**No. of Lectures**	**CO No.**
I	Fuzzy sets-Basic definitions. α-level sets. Convex fuzzy sets. Basic operations on fuzzy sets. Types of fuzzy sets. Cartesian products, Algebraic products. Bounded sum and difference, t-norms and t-conorms.	12	1
II	The Extension Principle- The Zadeh's extension principle. Image and inverse image of fuzzy sets. Fuzzy numbers. Elements of fuzzy arithmetic.	12	2
III	Fuzzy Relations on Fuzzy sets. Composition of Fuzzy relations. Min-Max composition and its properties.	12	3
IV	Fuzzy equivalence relations. Fuzzy compatibility relations. Fuzzy relation equations. Fuzzy graphs. Similarity relation.	12	4
V	Possibility Theory-Fuzzy measures. Evidence theory. Necessity measure. Possibility measure. Possibility distribution. Possibility theory and fuzzy sets. Possibility theory versus probability theory.	12	5

Textbooks & References

[1] Hans-Jürgen Zimmermann. *Fuzzy set theory—and its applications.* Springer Science & Business Media, 2011.

[2] George Klir and Bo Yuan. *Fuzzy sets and fuzzy logic.* Prentice hall New Jersey, 1995.

[3] M Ganesh. *Introduction to fuzzy sets and fuzzy logic.* PHI Learning Pvt. Ltd., 2006.

[4] James J Buckley and Esfandiar Eslami. *An introduction to fuzzy logic and fuzzy sets.* Springer Science & Business Media, 2002.

[5] Kazuo Tanaka and Kazuo Tanaka. *An introduction to fuzzy logic for practical applications.* Springer, 1997.

10.14 ME14: Wavelets

Learning Objective (LO): The aim of this course is to introduce students to the theory and applications of wavelets, including their construction, orthonormal bases, and the Balian-Low theorem. Students will develop the skills to analyze signals and data using wavelet transforms and apply these techniques to problems in mathematics, engineering, and data science.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand different methods of constructing wavelets, focusing on orthonormal bases and the Balian-Low theorem.	U
2	Analyze local sine and cosine bases and their relationship with wavelet construction, including the concept of unitary folding operators.	An
3	Apply multiresolution analysis techniques to construct compactly supported wavelets, and explore band-limited wavelets.	Ap
4	Evaluate the orthonormality and completeness of wavelet bases, with a focus on Lemarie-Meyer wavelets, Franklin wavelets, and spline wavelets.	E
5	Explore orthonormal bases of periodic splines and piecewise linear continuous functions for $L^2(\mathbb{T})$, and the periodization of wavelets on the real line.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
CO	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	1	2	2	-	2	1	2	2	-	3	2	3	3	1	1	2	-
CO2	1	2	2	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO3	1	2	1	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	1	2	2	-	2	1	3	3	-	3	2	3	3	3	2	1	-
CO5	1	1	2	-	2	1	3	2	-	3	2	3	3	2	2	2	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Preliminaries-Different ways of constructing wavelets- Orthonormal bases generated by a single function: the Balian-Low theorem. Smooth projections on $L^2(\mathbb{R})$.	13	1
II	Local sine and cosine bases and the construction of some wavelets. The unitary folding operators and the smooth projections.	13	2
III	Multiresolution analysis and construction of wavelets. Construction of compactly supported wavelets and estimates for its smoothness. Band limited wavelets.	12	3
IV	Orthonormality. Completeness. Characterization of Lemarie-Meyer wavelets and some other characterizations. Franklin wavelets and Spline wavelets on the real line.	11	4
V	Orthonormal bases of piecewise linear continuous functions for $L^2(\mathbb{T})$. Orthonormal bases of periodic splines. Periodization of wavelets defined on the real line.	11	5

Textbooks & References

[1] Albert Boggess and Francis J Narcowich. *A first course in wavelets with Fourier analysis*. John Wiley & Sons, 2015.

[2] Eugenio Hernández and Guido Weiss. *A first course on wavelets*. CRC press, 1996.

[3] Przemyslaw Wojtaszczyk. *A mathematical introduction to wavelets*. Cambridge University Press, 1997.

[4] David F Walnut. *An introduction to wavelet analysis*. Springer Science & Business Media, 2002.

[5] Gerald Kaiser and Lonnie H Hudgins. *A friendly guide to wavelets*. Springer, 1994.

10.15 ME15: Mathematical Methods

Learning Objective (LO): The aim of this course is to equip students with the understanding and application of mathematical methods, including integral equations, Fourier transforms, and their significance in solving engineering and scientific problems.

Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the different types of integral equations, including Fredholm and Volterra equations, and their significance in mathematical modeling.	U
2	Analyze properties of kernels such as symmetric, degenerate, and iterated kernels, and solve integral equations using eigenvalues and eigenfunctions.	An
3	Apply methods like successive approximations and Neumann series to solve Fredholm integral equations, and understand fundamental theorems and Green's functions.	Ap
4	Evaluate concepts in the calculus of variations, including Euler-Lagrange equations, natural boundary conditions, and transversality conditions, with practical applications.	E
5	Apply variational methods to boundary value problems (BVPs), explore methods like Euler's Finite Difference and Ritz, and solve problems involving eigenvalues and eigenfunctions.	Ap

CL: Cognitive Levels (R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	3	2	2	-	2	1	2	2	-	3	2	3	3	1	1	2	1
CO2	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO3	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	1	1
CO4	3	3	3	-	2	1	3	3	-	3	2	3	3	3	2	1	1
CO5	3	3	3	-	2	1	3	2	-	3	2	3	3	2	2	2	1

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	Topics	No. of Lectures	CO No.
I	Integral equations, Introduction, Abel's Problem, Fredholm Integral Equations of first, second and third kinds, Homogeneous Fredholm Integral Equation, Volterra integral equations of first, second and third kinds. Homogeneous Volterra integral equation. Singular Integral Equations.	13	1
II	Symmetric Kernels, Degenerate Kernels, Iterated Kernels, Resolvent Kernels, Eigenvalues and Eigenfunctions of Integral operator, Solution by Eigenvalues and eigenfunctions Method.	11	2
III	Solution of Fredholm Integral Equations of the second kind with degenerate kernels, Method of Successive Approximations, Method of Successive Substitutions. Neumann series. Fredholm's First, second and third Fundamental Theorems, Green's Function. Modified Green's Function.	12	3
IV	Calculus of variations: Introduction. Euler-Lagrange equations, Invariance of Euler's Equations. Field of Extremals, Natural boundary conditions, Transversality conditions, Simple applications of variational principle, Sufficient conditions for extremum of a functional.	12	4
V	Variational formulation of BVP, Moving Boundary problems, Euler's Finite Difference Method, Ritz Method, Variational methods for finding Eigenvalues and Eigenfunctions.	12	5

Textbooks & References

[1] FB Hildebrand. *Methods of Applied Mathematics*. Prentice-Hall, 4th printing, 1958.

[2] Filip Rindler. *Calculus of variations*. Springer, 2018.

[3] AS Gupta. *Calculus of variations with applications*. PHI Learning Pvt. Ltd., 1996.

[4] MD Raisinghania. *Integral equations and boundary value problems*. S. Chand Publishing, 2007.

10.16 ME16: Fourier Analysis

Learning Objective (LO): The aim of this course is to develop students' understanding of Fourier series, Fourier transforms, and their applications in analyzing periodic and non-periodic functions in engineering and science.
Course Outcomes (CO):

CO No.	Expected Course Outcomes At the end of the course, the students will be able to :	CL
1	Understand the convergence properties of Fourier series and their importance in representing periodic functions.	U
2	Analyze uniqueness, summability methods, and the significance of summability kernels like Fejer's and Dirichlet's kernels in Fourier series.	An
3	Apply Fourier transforms to functions in various spaces such as L^1, L^2, and L^p, and explore key theorems like Poisson summation, Hausdorff-Young, and Riesz-Thorin.	Ap
4	Evaluate Fourier transforms of rapidly decreasing functions and distributions, and apply theorems such as Plancherel, Paley-Weiner, and Fourier inversion.	E
5	Explore the calculus of distributions, tempered distributions, and Fourier transforms of distributions with applications to partial differential equations.	Ap

CL: Cognitive Levels (**R**-Remember; **U**-Understanding; **Ap**-Apply; **An**-Analyze; **E**-Evaluate; **C**-Create).

CO-PO/PSO Mapping for the course:

PO / CO	POs											PSOs					
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6
CO1	1	2	1	-	2	1	2	2	-	3	2	3	3	1	1	2	-
CO2	2	1	2	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO3	1	1	2	-	2	1	3	2	-	3	2	3	3	2	2	1	-
CO4	1	1	1	-	2	1	3	3	-	3	2	3	3	3	2	1	-
CO5	1	1	2	-	2	1	3	2	-	3	2	3	3	2	2	2	-

"3" - Strong; "2" - Moderate; "1"- Low; "-" No Correlation

Detailed Syllabus:

Unit No.	**Topics**	**No. of Lectures**	**CO No.**
I	Fourier series, Discussion of convergence of Fourier series.	12	1
II	Uniqueness of Fourier Series, Convolutions, Cesaro and Abel Summability, Fejer's theorem, Dirichlet's theorem, Poisson Kernel and summability kernels. Example of a continuous function with divergent Fourier series.	13	2
III	Summability of Fourier series for functions in L^1, L^2 and L^p spaces. Fourier-transforms of integrable functions. Basic properties of Fourier transforms. Poisson summation formula. Hausdorff-Young inequality, Riesz-Thorin Interpolation theorem.	12	3
IV	Schwartz class of rapidly decreasing functions, Fourier transforms of rapidly decreasing functions, Riemann Lebesgue lemma, Fourier Inversion Theorem, Fourier transforms of Gaussians, Plancherel theorem, Paley-Weiner theorem.	12	4
V	Distributions and Fourier Transforms: Calculus of Distributions, Tempered Distributions: Fourier transforms of tempered distributions, Convolutions, Applications to PDEs.	11	5

Textbooks & References

[1] Y Katznelson. An introduction to harmonic analysis. dover publications, new york, 1976.

[2] Robert E Edwards. *Fourier Series: A Modern Introduction Volume 2*. Springer Science & Business Media, 2012.

[3] Elias M Stein. *Fourier Analysis. An introduction.* 2003.

[4] Walter Rudin. *Fourier analysis on groups.* Courier Dover Publications, 2017.