Head of the Department
Mathematics
Institute of Applied Sciences & Humanities
GLA University, Mathura

GLA University, Mathura

(NAAC Accredited 'A+' Grade)

Curriculum and Syllabi
of
M.Sc. Mathematics

(w. e. f. Session 2024-2025)

With
Choice Based Credit System (CBCS)

DEPARTMENT OF MATHEMATICS
Institute of Applied Sciences and Humanities

Approved by :	**BOS**	**Academic Council**	**Executive Council**
Approval Status :	✓	✓	✓
Approval Date :	16.06.2022	18.06.2022	01.07.2022

TABLE OF CONTENTS

S. NO.	CONTENTS
	VISION AND MISSION
1	BACKGROUND i)NEP-2020 ii)ABOUT MATHEMATICS iii)ABOUT THE PROGRAMME (OBJECTIVES, DURATION AND ELIGIBILITY) iv)QUALIFICATION DESCRIPTORS (POSSIBLE CAREER PATH WAYS)
2	PROGRAMME OUTCOMES (POs)
3	STRUCTURE OF MASTER'S COURSE
4	SEMESTER-WISE COURSES AND CREDIT DISTRIBUTION
5	COURSE-LEVEL LEARNING OUTCOMES

Head of the Department
Mathematics
Institute of Applied Sciences & Humanities
GLA University, Mathura

VISION AND MISSION

Vision and Mission of the University

Vision

We envision ourselves as a pace-setting university of Academic Excellence focused on education, research and development in established and emerging professions.

Mission

M1: To impart quality professional education, to conduct commendable research and to provide credible consultancy and extension services as per current and emerging socio-economic needs.

M2: To continuously enhance and enrich the teaching/learning process and set such standards, education and otherwise, that other institutes would want to emulate.

M3: To be totally student-centric, thus promoting the overall growth and development of intellect and personality of our prime stakeholders, namely students, so that our alumni are worthy citizens and highly sought-after professionals worldwide.

M4: To empower the members of faculty and staff so that the university's ambience is one of harmony, mutual respect, cooperative endeavour and receptivity towards positive ideas.

M5: To proactively seek regular feedback from all the stakeholders and take appropriate measures based on them thus leading to excellent learning process. Be totally student-centric, thus promoting the overall growth and development of intellect and personality of our prime stakeholders, namely students, so that our alumni are worthy citizens and highly sought-after professionals worldwide.

Vision and Mission of the Department

Vision

The department aims to be a center of excellence in Mathematics, computing and is vigorously engaged in both research and teaching.

Mission

M-1: To perform widely recognized research in focused areas of mathematical and statistical theory, methodology, and education.

M-2: To explore applications of Mathematics and Statistics and engage in collaborative research in an interdisciplinary environment.

M-3: To discover, mentor, and nurture mathematically inclined students, and provide them a supportive environment that fosters intellectual growth.

M-4: To prepare our postgraduate students to develop the attitude and ability to apply mathematical methods and ideas in a wide variety of careers.

M-5: To provide professional services based on our diverse mathematical and statistical expertise to the scientific, technical, and educational community.

1. BACKGROUND

i) National Educational Policy (NEP) - 2020

The curricular reforms are instrumental for the desired learning outcomes. In view of this, the Department of Mathematics of Institite of Applied Sciences and Humanities of GLA University, Mathura, U.P. took initiative to revise the curriculum of its postgraduate program in alignment with National Education Policy-2020. The key features of the policy were discussed in the meeting of heads of various departments with the hon'ble Vice Chancellor and the action plan was made with well-defined responsibilities and timeline for academic reforms.

The process of modifying the curriculum started with the series of webinars and discussions conducted by the University to orient the teachers about the key features of the policy, enabling them to revise the curriculum in sync with the policy. Proper orientation of the faculty about the vision and provisions of NEP-2020 made it easier for them to incorporate the vital aspects of the policy in the revised curriculum focused on creating holistic and innovative individuals equipped with the key skills for the development of an enlightened, socially conscious, skilled and self-sustained nation.

The revised curricula articulate the spirit of the policy by emphasizing upon—integrated approach to learning; innovative pedagogy and assessment strategies; multidisciplinary education; critical thinking; ethical values; entrepreneurial and professional skills; social, moral and environmental awareness; holistic, discussion-based, and analytical learning; flexibility in choice of courses; student-centric participatory learning; offering multiple entry and exit points; integration of extra-curricular and curricular aspects; closer collaborations between industry and higher education institutions for science programs; and formative assessment tools to be aligned with the learning outcomes, capabilities, and dispositions as specified for each course. The University has also developed consensus on adoption of Blended Learning with 40% component of online teaching and 60% face to face classes for each program.

The revised curricula of PG program could be devised with efforts of the faculty and head of the department. The draft prepared by the department was discussed in a series of discussion sessions conducted at department and the University level. The Dean, Academic affairs of the University conducted a series of meetings with Heads and Deans to deliberate upon the parameters of the revised curriculum to formulate a uniform template featuring background, Programme Outcomes (POs), Programme Specific Outcomes (PSOs), Structure of Masters Course, Semester-wise Courses and Credit Distribution, Course-level Learning Outcomes, Teaching-Learning Process. The experts of the Board of Studies contributed to a large extent in giving the final shape to the revised curriculum.

ii) About Mathematics

"Mathematics is the most beautiful and the most powerful creation of the human spirit."

- Stefan Banach

Mathematics is a vital tool for global knowledge and communication that organizes and prevents chaos in our life. Mathematics aids in our understanding of the world and is a good tool for developing mental discipline. Logical reasoning, critical thinking, creative thinking, abstract or spatial thinking, problem-solving abilities, and even effective communication skills are all fostered by mathematics. Mathematics is required to know all other fields of sciences. In one way or another, they all rely on mathematics. The scale of mathematics influences the discipline and mastery of any other science or art.

iii) About the programme

(a) **Objectives:** M.Sc. programme in Mathematics at GLA University, Mathura, aims to help in building foundation in Statistics, Data Analysis, Data Mining, Geometry, Topology, Algebra, Economics and Applied Mathematics. M.Sc. in Mathematics involves advanced studies of Mathematics and Statistics laying a strong foundation which would support employability in industry as well as background for research. While pursuing M.Sc. (Mathematics) degree from GLA University, the students will develop practical knowledge, critical thinking, data handling, quantitative aptitude and conceptual skills. With an objective to foster the analytical skills among the students, M.Sc. (Mathematics) course is the best for those who want to formulate the calculative and mathematical approach.

(b) **Duration:** M.Sc. Mathematics is a full time post graduate level program offered by the Department of Mathematics, IAH, GLA University. This is a two year program, consisting of four semesters with two semesters per year.

(c) **Eligibility:**

- The admission aspirant to the program must have studied Mathematics in Graduation and have scored at least 50% marks in aggregate, **OR,**
- She / he must have studied Mathematics at 10+2 level.
- She / he must have a valid GLAET score

Qualification Descriptors (Possible Career Pathways)

Scope of Employability

After successfully completing this postgraduate program, the students receive a master degree "**Master of Science in Mathematics**". Upon completion of this program, the students will be able to further extend their research in Mathematics. They will also be expected to develop life skills in addition to mathematical ability, as are required to have a wealthy life.

The following career paths possibly open up as a result of pursuing a master degree in Mathematics:

1. **Teaching**
2. **Research**
3. **Banking**
4. **Actuarial Sciences**
5. **Data Scientist**
6. **Military Operations**
7. **Market Researcher**
8. **Numerical Analyst**
9. **Research Analyst**
10. **Foreign Exchange Traders**
11. **Production Manager**
12. **Investment Researcher**
13. **Information Scientist**
14. **System Analyst**
15. **Market Research Analyst**

Head of the Department
Mathematics
Institute of Applied Sciences & Humanities
GLA University, Mathura

2. PROGRAMME OUTCOMES (POs)

The students enrolled in the Master's Program offered by the Department of Mathematics under Institute of Applied Sciences and Humanities will have the opportunity to learn and master the following components in addition to attain important essential skills and abilities:

PO No.	PROGRAM OUTCOMES (POs)
PO- 1	Independently carry out research /investigation and development work to solve practical problems.
PO- 2	Write and present a substantial research report/document.
PO- 3	Demonstrate a degree of mastery, at a level higher than the requirements in the appropriate bachelor program, over the area as per the program's specialization.

Head of the Department
Mathematics
Institute of Applied Sciences & Humanities
GLA University, Mathura

3. STRUCTURE OF MASTER'S COURSE

Types of Courses	Nature	Total Credits	%
Program Core Courses(C)	Compulsory	**44**	**44%**
Elective Courses (DSE)	Discipline Specific Elective Courses	**36**	**36%**
Skilled-based Courses (SEC)	Skill Enhancement Compulsory Courses	**4**	**4%**
Ability Enhancement Courses (AECC)	Compulsory	**16**	**16%**
Total		**100**	**100%**

Note: The Scheme and Syllabus of the programme are subject to change as per the UGC guidelines, NEP-2020 and University ordinance.

Head of the Department
Mathematics
Institute of Applied Sciences & Humanities
GLA University, Mathura

Course Type

Program Core Courses (C)
Discipline Specific Elective Courses (DSE)
Skill Enhancement Course (SEC)
Ability Enhancement Compulsory Course (AECC)

Total Credits: 100, Semester-wise distribution of credits: 24+ 28 + 24 + 24

PROGRAM CORE COURSES(C)

S. No.	Course Code	Course Title	L	T	P	J	Credit
1	MMAC 0001	Real Analysis	3	1	0	0	4
2	MMAC 0002	Abstract Algebra	3	1	0	0	4
3	MMAC 0003	Ordinary Differential Equations	3	1	0	0	4
4	MMAC 0004	Linear Algebra	3	1	0	0	4
5	MMAC 0005	Statistical Analysis	3	1	0	0	4
6	MMAC 0006	Operational Research - I	3	1	0	0	4
7	MMAC 0007	Topology	3	1	0	0	4
8	MMAC 0009	Functional Analysis	3	1	0	0	4
9	MMAC 0010	Partial Differential Equations-I	3	1	0	0	4
10	MMAC 0013	Numerical Analysis	3	1	0	0	4
11	MMAC 0014	Complex Analysis	3	1	0	0	4

Head of the Department
Mathematics
Institute of Applied Sciences & Humanities
GLA University, Mathura

Discipline Specific Elective Courses (DSE)

Bouquet 1

(Offered to the students of M.Sc. Mathematics by the Department)

S. No.	Course Code	CourseTitle	L	T	P	J	Credit
1	MMAE 0001	Differential Geometry	4	0	0	0	4
2	MMAE 0002	Special Relativity and Tensor Calculus	4	0	0	0	4
3	MMAE 0003	General Relativity and Cosmology	4	0	0	0	4
4	MMAE 0004	Special Functions	4	0	0	0	4
5	MMAE 0006	Partial Differential Equations-II	4	0	0	0	4
6	MMAE 0007	Fluid Dynamics-I	4	0	0	0	4
7	MMAE 0008	Fluid Dynamics-II	4	0	0	0	4
8	MMAE 0009	Discrete Mathematics	4	0	0	0	4
9	MMAE 0010	Integral Equation	4	0	0	0	4
10	MMAE 0011	Optimization Techniques	4	0	0	0	4
11	MMAE 0012	Non-Linear Programming	4	0	0	0	4
12	MMAE 0013	Operator Theory	4	0	0	0	4
13	MMAE 0014	Measure Theory and Integration	4	0	0	0	4
14	MMAE 0015	Fixed Point Theory	4	0	0	0	4
15	MMAE 0016	Finite Element Method	4	0	0	0	4
16	MMAE 0017	Operational Research-II	4	0	0	0	4
17	MMAE 0018	Fractional Calculus	4	0	0	0	4
18	MMAE 0019	Mathematical Modeling	4	0	0	0	4
19	MMAE 0020	Fuzzy Set Theory	4	0	0	0	4
20	MMAE 0021	Numerics of Ordinary Differential Equations	4	0	0	0	4
21	MMAE 0022	Numerics of Partial Differential Equations	4	0	0	0	4
22	MMAE 0023	Mathematics for Finance	4	0	0	0	4
23	MMAE 0024	Coding Theory	4	0	0	0	4
24	MMAE 0025	Cryptography	4	0	0	0	4

Head of the Department
Mathematics
Institute of Applied Sciences & Humanities
GLA University, Mathura

Bouquet 2

(Offered to the Students of Specialization Data Science)

S.No.	Coursecode	Coursetitle	L	T	P	J	Credit
1.	MMAE 0101	Probability Theory and Distributions	3	0	2	0	4
2	MMAE 0102	Regression Analysis and Predictive Modelling	3	0	2	0	4
3	MMAE 0103	Time Series Analysis and Forecasting	3	0	2	0	4
4	MCAC 0009	Database Management System	3	0	0	0	3
5	MCAC 0807	Database Management System Lab	0	0	2	0	1
6	MMAE 0104	Machine Learning for Data Science	3	0	2	0	4
7	MMAE 0105	Deep Learning	3	0	2	0	4
8	MMAE 0106	Multivariate Analysis and Stochastic Processes	3	0	2	0	4
9	MMAE 0107	Big Data Analytics	3	0	2	0	4
10	MCAE 0306	Cloud Computing	3	0	0	0	3
11	MCAE 0372	Cloud Computing Lab	0	0	2	0	1
12	MMAE 0108	Statistical Inference	3	0	2	0	4
13	MMAE 0109	Actuarial Statistics	3	0	2	0	4
14	MMAE 0111	Statistical Computing	3	0	2	0	4
15	MMAE 0112	Artificial Intelligence for Data Science	3	0	2	0	4
16	MMAE 0113	Pattern Recognition	3	0	2	0	4
17	MMAE 0114	Design of Experiments and Analysis of Variance	3	0	2	0	4
18	MMAE 0115	Statistical Quality Control	3	0	2	0	4
19	MMAE 0116	Bio-Statistics	3	0	2	0	4
20	BCSE 0152	Data Mining and Warehousing	3	0	0	0	3
21	BCSE 0181	Data Mining and Warehousing Lab	0	0	2	0	1
22	MMAE 0117	Econometrics	3	0	2	0	4
23	MMAE 0118	Survival Analysis	3	0	2	0	4
24	MMAE 0009	Discrete Mathematics	4	0	0	0	4
25	MMAE 0011	Optimization Techniques	4	0	0	0	4

Head of the Department
Mathematics
Institute of Applied Sciences & Humanities
GLA University, Mathura

Skill Enhancement Courses (SEC)

This may include acourse based on Theoretical/Experimental/Computational Techniques/Methods.

S.No.	Course Code	Course Title	L	T	P	J	Credit
1.	MCAC 0016	Programming in Python	3	0	0	0	3
2.	MCAC 0810	Python Programming Lab	0	0	2	0	1
3.	MELH 0006	Technical Writing	4	0	0	0	4

Ability Enhancement Compulsory Courses (AECC)

S.No.	Course Code	Course Title	L	T	P	J	Credit
1.	MMAJ 0962	Project-I	0	0	0	4	4
2.	MMAJ 0963	Project-II	0	0	0	4	4
3.	MMAJ 0964	Project-III	0	0	0	4	4
4.	MMAJ 0965	Project-IV	0	0	0	4	4

Head of the Department
Mathematics
Institute of Applied Sciences & Humanities
GLA University, Mathura

4. SEMESTER-WISE COURSES AND CREDIT DISTRIBUTION

SEMESTER-I

Total Credits: 24 (C: 20, AECC: 4)

Sr. No.	Course No.	Course Code	Course Title	L	T	P	J	Hrs/Week	Total Credits
Program Core Courses (C)									
1	1	MMAC 0001	Real Analysis	3	1	0	0	4	4
2	2	MMAC 0002	Abstract Algebra	3	1	0	0	4	4
3	3	MMAC 0003	Ordinary Differential Equation	3	1	0	0	4	4
4	4	MMAC 0004	Linear Algebra	3	1	0	0	4	4
5	5	MMAC 0005	Statistical Analysis	3	1	0	0	4	4
Ability Enhancement Compulsory Course (AECC)									
6	6	MMAJ 0962	Project-I	0	0	0	4	4	4

SEMESTER-II

Total Credits: 28 (C: 12, DSE: 8, SEC: 4, AECC: 4

Sr. No.	Course No	Course Code	Course Title	L	T	P	J	Hrs/ Week	Total Credits
Program Core Courses (C)									
1	7	MMAC 0006	Operational Research - I	3	1	0	0	4	4
2	8	MMAC 0007	Topology	3	1	0	0	4	4
3	9	MMAC 0009	Functional Analysis	3	1	0	0	4	4
Discipline Specific Elective Courses (DSE)									
4	10	MMAE 0001-0004, 0006-0025 / MMAE 0101-0109, 0111-0118; MCAC 0009, 0807; MCAE 0306, 0372; BCSE 0152, 0181	DSE-I	4/3	0	0/2	0	4	4
5	11		DSE-II	4/3	0	0/2	0	4	4
Skill Enhancement Course (SEC)									
6	12	MELH 0006	Technical Writing	4	0	0	0	4	4
Ability Enhancement Compulsory Course (AECC)									
7	13	MMAJ 0963	Project-II	0	0	0	4	4	4

Head of the Department
Mathematics
Institute of Applied Sciences & Humanities
GLA University, Mathura

SEMESTER-III

Total Credits: 24 (C: 12, DSE: 8, AECC: 4)

Sr. No.	Course No.	Course Code	Course Title	L	T	P	J	Hrs/Week	Total Credits
Program Core Courses (C)									
1	14	MMAC 0010	Partial Differential Equation-I	3	1	0	0	4	4
2	15	MMAC 0013	Numerical Analysis	3	1	0	0	4	4
3	16	MMAC 0014	Complex Analysis	3	1	0	0	4	4
Discipline Specific Elective Courses (DSE)									
4	17	MMAE 0001-0004, 0006-0025 / MMAE 0101-0109, 0111-0118; MCAC 0009, 0807; MCAE 0306, 0372; BCSE 0152, 0181	DSE-III	4/3	0	0/2	0	4	4
5	18		DSE-IV	4/3	0	0/2	0	4	4
Ability Enhancement Compulsory Course (AECC)									
6	19	MMAJ 0964	Project-III	0	0	0	4	4	4

SEMESTER-IV

Total Credits: 24 (DSE: 20, AECC: 4)

Sr. No.	Course No.	Course Code	Course Title	L	T	P	J	Hrs/Week	Total Credits
Discipline Specific Elective Courses (DSE)									
1	20	MMAE 0001-0004, 0006-0025 / MMAE 0101-0109, 0111-0118; MCAC 0009, MCAC 0807; MCAE 0306, MCAE 0372; BCSE 0152, BCSE 0181	DSE-V	4/3	0	0/2	0	4	4
2	21		DSE-VI	4/3	0	0/2	0	4	4
3	22		DSE-VII	4/3	0	0/2	0	4	4
4	23		DSE-VIII	4/3	0	0/2	0	4	4
5	24		DSE-IX	4/3	0	0/2	0	4	4
Ability Enhancement Compulsory Course (AECC)									
6	25	MMAJ 0965	Project-IV	0	0	0	4	4	4

SYLLABI OF SUBJECTS

PROGRAM CORE COURSES (C)

5. COURSE-LEVEL LEARNING OUTCOMES

Course No: 1	**Course Name:** Real Analysis						**Course Code:** MMAC 0001	
Batch:	**Programme:** M.Sc. Mathematics	**Semester:**	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
2024-2026		I	3	1	0	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Nil
Course Objective	This course will develop a profound understanding of countable and uncountable sets, sequences and series of real numbers. This will also make the students able to prove the results of uniform continuity and differentiability and test the uniform convergence of sequences of functions. Further, a deep understanding of measurable functions, Riemann integration and Lebesgue integration will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Learn the concept of countability of real numbers and convergence of sequences. **CO2:** Understand uniform continuity and differentiability, and functions of several variables. **CO3**: Recognize the difference between pointwise and uniform convergence of sequence of functions. **CO4:** Apply tests for uniform convergence. **CO5:** Learn functions of bounded variation and measurable functions. **CO6:** Determine the Riemann and Lebesgue integrability of a function.

COURSE SYLLABUS

Module No.	**Content**	**Hours**
I	**[Course Outcome(s) No.: 1 and 2]** Countable and uncountable sets, Convergence of sequences of real numbers. **Functions of real variable**: Uniform continuity and differentiability. **Functions of several variables:** Limit, Continuity, Differentiability, Partial differentiation, Directional derivatives, Taylor's series, Inverse function theorem, Implicit function theorem, Jacobians, Fubini's theorem.	20
II	**[Course Outcome(s) No.: 3, 4, 5 and 6]** Sequence and series of functions, Pointwise and uniform convergence, Cauchy's criterion for uniform convergence, Weierstrass M-test, Abel's and Dirichlet's test for uniform convergence, Riemann integration, Functions of bounded variation, Riemann Stieltjes integration, Lebesgue measure, Lebesgue integral, Measurable sets, Measurable functions.	20

Text Books:

- W. Rudin, Principles of Mathematical Analysis, McGraw-Hill, 2017.
- T. M. Apostol, Mathematical Analysis, Narosa Publishing House, 2002.
- S. C. Malik & S. Arora, Mathematical Analysis, New Age International Ltd., 2017.
- R. Bartle, The Elements of Integration and Lebesgue Measure, Wiley Classics Library, 1995.
- D. Somasundaram & B. Chaudhary, A First Course in Mathematical Analysis, Narosa Publishing House, 1996.

Reference Books:

- K. Ross, Elementary Analysis, The Theory of Calculus, Springer, 2013.
- H. L. Royden, Real Analysis, Macmillan Publishing Company, 2015.
- P. K. Jain & V. P. Gupta, Lebesgue Measure and Integration, New Age International Ltd., 2020.

<table>
<tr><td colspan="2">Course No: 2</td><td colspan="3">Course Name: Abstract Algebra</td><td colspan="5">Course Code: MMAC 0002</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme:
M.Sc. Mathematics</td><td rowspan="2">Semester:
I</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td colspan="2">Contact Hrs Per Week:4</td></tr>
<tr><td>3</td><td>1</td><td>0</td><td>0</td><td>4</td><td colspan="2">Total Hours: 40</td></tr>
<tr><td colspan="3" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="9">This course will develop a profound understanding of group action and classification of groups. This will make the students able to prove the results based on composition series, commutator subgroups and solvability of groups. This course will also provide the knowledge of modules, field extensions and Galois groups. This course focuses on employability and skill development aligned with all CO's.</td></tr>
<tr><td>Course Outcomes</td><td colspan="9">After studying these topics, the students will be able to:
CO1: Learn the concept of internal and external direct products and use them to understand the group action and classification of groups.
CO2: Understand composition series, commutator subgroups and solvability of groups.
CO3: Know the concept of modules, and Noetherian and Artinian rings.
CO4: Determine the field extensions and use them in finding of splitting fields and Galois groups.</td></tr>
</table>

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1 and 2]** **Group Theory:** Internal and External direct products and their relations, Group action, Conjugacy classes, Class equation of a group, Automorphisms, Inner automorphism, Cauchy's theorem, Sylow's theorem, Simplicity of groups of ordersp^n, pq, p^2q and $p^2q^2 (n > 1, p$ and q are primes). Nilpotent groups, Composition series, Jordan-Holder theorem, Commutator subgroups, Solvable groups, Necessary and sufficient conditions for solvability, Insolvability of $S_n (n \geq 5)$.	20
II	**[Course Outcome(s) No.: 3 and 4]** **Ring Theory:** Modules, Simple and Semi-simple rings, Schur's lemma, Free modules, Noetherian and Artinian rings and their identity. **Fields:** Extension fields, Algebraic and Transcendental extension, Splitting fields, Separable extension, Normal extension, Perfect field, finite fields, Galois groups, Fundamental theorem of Galois theory.	20

Text Books:

- J. A. Gallian, Contemporary Abstract Algebra, Brooks/Cole, Cengage Learning, 2010.
- I. N. Herstein, Topics in Algebra, John Wiley & Sons, 2006.
- C. P. Milies & S. K. Sehgal, An Introduction to Group Rings, Kluwer Academic Publishers, 2002.

Reference Books:

- V. K. Khanna & S. K. Bhambri, A Course in Abstract Algebra, Vikas Publishing House, 2016.
- F. W. Anderson & K. R. Fuller, Rings and Categories of Modules, Springer-Verlag, 1992.
- D. S. Dummit & R. M. Foote, Abstract Algebra, Wiley, 2003.
- P. B. Bhattacharya, S. K. Jain & S. R. Nagpaul, Basic Abstract Algebra, Cambridge University Press, 1994.

Course No: 3	**Course Name:** Ordinary Differential Equations						**Course Code:** MMAC 0003	
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** I	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
			3	1	0	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Nil
Course Objective	This course will develop a profound understanding for finding the solution of nth order differential equations. This course will also make the students able to find the solution of boundary value problems and analyze the stability of dynamical systems. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Understand initial and boundary value problems and find the solution of nth order homogeneous and non-homogeneous differential equations. **CO2:** Determine the Eigen values and Eigen functions and learn their applications. **CO3:** Construct Green's function for the solution of boundary value problems. **CO4:** Find the stability of linear and non-linear dynamical systems.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1 and 2]** Introduction, Initial and Boundary value problems, Existence and Uniqueness of solutions of ordinary differential equation of first order, Lipschitz condition, Picard's method, Existence and Uniqueness theorem for ordinary differential equation of higher order, Strum-Liouville boundary value problem, Orthogonal sets of function, Eigen values and Eigen functions, Eigen function expansions, Separation and Comparison theorems.	20
II	**[Course Outcome(s) No.: 3 and 4]** Green's functions, Construction of Green's function and its application to solve the boundary value problems, Stability of autonomous system of differential equations, Critical point of an autonomous system and their classification as stable, asymptotically stable and strictly stable. Stability of linear system with constant coefficient, Linear plane autonomous system, Perturbed system, Method of Lyapunov for non-linear systems.	20

Text Books:

- M. D. Raisinghania, Ordinary Differential Equations, S. Chand & Co., 2019.
- J. N. Sharma & R. K. Gupta, Differential Equations, Krishna Prakashan Media (P) Ltd., 2019.
- E. A. Coddington & N. Levinson, Theory of Ordinary Differential Equations, McGraw Hill, 2017.

Reference Books:

- G. Birkhoff & G. C. Rota, Ordinary Differential Equations, John Wiley and Sons Inc., 1989.
- S. L. Ross, Differential Equations, John Wiley and Sons Inc., 1984.
- W. E. Boyce & R. C. Di Prima, Elementary Differential Equations and Boundary Value Problems, John Wiley and Sons Inc., 2009.
- P. Hartman, Ordinary Differential Equations, John Wiley & Sons, 1982.

<table>
<tr><td>Course No: 4</td><td colspan="5">Course Name: Linear Algebra</td><td colspan="4">Course Code: MMAC 0004</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme:
M.Sc. Mathematics</td><td rowspan="2">Semester:
I</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td colspan="2">Contact Hrs/week: 4</td></tr>
<tr><td>3</td><td>1</td><td>0</td><td>0</td><td>4</td><td colspan="2">Total Hours: 40</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="8">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="8">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="9">This course will develop a profound understanding of matrices, decomposition methods and quadratic forms. This course will make the students able to understand vector spaces and inner product spaces. Further, a deep understanding of analysis methods to solve the real life problems will be developed in this course. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="9">After studying these topics, the students will be able to:
CO1: Understand the concept of vector space and its application in statistics.
CO2: Apply Gram-Schmidt orthogonalization process for QR decomposition.
CO3: Know the linear transformation and its matrix representation.
CO4: Understand the concept related to definiteness of matrices and related results.
CO5: Develop problem solving techniques for decomposition of matrices.
CO6: Compute g-inverses by different methods.
CO7: Apply the concept of sparse matrices in solving real life problems.
CO8: Extract information from data by using the concepts of linear discriminant analysis and canonical correlation analysis.</td></tr>
</table>

<table>
<tr><td colspan="3">COURSE SYLLABUS</td></tr>
<tr><td>Module No.</td><td>Content</td><td>Hours</td></tr>
<tr><td>I</td><td>[Course Outcome(s) No.: 1, 2 and 3]
Vector spaces, Subspaces, Linearly dependent and independent sets, Spanning set, Basis and dimension, Linear transformation, Kernel, Range, Matrix representation of a linear transformation, Rank-nullity theorem, Eigen values and Eigen vectors, Inner product spaces, Orthogonal sets, Gram-Schmidt orthogonalization process.</td><td>20</td></tr>
<tr><td>II</td><td>[Course Outcome(s) No.: 4, 5, 6, 7 and 8]
Quadratic forms, Definiteness and related results. Gauss Elimination, Row canonical form, Diagonal form, Triangular form, Gauss-Jordan-LU decomposition, System of equations, Spectral decomposition, Singular value decomposition.
Applications in Statistics: Generalized inverses (g-inverse), Method of constructing g-inverses, General solution to a system of linear equations, Sparse matrices, Linear discriminant analysis and Canonical correlation analysis.</td><td>20</td></tr>
</table>

Text Books:

- D. A. Harville, Matrix Algebra from a Statistician’s Perspective, Springer, 1997.
- D. C. Lay, S. R. Lay & J. J. McDonald, Linear Algebra and its Applications, Pearson, 2023.

Reference Books:

- K. M. Abadir & R. Magnus, Matrix Algebra, Cambridge University Press, 2006.
- C. D. Meyer, Matrix Analysis and Applied Linear Algebra, SIAM, 2000.

<table>
<tr><td>Course No: 5</td><td colspan="2">Course Name: Statistical Analysis</td><td colspan="7">Course Code: MMAC 0005</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme:
M.Sc.
Mathematics</td><td rowspan="2">Semester:
I</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td colspan="2">Contact Hrs Per Week:4</td></tr>
<tr><td>3</td><td>1</td><td>0</td><td>0</td><td>4</td><td colspan="2">Total Hours: 40</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="8">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="8">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="9">This course will develop a profound understanding of various statistical methods which can be applied on data analysis and other real problems. This will also make the students able to understand probability distributions and apply on real data problems. Further, a deep understanding of testing of hypothesis will be developed in this course. This course focuses on employability and skill development aligned with all CO's.</td></tr>
<tr><td>Course Outcomes</td><td colspan="9">After studying these topics, the students will be able to
CO1: Understand the basic concepts of statistical analysis, variables, data and measures of central tendency and dispersion.
CO2: Apply the methods to actual quantitative data and interpreting the results of the analysis.
CO3: Perform correlation and regression analysis of given data.
CO4: Learn the concept of probability and probability distributions.
CO5: Understand methods of estimation and apply the testing of hypothesis on various problems.</td></tr>
<tr><td colspan="10">COURSE SYLLABUS</td></tr>
<tr><td>Module No.</td><td colspan="8">Content</td><td>Hours</td></tr>
<tr><td>I</td><td colspan="8">[Course Outcome(s) No.: 1, 2 and 3]
Introduction to Statistical Analysis: What is statistics? Types of statistics, Population vs Sample, Basic terminology, Measurement & Scaling: characteristics.
Types of Variables: Nominal and Ordinal, Interval & Ratio scales, Quantitative variables, Qualitative or categorical variables, Continuous and Discrete random variables.
Data: Sources of data, Cross-section data, Time-series data.
Measures of central tendency and Dispersion, Position quartiles, Inter-Quartile range and Percentiles. Frequency distributions (relative, cumulative).
Correlation and Regression Analysis: Covariance, Karl Pearson's correlation coefficient, Rank correlation, Outliers, Regression.</td><td>20</td></tr>
<tr><td>II</td><td colspan="8">[Course Outcome(s) No.: 4 and 5]
Analysis of Variance (ANOVA): One way and two-way classification.
Probability Distributions: Binomial, Poisson and Normal distributions.
Statistical Inference: Unbiasedness, Sufficiency, Methods of Estimation (MLE and method of moments), Interval estimation.
Testing Hypothesis: Population distribution, Sampling and Non-Sampling Errors, Testing of hypothesis.
The t- distribution: t-test for single mean, t-test for difference of mean, paired t-test.
The F- distribution: F-test for equality of popular variances.
Chi-squared goodness-of-fit test, Chi-square test of independence.</td><td>20</td></tr>
</table>

Text Books:

- S. C. Gupta & V. K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 2014.
- G. J. Kerns, Introduction to Probability and Statistics Using R, Lulu.com, 2014.

Reference Books:

- D. C. Montgomery & G. C. Runger, Applied Statistics and Probability for Engineers, Wiley India, 2013.
- A. M. Mood, F. A. Graybill & D. C. Boes, Introduction to the Theory of Statistics, Tata McGraw-Hill, 2017.
- H. A. David & H. N. Nagaraja, Order Statistics, John Wiley & Sons, 2003.

Course No: 7	**Course Name:** Operational Research-I	**Course Code:** MMAC 0006

Batch:	**Programme:**	**Semester:**	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
2024-2026	M.Sc. Mathematics	II	3	1	0	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Nil
Course Objective	This course will develop a profound understanding of linear and integer linear programming problems. The students will learn optimal decision policy and will be able to solve multistage decision problems. Further, a deep understanding of non-linear programming problems will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to **CO1:** Solve various linear programming problems. **CO2:** Find solution of integer linear programming and sequencing problems. **CO3:** Learn the mathematical tools to solve problems on dynamic programming. **CO4:** Understand nonlinear programming problems and methods to obtain their solutions.

COURSE SYLLABUS

Module No.	**Content**	**Hours**
I	**[Course Outcome(s) No.: 1 and 2]** **Linear Programming Problems (LPP):** Introduction, Simplex method, Method of artificial variable – Big M method and Two phase method, Duality, Dual simplex method, Sensitivity analysis. **Integer Linear Programming Problems:** Introduction, mixed integer programming problems, cutting plane method, Branch and bound method. **Sequencing Problem:** Introduction, Assumptions, Johnson's procedure for njobs on two machines and n jobs on m machines, 2 jobs through m machines.	20
II	**[Course Outcome(s) No.: 3 and 4]** **Dynamic Programming:** Introduction, Terminology, Optimal decision policy, Bellmann principle of optimality, Multistage decision problems, Programming under certainty, Approach for solving LPP. **Non Linear Programming Problems (NLPP):**Introduction, Formulation, Concave and Convex Functions, Solution of NLPP having one and more than one inequality constraints using Kuhn-Tucker conditions, Method of Lagrange multipliers.	20

Text Books:

- P. K. Gupta & D. S. Hira, Operations Research, S. Chand & Co., 2015.
- J. K. Sharma, Operations Research Theory and Applications, Macmillian India Ltd., 2017.
- K. Swarup, P. K. Gupta & M. Mohan, Operations Research, Sultan Chand & Sons, 2014.

Reference Books:

- S. D. Sharma, Operations Research, Kedar Nath & Ram Nath Publications, 2012.
- H. A. Taha, Operations Research: An Introduction, Pearson Education, 2014.
- D. C. Sanyal & K. Das, Linear programming and Game Theory, U. N. Dhur & Sons (P) Ltd., 2020.

Course No: 8	Course Name: Topology							Course Code: MMAC 0007	
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** II	**L** 3	**T** 1	**P** 0	**J** 0	**Credits** 4	**Contact Hrs Per Week:4** **Total Hours: 40**	

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Nil
Course Objective	This course will develop a profound understandingof topological spaces, continuous functions and metrizable spaces. Further, a deep understanding of connected, compact and countability axioms and separation axioms will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Understand topology, topological spaces and topology generated by basis and sub basis. **CO2:** Determine the nature of different points of a set. **CO3:** Learn continuous maps and understand product, quotient and metric topologies. **CO4:** Characterize the connected, compact and countable spaces. **CO5:** Know separation axioms and basic properties.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1, 2 and 3]** Topological spaces, Basis and Sub basis, Ordered topology, Limit points, Adherent points, Isolated points, Derived sets, Dense sets, Closure, Interior, Exterior and Boundary points of a set, Subspaces, Continuity and Related results, The Pasting lemma. Homeomorphism, Product topology, Product of topological spaces, Metric topology, Metrizable space, Quotient topology.	20
II	**[Course Outcome(s) No.: 4 and 5]** Connected and Disconnected spaces, Components, Path connected spaces, Path components, totally disconnected spaces, locally connected spaces. Compact spaces, Limit point compact and sequentially compact spaces, Local compactness, First and Second countable spaces, Separable space, Separation axioms: T_0, T_1, T_2, T_3, $T_{3^{1/2}}$, T_4 spaces, Characterizations and basic properties.	20

Text Books:

- J. R. Munkres, Topology, A First Course, PHI, 2000.
- G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Inc., 2017.
- J. N. Sharma & J. P. Chauhan, Topology (General and Algebraic), Krishna Prakashan, 2019.

Reference Books:

- J. L. Kelley, General topology, Springer Verlag, 2017.
- K. D. Joshi, An introduction to general topology, Wiley Eastern Ltd., 2017.

Course No: 9	**Course Name:** Functional Analysis					**Course Code:** MMAC 0009		
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** II	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
			3	1	0	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Nil

Course Objective	This course will develop a profound understanding of normed linear spaces. This course also includes bounded, unbounded and closed operators, orthonormal basis and their properties. Further, a deep understanding of standard theorems and their applications will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Understand Banach and Hilbert spaces, and standard theorems defined on these spaces **CO2:** Differentiate bounded, unbounded and closed operators **CO3:** Check convergence of operators by using a suitable norm and compute the dual spaces **CO4:** Find orthonormal basis and learn its applications **CO5:** Apply uniform boundedness theorem, open mapping theorem and closed graph theorem

COURSE SYLLABUS

Module No.	**Content**	**Hours**
I	**[Course Outcome(s) No.: 1, 2 and 3]** Normed linear spaces, Banach spaces, Hilbert Spaces and basic properties, Heine Borel theorem, Riesz lemma and best approximation property, Inner product spaces, Projection Theorem, Bounded operators, Space of bounded operators, unbounded operators, Riesz representation theorem, Convergence of sequence of operators, Closed operator.	20
II	**[Course Outcome(s) No.: 4 and 5]** Orthonormal bases, Bassel inequality and Parseval's Formula, Riesz Fischer theorem, Hahn Banach extension theorem, Uniform boundedness principle, Closed graph theorem and Open mapping theorem, Applications.	20

Text Books:

- M. T. Nair, Functional Analysis, A first course, PHI, 2001.
- B. V. Limaye, Functional Analysis, New Age International, 2014.
- G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, Inc. 2017.

Reference Books:

- E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley and Sons, 2007.
- A. H. Siddiqi, K. Ahmad & P. Manchanda, Introduction to Functional Analysis with Applications, Anamaya Publishers, 2007.
- G. Bachman & L. Narici, Functional Analysis, Dover Publications, 2012.
- J. B. Conway, A Course in Functional Analysis. Springer, 2010.

<table>
<tr><td>Course No: 15</td><td colspan="2">Course Name: Partial Differential Equations-I</td><td colspan="6">Course Code: MMAC 0010</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme:
M.Sc. Mathematics</td><td rowspan="2">Semester:
III</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week:4</td></tr>
<tr><td>3</td><td>1</td><td>0</td><td>0</td><td>4</td><td>Total Hours: 40</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100
Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="8">This course will develop a profound understanding of initial and boundary value problems, heat, Laplace and wave equations and their solutions. This course also includes the first order hyperbolic equations and classification of second order partial differential equations. Further, a deep understanding of method of separation of variables to find the solution of partial differential equations will be developed in this course. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="8">After studying these topics, the students will be able to:
CO1: Solve first order hyperbolic equations.
CO2: Classify the second order partial differential equations.
CO3: Understand initial and boundary value problems and related terms.
CO4: Learn the basics of Laplace, heat and wave equations and methods to find their solutions.
CO5: Know method of separation of variables to solve partial differential equations.</td></tr>
</table>

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1, 2, 3 and 4]** Introduction, Cauchy’s method of characteristics for solving first order hyperbolic equations, Classification of second order partial differential equations, Normal forms and characteristics. **Initial and Boundary Value Problems:** Lagrange-Green’s identity and uniqueness by energy methods. Stability theory, energy conservation and dispersion. **Laplace equation:** Mean value property, Weak and Strong maximum principle, Green’s function, Poisson’s formula, Dirichlet’s principle, Existence of solution using Perron’s method (without proof).	20
II	**[Course Outcome(s) No.: 4 and 5]** **Heat equation:** Initial value problem, Fundamental solution, Weak and Strong maximum principle and Uniqueness results. **Wave equation:** Uniqueness, D’Alembert’s method, Method of spherical means and Duhamel’s principle. Methods of separation of variables for heat, Laplace and wave equations.	20

Text Books:

- L. C. Evans, Partial Differential Equations: (Graduate Studies in Mathematics), AMS, 2014.
- I. N. Snedden, Elements of Partial Differential Equation, Dover Publications, 2006.
- H. F. Weinberger, A First Course in Partial Differential Equation: with Complex Variables and Transform Methods, Dover Publications, 2012.
- S. L. Ross, Differential Equations, Wiley, 2007.

Reference Books:

- P. V. O’Neil, Advanced Engineering Mathematics, Cengage Learning Custom Publishing, 2011.
- M. D. Raisinghania, Advanced Differential Equation, S. Chand Publishing, 2018.

Course No: 16	Course Name: Numerical Analysis						Course Code: MMAC 0013		
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** III	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**	
			3	1	0	0	4	**Total Hours: 40**	
Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks		**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Nil							

Course Objective	This course aims to give exposure to some advanced numerical methods. The course objective is to acquaint the students with a wide range of advanced numerical methods to solve systems of algebraic and transcendental equations, linear system of equations, difference equations, tridiagonalization and decomposition of a matrix and mainly some finite difference methods for numerical solutions of partial differential equations. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Learn numerical technique to find the numerical solutions of system of linear and nonlinear equations and some curve fitting problems. **CO2**: Solve difference equations and decompose a matrix. **CO3:** Understand finite difference methods for numerical solutions of partial differential equations especially heat, Laplace and Poisson equations. **CO4:** Familiarize the students with advantages and limitations of numerical techniques.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1 and 2]** Errors in numerical computation, Fixed point iterative method for the system x = g(x) and its sufficient condition for convergence, Chebyshev method, Lin-Bairstow's method for complex roots, Newton-Raphson method, Spline interpolation, Householder method for tridiagonalization of symmetric matrix. **Difference Equations**: Introduction, Solution of difference equations using generating functions. **Matrix Decomposition**: QR method, Singular value decomposition (SVD) of a matrix.	20
II	**[Course Outcome(s) No.: 3 and 4]** **Boundary Value Problems**: Finite difference approximation to derivatives, Mesh points, Standard and Diagonal five point formulae, Finite difference method. **Numerical Solution of Partial Differential Equations**: Solution of Laplace's equation by point Jacobi's method, Liebmann's iteration process and Successive over-relaxation (SOR) method, Poisson's equation and its solution.Solution of heat equations by Bender-Schmidt explicit finite difference scheme.	20

Text Books:

- R. K. Gupta, Numerical Methods: Fundamentals and Applications, Cambridge University Press, 2019.
- K. Atkinson & W. Han, Theoretical Numerical Analysis, Springer Science & Business Media, 2010.
- M. Goyal, Computer Based Numerical and Statistical Techniques, University Science Press, 2017.
- S. S. Sastry, Introductory Methods of Numerical Analysis, PHI, 2012.

Reference Books:

- M. K. Jain, S. R. K. Iyengar & R. K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International Publishers, 2019.
- G. D. Smith, Numerical solution of Partial Differential Equations: Finite Difference Methods, Oxford University Press, 1985.
- B. Bradie, A friendly introduction to Numerical Analysis, Pearson Education, 2007.

Course No: 17	**Course Name:** Complex Analysis					**Course Code:** MMAC 0014			
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** III	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**	
			3	1	0	0	4	**Total Hours: 40**	

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Nil
Course Objective	This course will develop a profound understanding of residues to evaluate complex contour integrals. This will also make the students able to understand various transformations, steady temperatures and standard theorems and prove related results. Further, a deep understanding of analytic continuation will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Learn Cauchy's residue theorem and compute complex contour integrals. **CO2**: Understand the concept of bilinear transformation and conformal mapping. **CO3:** Transform harmonic functions and other forms. **CO4:** Prove standard theorems based on analytic functions and simply connected regions. **CO5:** Understand analytic continuation and related results.

COURSE SYLLABUS

Module No.	**Content**	**Hours**
I	**[Course Outcome(s) No.: 1 and 2]** Calculus of Residues, Application of Cauchy's residue theorem in the evaluation of real integrals, Contour integrals, The argument principle, Inverse mapping theorem, Definition and examples of conformal mapping, Linear functions, Function 1/z, Bilinear transformations, their properties and classifications.	20
II	**[Course Outcome(s) No.: 3, 4 and 5]** Transformation of Harmonic functions, Functions z^2 and $z^{1/2}$, Transformations w = exp. (z) and w = sin z, Open mapping theorem and Hurwitz's theorem, Riemann mapping theorem, Analytic continuation, Uniqueness of direct analytic continuation, Uniqueness of analytic continuation along a curve, Power series method of analytic continuation, Schwarz reflection principle.	20

Text Books:

- V. R. Churchill & J. W. Brown, Complex Variables and Applications, McGraw-Hill Publishing Company, 2013.
- S. Ponnusamy, Foundations of Complex Analysis, Narosa Publishing House, 2011.
- H. A. Priestly, Introduction to Complex Analysis, Clarendon Press, 2006
- J. B. Conway, Functions of one Complex Variable, Springer, 1995.
- L. V. Ahlfors, Complex Analysis, McGraw Hill Education, 2017.

Reference Books:

- S. Lang, Complex Analysis, Springer Nature, 2013.
- M. J. Ablowitz & A. S. Fokas, Complex Variables: Introduction and Applications, Cambridge University Press, 2003.
- W. Rudin, Real and Complex Analysis, McGraw Hill Education, 2017.
- E. T. Copson, An Introduction to the Theory of Functions of Complex Variables, Oxford University Press, 1970.

SYLLABI OF SUBJECTS

DISCIPLINE SPECIFIC ELECTIVE COURSES (DSE)

- **BOUQUET 1:** MATHEMATICS

<table>
<tr><td>Course No: 1</td><td colspan="3">Course Name: Differential Geometry</td><td colspan="6">Course Code: MMAE 0001</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme:
M.Sc.
Mathematics</td><td rowspan="2">Semester:
II/III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week:4</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>0</td><td>4</td><td>Total Hours: 40</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="8">This course will develop a profound understanding of surfaces, tangent planes, normal fields and smooth functions. The students will learn the concepts of curvatures defined on surfaces and isometries of surfaces. Further, a deep understanding of differential functions and integration on manifolds will be developed in this course. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="8">After studying these topics, the students will be able to
CO1: Understand various basic concepts defined for the functions of several variables.
CO2: Identify regular surfaces, find tangent and normal vectors and determine orientability.
CO3: Understand smooth functions, curvatures and isometries of surfaces.
CO4: Solve the problems based on Gauss map, Weingarten map and normal sections
CO5: Learn the concept of differentiation and integration on manifolds.</td></tr>
<tr><td colspan="9">COURSE SYLLABUS</td></tr>
<tr><td>Module No.</td><td colspan="7">Content</td><td>Hours</td></tr>
<tr><td>I</td><td colspan="7">[Course Outcome(s) No.: 1 and 2]
Functions on Euclidean spaces, Continuity, Differentiability, Partial and Directional derivatives, Chain rule, Inverse function theorem, Implicit function theorem, Smooth Urysohn lemma, Partition of unity, Change of variables.
Regular surfaces in R^3, Coordinate neighbourhoods, Tangent vectors, Tangent plane, Normal fields, Orientability, Examples of surfaces, Level sets of smooth functions on R^3.</td><td>20</td></tr>
<tr><td>II</td><td colspan="7">[Course Outcome(s) No.: 3, 4 and 5]
Smooth functions on surfaces, Differential of a smooth function, Gauss map, Shape operator (or the Weingarten map), Normal sections, Principal curvatures, Gaussian and Mean curvature, Theorem a Egregium, Isometries of surfaces.
Differential manifolds, Differential functions on manifolds, Tangent spaces, Vector fields, Differential forms on manifolds, Orientations, Integration on manifolds, Stoke’s theorem on manifolds.</td><td>20</td></tr>
<tr><td colspan="9">Text Books:
➢ A. Pressley, Elementary Differential Geometry, Springer, 2001.
➢ A. Gray, Modern Differential Geometry of Curves and Surfaces with Mathematica, CRC Press, 2006.

Reference Books:
➢ M. Spivak, Calculus on Manifolds: A Modern Approach to Classical Theorems of Advanced Calculus, Westview Press, 1971.
➢ J. R. Munkers, Analysis on Manifolds, Westview Press, 1997.</td></tr>
</table>

<table>
<tr><td>Course No: 2</td><td colspan="2">Course Name: Special Relativity and Tensor Calculus</td><td colspan="7">Course Code: MMAE 0002</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme: M.Sc. Mathematics</td><td rowspan="2">Semester:
II/III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week:4</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>0</td><td>4</td><td>Total Hours: 40</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100
Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="8">This course will develop a profound understanding of special theory of relativity and relativistic mechanics. The students will learn the concepts of tensors, Christoffel symbols, curvature tensor, covariant differentiation and their applications. This course focuses on employability and skill development aligned with all CO's.</td></tr>
<tr><td>Course Outcomes</td><td colspan="8">After studying these topics, the students will be able to:
CO1: Know the basics of Einstein's special theory of relativity.
CO2: Learn different types of tensors and compute transformation equations.
CO3: Calculate Christoffel symbols &usethem in computing different curvature tensors.
CO4: Understand covariant differentiation, Bianchi identities and their applications.</td></tr>
<tr><td colspan="9">COURSE SYLLABUS</td></tr>
<tr><td>Module No.</td><td colspan="7">Content</td><td>Hours</td></tr>
<tr><td>I</td><td colspan="7">[Course Outcome(s) No.: 1]
Inertial frames, Speed of light and Galilean relativity, Michelson-Morley experiment, Postulates of special theory of Relativity, Lorentz transformation equations and its geometrical interpretation, Group properties of Lorentz transformations, Composition of parallel velocities, Length contraction, Time dilation, Geometrical representation of space-time: Four dimensional Minkowskian space-time of special relativity, Time-like, light-like and space-like intervals, Null cone, Proper time, Word line of a particle, Four vectors and tensors in Minkowskian space-time.
Variation of mass with velocity, Equivalence of mass and energy, Transformation equations for mass momentum and energy, Energy momentum four vector, Relativistic force and Transformation equations for its components, Energy momentum tensor of a continuous material distribution, Electromagnetism, Densities of electric charge and current, Propagation of electric and magnetic field strengths, Transformation equations for electromagnetic four potential vector, Transformation equations for electric and magnetic field strengths. Gauge transformation in tensor form. Lorentz force on a charged particle, Energy momentum tensor ofan electromagnetic field.</td><td>20</td></tr>
<tr><td>II</td><td colspan="7">[Course Outcome(s) No.: 2, 3 and 4]
Transformation of coordinates, Contravariant and covariant vectors, Gradient and tangent vectors, Metric tensor, Scalar invariants, Scalar product of two vectors, Tensors of any order, Symmetric and Skew-symmetric tensors, Addition and Multiplication of tensors, Contraction, Composition and Quotient law, Reciprocal symmetric tensors of second order, Fundamental tensors, Associated covariant and Contravariant vectors, Inclination of two vectors and Orthogonal vectors.
Christoffel symbols, Law of transformation of Christoffel symbols, Covariant derivatives of covariant and contravariant vectors, Parallel transport, Covariantdifferentiation of tensors, Curvature tensor, Ricci tensor, Curvature tensor identities, Bianchi identity, Einstein tensor.</td><td>20</td></tr>
</table>

Text Books:

- S. B. Banerji, Special Theory of Relativity, PHI, 2010.
- K. D. Krori, Fundamentals of Special and General Relativity, PHI Publication, 2010.
- J. V. Narlikar, An Introductions to Relativity, Cambridge University Press, 2010.

Reference Books:

- Feynman, The Feynman Lectures on Physics, Pearson Education India, 2012.
- A. Einstein, The Meaning of Relativity, New Age International Private Limited, 2006.
- D. Bohm, The Special Theory of Relativity, Routledge, 2006.
- T. M. Helliwell, Special Relativity, University Science Books, 2009.
- L. P. Eisenhart, Reimannian Geometry, Princeton University Press, 1997.

<table>
<tr><td>Course No: 3</td><td colspan="2">Course Name: General Relativity and Cosmology</td><td colspan="7">Course Code: MMAE 0003</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme: M.Sc. Mathematics</td><td rowspan="2">Semester:
III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week:4</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>0</td><td>4</td><td>Total Hours: 40</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Special Relativity and Tensor Calculus</td></tr>
<tr><td>Course Objective</td><td colspan="8">This course will develop a profound understanding of general relativity, and Schwarzschild and Reissner-Nordström solutions.The students will learn the concepts of static cosmological models, Friedmann models, cosmological implications and their applications. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="8">After studying these topics, the students will be able to:
CO1: Find Einstein's field equations and express its physical significance.
CO2: Understand Schwarzschild internal and external solutions.
CO3: Determine the Einstein-Maxwell equations, Reissner-Nordström solution and their applications.
CO4: Derive modified field equations for cosmological models.
CO5: Calculate various cosmological implications and compare them with the actual universe.
CO6: Deal with the cosmological models with Lambda-term.</td></tr>
<tr><td colspan="9">COURSE SYLLABUS</td></tr>
<tr><td>Module No.</td><td colspan="7">Content</td><td>Hours</td></tr>
<tr><td>I</td><td colspan="7">[Course Outcome(s) No.:1, 2 and 3]
Principle of equivalence and general covariance, Geodesic principle, Newtonian approximation of relativistic equations of motion, Einstein's field equations and its Newtonian approximation, Schwarzschild external solution and its isotropic form, Planetary orbits and analogues of Kepler's Laws in general relativity, Advance of perihelion of a planet, Bending of light rays in a gravitational field, Gravitational redshift of spectral lines, Radar echo delay, Energy-momentum tensor of a perfect fluid, Schwarzschild internal solution, Boundary conditions, Energy momentum tensor of an electromagnetic field, Einstein-Maxwell equations, Reissner-Nordström solution.</td><td>20</td></tr>
<tr><td>II</td><td colspan="7">[Course Outcome(s) No.: 4, 5 and 6]
Cosmology-physical universe, Mach's principle, Einstein modified field equations with cosmological term, Static cosmological models of Einstein and De-Sitter, their derivation, properties and comparison with the actual universe, Hubble's law, Cosmological principles, Weyl's postulate, Derivation of Robertson-Walker metric, Hubble and Deceleration parameters, Redshift, Redshift versus distance relation, Angular size versus redshift relation and source counts in Robertson-Walker spacetime, Friedmann models, Fundamental equations of dynamical cosmology, Critical density, Closed and open universes, Age of the universe, Matter dominated era of the universe, Einstein-de Sitter model, Particle and event horizons, Eddington Lemaitre models with Lambda-term, Perfect cosmological principle, Steady state cosmology.</td><td>20</td></tr>
</table>

Text Books:

- K. D. Krori, Fundamentals of Special and General Relativity, PHI Publication, 2010.
- S. R. Roy & R. Bali, Theory of Relativity, Jaipur Publishing House, 2008.
- S. Weinberg, Gravitation and Cosmology, Principles and applications of General Relativity, Wiley Publishing, 2005.
- J. V. Narlikar, An Introduction to Relativity, Cambridge University Press, 2010.
- J. V. Narlikar, Cosmology, Cambridge University Press, 2003.
- I. B. Khriplovich, General Relativity, Springer Science & Business Media, 2005.

Reference Books:

- C. E. Weatherbum, An Introduction to Riemannian Geometry and the Tensor Calculus, Cambridge University Press, 2008.
- H. Stepheni, General Relativity: An IntMMroduction to the Theory of Gravitational Field, Cambridge University Press, 1990.
- S. Eddinglon, The Mathematical Theory of Relativity, Cambridge University Press, 1965.
- J. V. Narlikar, General Relativity and Cosmology, Palgrave, 2013.
- R. Adler, M. Bazin & M. Schiffer, Introduction to General Relativity, McGraw Hill Inc., 1975.
- B. Schutz, A First Course in General Relativity, Cambridge University Press, 1990.
- S. Weinberg, Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity, John Wiley & Sons, Inc., 1972.
- R. K. Sachs & H. Wu., General Relativity for Mathematician, Springer Verlag, 1977.
- J. L. Synge, Relativity: The general Theory, Elsevier Science Publishing Co., 1976.

<table>
<tr><td>Course No: 4</td><td colspan="2">Course Name: Special Functions</td><td colspan="7">Course Code: MMAE 0004</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme: M.Sc. Mathematics</td><td rowspan="2">Semester:
II/III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week:4</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>0</td><td>4</td><td>Total Hours: 40</td></tr>
<tr><td rowspan="2" colspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="8">This course will develop a profound understanding of hyper geometric functions and their properties. The students will learn the concepts offunctionals, variational problems and the applications of special functions in solving differential equations. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="8">After studying these topics, the students will be able to
CO1: Solve, expand and interpret solutions of many types of important differential equations by making use of special functions and orthogonal polynomials.
CO2: Derive the formulae and results of certain classical special functions and orthogonal polynomials by different methods.
CO3: Achieve the knowledge to analyze Euler’s equations which help in exploring the role of special functions.
CO4: Achieve the knowledge to analyze the problem using Variational problems with fixed boundaries and contiguous hyper geometric and Elliptic, Theta, and the Dirac-Delta functions.</td></tr>
</table>

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1 and 2]** Analytical study of Beta and Gamma functions with complex arguments, Hyper geometric Functions, Generalized and confluent hyper geometric functions, Legendre and Bessel Functions with Complex arguments. Chebyshev, Laguerre and Hermite polynomials, Orthogonal sets of Function, Elliptic functions of Weierstrass and Jacobian including Theta functions, Jacobian polynomials, The Dirac-Delta function.	20
II	**[Course Outcome(s) No.: 3 and 4]** Euler’s equation for functionals containing first order derivative and one independent variable, Extremals, Functionals dependent on high order derivatives, Functionals dependent on more than one independent variable, Variational problems in parametric form, Invariance of Euler’s equation under coordinates transformation.	20

Text Books:

- M. A. Pathan, P. K. Banerji, V. B. L. Chaurasia & M. C. Goyal: Special Functions and Calculus of Variations, Indus Valley Publications, 2004.
- N. Saran, S. D. Sharma & T. N. Trivedi, Special Functions, Pragati Prakashan, 2019.
- A. S. Gupta: Calculus of Variations with Applications, Prentice Hall of India, 1997.
- M. D. Raisinghania, Ordinary and Partial Differential equations, S. Chand and Company Ltd., 2020.

Reference Books:

- E. D. Rainvelle, Special Functions, Chelsea Pub Co, 1971.
- S. L. Loney, An Elementary Treatise on the Dynamics of a Particle and Rigid Bodies, Cambridge University Press, 2018.
- I. M. Gilgand & S. V. Fomin, Calculus of Variations, Dover Publications Inc., 2000.
- E. T. Copson, An Introduction to the Theory of Functions of Complex Variables: Oxford University Press, 1970.

Course No: 5	**Course Name**: Partial Differential Equations-II		**Course Code:** MMAE 0006					
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
			4	0	0	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Partial Differential Equations-I
Course Objective	This course will develop a basic understanding of Green's function and its properties. The students will learn the use of energy methods to discuss the uniqueness of solution of heat flow and wave equations along with their more applications in science and engineering. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to **CO1:** Understand the concept of Green's functions. **CO2**: Use Green's function to find the solutions of PDEs. **CO3:** Find the fundamental solutions of heat and Laplace equations. **CO4:** Use the energy method to find the solutions of different PDEs. **CO5:** Solve the Wave equation and interpret the solution. **CO6:** Use the energy method to discuss the uniqueness of solution.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1, 2, 3 and 4]** Green's formula, Corrector function (defination only), Green's function and its derivation, Representation formulausing Green's function, Symmetry of Green's function, Energy methods: Uniqueness, Dirichlet Principle, Heat Equations: Fundamental solution of heat equation, Uniqueness of heat equation: Energy methods.	20
II	**[Course Outcome(s) No.: 4, 5 and 6]** Wave equation-Physical interpretation, Solution for one dimensional wave equation, Reflection method, Derivation of Euler-Poisson Darboux equation, Kirchhoff's and Poisson's formulae (for n=2, 3 only), Solution of non-homogeneous wave equation for n=1, 3. Energy method: Uniqueness of solution.	20

Text Books:

- L. C. Evans, Partial Differential Equations: Graduate Studies in Mathematics, AMS, 2015.
- I. N. Snedden, Elements of Partial Differential Equation, Dover Publications, 2006.
- P. V. O'Neil, Advanced Engineering Mathematics, Cengage Learning Custom Publications, 2011.
- H. F. Weinberger, A First Course in Partial Differential Equation: with Complex Variables and Transform Methods, John Wiley & Sons, 2012.

Reference Books:

- M. D. Raisinghania, Advanced Differential Equation, S. Chand and Company Ltd., 2018.
- S. L. Ross, Differential Equations, Wiley, 2007.

Course No: 6	Course Name: Fluid Dynamics-I	Course Code: MMAE 0007

Batch:	Programme:	Semester:	L	T	P	J	Credits	Contact Hrs Per Week:4
2024-2026	M.Sc. Mathematics	II/III	4	0	0	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Nil

Course Objective	This course will develop a profound understanding of fluid flow behaviors. The students will learn the concept of various fluid motions and stream function. Further, a deep understanding of two and three dimensional inviscid fluid flows will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to **CO1:** Derive the path lines and the streamlines in cartesian and polar forms of a velocity field. **CO2**: Find the stream function from a velocity field. **CO3:** Learn Euler's and Bernoulli's equations of motion of fluid. **CO4:** Understand inviscid fluid flow and use the continuity equation to determine whether an inviscid flow is incompressible.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1 and 2]** **Kinematics of Fluids in Motion:** Real fluids and ideal fluids, Velocity of a fluid at a point, Stream lines and path lines, Mathematical forms in various fluid motions (steady and unsteady, compressible and incompressible, rotational and irrotational etc.), The velocity potential, The velocity vector, Local and particle rates of change, Equation of continuity, Acceleration of fluid. This course focuses on employability and skill development aligned with all CO's.	20
II	**[Course Outcome(s) No.: 3 and 4]** **Equations of Motion of fluid:** Euler's equations of motion, Bernoulli's equation. **Two and Three Dimensional Inviscid Fluid Flows**: Complex potential, Sources, Sinks, Doublets, Images with respect to plane and circle, Milne Thomson circle theorem, Blasius theorem, Motion past a circular cylinder, Axisymmetric flows, Stokes's stream function, Motion past a sphere, D-Alembert's paradox.	20

Text Books:

- F. Chorlton, Textbook of Fluid Dynamics, CBS Publishers & Distributors, 2004.
- G. K. Batchelor, An Introduction to Fluid Dynamics, Cambridge University Press, 2012.

Reference Books:

- M. D. Raisinghania, Fluid Dynamics, S. Chand and Company Ltd., 2003.
- D. E. Rutherford, Fluid Dynamics, Oliver and Boyd Ltd, 1978.

Course No: 7	**Course Name**: Fluid Dynamics-II							**Course Code:** MMAE 0008
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** III/IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
			4	0	0	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Fluid Dynamics - I

Course Objective	This course will develop a profound understanding of flow of fluid and Navier-Stoke equations. Further, a deep understanding of boundary layer theory and nano-fluids will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to **CO1:** Derive some exact solutions of Navier-Stokes equations. **CO2**: Analyze properties of various fluid flows. **CO3:** Understand the boundary layer, momentum and energy integral equations and find their separations. **CO4:**Learn the nano-fluids and their applications.

COURSESYLLABUS

Module No.	Content	Hours
I	**[Course Outcome (s) No.: 1 and 2]** **Navier-Stokes Equations and its Exact Solutions:** Navier-Stoke's equations, Rate of change of circulation, Diffusion of vorticity, Vorticity equation and Energy dissipation due to viscosity, Exact solutions of Navier-Stokes equations: Couette flow, Poiseuille flow, Hagen-Poiesuille flow through a pipe, Flow through annular region, Stokes first problem.	20
II	**[Course Outcome(s) No.: 3 and 4]** **Boundary Layer Theory:** Laminar boundary layer, Two-dimensional boundary layer equations, Blasius equation, Boundary layer parameters, Separation of boundary layer, momentum and energy integral equation. **Nano Fluids:** Introduction to nano fluids, Some applications of nano fluids.	20

Text Books:

- F. Chorlton, Textbook of Fluid Dynamics, CBS Publishers & Distributors, 2004.
- M. D. Raisinghania, Fluid Dynamics, S. Chand and Company Ltd., 2003.

Reference Books:

- G. K. Batchelor, An Introduction to Fluid Dynamics, Cambridge University Press, 2012.
- D. E. Rutherford: Fluid Dynamics, Oliver and Boyd Ltd., 1978.
- H. Schlichting, Boundary Layer theory, Mc Graw Hill, 2014.
- S. K. Das, S. U. S. Choi, W. Yu & T. Pradeep, Nano Fluid Science and Technology, Wiley-Interscience, 2008.

<table>
<tr><td colspan="2">Course No: 8</td><td colspan="3">Course Name: Discrete Mathematics</td><td colspan="5">Course Code: MMAE 0009</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme:
M.Sc. Mathematics</td><td rowspan="2">Semester:
II/III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td colspan="2">Contact Hrs Per Week:4</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>0</td><td>4</td><td colspan="2">Total Hours: 40</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="8">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="8">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="9">This course will develop a profound understanding of partially ordered sets, lattices, Boolean algebra and their applications. Further, a deep understanding of spectra of finite graphs and regular graphs, Cayley graphs and Ramanujan graphs will be developed in this course. This course focuses on employability and skill development aligned with all CO's.</td></tr>
<tr><td>Course Outcomes</td><td colspan="9">After studying these topics, the students will be able to:
CO1: Understand partially ordered sets, lattices, their types and lattice homomorphism.
CO2: Learn projective Intervals, Schreier's Refinement Theorem and isomorphism theorem of modular lattices.
CO3: Apply the De Morgan Formulae with examples.
CO4: Use the concepts of Boolean algebra and truth table.
CO5: Understand the concepts of spectra of graphs and application of spectra.
CO6:Calculate the energies of different types of graphs.</td></tr>
<tr><td colspan="10">COURSESYLLABUS</td></tr>
<tr><td>Module No.</td><td colspan="8">Content</td><td>Hours</td></tr>
<tr><td>I</td><td colspan="8">[Course Outcome (s) No.: 1, 2 and 3]
Lattice Theory: Partially ordered sets, Diagrams, Lower and Upper Bounds, Lattices, The lattices theoretical duality principle, Semi lattices, Lattices as partially ordered sets, Diagrams of lattices, Sub lattices, Lattice homomorphism, Axiom systems of lattices, Complete lattices, Distributive lattices, Modular lattices, Characterization of modular and distributive lattices, Similar intervals, Projective intervals, Zessenhau's lemma, Schreier's refinement theorem, Independent sets with properties, The isomorphism theorem of modular lattices.
Boolean Algebra I: De Morgan formulae, Complete Boolean algebras, Boolean algebras and Boolean rings, The algebra of relations, Boolean homomorphism, Representation theorem.</td><td>20</td></tr>
<tr><td>II</td><td colspan="8">[Course Outcome(s) No.: 4, 5 and 6]
Boolean Algebra II: Boolean expression, Algorithm for finding sum-of-products form, Minimal sum-of-products, Consensus of fundamental products, Algorithm, Logic, Gates and Circuits, Boolean functions and its truth table.
Spectra of finite graphs, Characteristic polynomials, Spectra, Spectra of K_n, C_n and P_n, Bounds of spectra, The spectra of regular graphs, The spectrum of the complement of a regular graph, Spectra of line graphs of regular, Spectrum of the complete Bipartite graph $K_{p;q}$, Cayley graphs, Unitary Cayley graphs spectrum of the Cayley graph Xn, Strongly regular graphs, Ramanujan graphs, Energy of a graph, Maximum energy of k-regular graphs, Energy of Cayley graphs.</td><td>20</td></tr>
<tr><td colspan="10">Text Book:
N. Jacobson: Lectures in Abstract Algebra, Basic Concepts, Springer-Verlag, 2012.
Reference Book:
G. Szasz, Introduction to Lattice Theory, Academic Press, 1963.</td></tr>
</table>

Course No: 9	**Course Name**: Integral Equation							**Course Code:** MMAE 0010	
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** II/III/IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**	
			4	0	0	0	4	**Total Hours: 40**	

TotalEvaluationMarks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Ordinary Differential Equations

Course Objective	This course will develop a profound understanding of integral equations and their applications. The main objective of the course is to make the learner familiarize with the types of kernel, and the solution of integral equations using various methods. Further, the students will learn the methods to find the solution of integral and integro-differential equations using Laplace transform. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1**: Understand the classification integral equations. **CO2**: Convert initial and boundary value problems to an integral equation. **CO3**: Use the concept of different kernels and techniques for solving various kinds of integral equation. **CO4**: Apply integral transforms to find the solution of integral equations. **CO5**: Solve integro-differential equations arising in different fields.

COURSE SYLLABUS

Module No.	**Content**	**Hours**
I	**[Course Outcome(s) No.: 1, 2 and 3]** Definition and Classification of Fredholm and Volterra integral equations, Conversion of initial and boundary value problems to an integral equation, Eigen values and Eigen functions. Types of kernels: Symmetric kernel, Separable kernel, Iterated kernel, Resolvent kernel, Solution of Fredholm and Volterra integral equations using Resolvent kernel, Successive approximation and Neumann series method.	20
II	**[Course Outcome(s) No.: 4 and 5]** Integral transforms for solving integral equations, Solution of Abel's equation using Laplace transform, Application of Laplace transform to the solution of Volterra integral equations with convolution type kernels, Solution of integro-differential equations using Laplace transform.	20

Text Books:

- R. P. Kanwal, Linear Integral Equation, Theory and Techniques, Academic Press, 2014.
- A. Jerri, Introduction to Integral Equations with Applications, John Wiley & Sons, 1999.
- M. D. Raisinghania, Integral Equations and Boundary Value Problems, S. Chand and Company Ltd., 2016.

Reference Books:

- A. M. Wazwaz, A First Course in Integral Equations, World Scientific Publishing Co., 2015.
- R. Kumar & N. Kumar, Differential Equations and Calculus of Variations, CBS Publishers and Distributors Pvt. Ltd., 2013.

<table>
<tr><td>Course No: 10</td><td colspan="3">Course Name: Optimization Techniques</td><td colspan="6">Course Code: MMAE 0011</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme: M.Sc. Mathematics</td><td rowspan="2">Semester:
III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td colspan="2">Contact Hrs Per Week:4</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>0</td><td>4</td><td colspan="2">Total Hours: 40</td></tr>
<tr><td colspan="3" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="9">This course will develop a profound understanding of optimization, optimization algorithms and their applications in Engineering. This course includes various methods to solve constrained and unconstrained optimization problems. Further, a deep understanding of modern methods of optimization will be developed in this course. This course focuses on employability and skill development aligned with all CO's.</td></tr>
<tr><td>Course Outcomes</td><td colspan="9">After studying these topics, the students will be able to:
CO1: Know the basic concepts of optimization, optimality criteria and applications.
CO2: Understand theoretical working of different optimization techniques.
CO3: Learn the concepts of various optimization algorithms to find the solution of constrained and unconstrained optimization problems.
CO4: Know various modern methods of optimization.</td></tr>
</table>

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1 and 2]** Introduction to Optimization, Engineering application of Optimization, Optimal problem formulation, Classification of optimization problem, Convex sets, Convex functions and their properties, Optimum design concepts: Definition of Global and Local optima, Optimality criteria, Review of basic calculus concepts, Global optimality, Optimization algorithms for solving unconstrained optimization problems, Gradient based method: Cauchy's steepest descent method, Newton's method, Conjugate gradient method.	20
II	**[Course Outcome(s) No.: 3 and 4]** Optimization algorithms for solving constrained optimization problems, Direct methods, Penalty function methods, Steepest descent method, Engineering applications of constrained and unconstrained algorithms. Modern methods of optimization: Genetic algorithms, Simulated annealing, Ant colony optimization, Tabu search, Neural-Network based optimization, Use of MATLAB to solve optimization problems.	20

Text Books:

- S. S. Rao, Engineering Optimization, Theory and Practice, New Age International Publishers, 2012.
- K. Deb, Optimization for Engineering Design Algorithms and Examples, PHI, 2000.
- C. Mohan & K. Deep, Optimization Techniques, New Age India Pvt. Ltd, 2009.

Reference Books:

- K. V. Mittal & C. Mohan, Optimization Methods in System Analysis and Operations Research, New Age India Pvt. Ltd, 2016.
- A. Ravindran, D. T. Phillips & J. J. Solberg, Operations Research: Principles and Practice, John wiley and Sons, 1987.
- J. C. Pant, Introduction to Optimization/Operations Research, Jain Brothers, 2008.

Course No: 11	**Course Name:** Non-Linear Programming	**Course Code:** MMAE 0012

Batch:	**Programme:**	**Semester:**	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
2024-2026	M.Sc. Mathematics	IV	4	0	0	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Operational Research

Course Objective	This course will develop a profound understanding ofconvex and concave functions, their generalizations, optimality, duality and related results. Further, a deep understanding ofnonlinear programming, and optimality and duality for nonlinear programming problems will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to **CO1:** Understand the concept of convex and concave functions and their generalizations **CO2**: Apply the optimality and duality for generalized convex and concave functions. **CO3:** Understand the nonlinear programming problems and find their optimality and duality. **CO4:** Learn optimality theorems for nonlinear programming problems and their applications.

COURSE SYLLABUS

Module No.	**Content**	**Hours**
I	**[Course Outcome(s) No.: 1, 2 and 3]** Pseudo convex and pseudo concave function, Relationship between pseudo convex function and quasi convex function, Differential convex function and Pseudo convex function, Optimality and Duality for generalized convex and concave function, Sufficient optimality theorem, Generalized Kuhn-Tucker sufficient optimality theorem, Generalized Fritz- John stationary point necessary optimality theorem, Kuhn-Tucker necessary optimality conditions under the week constraint qualifications.	20
II	**[Course Outcome(s) No.: 2, 3 and 4]** Optimality and duality in the presence of nonlinear equality constraints, Sufficient optimality criteria, Minimum principal, Necessary optimality criteria, Xo not open. Minimum principal, Necessary optimality theorem. Fritz- John and Kuhn-Tucker stationary point necessary optimality criteria Xo open, duality with nonlinear equality constraints.	20

Text Book:

- M. S. Bazaraa & C. M. Shetty, Nonlinear Programming, Theory and Algorithms, Wiley, 2005.

Reference Book:

- M. Avrieal, Nonlinear Programming: Analysis and Method, Dover Publications, 2014.

<table>
<tr><td colspan="2">Course No: 12</td><td colspan="2">Course Name: Operator Theory</td><td colspan="6">Course Code: MMAE 0013</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme: M.Sc. Mathematics</td><td rowspan="2">Semester:
III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td colspan="2">Contact Hrs Per Week:4</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>0</td><td>4</td><td colspan="2">Total Hours: 40</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="8">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="8">Pre-requisite of course: Functional Analysis</td></tr>
<tr><td>Course Objective</td><td colspan="9">This course will develop a profound understanding of dual spaces, reflexive spaces and their applications. The students will learn the concepts of various operators defined on Banach and Hilbert spaces. Further, a deep understanding of spectral theory of operators will be developed in this course. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="9">After studying these topics, the students will be able to
CO1: Understand the concept of dual space and determine it for various spaces
CO2: Learn reflexivity and find approximations in these spaces.
CO3: Learn various operators on Banach and Hilbert spaces and their properties
CO4: Understand the spectral results for operators on Banach and Hilbert spaces.</td></tr>
<tr><td colspan="10">COURSE SYLLABUS</td></tr>
<tr><td>Module No.</td><td colspan="8">Content</td><td>Hours</td></tr>
<tr><td>I</td><td colspan="8">[Course Outcome(s) No.: 1, 2 and 3]
Dual space, Representation of duals of the spaces $c_0$with p-norms, $c_0$and c with supremum-norm, l_p,C[a,b] and L_p, Reflexivity, Weak and weak* convergences, Best approximation in reflexive spaces, Operators on Banach and Hilbert spaces, Compact operators and its properties, Integral operators as compact operators.</td><td>20</td></tr>
<tr><td>II</td><td colspan="8">[Course Outcome(s) No.: 3 and 4]
Adjoint of operators between Hilbert spaces, Self-adjoint, Normal and Unitary operators, Numerical range and numerical radius, Hilbert-Schmidt operators, Spectral results for Banach and Hilbert space operators, Eigen spectrum, Approximate Eigen spectrum, Spectrum and resolvent, Spectral radius formula, Spectral mapping theorem, Riesz-Schauder theory, Spectral results for normal, self-adjoint and unitary operators.</td><td>20</td></tr>
</table>

Text Books:

- M. T. Nair, Functional Analysis: A First Course, Prentice Hall of India, 2014.
- B. V. Limaye, Functional Analysis, New Age International (P) Ltd., 2008.

Reference Books:

- E. Kreyszig, Introduction to Functional Analysis with Applications, Wiley, 1989.
- Bollobas, Linear Analysis, Cambridge University Press, 1999.
- A. H. Siddiqi, K. Ahmad & P. Manchanda, Introduction to Functional Analysis with Applications, Anamaya Publishers, 2006.

<table>
<tr><td colspan="2">Course No: 13</td><td colspan="2">Course Name: Measure Theory and Integration</td><td colspan="6">Course Code: MMAE 0014</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2" colspan="2">Programme: M.Sc. Mathematics</td><td rowspan="2">Semester:
III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week:4</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>0</td><td>4</td><td>Total Hours: 40</td></tr>
<tr><td colspan="3" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Functional Analysis</td></tr>
<tr><td>Course Objective</td><td colspan="9">This course will develop a profound understanding ofbasics of measurable sets, Lebesgue measure and measurable functions. The students will learn the concepts of point wise convergence, convergence theorem and related theorems. Further, a deep understanding of Lebesgue integration and its applications will be developed in this course. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="9">After studying these topics, the students will be able to:
CO1: Use the concept of outer measure and related results.
CO2: Understand the concepts of measurable sets and measurable functions.
CO3: Check point wise convergence and understand related results.
CO4: Learn the construction of the Lebesgue integral and its applications.</td></tr>
<tr><td colspan="10">COURSE SYLLABUS</td></tr>
<tr><td>Module No.</td><td colspan="8">Content</td><td>Hours</td></tr>
<tr><td>I</td><td colspan="8">[Course Outcome (s) No.: 1 and 2]
Review of Riemann-Stieltje’s integral, Algebras of sets, Borel subsets of R-Lebesgue outer measure and its properties, Algebras of measurable sets in R-nonmeasurable set, Example of measurable set which is not a Borel set, Lebesgue measure and its properties, Measurable functions.</td><td>20</td></tr>
<tr><td>II</td><td colspan="8">[Course Outcome(s) No.: 3 and 4]
Point wise convergence and Convergence in measure, Egoroff theorem, Lebesgue integral, Lebesgue criterion of Riemann integrability, Fatou’s lemma, Convergence theorem, Differentiation of an integral, Absolute continuity with respect to Lebesgue measure, Lebesgue integral in the plane, Fubini’s theorem.</td><td>20</td></tr>
<tr><td colspan="10">Text Books:
➢ De Barra, Measure Theory and Integration, Wiley Eastern Ltd., 2013.
➢ I. K. Rana, An Introduction to Measure and Integration, Narosa, 2007.

Reference Books:
➢ H. L. Royden, Real Analysis, Prentice Hall India Learning, 2011.
➢ P. K. Jain & V. P. Gupta, Lebesgue Measure and Integration, New Age International (P) Ltd., 2006.
➢ K. P. Gupta & S. Sharma, Measure and Integration, Krishna Prakashan, 2019.</td></tr>
</table>

<table>
<tr><td colspan="2">Course No: 14</td><td colspan="2">Course Name: Fixed Point Theory</td><td colspan="6">Course Code: MMAE 0015</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme: M.Sc. Mathematics</td><td rowspan="2">Semester:
IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td colspan="2">Contact Hrs Per Week:4</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>0</td><td>4</td><td colspan="2">Total Hours: 40</td></tr>
<tr><td colspan="3" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Functional Analysis</td></tr>
<tr><td>Course Objective</td><td colspan="9">This course will develop a profound understanding of Banach's contraction principle, Caristi-Ekeland principle and other related results. The students will learn the concepts of hyper convex spaces and normal structures in metric spaces. Further, a deep understanding of continuous mappings defined on metric spaces and fixed point set structures will be developed in this course. This course focuses on employability and skill development aligned with all CO's.</td></tr>
<tr><td>Course Outcomes</td><td colspan="9">After studying these topics, the students will be able to
CO1: Understand Banach's contraction principle, its extension and applications.
CO2: Learn hyper convex spaces and their characteristics.
CO3: Understand fixed point theorem and know the structure of the fixed point set.
CO4: Determine the continuous mapping between Banach spaces.
CO5: Learn Brouwer's theorem, Schauder's theorem and related results.
CO6: Apply various mappings of metric fixed point theory.</td></tr>
<tr><td colspan="10">COURSE SYLLABUS</td></tr>
<tr><td>Module No.</td><td colspan="8">Content</td><td>Hours</td></tr>
<tr><td>I</td><td colspan="8">[Course Outcome(s) No.: 1, 2 and 3]
Metric Contraction Principles: Banach's contraction principle, Further extension of Banach's principle, The Caristis Ekeland principle, Equivalents of the Caristi-Ekeland principle, set valued contractions, Generalized contractions.
Hyper convex Spaces and Normal Structures in Metric Spaces: Hyper convexity, Properties of hyper convex spaces, A fixed point theorem, Approximate fixed points. Normal structures in metric spaces, Fixed point theorem, Structure of the fixed point set, Fixed point set structure, Separable case.</td><td>20</td></tr>
<tr><td>II</td><td colspan="8">[Course Outcome(s) No.: 4, 5 and 6]
Continuous Mapping in Banach Spaces: Brouwer's theorem, Further comments on Brouwer's theorem, Schauder's theorem, Stability of Schauder's theorem, Leray - Schauder degree, Condensing mappings, Continuous mappings in hyper convex spaces.
Metric Fixed Point Theory: Contraction mappings, Basic theorems for non-expansive mappings, Structure of the fixed point set, Asymptotically regular mappings, Set valued mappings.</td><td>20</td></tr>
</table>

Text Book:

- M. A. Khamsi & W. A. Kirk, An Introduction to Metric Spaces and Fixed Point Theory, Wiley-Interscience, 2001.

Reference Books:

- E. Zeidler, Nonlinear Functional Analysis and its Applications, Springer-Verlag, 1998.
- D. R. Smart, Fixed Point Theory, Cambridge University Press, 1980.
- V. I. Istratescu, Fixed Point theory: An Introduction, Springer, 2001.
- Q. H. Ansari, Metric Spaces Including Fixed Point Theory and Set-Valued Maps, Alpha Science International, 2010.

Course No: 15	**Course Name**: Finite Element Method							**Course Code:** MMAE 0016
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
			4	0	0	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Numerical Analysis
Course Objective	The course aims to provide the fundamental concepts of the finite element method mainly including shape functions and general linear and higher order elements up to 2 dimensions. The course objective is to acquaint the students about application of finite element methods for solving various boundary value problems. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Understand the general theory of Finite Element method and its difference with finite difference method **CO2:** Use the role and significance of shape functions in finite element formulations and use of linear, quadratic, and cubic shape functions for interpolation **CO3:** Formulate some important 1, 2 and 3 dimensional elements **CO4:** Apply the weighted residual and variational approaches in solving some boundary value problems.

COURSE SYLLABUS

Module No.	**Content**	**Hours**
I	**[Course Outcome(s) No.: 1, 2 and 3]** Introduction to finite element methods, concept of discretization, different coordinates, one dimensional finite elements, concept of shape functions, stiffness matrix, connectivity, boundary conditions, and equilibrium equation. Numerical integration, construction of shape functions: linear elements (one dimensional bar element, two dimensional-triangular and rectangular elements).	20
II	**[Course Outcome(s) No.: 3 and 4]** Weighted residual and variational approaches (Galerkin method, collocation method, Rayleigh Ritz method etc.), Solving one-dimensional problems. Application of finite element methods for solving various boundary value problems, Computer procedures for finite element analysis.	20

Text Books:

- S. S. Rao, The Finite Element Method in Engineering, Butterworth-Heinemann, 2010.
- T. J. R. Hughes, The Finite Element Method (Linear Static and Dynamic Finite Element Analysis). Courier Corporation, 2007.

Reference Book:

- O. C. Zienkiewicz & R. L. Taylor. The Finite Element Method: The Basis, Butterworth-Heinemann, 2000.

<table>
<tr><td>Course No: 16</td><td colspan="3">Course Name: Operational Research-II</td><td colspan="6">Course Code: MMAE 0017</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme: M.Sc. Mathematics</td><td rowspan="2">Semester:
III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td colspan="2">Contact Hrs Per Week:4</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>0</td><td>4</td><td colspan="2">Total Hours: 40</td></tr>
<tr><td colspan="2">Total Evaluation Marks: 100
Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="8">Examination Duration: Mid Term (2 hours), End Term (3 hours)
Pre-requisite of course: Operational Research - I</td></tr>
<tr><td>Course Objective</td><td colspan="9">This course will develop a profound understanding of inventory control models and Markovian queuing models. Further, a deep understanding of network diagram, critical path method, programming evaluation and review technique (PERT) and cost analysis will be developed in this course. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="9">After studying these topics, the students will be able to:
CO1: Understand critical path method, programming evaluation and review technique and other related concepts.
CO2: Learn EOQ and deterministic inventory models.
CO3: Understand probabilistic models of inventory control.
CO4: Know the basics of queuing theory and understand Markovian queuing models.</td></tr>
<tr><td colspan="10">COURSE SYLLABUS</td></tr>
<tr><td>Module No.</td><td colspan="8">Content</td><td>Hours</td></tr>
<tr><td>I</td><td colspan="8">[Course Outcome(s) No.: 1 and 2]
CPM and PERT: Introduction, Network diagram, Events and Activities, Project planning, Critical events and Activities, Critical path method (CPM), Float, Slack, and Programming evaluation and Review technique (PERT), Resources and man power leveling, Cost analysis and Crashing the network, Resource scheduling.
Inventory Control I: General inventory model, Static economic order quantity (EOQ) models, Deterministic inventory models-production model-Buffer stock.</td><td>20</td></tr>
<tr><td>II</td><td colspan="8">[Course Outcome(s) No.: 3 and 4]
Inventory Control II: Price break models, Probabilistic Models-Newspaper boy problem.
Queuing Theory: Introduction to queuing models, Basic components of queuing system, General birth-death equation, Steady-state solution of Markovian queuing models (M/M/1, M/M/c, M/M/1/k, M/M/c/k).</td><td>20</td></tr>
</table>

Text Books:

- P. K. Gupta & D. S. Hira, Operations Research, S. Chand & Co., 2008.
- J. K. Sharma, Operations Research Theory and Applications, Macmillian India Ltd., 2016.
- K. Swarup, P. K. Gupta & M. Mohan, Operations Research, Sultan Chand & Sons, 2010.

Reference Books:

- S. D. Sharma, Operations Research, Kedar Nath & Ram Nath Publications, 2012.
- H. A. Taha, Operations Research: An Introduction, Pearson Education, 2010.
- D. Chatterjee, Linear Programming and Game Theory, Prentice Hall, India, 2006.

Course No: 17	**Course Name:** Fractional Calculus							**Course Code:** MMAE 0018
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
			4	0	0	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Differential Equations, Numerical Analysis
Course Objective	This course will develop a profound understanding of fractional integral, fractional derivative and their Laplace transform. Further, a deep understanding of numerical methods to find the solution of fractional differential equations will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Know the concept of Euler's and Mittag-Leffler Function. **CO2:** Understand the fractional integral and derivatives. **CO3:** Evaluate Laplace transform of fractional integrals and derivatives. **CO4:** Apply the numerical methods in solving fractional differential equations. **CO5:**Solve real-life fractional nonlinear models.

COURSE SYLLABUS

Module No.	**Content**	**Hours**
I	**[Course Outcome(s) No.: 1, 2 and 3]** **Special Functions** – Euler's functions, Integral functions, One and two parameter Mittag-Leffler functions. **Fractional Calculus**– Introduction, Definition, Fractional integral of orderα,Grünwald–Letnikovfractional derivative,Riemann-Liouville (RL) fractional derivative of order α with its properties, Liouville-Caputo fractional derivative of order α with its properties, Laplace transform of fractional integrals and derivatives.	20
II	**[Course Outcome(s) No.: 3 and 4]** **Fractional Differential Equations (FDE)**– Riemann-Liouville and Caputo fractional differential equations, Existence and uniqueness for the Caputo problem, Linear and nonlinear fractional differential equation, Solution by Adomian decomposition method (ADM), Fractional systems of differential equations, Time-fractional and Space-fractional differential equations,Numerical solution by fractional variational iteration method (FVIM).	20

Text Books:

- C. Milici, G. Draganescuand & J. T. Machado, Introduction to Fractional Differential Equations: Nonlinear Systems and Complexity, Springer Nature Switzerland AG, 2019.
- A. A. Kilbas, H. M. Srivastava & J. J. Trujillo, Theory and Applications of Fractional Differential Equations, Elsevier B.V., Amsterdam, 2006.

Reference Books:

- I. Podlubny, Fractional Differential Equations, Academic Press, 1999.
- E. Don, Schaum's Outline of Mathematica and the Wolfram Language, Mc Graw Hill Education, 2018.

Course No: 18	**Course Name:** Mathematical Modeling		**Course Code:** MMAE 0019					
Batch:	**Programme:**	**Semester:**	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
2024-2026	M.Sc. Mathematics	IV	4	0	0	0	4	**Total Hours: 40**
Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Ordinary and Partial Differential equations							

Course Objective	This course provides introduction of mathematical modeling and analysis in biological sciences. The major content of this course is chosen from population dynamics. This course covers the fundamentals of deterministic models in both discrete and continuous time domains. This course includes both linear and non-linear models with sufficient amount of theoretical background. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Understand the mathematical model and explain the series of steps involved in a mathematical modeling process. **CO2**: Apply the concept of mathematical modeling through difference equations in discrete time linear and discrete time nonlinear models. **CO3:** Use applications of mathematical modeling and make students appreciate the power and limitations of mathematics in solving practical real-life problems. **CO4:** Apply mathematical modeling in continuous time models.

COURSESYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1 and 2]** Overview of mathematical modeling, Types of mathematical models and methods to solve them, Discrete time linear models – Fibonacci rabbit model, Cell-growth model, Prey-predator model, Analytical solution methods and stability analysis of system of linear difference equations, Graphical solution – Cobweb diagrams, Discrete time age structured model – Leslie Model, Jury's stability test. Discrete time non-linear models-Different cell division models, Prey-predator model, Stability of non-linear discrete time models, Logistic difference equation.	20
II	**[Course Outcome(s) No.: 3 and 4]** Introduction to continuous time models – Limitations and Advantage of discrete time model, Need of continuous time models, Continuous time models – model for growth of microorganisms, Chemostat, Stability and linearization methods for system of ordinary differential equations. Continuous time single species model – Allee effect, Qualitative solution of differential equations using phase diagrams, Continuous time models – Lotka-Volterra competition model, Prey predator models.	20

Text Books:

- J. N. Kapur, Mathematical Modelling, New Age International, 2015.
- M. M. Meerschaert, Mathematical Modelling. Academic Press, 2013.
- A. Rutherford, Mathematical Modelling Techniques. Courier Corporation, 2012.
- R. J. Elliott & P. E. Kopp, Mathematics of Financial Markets. Springer Verlag, New York Inc, 2018.

Reference Books:

- L. D. Clive, Principles of Mathematical Modelling, Elsevier, 2004.
- E. A. Bender, An Introduction to Mathematical Modelling, Courier Corporation, 2000.

<table>
<tr><td>Course No: 19</td><td colspan="3">Course Name: Fuzzy Set Theory</td><td colspan="6">Course Code: MMAE 0020</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme: M.Sc. Mathematics</td><td rowspan="2">Semester:
III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td colspan="2">Contact Hrs Per Week:4</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>0</td><td>4</td><td colspan="2">Total Hours: 40</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100
Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="8">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="8">Pre-requisite of course: Discrete Mathematics</td></tr>
</table>

Course Objective	In this course, we study about the applications of integral equations in real life problems. The main objective of the course is to make the learner familiarize with the types of kernel, and the solution of integral equations using various methods. Differential equations can be studied for their solutions by transforming them into integro-differential equations using Laplace transform. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to **CO1**: Use the concept of different kernels and techniques for solving various kinds of integral equations. **CO2**: Determine use of integral equations. **CO3:** Recognizeto co-relate differential and integral equations. **CO4:** Solve integral equations arising in different fields.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1 and 2]** Fuzzy set, Standard operations of fuzzy set, Fuzzy complement, Fuzzy union and fuzzy intersection, other operations in fuzzy set. t-norms and t-conorms. Interval, Fuzzy number, Operation of interval, operation of - cut interval, Operation of triangular and general fuzzy numbers, Approximation of triangular and trapezoidal fuzzy numbers, Bell shape fuzzy number, Function with fuzzy constraint, Propagation of fuzziness by crisp function, Fuzzifying function of crisp variable, maximizing and minimizing set, maximum value of crisp function.	20
II	**[Course Outcome(s) No.: 3 and 4]** Integration and differentiation of fuzzy function product set, definition and characteristics of relation, representation methods of relations, operations on relations, path and connectivity in graph, fundamental properties, equivalence relation, compatibility relation, pre-order relation, order relation, definition and examples of fuzzy relation, fuzzy matrix, operations on fuzzy relation. Composition of fuzzy relation, - cut of fuzzy relation, projection and cylindrical extension, extension by relation, extension principle, extension by fuzzy relation, fuzzy distance between fuzzy sets, graph and fuzzy graph, fuzzy graph and fuzzy relation, - cut of fuzzy graph.	20

Text Books:

- C. Mohan, An Introduction to Fuzzy Set Theory and Fuzzy Logic. Anshan Publishers, 2015.
- K. H. Lee, First Course on Fuzzy Theory and Applications, Springer, 2005.

Reference Books:

- J. Yen & R. Langari, Fuzzy Logic - Intelligence, Control and Information, Pearson Education, 1999.
- H. J. Zimmerman, Fuzzy Set Theory and its Applications, Allied Publishers Ltd., New Delhi, 1991.

Course No: 20	**Course Name:** Numerics of Ordinary Differential Equations						**Course Code:** MMAE 0021	
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** III/IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
			4	0	0	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Ordinary Differential Equations, Numerical Analysis
Course Objective	This Course will develop a profound understanding of one-step and multi-step methods along with their consistency convergence and stability. Further a basic understanding of boundary value problems and their solutions will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** classify the differential equation like linear, non-linear, IVP or BVP **CO2**: Solve the different type of differential equations numerically whose solution is not necessarily given. **CO3:** Check the consistency and stability of any numerical method **CO4:** Construct higher order numerical method for IVPs.

COURSE SYLLABUS

Module No.	**Content**	**Hours**
I	**[Course Outcome(s) No.: 1 and 2]** Approximation of initial value problem for ordinary differential equations: one-step methods including the explicit and implicit Euler methods, the trapezium rule method and Runge-Kutta methods. Linear Multi-step methods: consistency, zero stability and convergence, absolute stability.	20
II	**[Course Outcome(s) No.: 3 and 4]** Predictor-corrector methods, stiffness, stability regions, Gear's methods and their implementation. Nonlinear stability. Boundary value problems: shooting methods, matrix methods collocation**.**	20

Text Books:

- H. B. Keller, Numerical methods for Two-point Boundry Value Problems, SIAM, 1976.
- J. D. Lambert, Computational Methods in Ordinary Differential Equations, John Wiley & Sons, 1991.

Reference Books:

- L. E. Hairer, S. P. Norsett & G. Wanner, Solving Ordinary Differential Equations I: Nonstiff Problems, Springer-Verlag, 1987.
- P. Henrici, Discrete Variable Methods in Ordinary Differential Equations, Wiley, 1962.
- K. W. Morton, Numerical Solution of Ordinary Differential Equations, Oxford University Computing Laboratory, 1987.
- A. M. Staurt & A. R. Humphries, Dynamical Systems and Numerical Analysis, Cambridge University Press, 1996.

Course No: 21	**Course Name:** Numerics of Partial Differential Equations							**Course Code:** MMAE 0022
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
			4	0	0	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Partial Differential Equations, Numerical Analysis

Course Objective	This course will develop a profound understanding of finite difference schemes for partial differential equations and initial and boundary value problems. The students will be able to examine the consistency and convergence of solutions and analyze their stability. Further, a deep understanding of finite element methods to find the solution of ordinary differential equations, will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Understand finite difference schemes to find the solution of partial differential equations. **CO2**: Examine consistency, stability and convergence of solutions. **CO3:** Know finite difference schemes to find the solution of initial and boundary value problems. **CO4:** Learn finite element methods to solve ordinary differential equations.

COURSE SYLLABUS

Module No.	**Content**	**Hours**
I	**[Course Outcome(s) No.: 1 and 2]** Finite Differences, Finite difference schemes for initial value problems, Explicit FTCS, Backward Euler and Crank-Nicolson schemes, Stability, Consistency and Convergence of finite difference scheme by Von Neumann method and matrix method, ADI scheme for two dimensional heat conduction equation.	20
II	**[Course Outcome(s) No.: 3 and 4]** Finite difference solution of Laplace and Poisson's equations, Finite difference scheme for one dimensional wave equation, Lax Wendroff method, Upwind scheme, Courant-Friedrichs-Lewy (CFL) conditions, Finite element method for two point BVP, Method of weighted residuals, Variational methods.	20

Text Books:

- G. D. Smith, Numerical Solutions to Partial Differential Equations, Oxford University Press, 1986.
- J. C. Strikwerda, Finite Difference Schemes and Partial Differential Equations, SIAM, 2004.
- J. N. Reddy, An Introduction to Finite Element Method, McGraw Hill, 2005.

Reference Books:

- L. Lapidus & G. F. Pinder, Numerical Solutions to Partial Differential Equations in Science and Engineering, John Wiley, 1982.
- K. W. Morton & D. F. Mayers, Numerical Solutions to Partial Differential Equations, Cambridge University Press, 2005.
- C. Johnson, Numerical Solutions to Partial Differential Equations by the Finite Element Method, Dover Publications, 2009.

<table>
<tr><td colspan="2">Course No: 22</td><td colspan="2">Course Name: Mathematics for Finance</td><td colspan="7">Course Code: MMAE 0023</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2" colspan="2">Programme: M.Sc. Mathematics</td><td rowspan="2">Semester:
II/III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td colspan="2">Contact Hrs Per Week:4</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>0</td><td>4</td><td colspan="2">Total Hours: 40</td></tr>
<tr><td colspan="3" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="8">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="8">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="10">This course will develop a profound understanding of financial management theory and time value of money. The students will be able to find out the cost of a capital and learn capital budgeting techniques. Further, a deep understanding of capital structure theoreis, dividend policies and inventory management techniques will be developed in this course. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="10">After studying these topics, the students will be able to:
CO1: Understanding the basic of finance concepts like time value of money, return, and risk as the building blocks of finance theory.
CO2: Identifying the financial viability of a capital budgeting exercise in various situations and application in decision making.
CO3: Identifying the various cost of capital its component and methods of calculation.
CO4: Understand the theories of the relationship between capital structure and the value of the firm.
CO5: Outlining the issues of dividend policy and the logic of dividend relevance and its irrelevance.
CO6: Applying the inventory management techniques.</td></tr>
<tr><td colspan="11">COURSE SYLLABUS</td></tr>
<tr><td>Module No.</td><td colspan="9">Content</td><td>Hours</td></tr>
<tr><td>I</td><td colspan="9">[Course Outcome(s) No.: 1, 2 and 3]
Financial Management – Introduction, Nature and scope of financial management, Goals and main decisions of financial management,
Time value of Money –Time preference for money, Present value and Future value of money, Annuities and its kinds.
Cost of Capital: Concept and measurement of cost of Capital, Debt vs. Equity, Cost of equity, Cost of preference shares, Cost of retained earnings. Weighted average cost of capital (WACC) and Marginal cost of capital.
Capital Budgeting: Introduction, Investment decision, Nature and techniques of capital budgeting, Traditional methods: Payback period method, Average rate of return method, Time-adjusted methods: Net present value, Internal rate of return method, Profitability index method, Discounted payback period method.</td><td>20</td></tr>
<tr><td>II</td><td colspan="9">[Course Outcome(s) No.: 4, 5 and 6]
Capital Structure Decisions: Capital structure vs. financial structure – Capitalization, Leverages: Financial leverage, Operating leverage and Composite leverage. EBIT-EPS analysis, Indifference of financial leverage.
Theories –The Modigliani miller theory –A critical appraisal.
Dividend Decisions: Dividends and value of the firm, Relevance of dividends, Factors determining dividend policy, dividend and valuation of the firm-The basic models: Walter model and Gordon model.
Inventory Management: Meaning and importance; Dangers of excessive and inadequate inventory; Techniques of inventory management viz. Economic order quantity, A.B.C. analysis technique.
Uses of excel in financial management.</td><td>20</td></tr>
</table>

Text Books:

- I. M. Pandey, Financial Management, Vikas Publishing House, 2015.
- R. M. Kishore, Financial Management- Theory, Problem, Cases, Taxmann Publication, 2020.

Reference Books:

- M. Y. Khan & P. K. Jain, Financial Management, Tata McGraw-Hill Publication, 2018.
- P. Chandra, Financial management, Tata McGraw-Hill Publication, 2011.
- R. Brealey, S. Mayers, F. Allen, & P. Mohanty, Principle of Corporate Finance, Tata McGraw-Hill Publication, 2018.
- S. N. Maheswari, Financial Management, Vikas Publishers, 2007.

Course No: 23	**Course Name:** Coding Theory							**Course Code:** MMAE 0016
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** II/III/IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
			4	0	0	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Abstract Algebra
Course Objective	This course will develop a profound understanding of linear codes, encoding and decoding of linear codes and their applications. Further, a deep understanding of cyclic, BCH and quaternary linear codes, and their advantages in finding the solution of mathematical problems will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to **CO1**: Calculate the parameters of given codes and their dual codes using standard matrix and polynomial operations. **CO2:** Encode and decode information by applying algorithms associated with well-known codes. **CO3**: State and prove the fundamental theorems about error-correcting codes. **CO4:** Compare the error-detecting/correcting facilities of given codes for a given binary symmetric channel. **CO5:** Design simple linear or cyclic codes with required properties. **CO6:** Solve mathematical problems involving error-correcting codes by linking them to concepts from elementary number theory, combinatorics, linear algebra, and elementary calculus.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1 and 2]** **Linear Codes**: Brief introduction to coding theory, Linear codes, Hamming weight, Hamming code, Bases for linear codes, Generator matrix and Parity-check matrix, Equivalence of linear codes, Encoding with a linear code, Decoding of linear codes, Cosets, Nearest neighbor decoding for linear codes, Syndrome decoding, Golay code, Reed-Solomon code.	20
II	**[Course Outcome(s) No.: 3, 4, 5 and 6]** **Cyclic codes**: Definition of cyclic codes, Generator polynomials, Generator and parity-check matrices, Decoding of cyclic codes, Burst-error-correcting codes, BCH codes, Parameters of BCH codes, Decoding of BCH codes, Quaternary linear codes and their generator matrices.	20

Text Books:

- S. Ling & C. Xing: Coding Theory: A First Course Cambridge University Press, 2004.
- D. R. Hankerson, D. G. Hoffman, D. A. Leonard, C. C. Lindner, K. T. Phelps, C. A. Rodger & J. R. Wall, Coding Theory and Cryptography: The Essentials, CRC Press, 2000.

Reference Books:

- Z. X. Wan: Quaternary codes, World Scientific, Publishing Company Pvt. Ltd., 1997.

Course No: 24	**Course Name:** Cryptography						**Course Code:** MMAE 0017	
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** II/III/IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
			4	0	0	0	4	**Total Hours: 40**
Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks		**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Abstract Algebra						

Course Objective	This course will develop a profound understanding of congruences, primitive roots, various types of numbers, Fermat's last theorem and their applications. The students will also learn the concept of cryptography, Caesar Cipher, Diffie-Hellman RSA public key cryptosystem and applications of cryptography. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Understand congruences, primitive roots and their applications. **CO2**: Use the basics of RSA security and be able to break the simplest instances and analyze the basic concepts of remote coin flipping, elliptic curve based cryptography. **CO3:** Apply the theorems: Fermat's last theorem, prime number theorem and zeta function. **CO4:** Understand and use the numbers: perfect numbers, Fermat numbers, Mersenne primes and amicable numbers, Fibonacci numbers.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1 and 2]** Modular arithmetic, Congruence, Primitive roots, Cryptography introduction, Caesar Cipher, Diffie-Hellman RSA public key cryptosystem, Knapsack cryptosystem, Application of primitive roots to cryptography, Applications of cryptography in primality testing and factorization of large composite numbers, Remote coin flipping, Elliptic curve based cryptography.	20
II	**[Course Outcome(s) No.: 3 and 4]** Perfect numbers, Fermat numbers, Mersenne primes and Amicable numbers, Fibonacci numbers, Representation of integers as sum of squares, Linear and non-linear Diophantine equations, Fermat's last theorem, Prime number theorem and Zeta function.	20

Text Books:

- H. C. A. Tilborg, Fundamentals of Cryptology, Springer, 2013.
- J. A. Buchmann, Introduction to Cryptology, Springer Science & Business Media, 2012.
- D. M. Burton, Elementary Number Theory, Tata McGraw Hill Publishing House, 2006.
- A. J. Menezes, P. C. V. Oorschot and S. A. Vanstone, Handbook of Applied Cryptography, CRC Press, 1996.
- D. R. Hankerson, D. G. Hoffman, D. A. Leonard, C. C. Lindner, K. T. Phelps, C. A. Rodger & J. R. Wall, Coding Theory and Cryptography: The Essentials, CRC Press, 2000.

Reference Books:

- N. Koblitz, A Course in Number Theory and Cryptography, Springer, 1994.
- G. J. Simmons, Contemporary Cryptology, The Science of Information Integrity, IEEE Press, 1992.

SYLLABI OF SUBJECTS

DISCIPLINE SPECIFIC ELECTIVE COURSES (DSE)

- **BOUQUET 2**: DATA SCIENCE

<table>
<tr><td colspan="2">Course No: 1</td><td colspan="3">Course Name: Probability theory and Distributions</td><td colspan="5">Course Code: MMAE 0101</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme:
M.Sc. Mathematics</td><td rowspan="2">Semester:
II</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td colspan="2">Contact Hrs Per Week:4</td></tr>
<tr><td>3</td><td>0</td><td>2</td><td>0</td><td>4</td><td colspan="2">Total Hours: 40</td></tr>
<tr><td colspan="3" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="9">This course will develop a profound understanding of probability laws, probability distributions and their applications. This course will make the students able to calculate expectations and generating functions. Further, a deep understanding of sampling distributions for the testing of hypothesis will be developed in this course. This course focuses on employability and skill development aligned with all CO's.</td></tr>
<tr><td>Course Outcomes</td><td colspan="9">After studying these topics, the students will be able to:
CO1: Apply techniques to solve day to day problems related to probability.
CO2: Calculate different types of expectation and use different inequalities in statistics.
CO3: Compute different types of generating functions.
CO4: Understand different probability distributions and their uses in real life problems.
CO5: Understand sampling distributions and use it for hypothesis testing.
CO6: Apply order statistics, lay exploiting and their properties, particularly their distributions.</td></tr>
<tr><td colspan="10">COURSE SYLLABUS</td></tr>
<tr><td>Module No.</td><td colspan="8">Content</td><td>Hours</td></tr>
<tr><td>I</td><td colspan="8">[Course Outcome(s) No.: 1, 2 and 3]
Probability and Random Variables: Random experiments, Empirical probability, Algebra of events, Laws of probability, Conditional probability, Independence, Bayes' Law, One-dimensional random variable, Distribution functionandits properties, Bivariate random variables and their distributions (joint, marginal and conditional), Functions of random variables, Transformation technique.
Mathematical Expectation: Expectation, Variance, Covariance, Conditional expectation, Markov, Holder, Jensen and Chebyshev's inequality, Weak and strong laws of large numbers, Kolmogorov's theorem, Central limit theorem.
Generating Functions: Probability generation function (p.g.f.), Moment generating function (m.g.f.), Characteristic function.</td><td>20</td></tr>
<tr><td>II</td><td colspan="8">[Course Outcome(s) No.: 4, 5 and 6]
Discrete Distributions: Bernoulli, Binomial, Poisson, Geometric, Hyper geometric, Negative Binomial and Discrete Uniform distributions.
Continuous Distributions: Normal, Uniform, Exponential, Gamma, Beta (Type I and Type II), Cauchy, Weibull, Lognormal, Logistic, Laplace, Pareto and Rayleigh distributions. Concept of truncated distributions.
Sampling Distributions: Sampling distribution of mean, Finite populations, Sampling distribution of proportion, Finite populations, Distribution of sample variance, Chi-square distribution, t and F distributions, Order statistic.</td><td>20</td></tr>
</table>

Text Books:

- P. Mukhopadhyay, An Introduction to the Theory of Probability, World Scientific, 2012.
- P. L. Meyer, Introductory Probability and Statistical Applications, Oxford and IBH Publishers, 1970.

Reference Book:

- V. K. Rohtagi & A. K. Md. Ehsanes Saleh, An Introduction to Probability and Statistics, John Wiley & Sons, 2015.

<table>
<tr><td colspan="2">Course No: 2</td><td colspan="3">Course Name: Regression Analysis and Predictive Modelling</td><td colspan="5">Course Code: MMAE 0102</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2" colspan="2">Programme:
M.Sc. Mathematics</td><td rowspan="2">Semester:
II</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week:4</td></tr>
<tr><td>3</td><td>0</td><td>2</td><td>0</td><td>4</td><td>Total Hours: 40</td></tr>
<tr><td colspan="3" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="9">This course will develop a profound understanding of normed linear spaces. This course also includes bounded, unbounded and closed operators, orthonormal basis and their properties. Further, a deep understanding of standard theorems and their applications will be developed in this course. This course focuses on employability and skill development aligned with all CO's.</td></tr>
<tr><td>Course Outcomes</td><td colspan="9">After studying these topics, the students will be able to:
CO1: Understand the concept of estimation of parameters in regression model.
CO2: Apply and use Gauss-Markov theorem to obtain best linear unbiased estimates.
CO3: Understand the Difference between R-Squared and Adjusted R-Squared and interpret them as a measure of goodness of fit.
CO4: Apply tests for linear hyphothesis testing to determine the relationship between the response and predictor variables.
CO5: Learn and apply methods for model adequacy checking.
CO6: Understand different Scenarios and the approach adopted when the underlying assumptions of multiple linear regression model fails.
CO7: Understand the type of heteroscedasticity present in the model and apply methods accordingly.
CO8: Understand the problem of multicollinearity and how to deal with it.</td></tr>
</table>

COURSE SYLLABUS

<table>
<tr><th>Module No.</th><th>Content</th><th>Hours</th></tr>
<tr><td>I</td><td>[Course Outcome(s) No.: 1, 2, 3 and 4]
Multiple linear regression model and assumptions, estimation of parameters, estimable functions, error and estimation space, Gauss-Markov theorem, use of g-inverse.
Model in deviation form, ANOVA for linear model, R^2, adjusted R^2 and other model selection criterion, tests of linear hypothesis, forecasting.
Model Adequacy Checking: checking of linear relationship, residual analysis and scaling of residuals, regression variable hull, PRESS residuals, R-student residuals, residual plots, partial residual plots, detection and treatment of outliers, Diagnostics for leverage and influence, measures of influence.</td><td>20</td></tr>
<tr><td>II</td><td>[Course Outcome(s) No.: 5, 6, 7, and 8]
Estimation of parameters by generalized least squares (GLS) in linear models with non-spherical disturbances, Gauss Markov theorem for GLS estimator, estimation under heteroscedasticity and tests of heteroscedasticity, tests for autocorrelation, estimation and forecasting under autocorrelated disturbances.
Generalized Linear Models: Logistic Regression, Poisson Regression and Generalized Linear model.
Multicollinearity: Introduction, sources of multicollinearity, effects of multicollinearity, variance Inflation factors (VIF), Methods of dealing with multicollinearity, Ridge Regression.</td><td>20</td></tr>
</table>

Text Books:

- N. R. Draper & H. Smith, Applied Regression Analysis, Wiley, 1998.
- J. Johnston, Econometric Methods, McGraw Hill, 1984.
- D. C. Montgomery, E. A. Peck & G. G. Vining, Introduction to Linear Regression Analysis, Wiley, 2006.

Reference Books:

- C. R. Rao, H. Toutenburg, Shalabh, C. Heumann & M. Schomaker, Linear Models and Generalizations-Least squares and Alternatives, Springer, 2007.
- J. F. Monahan, A Primer on Linear Models, CRC Press, 2008.
- A. I. Khuri, Linear Model Methodology, CRC Press, 2010.
- G. A. F. Seber, & A. J. Lee, Linear Regression Analysis, Wiley, 2003.

<table>
<tr><td>Course No: 3</td><td colspan="2">Course Name: Time Series Analysis And Forecasting</td><td colspan="7">Course Code: MMAE 0103</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme:
M.Sc. Mathematics</td><td rowspan="2">Semester:
III</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td colspan="2">Contact Hrs Per Week:4</td></tr>
<tr><td>3</td><td>0</td><td>2</td><td>0</td><td>4</td><td colspan="2">Total Hours: 40</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="8">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="8">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="9">This course will develop a profound understanding of time-series, its components and smoothing techniques. The students will learn various models for stationary and non-stationary time-series. Further, a deep understanding of ARCH and GARCH models of heteroscedasticity and spectral analysis will be developed in this course. This course focuses on employability and skill development aligned with all CO's.</td></tr>
<tr><td>Course Outcomes</td><td colspan="9">After studying these topics, the students will be able to:
CO1: Understand the components of time series and apply smoothing techniques to the data and better expose its important patterns.
CO2: Visualize time series as a stochastic process and be able to obtain the means, variances, covariances, acf and pacf to understand the behavior of time series data.
CO3: Understand the concept of stationarity and non-stationarity and apply the methods in real-time problems.
CO4: Estimate the statistical models and forecast them.
CO5: Analyze and forecast volatality with the help of ARCH and GARCH models.
CO6: Understand the application of frequency-domain time-series analysis.</td></tr>
</table>

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1, 2 and 3]** **Components of Time-Series and Smoothing Techniques:** Classical decomposition model, methods of estimation- Trend, Seasonal, Moving Averages: Simple, Centred and weighted, single and double exponential smoothing, Helt-Winters method. **Fundamental Concepts:** Time Series and Stochasting Process, Sample auto covariance function (acvf) and autocorrelation function (acf) at lag k, Partial autocorrelation function (pacf), correlosram, lag operators and Linear filters, Ergodicity and Stationarity, Stationarity and invertibility conditions. **Models for Stationary Time Series:** Estimation and forecasting, Wold Decomposition, general linear process and its acvf, acf, Auto Regressive (AR) process, Moving Average (MA) process, acf and pacf of AR and MA processes, Yule-walker equations for AR processes, mixed ARMA process. ARIMA (p,d,q) model, estimation of parameters, identification of processes with ACF, PACF, Model order estimation and forecasting.	20
II	**[Course Outcome(s) No.: 3, 4, 5 and 6]** **Non-Stationary Processes:** Forms of non-stationarity in time series, random walk model. Dickey fuller, augmented Dickey-Fuller and Phillips-perron tests for unit root. **Time Series Models of Heteroscedasticity:** ARCH and GARCH Processes. **Spectral Analysis:**Frequency domain analysis-spectral density and its properties, Spectral density function of stationary linear processes, cross-spectrum for multivariate processes, spectral distribution function, estimation of spectral density function, periodogram analysis.	20

Text Books:

- G. E. P. Box, G. M. Jenkins, G. C. Reinsel & G. M. Ljung, Time Series Analysis, Forecasting and Control, Wiley, 2015.
- P. J. Brockwell & R. A. Davis, Time Series: Theory and Methods, Springer, 2009.

Reference Books:

- G. Kirchgässner & J. Wolters, Introduction to Modern Time Series Analysis, Springer, 2007.
- C. W. J. Granger & M. Hatanaka, Spectral analysis of economic time series. (PSME-1), Princeton University Press, 2015.
- D. C. Montgomery, L. A. Johnson & J. S. Gardiner, Forecasting and Time Series Analysis, McGraw-Hill Companies, 1990.
- M. B. Priestley, Spectral Analysis and Time Series: Probability and Mathematical Statistics, 1981.

<table>
<tr><td colspan="2">Course No: 4</td><td colspan="4">Course Name: Database Management System</td><td colspan="5">Course Code: MCAC 0009</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme:
M.Sc. Mathematics</td><td rowspan="2">Semester:
III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week:4</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>0</td><td>3</td><td>Total Hours: 40</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="8">To acquire the knowledge of database design, data models and database languages and to study the physical and logical database designs, database modeling, relational, hierarchical, and network models. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="8">After the completion of the course, the student will:
CO1: Understand the basic concepts and the applications of database systems.
CO2: Design ER Model and Relational Database Schema for real world application, given unambiguous problem statement.
CO3: Implement SQL queries to access data, given relational database schema.
CO4: Implement views, constrains and index, PL/SQL procedures and functions for a given scenario.
CO5: Develop relational algebra expressions, given the relational database schema.
CO6: Understand and apply database normalization principles.
CO7: Describe the concepts of transaction and classification of database.</td></tr>
</table>

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1, 2, 3, 5 and 6]** **Introduction:** An Overview of Database Management System, Database System Vs File System, Database System Concept and Architecture, Data Model Schema and Instances, Data Independence, Database Language and Interfaces (DDL, DML, DCL), Database Development Life Cycle (DDLC) with Case Studies. **Data Modeling Using the Entity-Relationship Model:** ER Model Concepts, Notation for ER Diagram, Mapping Constraints, Keys, Specialization, Generalization, Aggregation, Reduction of an ER Diagram to Tables, Extended ER Model. **Relational Data Model and Language:** Relational Data Model Concepts, Integrity Constraints, Entity Integrity, Referential Integrity, Keys Constraints, Domain Constraints, Relational Algebra. **Database Design & Normalization I:** Functional Dependencies, Primary Key, Foreign Key, Candidate Key, Super Key, Normal Forms, First, Second, Third Normal Forms, BCNF, Non-Redundant Cover, Canonical Cover.	20
II	**[Course Outcome(s) No.: 3, 4, 6 and 7]** **Database Design & Normalization II:** 4th Normal Form, 5th Normal Form, Lossless Join Decompositions, MVD and JDs, Inclusion Dependence. **File Organization:** Indexing, Structure of Index files and types, Dense and Sparse Indexing. **Transaction Processing Concept:** Transaction System, Testing of Serializability, Serializability of Schedules, Conflict & View Serializable Schedule, Recoverability, Recovery from Transaction Failures, Log Based Recovery, Deadlock Handling. **Concurrency Control Techniques:** Concurrency Control, Locking Techniques for Concurrency Control, 2PL, Time Stamping Protocols for Concurrency Control, Validation Based Protocol. **Distributed Database:** Introduction of Distributed Database, Data Fragmentation and Replication.	20

Text Book:

- R. Elmasri & S. B. Navathe, Fundamentals of Database Systems, Pearson, 2010.

References Books:

- C. J. Date, An Introduction to Database Systems, Pearson, 1999.
- A. Silberschatz, H. Korth, S. Sudarshan, Database Systems Concepts, McGraw-Hill Education, 2005.
- B. C. Desai, An Introduction to Database Systems, Gagotia Publications, 2010.
- A. Majumdar & P. Bhattacharya, Database Management System, McGraw Hill Education, 2017.

<table>
<tr><td>Course No: 5</td><td colspan="3">CourseName: Database Management System Lab</td><td colspan="6">Course Code: MCAC 0807</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme: M.Sc. Mathematics</td><td rowspan="2">Semester:
III / IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td colspan="2">Contact Hrs Per Week:2</td></tr>
<tr><td>0</td><td>0</td><td>2</td><td>0</td><td>1</td><td colspan="2">Total Hours:20</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100

Internal: 50 Marks
External: 40 Marks
Attendance: 10 Marks</td><td colspan="8">Examination Duration: End Term (2 hours)</td></tr>
<tr><td colspan="8">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="9">To implement the concept of entity relationship approach and database languages. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="9">CO1: Apply SQL queries for DML and DDL.
CO2: Develop the SQL queries for real life scenarios.
CO3: Implement the procedural language (PL/SQL) and Triggers.</td></tr>
<tr><td colspan="10">COURSE SYLLABUS</td></tr>
<tr><td>Module No.</td><td colspan="8">Content</td><td>Hours</td></tr>
<tr><td>I / II</td><td colspan="8">• Introduction of Data Definition Language (DDL) and Its commands. (Create, Alter, Drop, Rename).
• Introduction of Data Manipulation Language (DML) and Its Commands (Insert, Update, Delete).
• Introduction of Transaction Control Language (T.C.L) & Data Control Language(D.C.L.)
• Creation, altering and dropping of tables and inserting rows into a table (use constraints while creating tables) examples using SELECT command.
• Queries using Aggregate functions (COUNT, SUM, AVG, MAX and MIN), GROUP BY, HAVING and Creation and dropping of Views.
• Queries using Conversion functions (to_char, to_number and to_date), string functions (Concatenation, lpad, rpad, ltrim, rtrim, lower, upper, initcap, length, substr and instr), date functions (Sysdate, next_day, add_months, last_day, months_between, least, greatest, trunc, round, to_char, to_date)
• To implement concept of Joins in SQL.
• To implement the concept of sub-queries.</td><td>20</td></tr>
</table>

Text Books:

- R. Elmasri & S. B. Navathe, Fundamentals of Database Systems, Pearson, 2010.
- P. Sadalage, & M. Fowler, NoSQL Distilled: A Brief Guide to the Emerging World of Polyglot Persistence, Addison Wesley, 2012.

References Books:

- C. J. Date, An Introduction to Database Systems, Pearson, 1999.
- A. Silberschatz, H. Korth & S. Sudarshan, Database Systems Concepts, McGraw-Hill Education, 2010.
- E. Redmond & J. R. Wilson, Seven Databases in Seven Weeks: A Guide to Modern Databases and the NoSQL Movement, O′Reilly, 2012.

Course No: 6		**Course Name:** Machine Learning for Data Science			**Course Code:** MMAE 0104				
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** III/IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**	
			3	0	2	0	4	**Total Hours: 40**	

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Regression Analysis and Predictive Modelling; Multivariate Analysis
Course Objective	This course will develop a profound understanding of different clustering algorithms and their applications to real-life problems. This course includes various methods to produce one optical predictive model. Further, a deep understanding of cross-validation techniques for applicability for algorithms will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	**CO1:** Understand the concept of Machine Learning of identify the techniques suitable for real-life data problems. **CO2:** Know and apply different clustering algorithms to real-life problems. **CO3:** Deal with missing data, classify unseen data. **CO4:** Learn methods to produce one optical predictive model. **CO5:** Apply cross-validation techniques for applicability for algorithms.

COURSE SYLLABUS

Module No.	**Content**	**Hours**
I	**[Course Outcome(s) No.: 1, 3]** The basic concept of machine learning, types of machine learning: supervised and unsupervised. Associations, Classification Trees and Regression Trees, Probably Approximately Correct Learning (PAC), Support Vector Machines. Nearest Neighbor Methods, Validation: Nearest neighbor prediction, K-nearest neighbor methods, Weighted neighbor methods, Kernel density estimation. Bayesian Classifiers and Error Rates. **Linear Discrimination**: Generalizing the Linear Model, Pairwise Separation, Gradient Descent, Logistic Discrimination.	20
II	**[Course Outcome(s) No.: 2, 4 and 5]** **Clustering**: Introduction, Similarity measures, Ward's Hierarchical Clustering, Non-hierarchical clustering, K-Means Clustering, choosing the number of clusters. Mixtures of Latent Variable Models. **Multivariate Data**: Parameter Estimation, Estimation of Missing Values, Gaussian mixures, Expectation-Maximization (EM) algorithm, Multivariate Classification, Tuning Complexity, Discrete Features. **Support vector machines** (SVM): linear SVM, Lagrangian optimization and duality, kernel trick, VC dimension. **Ensemble Methods**: Stacking, Bagging and Boosting.	20

Text Books:

- H. Daumé, A course in Machine Learning, Alanna Maldonado, 2023.
- R. S. Michalski, J. G. Carbonell & T. M. Mitchell, Machine learning: An Artificial Intelligence Approach, Morgan Kaufmann Publishers, 1984.

Reference Books:

- A. Ethem, Introduction to Machine Learning, PHI Learning Pvt. Ltd, 2015.
- P. Dangeti, Statistics for Machine Learning, Packt Publishing Ltd., 2017.

Course No: 7	**Course Name:** Deep Learning	**Course Code:** MMAE 0105

Batch:	**Programme:**	**Semester:**	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs. Per Week:4**
2024-2026	M.Sc. Mathematics	IV	3	0	2	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Nil
Course Objectives	This course will develop a profound understanding of deep learning techniques and their applications to real-life data problems. This course includes the concept of neural network (artificial, deep, recurrent) and its optimization. Further, a general understanding of deep generative models will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	**CO1:** Learn the fundamental concept of deep learning. **CO2:** Identify suitable deep learning techniques to real-life data problems. **CO3:** Understand the concept of neural network (artificial, deep, recurrent) and its optimization. **CO4:** Develop deep generative models.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome (s) No.: 1 and 2]** **Artificial Neural Network**: Introduction, connectionism theory of human mind, McCulloch–Pitts unit and Threshold logic, Linear Perceptron, Perceptron Learning Algorithm, feed-forward networks, input, hidden and output layers, organization of neural networks. Estimation of the weights, different learning modes, Multilayer Perceptron. **Deep Neural Network**: Architectures, Properties of CNN representations: invertibility, stability, invariance, convolution, pooling of layers, CNN and Tensorflow, Difficulty of training deep neural networks, Greedy layerwise training. **Neural network optimization**: Different optimizers for neural networks- Adaptive Gradient Algorithm (Adagrad), Adadelta, Root mean square propagation (RMSprop), Adaptive moment estimation (Adam), Nesterovaccelerated gradient (NAG). Saddle point problem in neural networks, Regularization methods (dropout, drop connect, batch normalization).	20
II	**[Course Outcome(s) No.: 3 and 4]** **Recurrent Neural Networks** (RNNs): Long short term memory (LSTM) and Gated recurrent unit (GRU), Encoder-decoder architectures, Auto-encoders (standard, de-noising, contractive, etc), Variational Autoencoders, Kohonen Self organizing map (SOM): Back propagation through time, Long Short Term Memory, Gated Recurrent Units, Bidirectional LSTMs, Bidirectional RNNs. Reinforcement learning in neural network, Restrictive Boltzmann Machines (RBMs), gradient computations in RBMs, Deep Boltzmann Machine, Markov Chain Monte Carlo (MCMC) and Gibbs Sampling for Deep Learning, Convolution neural networks: LeNet and AlexNet.	20

Text Books:

- A. Courville, I. Goodfellow & Y. Bengio, Deep Learning (Adaptive Computation and Machine Learning series), MIT Press, 2016.
- C. M. Bishop, Neural Networks for Pattern Recognition, Clarendon Press, 1995.

Reference Book:

- N. Buduma & N. Locascio, Fundamentals of Deep Learning: Designing Next-Generation Machine Intelligence Algorithms, O'Reilly Media, 2017.

Course No: 8	**Course Name:** Multivariate Analysis and Stochastic Processes	**Course Code:** MMAE 0106

Batch:	**Programme:**	**Semester:**	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
2024-2026	M.Sc. Mathematics	IV	3	0	2	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2hours), End Term (3 hours) **Pre-requisite of course:** Nil
Course Objective	This course will develop a profound understanding of multivariate statistics and stochastic processes. The students will learn the concepts of different multivariate distributions along with their applications. Under this course, the students will also learn the concepts of Markov chains. Further a deep understanding of associations between sets of variables and important patterns within data along with the concepts of Poisson, Birth, Death and Renewal processes will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Understand and apply the fundamental concept of multivariate data analysis. **CO2:** Learn different multivariate distributions and apply them to real-life problems. **CO3:** Discriminate objects under study and assess the adequacy of classification. **CO4:** Identify and quantify the associations between the sets of variables and important patterns within the data. **CO5:** Understand and underlying concepts of stochastic processes. **CO6**: Model systems and phenomena that appear to vary in a random manner. **CO7:** Understand the concept of Markov chains and classification of states. **CO8:** Learn Poisson, Birth, Death and Renewal processes and their applications in various scenarios. **CO9:** Know the queuing processes.

COURSE SYLLABUS

Module No.	**Content**	**Hours**
I	**[Course Outcome(s) No.: 1, 2, 3 and 4]** Multivariate normal distribution, moment generating function and Characteristic function, marginal and conditional distributions, multiple and partial correlation coefficients. Wishart distribution and its properties. Distribution of Hotelling's T^2 statistic, Mahalanobis' D^2, and their applications. Discrimination between two multivariate normal populations, Principal components, their maximum likelihood estimators and sample variances, Canonical correlations and variables, Factor analysis, Estimation of factor loadings, Factor rotation, Estimation of factor scores.	20
II	**[Course Outcome(s) No.: 5, 6, 7, 8 and 9]** Two state Markov sequences, Markov chains, determination of n-step transition probabilities, Chapman-Kolmogorov equations, first return and first passage probabilities, classification of states, communicating states, periodicity, stationary probability distributions and limit theorems for ergodic chains. Continuous time Markov processes, Poisson (point) process, Inter arrival time distribution, Random walk and Brownian motion as a random walk, gambler's ruin problem. Birth and death processes, renewal processes, renewal processes-ordinary, modified, equilibrium, renewal functions. Integral equation of renewal theory. Distribution of the number of renewals. The elementary renewal theorem, Queueing Theory: M/M/1, M/M/k and M/G/1 queueing processes.	20

Text Books:

- T. W. Anderson, An Introduction to Multivariate Statistical Analysis, Wiley, 2009.
- R. A. Johnson, & D. W. Wichern, Applied Multivariate Analysis, Wiley, 2002.
- M. S. Srivastava, & C.G. Khatri, Introduction to multivariate statistics, North-Holland, 1979.
- N. C. Giri, Multivariate statistical inference, Academic Press, 1977.
- S. R. Adke & S. M. Manjunath, An Introduction to Finite Markov Processes, Wiley Eastern, 1984.
- E. Cinlar, Introduction to Stochastic Processes, Prentice Hall, 1975.
- W. Feller, Introduction to Probability and Applications, New Age India International, 1968.
- T. E. Harris, The Theory of Branching Processes, Springer Verlag, 1963.

Reference Books:

- A. M. Kshirsagar, Multivariate analysis, Marcel Dekker, 1972.
- R. J. Muirhead, Aspects of Multivariate Statistical Theory, Wiley Interscience, 1982.
- A. C. Rencher, Multivariate Statistical Inference and its Applications, Wiley Interscience, 1998.
- P. G. Hoel, S. C. Port, & C. J. Stone, Introduction to Stochastic Processes, University Book Stall,1991.
- S. Karlin, & H. M. Taylor, A First Course in Stochastic Processes, Academic Press, 1995.
- J. Medhi, Stochastic Processes, New Age India International, 2012.
- S. M. Ross, Stochastic Processes, John Wiley & Sons Inc, 1996.

<table>
<tr><td>Course No: 9</td><td colspan="2">Course Name: Big Data Analytics</td><td colspan="6">Course Code: MMAE 0107</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme:
M.Sc.
Mathematics</td><td rowspan="2">Semester:
IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week:4</td></tr>
<tr><td>3</td><td>0</td><td>2</td><td>0</td><td>4</td><td>Total Hours: 40</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Nil</td></tr>
</table>

Course Objective	This course will develop a basic understanding of big data and appropriate techniques to solve real-life data problems. The students will learn to analyze the big data with tools like Hadoop, Map Reduce and Big SQL. Further, a deep understanding of Managing streaming data, and applying algorithms to find similar items will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Understand the basic concept of Big data. **CO2:** Apply appropriate techniques to solve real-life data problems. **CO3:** Analyze big data with tools like Hadoop, MapReduce and Big SQL. **CO4:** Manage streaming data, and apply algorithms to find similar items.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1, 2 and 3]** Introduction to Big Data, Characteristics of Big Data and Scalability. **Hadoop:** History of Hadoop, Apache Hadoop, Analysing Data with Unix tools, Analysing Data with Hadoop, Hadoop Distributed File System. **Map Reduce:** Anatomy of a Map Reduce Job Run, Failures, Job Scheduling, Shuffle and Sort, Task Execution, Map Reduce Types and Formats, Map Reduce Features. **Hadoop Ecosystem:** Pig, Hive, Hbase, Big SQL.	20
II	**[Course Outcome(s) No.: 4]** Near-Neighbor search, Shingling documents, Similarity preserving summary of sets, Different distance measures, Locality sensitive hashing and its applications. **Mining data streams:** Stream Data model, Sampling data in a stream, Filtering streams, counting distinct elements in a stream, Application of stream algorithms in counting. **Finding Frequent Items:** Market-Basket Analysis, Market-baskets and Apriori algorithm, Limited pass algorithms, Counting frequent sets in a stream. **Link Analysis:** Page Rank, Computation of Page Rank, Topic sensitive page rank, Link spam.	20

Text Books:

- J. Leskovec, A. Rajaraman, & J. D. Ullman, Mining of Massive Datasets, Cambridge University Press, 2020.
- Z. Radtka & D. Miner, Hadoop with Python. O'Reilly Media, 2016.

References Books:

- T. White, Hadoop - The Definitive Guide, O'Reilly Media, 2012.
- S. Acharya, & S. Chellappan, Big Data and Analytics, Wiley, 2015.

<table>
<tr><td colspan="2">Course No: 10</td><td colspan="3">Course Name: Cloud Computing</td><td colspan="5">Course Code: MCAE 0306</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2" colspan="2">Programme:
M.Sc. Mathematics</td><td rowspan="2">Semester:
IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week:3</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>0</td><td>3</td><td>Total Hours:30</td></tr>
<tr><td colspan="3" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="9">This course covers aims to explain various technologies related to Cloud Computing and their Practical implementations, discuss different architectural models of cloud computing, the concepts of virtualization and cloud orchestration. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="9">After successful completion of this student will be able to:
CO1: Describe importance of virtualization along with their technologies like system, network, and storage virtualizations.
CO2: Identify the architecture and infrastructure of cloud computing, including SaaS, PaaS, IaaS, XaaS, Public Cloud, Private Cloud, Hybrid Cloud and the core issues of cloud computing such as security, privacy, and interoperability.
CO3: Justify the need of new technology of Virtualization & Cloud Computing and its ecological impact.
CO4: Identify the known threats, risks, vulnerabilities and privacy issues associated with Cloud based IT services.
CO5: Apply fundamental concepts in cloud infrastructures to understand the tradeoffs in power, efficiency and cost.
CO6: Identify the Challenges in managing heterogeneous clouds.
CO7: Analyze various cloud programming models and apply them to solve problems on the cloud.
CO8: Describe the key components of Amazon web Service.</td></tr>
<tr><td colspan="10">COURSE SYLLABUS</td></tr>
<tr><td>Module No.</td><td colspan="8">Content</td><td>Hours</td></tr>
<tr><td>I</td><td colspan="8">[Course Outcome(s) No.: 1, 2, 3]
Overview of Cloud Computing- Brief history and Evolution of Cloud Computing, Traditional vs. Cloud Computing, Importance of Cloud Computing, Cloud service models (IaaS, PaaS & SaaS). Cloud deployment models (Public, Private, Hybrid and Community Cloud), Benefits and Challenges of Cloud Computing.
Working with Private Cloud –Concept of Hypervisor, Basics of virtualization, Virtualization technologies, Server virtualization, VM migration techniques, Role of virtualization in Cloud Computing. Business cases for the need of Cloud computing environment, Concept of Private Cloud, Characteristics of Private Cloud, Private Cloud deployment models, Private Cloud Vendors, Private Cloud Building blocks (Physical Layer, Virtualization Layer, Cloud Management Layer), Virtual Private Cloud. Case study on (one out of CloudStack, OpenStack, Eucalyptus, IBM or Microsoft).
Working with Public Clouds –Concept of Public Cloud, Importance of Public Cloud, When to opt for Public Cloud, Public Cloud Service Models, and Public Cloud players. Infrastructure as a Service Offerings, IaaS Vendors, PaaS offerings, PaaS vendors, Software as a Service. Implementing public cloud (one out of AWS, Windows Azure, IBM or Rackspace).</td><td>20</td></tr>
</table>

II	**[Course Outcome(s) No.: 4, 5, 6, 7 and 8]** **Overview of Cloud Security -**Security concerns in Traditional IT, Challenges in Cloud Computing in terms of Application, Server, and Network Security. Security reference model, Abuse and Nefarious Use of Cloud Computing, Insecure Interfaces and APIs (Malicious Insiders, Shared Technology Issues, Data Loss or Leakage, Account or Service Hijacking, Unknown Risk Profile), Attacks in Cloud Computing, Vendors offering Cloud Security for public and private clouds. **Overview of Multi-Cloud Management Systems-** Explain concept of multi-cloud management, Challenges in managing heterogeneous clouds, benefits of multi-cloud management systems. Case study on Multi-Cloud Management System (Right Scale Cloud Management System) **Business Clouds-** Cloud Computing in Business, Various Biz Clouds focused on industry domains (Retail, Banking and Financial sector, Life Sciences, Social networking, Telecom, Education). Cloud Enablers (Business Intelligence on cloud, Big Data Analytics on Cloud), Role of Cloud computing in SCM and CRM. Future directions in Cloud Computing - Future technology trends in Cloud Computing with a focus on Cloud service models, deployment models, cloud applications, and cloud security. Migration paths for cloud, Selection criteria for cloud deployment. Current issues in cloud computing leading to future research direction.	20

Text Book:

- R. Buyya, J. Broberg & A. Goscinski, Cloud Computing: Principles and Paradigms, Wiley, 2011.

Reference Books:

- A. Velte, T. Velte & R. Elsenpeter, Cloud Computing A Practical Approach, McGraw Hill Education, 2010.
- J. F. Ransome & J. W. Rittinghouse, Cloud Computing: Implementation, Management and Security, CRC Press Inc, 2009.
- B. Sosinsky, Cloud Computing Bible, Wiley, 2011.
- J. Rhoton & R. Haukioja, Cloud Computing Architected: Solution Design Handbook, Recursive Limited, 2011.
- R. L. Krutz, & R. D. Vines, Cloud Security: A comprehensive Guide to Secure Cloud Computing, John Wiley & Sons, 2010.

Course No: 11	**Course Name:** Cloud Computing Lab	**Course Code:** MCAE 0372						
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:2**
			0	0	2	0	1	**Total Hours:20**

Total Evaluation Marks: 100 **Internal:** 50 Marks **External:** 40 Marks **Attendance**: 10 Marks	**Examination Duration:** End Term (2 hours) **Pre-requisite of course:** Nil
Course Objective	This lab aims to understand the concept of cloud and virtualization by the help of VMware. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After completion of Lab, student will be able to: **CO1:** Understanding about the virtualization by the help of VMware. **CO2:** Understanding of CISCO packet tracer to build a cloud network infrastructure. **CO3:** Explain the key components of Amazon web Service and Microsoft Azure.

COURSE SYLLABUS

Module No.	Content	Hours
I	1. a) Introduction to Packet Tracer. b) Network Topologies. (Including explanation of Simple PDU & Complex PDU.) 2. Connecting 3 netwoks using routers. Also, configure DHCP and DNS server. 3. Configuration of different Application services (SMTP, FTP, HTTP, TFTP, DHCP & DNS) 4. Configuration of Vlan and Inter- Vlan Routing. 5. Configure GRE over IP tunnel (VPN). 6. Static NAT configuration. 7. Configure Wireless network. 8. Configure different IoT devices. 9. Study on VMware a. Creating a VM b. Networking on VM c. Merging and splitting disk on VM d. Cloning the guest OS e. Deploying VM with template f. Creating Snapshots g. Managing Users, Groups, Permissions and Roles 10. Crating a EC2 instance on AWS 11. Configuration of db in AWS. 12. Creation of S3 bucket with single IAM user in AWS.	20

Text/Reference Book:

- R. Buyya, J. Broberg & A. Goscinski, Cloud Computing: Principles and Paradigms, Wiley, 2011.

Course No: 12	Course Name: Statistical Inference					Course Code: MMAE 0108		
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** III/IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
			3	0	2	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Probability theory and Distributions
Course Objective	This course will develop a profound understanding of estimators, their characteristics and types. The students will learn the concepts of point and interval estimations and be able to test the hypothesis. Further, a deep understanding of large sample tests and non-parametric tests will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Understand the concept of a Statistic and use it for estimation purpose. **CO2:** Understand the notions of estimation theory and apply it to derive various estimates for different distributions. **CO3:** Apply the theorems directly to obtain the best estimates for the parameters. **CO4:** Differentiate between the concepts of point estimation and interval estimation and use them efficiently. **CO5:** Apply hypothesis testing for both simple and composite cases. **CO6:** Understand and apply large sample tests. **CO7:** Understand the difference between parametric and non-parametric methods of estimation.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1, 2, 3 and 4]** **Estimation Theory:** Parameters, statistic, estimator, characteristics of a good estimator, consistency, Unbiasedness, Sufficiency-factorization theorem, Minimal Sufficiency. Efficiency-Most Efficient estimator, Minimum Variance Unbiased (M. V. U.) Estimators. Completeness, Lehmann-scheffe's theorem, Rao-Blackwell theorem, Uniformly minimum variance unbiased estimator (UMVUE). **Point and Interval Estimation:** Maximum Likelihood Estimation, Method of Moments, Method of Least Squares, confidence intervals and its construction for mean & variance of a normal population, confidence limits.	20
II	**[Course Outcome(s) No.: 5, 6 and 7]** **Testing of Hypothesis:** Most Powerful Test (MP), Uniformly Most Powerful (UMP) tests, Likelihood Ratio Tests, Testing for mean and equality of variances for a Normal Population. **Large Sample Tests:** Test of significance of large samples, Sampling of attributes, test for single proportion, test for difference of proportions, test of significance for single mean, difference of means and standard deviations. **Non-Parametric Tests:** Sign Test, Signed Rank Test, Median Test, Mann-whitney test, Run Test, one sample Kolmogorov-Smirnov test, Kruskal-Wallis test. (Properties and Applications based, no proofs)	20

Text Books:

- V. K. Rohtagi. Statistical Inference, Dover Publications, 2013.
- C. R. Rao, Linear Statistical Inference and its applications, Wiley, 2009.

Reference Books:

- G. Casella & R. L. Berger, Statistical Inferenc, Cengage India Private Limited, 2007.
- R. Hogg, A Craig, & J. McKean, Introduction to Mathematical Statistics, Pearson, 2012.

<table>
<tr><td>Course No: 13</td><td colspan="2">Course Name: Actuarial Statistics</td><td colspan="6">Course Code: MMAE 0109</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme:
M.Sc. Mathematics</td><td rowspan="2">Semester:
III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week:4</td></tr>
<tr><td>3</td><td>0</td><td>2</td><td>0</td><td>4</td><td>Total Hours: 40</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="8">This course will develop a basic understanding of vital statistics and life tables. The students will learn the related concepts to insurance and annuities. Further, a deep understanding of probability models related to actuaries will be developed in this course. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="8">CO1: Understand the concept of vital statistics and life tables.
CO2: Understand and apply probability models related to actuaries.
CO3: Analyze claims by the use of poisson distribution.
CO4: Learn and understand the related concept to insurance and annuities.</td></tr>
</table>

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome (s) No.: 1, 2 and 3]** Utility theory, insurance and utility theory, models for individual claims and their sums, survival function, curtate future lifetime, force of mortality. Life table and its relation with survival function, examples, assumptions for fractional ages, some analytical laws of mortality, select and ultimate tables. Multiple life functions, joint life and last survivor status, insurance and annuity benefitsthrough multiple life functions evaluation for special mortality laws. Multiple decrement models, deterministic and random survivorship groups, associatedsingle decrement tables, central rates of multiple decrement, net single premiums and theirnumerical evaluations. Distribution of aggregate claims, compound Poisson distribution and its applications.	20
II	**[Course Outcome(s) No.: 4]** Principles of compound interest. Nominal and effective rates of interest and discount, forceof interest and discount, compound interest, accumulation factor, continuous compounding. Life insurance: Insurance payable at the moment of death and at the end of the year ofdeath-level benefit insurance, endowment insurance, diferred insurance and varying benefitinsurance, recursions, commutation functions. Life annuities: Single payment, continuous life annuities, discrete life annuities, lifeannuities with monthly payments, commutation functions, varying annuities, recursions, completeannuities-immediate and apportionable annuities-due. Net premiums: Continuous and discrete premiums, true monthly payment premiums,apportionable premiums, commutation functions, accumulation type benefits.Payment premiums, apportionable premiums, commutation functions, accumulation typebenefits.Net premium reserves: Continuous and discrete net premium reserve, reserves on asemicontinuous basis, reserves based on true monthly premiums, reserves on an apportionable ordiscounted continuous basis, reserves at fractional durations, allocations of loss to policy years,recursive formulas and differential equations for reserves, commutation functions. Some practical considerations: Premiums that include expenses-general expenses types ofexpenses, per policy expenses.Claim amount distributions, approximating the individual model, stop-loss insurance.	20

Text Books:

- M. E. Atkinson & D.C.M. Dickson, An Introduction to Actuarial Studies, Edward Elgar Publishing, 2000.
- T. Bedford & R. Cooke, Probabilistic Risk Analysis: Foundations and Methods, Cambridge University Press, 2001.
- N. L. Bowers, H. U. Gerber, J. C. Hickman, D. A. Jones & C. J. Nesbitt, Actuarial Mathematics, Society of Actuaries, 1997.
- P. K. Medina, & S. Merino, Mathematical Finance and Probability: A Discrete Introduction, Birkhauser Verlag AG, 2003.
- A. Neill, Life Contingencies, Butterworth-Heinemann, 1977.

Reference Books:

- P. Booth, R. Chadburn, D. Cooper, S. Habermann & D. James, Modern Actuarial Theory and Practice, Chapman and Hall, 1998.
- T. Rolski, H. Schmidli, V. Schmidt & J. Teugels, Stochastic Processes for Insurance and Finance, John Wiley, 1998.
- E. F. Spurgeon, Life Contingencies, Cambridge University Press, 2011.

Course No: 14	**Course Name:** Statistical Computing							**Course Code:** MMAE 0111
Batch:	**Programme:**	**Semester:**	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
2024-2026	M.Sc. Mathematics	IV	3	0	2	0	4	**Total Hours: 40**

TotalEvaluationMarks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Stochastic Processes
Course Objective	This course will develop a profound understanding of the computational methods applicable to Statistics. This course also includes numerical methods for solving problems. Further, a deep understanding of simulation of data through different procedures and Monte-Carlo method will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	**CO1:** Understand the Computational methods applicable to statistics. **CO2:** Apply numerical methods for solving problems. **CO3:** Simulate data through different procedures. **CO4:** Understand and apply Monte Carlo methods.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1 and 2]** Concept of central limit theorem and Markov chain. Pseudo-Random number generation, tests, Requisites of a good random number generator, Generation of random observations through inverse cdf, acceptance rejection and transformation methods. Simulation of Random Walk process. Numerical methods: Vector and matrix operations, Interpolation. Numerical root finding, matrix factorization. Eigenvalue and eigenvectors, simple optimization method-direct search, grid search, interpolatory search, gradient search. Newton-Raphson method, Muller's method, Aitken's extrapolation.	20
II	**[Course Outcome(s) No.: 3 and 4]** Expectation-Maximization (EM) Algorithm and Applications: EM algorithm for missing data and mixture models. Methods to compute integrals: Quadrature formula, double integration, Gaussian integration. Monte Carlo Methods: Monte Carlo integration and applications of Monte Carlo methods. Metropolis- Hastings and Gibbs sampling and related methods.	20

Text Books:

- S. V. Buuren, Flexible Imputation of Missing Data, Chapman and Hall/CRC, 2012.
- C. P. Robert & G. Casella, Monte Carlo Statistical Methods, Springer-Verlag, 2010.

Reference Books:

- W. R. Gilks, S. Richardson & D. Spiegelhalter, Markov Chain Monte Carlo in Practice, Chapman and Hall/CRC, 1995.
- W. J. Kennedy & J. E. Gentle, Statistical Computing, Routledge, 2021.

Course No: 15	**Course Name:** Artificial Intelligence for Data Science							**Course Code:** MMAE 0112
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** III/IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
			3	0	2	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Nil
Course Objective	This course will develop a profound understanding of Artificial Intelligence methods and their applications to real-life data problems. This course includes the applications of optimizing algorithm in problems to find the optimal solution quickly. Further, a deep understanding of techniques to read text, hear speech, and interpret it will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	**CO1:** Identify suitable Artificial Intelligence methods to real-life data problems. **CO2:** Understand the foundations of Artificial Intelligence. **CO3:** Apply Optimizing algorithm to problems to find the optimal solution quickly. **CO4:** Apply techniques to read text, hear speech, and interpret it.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1 and 2]** The AI problems, AI technique, philosophy and development of Artificial intelligence. State-space search, Uninformed and informed search techniques: BFS, A*, variations of A*. Local search and optimization: hill-climbing, simulated annealing. Minimax algorithm, alpha-beta pruning, stochastic games, Constraint- satisfaction problems. Logical agents, Propositional logic, First-order logic, Inference in FoL: forward chaining, backward chaining, resolution, Knowledge representation: Frames, Ontologies, Semantic web and RDF.	20
II	**[Course Outcome(s) No.: 3 and 4]** Facts and predicates, data types, goal finding, backtracking, simple object, compound objects, use of cut and fail predicates, recursion, lists, simple input/output, dynamic database. Probabilistic reasoning, Bayesian networks, Fuzzy logic. **Natural language Understanding**: Introduction to Languages and Grammars - Transformational Grammars of Natural Language, Two-Level Representation, Transition Networks from Grammar to Acceptor. Two Level Processing Systems RTN's and ATN's- Issues and Applications.	20

Text Book:

- D. Khemani, First Course in Artificial Intelligence, McGraw-Hill Education, 2018.

Reference Book:

- S. Russell & P. Norvig, Artificial Intelligence: A Modern Approach, Pearson Education: Upper Saddle River, 2010.

Course No: 16	**Course Name:** Pattern Recognition							**Course Code:** MMAE 0113
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** III/IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
			3	0	2	0	4	**Total Hours: 40**

Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks

Examination Duration: Mid Term (2 hours), End Term (3 hours)

Pre-requisite of course: Regression Analysis and Predictive Modelling; Multivariate Analysis

Course Objective	This course will develop a basic understanding of algorithms to automatically recognize pattern and regularities with their applications in real-life data problems. The students will learn the concepts of discriminant functions for classification. Further, a deep understanding of clustering algorithms to detect unusual patterns in the data will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	**CO1:** Apply algorithms to automatically recognize pattern and regularities in real-life data problems. **CO2:** Implement linear and non-linear classifiers to find hidden patterns. **CO3:** Use discriminant functions for classification. **CO4:** Understand and apply clustering algorithms to detect unusual patterns in the data.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1, 2 and 3]** Introduction, Features, Feature Vectors, Classifiers, Supervised, Unsupervised and Semi-Supervised Learning. Introduction to Bayes Decision Theory, Discriminant Functions, Bayes Classification for Normal Distributions, Estimation of Unknown Probability Distributions: ML Parameter Estimation, MAP Estimation, Bayesian Inference, Maximum Entropy Estimation, Mixture Models, Non-Parametric Estimation. The Naïve-Bayes Classifier, Bayesian Networks. Introduction to Linear Discriminant Functions and Decisions, Logistic Discrimination, Support Vector Machines for Separable Classes, SVM for Non-Separable Classes, SVM for Multiclass Case.	20
II	**[Course Outcome(s) No.: 2 and 4]** **Non-Linear Classifiers**: Two Layer and Three layer Perceptrons, Algorithms based on Exact Classification of Training Set, The Back-Propagation Algorithm, Generalized Linear Classifiers, Capacity of d-dimensional space in linear Dichotomies, Polynomial Classifiers, Radial Basis Function Networks, Universal Approximators, Probabilistic Neural Networks, SVM-Nonlinear Case, Combining Classifiers, Boosting, Class Imbalance Problem. **Clustering**: Introduction, Proximity Measures, Sequential Clustering Algorithms, Agglomerative Algorithms, Divisive Algorithms, Hierarchical Algorithms for Large Datasets, Hard Clustering Algorithms. Algorithms based on Graph Theory, Competitive Learning algorithms.	20

Text Book:

- S. Theodoridis & K. Koutroumbas, Pattern Recognition, Academic Press, 2008.

Reference Book:

- M. N. Murty & V. S. Devi, Introduction to Pattern Recognition and Machine Learning, World Scientific, 2015.

Course No: 17	**Course Name:** Design of Experiments and Analysis of Variance						**CourseCode:** MMAE 0114	
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** III/IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
			3	0	2	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Nil
Course Objective	This course will develop a basic understanding of design and application of suitable designs to real-life data problems. This course includes the application of the result of block designs and general factorial experiments. Further, a deep understanding of split plot experiment will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	**CO1:** Undestand the basic concepts of design. **CO2:** Apply suitable designs to real-life data problems. **CO3:** Estimate contrasts and different effects of the design and build an efficient model. **CO4:** Understand and apply the result of block designs and general factorial experiments. **CO5:** Efficiently apply the concept of split plot experiment to real-life data problems.

COURSE SYLLABUS

Module No.	**Content**	**Hours**
I	**[Course Outcome(s) No.: 1, 2 and 3]** Review of linear estimation and basic designs. ANOVA: Fixed effect models (Two-way classification with unequal and proportional number of observations per cell), Random and Mixed effect models (Two-way classification with m (>1) observations per cell). Tukey's test, general two-way classification. Intra and inter block analysis of Incomplete block design.	20
II	**[Course Outcome(s) No.: 3, 4 and 5]** General block design and its information matrix (C). Criteria for connectedness, balanced and orthogonality: Balanced Incomplete Block Design (BIBD) – Intra and inter block analysis, Simple lattice designs. Association schemes and partially balanced incomplete block designs – construction and parameter identification, Analysis of covariance. General factorial experiments, factorial effects, study of 2^n and 3^nfactorial experiments in randomized blocks, complete and partial confounding, construction of confounded factorial experiments, split plot experiment.	20

Text Books:

- M. N. Das & N. Giri, Design and Analysis of Experiments, New Age Publishers, 2017.
- A. Dean & D. Voss, Design and Analysis of Experiments, Springer, 1999.
- A. Dey, Theory of Block Designs, Wiley Eastern, 1986.
- N. Giri, Analysis of Variance, South Asian Publishers, 1986.

Reference Books:

- D. D. Joshi, Linear Estimation and Design of Experiments, Wiley Eastern, 1987.
- C. D. Montgomery, Design and Analysis of Experiments, Wiley, 1976.
- H.Toutenburg & Shalabh, Statistical Analysis of Designed Experiments, Springer, 2009.

<table>
<tr><td colspan="2">Course No: 18</td><td colspan="2">Course Name: Statistical Quality Control</td><td colspan="6">Course Code: MMAE 0115</td></tr>
<tr><td rowspan="2" colspan="2">Batch:
2024-2026</td><td rowspan="2">Programme: M.Sc. Mathematics</td><td rowspan="2">Semester:
III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week:4</td></tr>
<tr><td>3</td><td>0</td><td>2</td><td>0</td><td>4</td><td>Total Hours: 40</td></tr>
<tr><td rowspan="2" colspan="3">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="9">This course will develop a profound understanding of suitable charts used in the industries. This course includes the creation of inspection plans. Further, a basic understanding of control charts, process control and product control will be developed in this course. This course focuses on employability and skill development aligned with all CO's.</td></tr>
<tr><td>Course Outcomes</td><td colspan="9">CO1: Identify and apply suitable charts in the industries.
CO2: Understand the basic concept of control charts and their applications.
CO3: Create sampling inspection plans.
CO4: Understand the basics of process control and product control.</td></tr>
</table>

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1 and 2]** **Statistical Quality Control** (S.Q.C.): Introduction, Chance causes and Assignable causes of variation, Benefits of S.Q.C., Process control and product control, Control limits, specification limits and tolerance limits, Tools for statistical quality control. **Control charts for variables**: $\bar{X}$ and R charts, Criterion for detecting lack of control in these charts, Interpretation of charts.Control chart for standard deviation ($\sigma -$ chart). **Quality control and Sampling Inspection**: Basic concepts of process monitoring and control, General theory and review of control charts, O.C and ARL of control charts, CUSUM charts using V-mask and decision intervals, economic design of x- bar chart.	20
II	**[Course Outcome(s) No.: 3 and 4]** **Control charts for attributes**: Control chart for fraction defective (p-chart), Interpretation, Control chart for number of defectives (d-chart or np-chart), Interpretation, Control chart for number of defects per unit (c-chart), c-chart for variable sample size (u-chart), Applications of c-chart. Natural tolerance limits and specification limits, modified control limits. Acceptance sampling inspection plans, Sampling inspection plans for attributes. Review of sampling inspection techniques, single, double, multiple and sequential sampling plans and their properties, methods for estimating (n, c) using large sample and Bayesian techniques, curtailed and semi-curtailed sampling plans, Dodge's continuous sampling inspection plans for inspection by variables for one-sided and two-sided specifications.	20

Text Books:

- D. C. Montgomery, Introduction to Statistical Quality Control, John Wiley & Sons, 2008.
- G. B. Wetherill, Sampling Inspection and Quality Control, Chapman and Hall, 2013.

Reference Book:

- Schilling, G. Edward, Neubauer & Dean V, Acceptance Sampling in Quality Control, Chapman and Hall/CRC, 2009.

<table>
<tr><td>Course No: 19</td><td>Course Name: Bio-Statistics</td><td colspan="7">Course Code: MMAE 0116</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme:
M.Sc.
Mathematics</td><td rowspan="2">Semester:
III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week:4</td></tr>
<tr><td>3</td><td>0</td><td>2</td><td>0</td><td>4</td><td>Total Hours: 40</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Statistical Inference</td></tr>
<tr><td>Course Objective</td><td colspan="8">This course will develop a profound understanding of important survival distributions and their applications to real-life data problems. The students will learn the concepts of different censoring techniques to model the real data. Further, a deep understanding of stochastic epidemic models will be developed in this course. This course focuses on employability and skill development aligned with all CO's.</td></tr>
<tr><td>Course Outcomes</td><td colspan="8">CO1: Understand and apply important survival distributions to real-life data problems.
CO2: Analyze epidemiological data and clinical data.
CO3: Apply different censoring techniques to model the real data.
CO4: Understand stochastic epidemic models and design clinical trials.</td></tr>
</table>

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1, 2 and 3]** Functions of survival time, survival distributions and their applications viz. exponential, gamma, Weibull, Rayleigh, Lognormal, death density function for a distribution having bath-tubshape hazard function. Tests of goodness of fit for survival distributions (WE test for exponential distribution, W-test for lognormal distribution, Chi-square test for uncensored observations). Parametric methods for comparing two survival distributions viz. L.R test, Cox's F-test. P-value, Analysis of Epidemiologic and Clinical Data: Studying association between a disease and a characteristic: (a) Types of studies in Epidemiology and Clinical Research (i) Prospective study (ii)Retrospective study (iii) Cross-sectional data, (b) Dichotomous Response and Dichotomous Risk Factor: 2 X 2 Tables (c) Expressing relationship between a risk factor and a disease (d) Inference forrelative risk and odds ratio for 2X2 table, Sensitivity, specificity and predictivities, Coxproportional hazard model. Type I, Type II and progressive or random censoring with biological examples, Estimationof mean survival time and variance of the estimator for type I and type II censored data withnumerical examples. Non-parametric methods for estimating survival function and variance of theestimator viz. Acturial and Kaplan –Meier methods.	20
II	**[Course Outcome(s) No.: 4]** Competing risk theory, Indices for measure-ment of probability of death under competingrisks and their inter-relations. Estimation of probabilities of death under competing risks bymaximum likelihood and modified minimum Chi-square methods. Theory of independent anddependent risks. Bivariate normal dependent risk model. Conditional death density functions. **Stochastic epidemic models**: Simple and general epidemic models (by use of random variable technique). Basic biological concepts in genetics, Mendels law, Hardy-Weinberg equilibirium, randommating, distribution of allele frequency (dominant/co-dominant cases), Approach to equilibiriumfor X-linked genes, natural selection, mutation, genetic drift, equilibirium when both naturalselection and mutation are operative, detection and estimation of linkage in heredity. Planning and design of clinical trials, Phase I, II, and III trials. Consideration in planning aclinical trial, designs for comparative trials. Sample size determination in fixed sample designs.	20

Text Books:

- S. Biswas, Applied Stochastic Processes: A Biostatistical and Population Oriented Approach, New Central Book Agency, 2007.
- D. Collett, Modelling Survival Data in Medical Research, Chapman & Hall/CRC, 2003.
- D. R. Cox & D. Oakes, Analysis of Survival Data, Chapman and Hall, 1984.
- R. C. E. Johnson, Probability Models and Statistical Methods in Genetics, John Wiley & Sons, 1971.
- W. J. Ewens, Mathematics of Population Genetics, Springer Verlag, 1979.
- W. J. Ewens & G.R. Grant, Statistical methods in Bio informatics: AnIntroduction, Springer, 2001.

Reference Books:

- L. M. Friedman, C. Furburg, & D. L. DeMets, Fundamentals of Clinical Trials, Springer Verlag, 1998.
- A. J. Gross & V. Clark, Survival Distribution; Reliability Applications in Biomedical Sciences, John Wiley & Sons, 1975.
- A. Indrayan, Medical Biostatistics, Chapman & Hall/CRC, 2008.
- E. T. Lee & J. Wang, Statistical Methods for Survival Data Analysis, Wiley–Blackwell, 2003.
- C. C. Li, First Course in Population Genetics, Boxwood Press, 1976.

<table>
<tr><td>Course No: 20</td><td colspan="2">Course Name: Data Mining and Warehousing</td><td colspan="6">Course Code: BCSE 0152</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme:
M.Sc. Mathematics</td><td rowspan="2">Semester:
III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week: 3</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>0</td><td>3</td><td>Total Hours: 30</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Nil</td></tr>
</table>

Course Objective	The Objective of this course is to introduce the basic concepts of Data Warehouse and Data Mining techniques. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Understand and apply the concept of data warehouse and mining in real-life applications. **CO2:** Apply the principle algorithms used in modern machine learning. **CO3:** Apply the information theory and probability theory to get the basic theoretical results in Data Mining. **CO4:** Apply Data mining algorithms to real datasets, evaluate their performance and appreciate the practical issues involved. **CO5:** Implement clustering using various clustering methods on data set.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1, 2 and 3]** **Data Warehousing:** Overview, Difference between Database System and Data Warehouse, Multi-dimensional Data Model: Concept Hierarchy, Three-Tier Architecture, Meta Repository, Data Warehouse & OLAP Technology, Types of OLAP Servers. Data Cubes Computations & Data Generalization. **Data Pre Processing:** Data Cleaning, Data Integration and Data Transformation, Data Reduction **Mapping the Data Warehouse** to a Multiprocessor Architecture, Multi-Dimensional Data Model. **Introduction:** Basics of Data Mining, Issues and Applications of Data Mining Techniques. Mining frequent Patterns: Basic Concepts of Association Rules Mining, Apriori Algorithm, FP-Growth. Multilevel Association Rules, Multi-Dimensional Association Rules.	15
II	**[Course Outcome(s) No.: 4 and 5]** **Classification and Predictions:** Classification & Prediction, Issues Regarding Classification and Prediction, Decision Tree, Bayesian Classification, Back Propagation, Neural Network, Nearest Neighbour Classifiers, Support Vector Machines, Prediction. **Data Mining Cluster Analysis:** Data Types in Cluster Analysis, Categories of Clustering Methods, Partitioning Methods. **Hierarchical Clustering**- CURE and Chameleon. **Density Based Methods**-DBSCAN, OPTICS. Grid Based Methods STING, CLIQUE. **Model Based Method** –Statistical Approach, Outlier Analysis, Mining Multimedia Data, Text Mining, Web Data Mining, Spatial Data Mining, Temporal Data Mining, Data Visualization.	15

Text Book:

- J. Han, M. Kamber & J. Pei, Data Mining Concepts and Techniques, Morgan Kauffmann, 2011.

Reference Books:

- M. H. Dunham, Data Mining: Introductory and Advanced Topics, Pearson Education, 2006.
- S. Anahory & D. Murray, Data Warehousing in the Real World: A Practical Guide for Building Decision Support Systems, Addison-Wesley, 1997.
- P. N. Tan, M. Steinbach & V. Kumar, Introduction to Data Mining, Pearson Education, 2016.
- C. C. Aggarwal, Data Mining: The Textbook, Springer, 2015.

<table>
<tr><td colspan="2">Course No: 21</td><td colspan="3">Course Name: Data Mining and Warehousing Lab</td><td colspan="6">Course Code: BCSE 0181</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2" colspan="2">Programme:
M.Sc. Mathematics</td><td rowspan="2">Semester:
III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td colspan="2">Contact Hrs. Per Week: 2</td></tr>
<tr><td>0</td><td>0</td><td>2</td><td>0</td><td>1</td><td colspan="2">Total Hours: 24</td></tr>
<tr><td colspan="3" rowspan="2">Total Evaluation Marks: 100

Internal: 50 Marks
External: 40 Marks
Attendance: 10 Marks</td><td colspan="8">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="8">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="10">The Objective of this course is to implement and run the programme based on the basic concepts of Data Warehouse and Data Mining techniques. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="10">After studying these topics, the students will be able to:
CO1: Implement the clustering technique like DBSCAN, K-NN, K Mean.
CO2: Implement SVM on two dimensional data set.</td></tr>
<tr><td colspan="11">COURSE SYLLABUS</td></tr>
<tr><td>Module No.</td><td colspan="9">Content</td><td>Hours</td></tr>
<tr><td>I</td><td colspan="9">[Course Outcome(s) No.: 1 and 2]
• Demonstration of pre-processing on different dataset
• Demonstration of Association rule process on different dataset using apriori algorithm
• Demonstration of classification rule process on different dataset using FP Tree algorithm
• Demonstration of classification rule process on different dataset using id3 algorithm
• Demonstration of classification rule process on different dataset using naïve bayes algorithm
• Demonstration of clustering rule process on different dataset using simple k-means
• Demonstration of clustering rule process on different dataset using simple k-mediods
• Demonstration of clustering rule process on different dataset using simple k-mode.
• Demonstration of clustering rule process on different dataset using DBSCAN.
• Demonstration of clustering rule process on different dataset using simple Hieratical based algorithm.
• Implementation of K-NN Algorithms on different data sets.
• Implementation of Sequential pattern SPADE algorithm on sequence data set.
• Implementation of Sequential pattern GSP algorithm on sequence data set.
• Implementation of SVM on a two dimensional data set.
• Demonstration of Decision Tree on Weka Tool.</td><td>24</td></tr>
<tr><td colspan="11">Text Book:
➢ T. Segaran, Programming Collective Intelligence Building Smart Web 2.0 Applications, O'Reilly, 2007.

References:
➢ M. Hall, E. Frank, G. Holmes, B. Pfahringer, P. Reutemann, & I. H. Witten, The WEKA Data Mining Software: An Update, ACM SIGKDD Explorations Newsletter, Vol. 11 (1), 10–18, 2009.
➢ https://www.cs.waikato.ac.nz/ml/weka/Witten_et_al_2016_appendix</td></tr>
</table>

<table>
<tr><td>Course No: 22</td><td colspan="2">Course Name: Econometrics</td><td colspan="6">Course Code: MMAE 0117</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme: M.Sc. Mathematics</td><td rowspan="2">Semester:
III/IV</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week:4</td></tr>
<tr><td>3</td><td>0</td><td>2</td><td>0</td><td>4</td><td>Total Hours: 40</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Regression Analysis and Predictive Modelling</td></tr>
<tr><td>Course Objective</td><td colspan="8">This course will develop a profound understanding of applying statistical inference to quantity economic phenomena. The students will learn the concept of modeling real-life data problems through SURE and Panel-Data models. Further, a deep understanding of estimation of statistical models will be developed in this course. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="8">CO1: Apply statistical inference to quantity economic phenomena.
CO2: Model real-life data problems through SURE and Panel-Data models.
CO3: Estimate statistical models in which the dependent variables are functions of other variables (SEM).
CO4: Understand the difference between casuality quarrelation cointegration and apply multivariate time series to real data.</td></tr>
<tr><td colspan="9">COURSE SYLLABUS</td></tr>
<tr><td>Module No.</td><td colspan="7">Content</td><td>Hours</td></tr>
<tr><td>I</td><td colspan="7">[Course Outcome(s) No.: 1 and 2]
Models with dummy independent variables and discrete and limited dependent variable, LOGIT, PROBIT, TOBIT and multinomial choice models, Poisson regression models.
Problem of multicollinearity, consequences and solutions, ridge regression and LASSO estimators.
Seemingly unrelated regression equation (SURE) model and its estimation, Panel data models: estimation in random effect and fixed effect models.
Simultaneous equations model, examples, concept of structural and reduced forms, problem of identification, rank and order conditions of identifiability.</td><td>20</td></tr>
<tr><td>II</td><td colspan="7">[Course Outcome(s) No.: 3 and 4]
Methods of estimation in simultaneous equations model, indirect least squares, two stage least squares and limited information maximum likelihood estimation, k class estimator, idea of three stage least squares and full information maximum likelihood estimation, prediction and simultaneous confidence intervals.
Multivariate time series processes and their properties, Vector autoregressive (VAR), vector moving average (VMA) and vector autoregressive moving average (VARMA) processes.
Granger causality, instantaneous Granger causality and feedback, characterization of causal relations in bivariate models, Granger causality tests, Haugh-Pierce test, Hsiao test.
Cointegration, Granger representation theorem (without proof), Bivariate cointegration and cointegration test in static model.</td><td>20</td></tr>
</table>

Text Books:

- P. G. Apte, Text books of Econometrics, Tata McGraw Hill, 1990.
- D. Gujarathi, Basic Econometrics, McGraw Hill, 1979.
- J. Johnston, Econometric methods, Third edition, McGraw Hill, 1984.
- G. G. Judge, W. E. Griffiths, R. C. H. Lütkepohl & T. C. Lee, The Theory and Practice of Econometrics, Wiley, 1985.

Reference Books:

- A. Koutsoyiannis, Theory of Econometrics, Macmillan Press, 1979.
- V. K. Srivastava & D.A.E. Giles, Seemingly Unrelated Regression Equations Models, Marcel Dekker, 1987.
- A. Ullah & H. D. Vinod, Recent Advances in Regression Methods, Marcel Dekker, 1981.

Course No: 23	**Course Name:** Survival Analysis							**Course Code:** MMAE 0118
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** III/IV	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week:4**
			3	0	2	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Nil
Course Objective	This course will develop a profound understanding of survival analysis and its applications to real-life data problems. The students will learn the formulation of the propotional liazard models for investigating the association between the variables. Further, a deep understanding of framing models for recurrent events will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	**CO1:** Understand the underlying concepts of survival analysis and apply it to real-life data problems. **CO2**: Analyze data in which the time until the event is of interest. **CO3:** Use the basic idea of censering in survival analysis and apply the methods accordingly. **CO4:** Formulate the propotional hazard models for investigating the association between the variables. **CO5:** Frame models for recurrent events.

COURSE SYLLABUS

Module No.	**Content**	**Hours**
I	**[Course Outcome(s) No.: 1, 2 and 3]** **Survival Analysis**-Introduction, Outlines and objectives, Applications.Basic terms and their inter-relationships. Various properties of hazard function. Types of censoring and truncation, Uses of Life table, Kaplan–Meier Survival Curves and the Log–Rank Test, Log–Rank Statistic for Several Groups. **Parametric Survival Models-** Exponential, Weibull, Gamma, Normal, Log-normal models.Estimation and testing procedures on these models.	20
II	**[Course Outcome(s) No.: 4 and 5]** **Proportional Hazard Models-** Assumption, the Cox Proportional Hazards Model and its Characteristics. The Stratified Cox Procedure.Extension of the Cox Proportional Hazards Model (Time-Dependent). **Recurrent Event Survival Analysis-** Introduction, outline and objectives, Competing Risks Survival Analysis-Competing risk events and Frailty models.	20

Text Books:

- P. D. Allison, Survival Analysis Using SAS: A Practical Guide, SAS Institute, 2010.
- D. G. Kleinbaum & M. Klein, Survival Analysis: A Self-Learning Text, Springer-Verlag, 2012.
- J. P. Klein & M. L. Moeschberger, Survival Analysis–Techniques for Censored and Truncated Data, Springer Verlag, 2005.

Reference Books:

- D. W. Hosmer, & S. Lemeshow, Applied Survival Analysis: Regression Modeling of Time to Event Data, Wiley-Interscience, 2008.
- M. Cleves, W. Gould, & R. Gutierrez, An introduction to survival analysis using STATA, Stata Press, 2010.

Course No: 24	**Course Name:** Discrete Mathematics	**Course Code:** MMAE 0009

Batch:	**Programme:**	**Semester:**	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week: 4**
2024-2026	M.Sc. Mathematics	III / IV	4	0	0	0	4	**Total Hours:40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Nil

Course Objective	This course will develop a profound understanding of partially ordered sets, lattices, Boolean algebra and their applications. Further, a deep understanding of spectra of finite graphs and regular graphs, Cayley graphs and Ramanujan graphs will be developed in this course. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After studying these topics, the students will be able to: **CO1:** Understand partially ordered sets, lattices, their types and lattice homomorphism. **CO2:** Learn projective Intervals, Schreier's Refinement Theorem and isomorphism theorem of moduler lattices. **CO3**: Apply the De Morgan Formulae with examples. **CO4**: Use the concepts of Boolean algebra and truth table. **CO5**: Understand the concepts of spectra of graphs and application of spectra. **CO6**: Calculate the energies of different types of graphs.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1, 2 and 3]** **Lattice Theory**: Partially ordered sets, Diagrams, Lower and Upper Bounds, Lattices, The lattices theoretical duality principle, Semi lattices, Lattices as partially ordered sets, Diagrams of lattices, Sub lattices, Lattice homomorphism, Axiom systems of lattices, Complete lattices, Distributive lattices, Modular lattices, Characterization of modular and distributive lattices, Similar intervals, Projective intervals, Zessenhau's lemma, Schreier's refinement theorem, Independent sets with properties, The isomorphism theorem of modular lattices. **Boolean Algebra** I: De Morgan formulae, Complete boolean algebras, Boolean algebras and boolean rings, The algebra of relations, Boolean homomorphism, Representation theorem.	20
II	**[Course Outcome(s) No.: 4, 5 and 6]** **Boolean Algebra II**: Boolean expression, Algorithm for finding sum-of-products form, Minimal sum-of-products, Consensus of fundamental products, Algorithm, Logic, Gates and Circuits, Boolean functions and its truth table. Spectra of finite graphs, Characteristic polynomials, Spectra, Spectra of K_n, C_n and P_n, Bounds of spectra, The spectra of regular graphs, The spectrum of the complement of a regular graph, Spectra of line graphs of regular, Spectrum of the complete Bipartite graph $K_{p;q}$, Cayley graphs, Unitary Cayley graphs spectrum of the Cayley graph Xn, Strongly regular graphs, Ramanujan graphs, Energy of a graph, Maximum energy of k-regular graphs, Energy of Cayley graphs.	20

Text Book:

- N. Jacobson: Lectures in Abstract Algebra: Basic Concepts, Springer-Verlag, 2012.

Reference Book:

- G. Szasz, Introduction to Lattice Theory, Academic Press, 1963.

SYLLABI OF SUBJECTS

SKILL ENHANCEMENT COURSES (SEC)

<table>
<tr><td>Course No: 1</td><td colspan="2">Course Name: Programming in Python</td><td colspan="6">Course Code: MCAC 0016</td></tr>
<tr><td rowspan="2">Batch:

2024-2026</td><td rowspan="2">Programme:
M.Sc.
Mathematics</td><td rowspan="2">Semester:

II</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credits</td><td>Contact Hrs Per Week:3</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>0</td><td>3</td><td>Total Hours:36</td></tr>
<tr><td colspan="2" rowspan="2">Total Evaluation Marks: 100

Mid Term: 30 Marks
End Term: 50 Marks
Internal Assessment: 20 Marks</td><td colspan="7">Examination Duration: Mid Term (2 hours), End Term (3 hours)</td></tr>
<tr><td colspan="7">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="8">This course introduces the solving of mathematical problems using Python programming using OO concepts and its connectivity with database. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="8">After completion of course, the student will be able to:
CO1: Understand the basics of Python Programming.
CO2: Apply the concepts of control structures and string manipulations of python programming.
CO3: Understand the use of data structures available in PythonList, Tuple and Dictionary.
CO4: Experiment user-defined functions and access built-in functions.
CO5: Experiment user-defined modules and access built-in modules- math, random, string, date, time, date time.
CO6: Develop the programs using the concept of File Handling.
CO7: Develop programs based on Exceptional Handling.</td></tr>
</table>

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1, 2, 3 and 4]** **Introduction to Python:** Introduction and Basics; Setting up path Python Data Variables & Operators: Data Variables and its types, id () and type () functions, Coding Standards; **Control Structures:** if-else, elif, Nested if, Iteration Control structures, Break, Continue & Pass; **String Manipulation:** Accessing Strings, Basic Operations, String slices Function and Methods. **Lists:** Introduction, accessing list, Operations, Working with lists, Function and Methods. **Tuple:** Introduction, accessing tuples, Operations, Working, Functions and Methods. **Dictionaries:** Introduction, accessing values in dictionaries, Working with dictionaries, Properties, Functions. **Functions:** Defining & Calling a function, Passing arguments to functions – Mutable & Immutable Data Types, Different types of arguments, Recursion, scope of variables.	18
II	**[Course Outcome(s) No.: 5, 6 and 7]** **Modules and Packages:** User-defined modules and Standard Library: random, numpy, sys, Math Module, String Module, List Module, Date & Time Module, Regular Expressions: match, search, replace; Introduction to PIP, Installing Packages via PIP **Input-Output:** Printing on screen, reading data from keyboard, Opening and Closing file, Reading and writing files, Functions. **Exception Handling:** Exception, Exception Handling, except clause, try? finally clause, User Defined Exceptions. Introduction to series and data frames & Python using Pandas. **Object Oriented Programming:** Creating Classes, Instance Variables & Access Specifiers, Methods & Complete Python Program, Importance of self, __init__ () method, Instance Methods.	18

Text Book:

- P. Barry, Head First Python: A Brain-Friendly Guide, O'Reilly Media, 2010.

Reference Book:

- B. Slatkin, Effective Python: 59 Specific Ways to Write Better Python, Addison Wesley, 2015.

<table>
<tr><td colspan="2">Course No: 2</td><td colspan="3">Course Name: Python Programming Lab</td><td colspan="5">Course Code: MCAC 0810</td></tr>
<tr><td rowspan="2">Batch:
2024-2026</td><td rowspan="2">Programme:
M.Sc. Mathematics</td><td rowspan="2">Semester:
II</td><td>L</td><td>T</td><td>P</td><td>J</td><td>Credit</td><td>Contact Hrs Per Week: 2</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>Total Hours: 24</td></tr>
<tr><td colspan="3" rowspan="2">Total Evaluation Marks: 100

Internal: 50 Marks
External: 40 Marks
Attendance: 10 Marks</td><td colspan="6">Examination Duration: End Term (2 hours)</td></tr>
<tr><td colspan="6">Pre-requisite of course: Nil</td></tr>
<tr><td>Course Objective</td><td colspan="8">This course introduces the solving of problems using Python programming using OO concepts and its connectivity with database. This course focuses on employability and skill development aligned with all CO’s.</td></tr>
<tr><td>Course Outcomes</td><td colspan="8">By the end of the course, students will learn to:
CO1: Apply OO concepts using Python programming.
CO2: Apply in-built packages defined in Python.
CO3: Apply front-end as Python Programming to connect with any back-end.</td></tr>
</table>

COURSE SYLLABUS

<table>
<tr><th>Module No.</th><th>Content</th><th>Hours</th></tr>
<tr><td>I</td><td>Programs based on the concepts of:
Building Python Modules
Obtaining user Data
Printing desired output
Programs based on the concepts of:
Conditional if statements
Nested if statements
Using else if and elif
Programs based on the concepts of Iteration using different kinds of loops

Usage of Data Structures
Strings
Lists
Tuples
Sets
Dictionary
Programs related to Object Oriented Concepts:

Creating Classes, Instance Variables, Access Specifiers, User defined Methods, Importance of self, __init__ () method, Class Methods and Static Methods, Using default parameters in Methods.

Handling Database Connectivity with Python:
Inserting and Retrieving Data
Use of Stored Procedures
Invoking stored functions</td><td>24</td></tr>
</table>

Text Book:

- P. Barry, Head First Python: A Brain-Friendly Guide, O’Reilly Media, 2010.

Reference Book:

- B. Slatkin, Effective Python: 59 Specific Ways to Write Better Python, Addison Wesley, 2015.

Course No: 3	**Course Name:** Technical Writing							**Course Code:** MELH 0006
Batch: 2024-2026	**Programme:** M.Sc. Mathematics	**Semester:** II	**L**	**T**	**P**	**J**	**Credits**	**Contact Hrs Per Week: 4**
			4	0	0	0	4	**Total Hours: 40**

Total Evaluation Marks: 100 **Mid Term:** 30 Marks **End Term:** 50 Marks **Internal Assessment**: 20 Marks	**Examination Duration:** Mid Term (2 hours), End Term (3 hours) **Pre-requisite of course:** Nil
Course Objective	The objective of this course is to make the students understand the concepts of various modes of written communication used to disseminate information within and outside an organization. This course focuses on employability and skill development aligned with all CO's.
Course Outcomes	After completion of course, the student will be able to: **CO1:** Understand communication features. **CO2:** Learn writing skills to write technical reports, formal messages and letters. **CO3:** Know the writing of technical proposals, research papers, dissertation reports etc. **CO4:** Make curriculum vitae, resume and agenda and minutes of a meeting.

COURSE SYLLABUS

Module No.	Content	Hours
I	**[Course Outcome(s) No.: 1 and 2]** Forms & features of communication factors facilitating communication-communication channels, Flow of communication, Language skills-LSRW, Barriers to communication, Words and Phrases, Sentences and Paragraphs, Art of condensation reading comprehension, Analyzing audience, Organizing contents, Preparing an outline, Visual Aids paragraph writing: characteristics and methods Technical reports, Importance, Preparatory steps and Structure letters, Memos and E-mails- structure, Principles, Types.	18
II	**[Course Outcome(s) No.: 3 and 4]** Technical proposals- Definition, Types, Structure and Style. Journal articles/ Research papers- Nature, Significance and essentials. Job Application-Resume, Curriculum Vitae and Cover letter. Interviews-Types, Preparation, Success and Failure Factors. Agenda and minutes of a meeting. Note making & summarizing Dissertation and Thesis- Definition, Characteristics Style and Presentation. Preparing List of References and Bibliography: Referencing Conventions.	18

Text Book:

- R. Meenakshi & S. Sharma, Technical Communication: Principles and Practice, Oxford University Press, New Delhi, 2015.

Reference Books:

- M. A. Rizvi, Effective Technical Communication, New Delhi, Tata McGraw Hill, 2005.
- R. C. Sharma & K. Mohan, Business Correspondence and Report Writing, Tata McGraw Hill, New Delhi, 2002.