MANIPUR UNIVERSITY
FOUR YEAR UNDERGRADUATE PROGRAMME (FYUP)
IN MATHEMATICS, 2025

INTRODUCTION

The Undergraduate (UG) syllabus of Mathematics in light of New Education Policy (NEP), 2020 consists of Major (Core) disciplines, Minor disciplines, Multi-Disciplinary Courses (MDC), Ability Enhancement Courses (AEC), Value Added Courses (VAC), Skill Enhancement Courses (SEC), Research Methodology, Dissertation (Collection of Data, Analysis and Preparation of Report) and Discipline Specific Electives (DSE).

The UG degree programme offers certificates, diplomas and degrees as follows:

UG Certificate: Certificate course consists of two Major disciplines, two Minor disciplines, two MDC, two AEC, two VAC and two SEC and one internship.

UG Diploma: Diploma course consists of eight Major disciplines, four Minor disciplines, three MDC, two AEC, three VAC, three SEC and one internship.

3-year UG Degree: 3-year UG degree course consists of fifteen Major disciplines, six Minor disciplines, three MDC, two AEC, three VAC, three SEC, Community engagement (NCC/NSS/Adult Education/Student mentoring/ NGO/ Govt. Institutions, etc.) and Internship.

4-year Honours/Honours with Research Degree: 4-year honours degree course consists of twenty Major disciplines, eight Minor disciplines, three MDC, two AEC, three VAC, three SEC, Community engagement (NCC/NSS/Adult Education/Student mentoring/ NGO/ Govt. Institutions, etc.), Internship, Research Methodology, three DSE/Dissertation.

AIMS FOR UG DEGREE IN MATHEMATICS

The UG Programme in mathematics is designed to teach students how to think critically, logically, and analytically, which enables them to employ mathematical reasoning in real-world situations. A UG degree in mathematics will expose students to a variety of intriguing and practical concepts that will help them in their preparation for a variety of mathematics-oriented jobs in industry, government, business, commerce, finance and research.

The programme covers broad range of topics on pure and applied mathematics. Also covers hands-on sessions in Computer Lab using various software, LaTaX, Python, MATLAB etc. which enables students to corelate and compare with recent developments in various branches of mathematics in a variety of organisations worldwide.

The programme aims to increase students' skill in mathematics as well as other cross-disciplinary subjects like commerce, physics, computer sciences, economics, and statistics etc. They have the option to undertake these courses through MOOCs/SWAYAM. They have flexibility to move from one discipline to another, to move one institution to another, to switch alternative modes of learning.

ATTRIBUTES OF A GRADUATE IN MATHEMATICS

Core Competency: Graduates will be well-versed in mathematical theories, concepts, and techniques, enabling them to solve challenging problems and pursue advanced study in mathematics or related fields.

Critical Thinking : Graduates will acquire the analytical and critical thinking abilities needed to formulate, evaluate, and resolve real-world issues using logical reasoning and mathematical modelling.

Problem-solving: Graduates will be adept at using computational tools and mathematical concepts to solve problems in a variety of sectors, including science, engineering, technology, and economics.

Communication Skills: Graduates will be able to effectively convey mathematical concepts, both orally and in writing, as well as collaborate in multidisciplinary teams to solve challenging problems.

Moral and Ethical Awareness: Graduates will exhibit a dedication to moral behaviour and professional obligations, which include comprehending how mathematical solutions affect society and maintaining a high standard of professional development.

Research Skills: Graduates will be equipped with the capacity to carry out autonomous research, enhancing their understanding of mathematics and stimulating their imagination in addressing abstract and practical issues.

Qualification Descriptors

The qualification descriptor suggests the generic outcomes and attributes to be obtained while obtaining the degree of B.A./B.Sc. (Major) Mathematics or B.A./B.Sc. with Mathematics as a minor subject. The qualification descriptors indicate the academic standards on the basis of following factors:

i. Level of knowledge
ii. Understanding
iii. Skills
iv. Competencies and attitudes
v. Values

PROGRAMME LEARNING OUTCOME

PLO1 **Disciplinary knowledge**: Bachelor degree in Mathematics is the culmination of in-depth knowledge of Algebra, Calculus, geometry, Real analysis, Differential equations and several other branches of pure and applied mathematics, this also leads to study of relevant areas such as computer science and other disciplines.

PLO2 **Communication Skills**: Ability to communicate the various mathematical concepts effectively using variety of examples mostly having real life applications and their geometric visualization. The skills and knowledge gained in this programme will lead to the proficiency in analytical reasoning which can be used to express thoughts and views in mathematically or logically correct statements.

PLO3 **Critical thinking and analytical reasoning**: The students undergoing this programme acquire the ability of critical thinking and logical reasoning and will apply in formulating or generalizing specific hypothesis, conclusion. The learner will be able to recognize and distinguish the various aspects of real-life problems.

PLO4 **Problem solving**: The Mathematical knowledge gained by the student through this programme develops an ability to solve the problems, identify and define appropriate computing requirements for its solutions. This programme will enhance the overall development.

PLO5 **Research related skills**: After the completion of this programme, the student will develop the capability of inquiring about appropriate questions relating to the Mathematical concepts, arguments. He/she will be able to define problems, formulate hypothesis, proofs, write the results obtained clearly.

PLO6 **Information/ digital literacy**: The completion of this programme will enable the learner to use appropriate softwares to solve the system of algebraic and differential equations.

PLO7 **Self-directed learning**: The student after the completion of the programme will be able to work independently, make an in-depth search of various areas of Mathematics and resources for self learning in order to enhance knowledge in mathematics.

PLO8 **Moral and ethical awareness / reasoning**: The student after the completion of the course will develop an ability to identify unethical behaviour such as fabrication, falsification or misinterpretation of data and adopting objectives, unbiased and truthful actions in all aspects of life in general and Mathematical studies in particular.

PLO9 **Lifelong learning**: This programme provides self directed learning and lifelong learning skills. With these skills, the learner will be able to think independently, improve personal development.

Programme Specific Outcomes

PSO1: Demonstrate the acquisition of comprehensive knowledge and coherent understanding in chosen elective and core subjects in mathematics.

PSO2: Apply mathematical techniques and tools, such as mathematical modeling, computational methods, and statistical analysis, to solve real-world problems in various fields.

PSO3: Possess strong analytical and critical thinking skills, enabling them to construct rigorous logical arguments, develop proofs, and solve complex mathematical problems.

PSO4: Proficient in using modern mathematical software and computational tools such as LaTeX, Python, MATLAB, and other relevant technologies to analyze data and solve mathematical problems.

PSO5: Communicate mathematical ideas and solutions to a variety of audiences, including mathematicians, scientists, engineers, and non-specialists, both orally and in writing.

PSO6: Formulate research questions, literature review, methodology, presentation of findings, and demonstrate dedication to lifelong learning and professional development.

PSO7: Utilize the skills that necessary for success in national level competitive exams, pursuing doctoral research degree, teaching and others.

Course Structure of the FOUR YEAR UNDERGRADUATE PROGRAMME (FYUP) IN MATHEMATICS, 2025 BASED ON NEP-2020

Sem.	Course		Title of the paper	Credit
	Category	Code		
I	**Major**	**MJC45MAT101(T)25**	Algebra	4
	Minor	**MNC45MAT101(T)25**	Algebra	4
	MDC	**MDC45MAT101(T)25**	Quantitative Aptitude	3
	AEC			4
	SEC	**SEC45MAT101(T)25** **SEC45MAT101(P)25**	LaTeX	3
	VAC			2
	Total Credit			20
II	**Major**	**MJC45MAT102(T)25**	Differential Calculus	4
	Minor	**MNC45MAT102(T)25**	Differential Calculus	4
	MDC	**MDC45MAT102(T)25**	Elementary Mathematics-I	3
	AEC			4
	SEC	**SEC45MAT102(T)25** **SEC45MAT102(P)25**	Python Programming	3
	VAC			2
	Total Credit			20
III	**Major**	**MJC50MAT203(T)25**	Co-ordinate Geometry	4
	Major	**MJC50MAT204(T)25**	Real Analysis	4
	Minor	**MNC50MAT203(T)25**	Co-ordinate Geometry	4
	MDC	**MDC50MAT203(T)25**	Elementary Mathematics-II	3
	SEC	**SEC50MAT203(T)25** **SEC50MAT203(P)25**	Microsoft Excel	3
	VAC			2
	Total Credit			20
IV	**Major**	**MJC50MAT205(T)25**	Abstract Algebra	4
	Major	**MJC50MAT206(T)25**	Ordinary Differential Equations	4
	Major	**MJC50MAT207(T)25**	Multivariate Calculus	4
	Major	**MJC50MAT208(T)25**	Numerical Analysis	4
	Minor	**MNC50MAT204(T)25**	Abstract Algebra	4
	Total Credit			20
V	**Major**	**MJC55MAT309(T)25**	Linear Algebra	4
	Major	**MJC55MAT310(T)25**	Partial Differential Equations	4
	Major	**MJC55MAT311(T)25**	Riemann Integration	4
	Major	**INT55MAT301(T)25**	Internship	4
	Minor	**MNC55MAT205(T)25**	Ordinary Differential Equations	4
	Total Credit			20
VI	**Major**	**MJC55MAT312(T)25**	Complex Analysis	4
	Major	**MJC55MAT313(T)25**	Metric Spaces	4
	Major	**MJC55MAT314(T)25**	Mechanics	4
	Major	**MJC55MAT315(T)25**	Linear Programming Problem	4
	Minor	**MNC55MAT206(T)25**	Numerical Analysis	4
	Total Credit			20

VII	**Major**	**MJC60MAT416(T)25**	Advanced Abstract Algebra	4
	Major	**MJC60MAT417(T)25**	Advanced Real Analysis	4
	Major	**MJC60MAT418(T)25**	Research Methodology	4
	Minor	**MNC60MAT307(T)25**	Linear Algebra	4
	For Honours with Research Dissertation Part 1			
	For Honours students (Choose any one from the following)			
	DSE-1	**DSE60MAT401(T)25**	Advanced Complex Analysis	4
		DSE60MAT402(T)25	Functional Analysis	
		DSE60MAT403(T)25	Graph Theory	
	Total Credit			20
VIII	**Major**	**MJC60MAT419(T)25**	Topology	4
	Major	**MJC60MAT420(T)25**	Measure Theory & Integration	4
	Minor	**MNC60MAT308(T)25**	Partial Differential Equations	4
	For Honours with Research Dissertation Part 2			
	For Honours students (Choose any two from the following)			
	DSE-2 + DSE-3	**DSE60MAT404(T)25**	Advanced Partial Differential Equations	4+4
		DSE60MAT405(T)25	Fixed Point Theory	
		DSE60MAT406(T)25	Cryptography	
	Total Credit			20

Academic level 4.5 and Semester – I
MJC45MAT101(T)25 : Algebra

Nature of Course	**Major**			
Course Code	**MJC45MAT101(T)25**			
Course Title	**Algebra**			
Course Level	**100**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc First Semester**			
Proposed by	**Board of Under-Graduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Set, function, matrix, determinant, polynomial, equation, inequation, means.**			
Pre Requisite Course Required	**10+2 Mathematics**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: The primary objective of this course is to introduce the basic tools of theory of equations, complex numbers, number theory and matrices to understand their linkage to the real-world problems.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	Employ De Moivre's theorem in a number of applications to solve numerical problems.
2.	Solve polynomial equations of degree three and four.
3.	Solve problems based on standard inequalities.
4.	Recognize consistent and inconsistent systems of linear equations by using rank.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	De Moivre's theorem	De Moivre's theorem for integer and rational indices, applications of De Moivre's theorem, summation of series	9	3	-	12
II	Polynomial equations	Polynomial functions, polynomial equations, fundamental theorem of algebra (statement only), Descarte's rule of signs, relation between roots and coefficients of a polynomial equation, symmetric function of the roots of an equation, sum of powers of the roots, Cardan's method of cubic and Ferrari's method for biquadratic equations.	9	3	-	12
III	Inequalities	Arithmetic mean, geometric mean, mean of m^{th} power, Cauchy-Schwartz inequality, inequalities of Holder, Minkowski and Chebyshev.	9	3	-	12
IV	Matrices	Rank of a matrix, linear independence, rank and elementary operations, row reduction and echelon forms, system of linear equations, solution of the matrix equation AX=B, solution sets of linear systems.	9	3	-	12

V	Matrices	Characteristic equation, eigenvectors and eigen values, Cayley- Hamilton theorem, inverse of matrix, orthogonal matrix.	9	3	-	12

Suggested Readings

1. **MK Singal, Asha Rani Singal,** (2020); *Algebra* (31st Ed) R Chand & Co, New Delhi.
2. **Chandrika Prasad,** (2014). *Text Book on Algebra and Theory of Equations* Pothishala Pvt. Ltd, Allahabad.

Additional Readings:

1. **Kolman, Bernard, & Hill, David R.** (2001). *Introductory Linear Algebra with Applications* (7th ed.). Pearson Education, Delhi. First Indian Reprint 2003.
2. **Lay, David C., Lay, Steven R., & McDonald, Judi J.** (2016). *Linear Algebra and its Applications* (5th ed.). Pearson Education.
3. **Andrilli, Stephen, & Hecker, David** (2016). *Elementary Linear Algebra* (5th ed.). Academic Press, Elsevier India Private Limited.

Teaching plan (MJC45MAT101(T)25: Algebra):

Week 1: De Moivre's theorem for integer and rational indices [1] Chapter 5 (Section 2, 4).
Week 2: Applications of De Moivre's theorem to various problems. [1] Chapter-5 (Section-3.1 to 3.4)
Week 3: Summation of series. [1] Chapter-5 (Section-3.5)
Week 4: Polynomial functions, polynomial equation, fundamental theorem of algebra (statement only), and related problems**.** [1] Chapter-4 (Section-5, 6, 7)
Week 5: Descarte's rule of signs, relation between roots and coefficients of a polynomial equation and related problems. [1] Chapter-4(section-7, 8, 9)
Week 6: Symmetric function of the roots of an equation, sum of powers of the roots and related problems. [1] Chapter-4(section-10, 11)
Week 7: Arithmatic mean, geometric mean, mean of m^{th} power and related problems. [2] Chapter-3 (Section-3.3, 3.4, 3.41, 3.42, 3.43, 3.5, 3.51)
Week 8: Cauchy-Schwartz inequality. [2] Chapter-3 (Section-3.7)
Weak 9: Inequalities of Holder, Minkowski and Chebyshev and related problems. [2] Chapter-3 (Section-3.7)
Week 10: Row reduction and Echelon forms, rank of a matrix, linear independence, rank and elementary operations.
[2] Chapter-6(Section-6.4, 6.41 to 6.46, 6.67, 6.7),
Week 11: System of linear equations, solution of the matrix equation AX=B;
[1] Chapter-6(Section-13, 15)
Week 12: Solution sets of linear systems; [1] Chapter 7 (Section-7.2 &7.3)
Week 13: Characteristic equation, eigenvectors and eigen values; [2] Chapter 6 (Section 6.6, 6.61).
Week 14: Cayley-Hamilton theorem; [2] Chapter 6 (Section 6.63).
Week 15: Inverse of matrix, orthogonal matrix. [2] Chapter-6 (Section-6.7, 6.8)

Assessment Methods

- Oral and written examinations,
- Closed-book and open-book tests,
- Problem-solving exercises,
- Individual and group project reports,
- Seminar and presentations,
- Interactive sessions,

Academic level 4.5 and Semester – I
MNC45MAT101(T)25 : Algebra

Nature of Course	**Minor**			
Course Code	**MNC45MAT101(T)25**			
Course Title	**Algebra**			
Course Level	**100**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc First Semester**			
Proposed by	**Board of Under-Graduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Set, function, matrix, determinant, polynomial, equation, inequation, means.**			
Pre Requisite Course Required	**10+2 Mathematics**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: The primary objective of this course is to introduce the basic tools of theory of equations, complex numbers, number theory and matrices to understand their linkage to the real-world problems.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	Employ De Moivre's theorem in a number of applications to solve numerical problems.
2.	Solve polynomial equations of degree three and four.
3.	Solve problems based on standard inequalities.
4.	Recognize consistent and inconsistent systems of linear equations by using rank.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	De Moivre's theorem	De Moivre's theorem for integer and rational indices, applications of De Moivre's theorem, summation of series	9	3	-	12
II	Polynomial equations	Polynomial functions, polynomial equations, fundamental theorem of algebra (statement only), Descarte's rule of signs, relation between roots and coefficients of a polynomial equation, symmetric function of the roots of an equation, sum of powers of the roots, Cardan's method of cubic and Ferrari's method for biquadratic equations.	9	3	-	12
III	Inequalities	Arithmetic mean, geometric mean, mean of m^{th} power, Cauchy-Schwartz inequality, inequalities of Holder, Minkowski and Chebyshev.	9	3	-	12
IV	Matrices	Rank of a matrix, linear independence, rank and elementary operations, row reduction and echelon forms, system of linear equations, solution of the matrix equation AX=B, solution sets of linear systems.	9	3	-	12

V	Matrices	Characteristic equation, eigenvectors and eigen values, Cayley- Hamilton theorem, inverse of matrix, orthogonal matrix.	9	3	-	12

Suggested Readings

1. **MK Singal, Asha Rani Singal,** (2020); *Algebra* (31st Ed) R Chand & Co, New Delhi.
2. **Chandrika Prasad,** (2014). *Text Book on Algebra and Theory of Equations* Pothishala Pvt. Ltd. Allahabad.

Additional Readings:

1. **Kolman, Bernard, & Hill, David R.** (2001). *Introductory Linear Algebra with Applications* (7th ed.). Pearson Education, Delhi. First Indian Reprint 2003.
2. **Lay, David C., Lay, Steven R., & McDonald, Judi J.** (2016). *Linear Algebra and its Applications* (5th ed.). Pearson Education.
3. **Andrilli, Stephen, & Hecker, David** (2016). *Elementary Linear Algebra* (5th ed.). Academic Press, Elsevier India Private Limited.

Teaching plan (MNC45MAT101(T)25: Algebra):

Week 1: De Moivre's theorem for integer and rational indices [1] Chapter 5 (Section 2, 4).
Week 2: Applications of De Moivre's theorem to various problems. [1] Chapter-5 (Section-3.1 to 3.4)
Week 3: Summation of series. [1] Chapter-5 (Section-3.5)
Week 4: Polynomial functions, polynomial equation, fundamental theorem of algebra (statement only), and related problems**.** [1] Chapter-4 (Section-5, 6, 7)
Week 5: Descarte's rule of signs, relation between roots and coefficients of a polynomial equation and related problems. [1] Chapter-4(section-7, 8, 9)
Week 6: Symmetric function of the roots of an equation, sum of powers of the roots and related problems. [1] Chapter-4(section-10, 11)
Week 7: Arithmatic mean, geometric mean, mean of m^{th} power and related problems. [2] Chapter-3 (Section-3.3, 3.4, 3.41, 3.42, 3.43, 3.5, 3.51)
Week 8: Cauchy-Schwartz inequality. [2] Chapter-3 (Section-3.7)
Weak 9: Inequalities of Holder, Minkowski and Chebyshev and related problems. [2] Chapter-3 (Section-3.7)
Week 10: Row reduction and Echelon forms, rank of a matrix, linear independence, rank and elementary operations.
[2] Chapter-6(Section-6.4, 6.41 to 6.46, 6.67, 6.7),
Week 11: System of linear equations, solution of the matrix equation AX=B;
[1] Chapter-6(Section-13, 15)
Week 12: Solution sets of linear systems; [1] Chapter 7 (Section-7.2 &7.3)
Week 13: Characteristic equation, eigenvectors and eigen values; [2] Chapter 6 (Section 6.6, 6.61).
Week 14: Cayley-Hamilton theorem; [2] Chapter 6 (Section 6.63).
Week 15: Inverse of matrix, orthogonal matrix. [2] Chapter-6 (Section-6.7, 6.8)

Assessment Methods

- Oral and written examinations,
- Closed-book and open-book tests,
- Problem-solving exercises,
- Individual and group project reports,
- Seminar and presentations,
- Interactive sessions,

Academic level 4.5 and Semester – I
MDC45MAT101(T)25 : Quantitative Aptitude

Nature of Course	**MDC**			
Course Code	**MDC45MAT101(T)25**			
Course Title	**Quantitative Aptitude**			
Course Level	**100**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	3	**3**	**0**	**3**
Course Audience	**BA/BSc First Semester**			
Proposed by	**Board of Under-Graduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Concept of unitary methods, ratio and proportion, mensuration, arrangements**			
Pre Requisite Course Required	**10 Mathematics**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: The main aim of this course is to gain knowledge of elementary ideas about arithmetic abilities which one finds in daily life. It will help the students from any background to get acquainted with this knowledge and get prepared for any competitive examinations.

Course Learning Outcomes: This course will enable the students to:

1.	gain sufficient ideas of mental and arithmetic abilities.
2.	handle mental/quantitative aptitude test questions with great ease.
3.	acquire the skill of solving problems of daily life quickly.
4.	formulate real-life problems mathematically and solve using quantitative techniques.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Arithmetic Ability I	Chain Rule –Time and Work – Pipes and Cisterns Time and Distance – Problems on Trains – Boats and Streams	12	-	-	12
II	Arithmetic Ability II	Simple Interest – Compound Interest – Stocks and Shares.	9	-	-	9
III	Arithmetic Ability III	Clocks – Area	6	-	-	6
IV	Arithmetic Ability IV	Volume and Surface Area	9	-	-	9
V	Arithmetic Ability V	Permutations and Combinations.	9	-	-	9

Suggested Readings

1. Scope and treatment as in "*Quantitative Aptitude*", S. Chand and Company Ltd. Ram Nagar, New Delhi (2007).

Additional Readings:

1. NCERT Mathematics text books for standard VIII, IX, X, XI.

Teaching plan (MDC45MAT101(T)25: Quantitative Aptitude):

1. **Week 1&2:** Chain Rule –Time and Work – Pipes and Cisterns,[1] Chapters 14, 15 & 16.
2. **Week 3&4: Time** and Distance-Problems on Trains-Boats and Streams [1] Chapters 21, 22 & 29.
3. **Week 5-7:** Simple Interest-Compound Interest-Stocks and Shares. [1] Chapters 17, 18 & 19.
4. **Week 8 & 9:** Clocks – Area [1] Chapters 24, 25.
5. **Week 10-12:** Volume and Surface Area. [1] Chapter 28.
6. **Week 13-15:** Permutations and Combinations. [1] Chapters 30 & 31.

Assessment Methods

- Oral and written examinations,
- Problem-solving exercises,
- Individual and group project reports,
- Interactive sessions,

Academic level 4.5 and Semester – I
SEC45MAT101(T)25 : La*TeX* (Theory)

Nature of Course	**SEC**			
Course Code	**SEC45MAT101(T)25**			
Course Title	**LaTeX (Theory)**			
Course Level	**100**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	2	**2**	**0**	**2**
Course Audience	**BA/BSc First Semester**			
Proposed by	**Board of Under-Graduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Basic Computer Literacy**			
Pre Requisite Course Required	**10+2 Mathematics**			
Faculty Eligibility and Specialization	**Master in Mathematics with Computer Programming knowledge**			

Course Objectives: The purpose of this course is to acquaint students with the latest typesetting skills, which shall enable them to prepare high quality typesetting, beamer presentation and webpages.

Course Learning Outcomes: After studying this course the student will be able to:

1.	typeset mathematical formulas, use nested list, tabular & array environments.
2.	create or import graphics.
3.	use beamer to create presentation.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Getting Started with La*TeX*	Introduction to *TeX* and La*TeX*, Typesetting a simple document, Adding basic information to a document, Environments, Footnotes, Sectioning and displayed material.	6	-	-	6
II	Mathematical Typesetting with La*TeX*-I	Accents and symbols, Mathematical Typesetting (Elementary and Advanced)**:** Subscript/ Superscript, Fractions, Roots, Ellipsis, Mathematical Symbols.	6	-	-	6
III	Mathematical Typesetting with La*TeX*-II	Arrays, Tables, Delimiters, Multiline formulas, Spacing and changing style in math mode.	6	-	-	6
IV	Graphics in La*TeX*	Graphics in LaTeX, Simple pictures using PS Tricks, Plotting of functions.	6	-	-	6
V	Beamer Presentation in La*TeX*	Beamer presentation.	6	-	-	6

Academic level 4.5 and Semester – I
SEC45MAT101(P)25 : La*TeX* (Practical)

Nature of Course	**SEC**			
Course Code	**SEC45MAT101(P)25**			
Course Title	**La*TeX* (Practical)**			
Course Level	**100**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	1	**1**	**0**	**2**
Course Audience	**BA/BSc First Semester**			
Proposed by	**Board of Under-Graduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Basic Computer Literacy**			
Pre Requisite Course Required	**10+2 Mathematics**			
Faculty Eligibility and Specialization	**Master in Mathematics with Computer Programming knowledge**			

Course Objectives: The purpose of this course is to acquaint students with the latest typesetting skills, which shall enable them to prepare high quality typesetting, beamer presentation and webpages.

Course Learning Outcomes: After studying this course the student will be able to:

1.	typeset mathematical formulas, use nested list, tabular & array environments.
2.	create or import graphics.
3.	use beamer to create presentation.

Detailed Syllabus Content

Unit	Unit Name	List of Practicals	L	T	P	Total
I	LaTeX Practical-1	[1] Chapter 9 (Exercises 4 to 10)	-	-	4	4
II	LaTeX Practical-2	[1] Chapter 10 (Exercises 1 to 4 and 6 to 9)	-	-	4	4
III	LaTeX Practical-3	[1] Chapter 11 (Exercises 1, 3, 4, and 5)	-	-	3	3
IV	LaTeX Practical-4	[1] Chapter 15 (Exercises 5, 6 and 8 to 11).	-	-	4	4

Suggested Readings

1. **Bindner, Donald & Erickson, Martin.** (2011). *A Student's Guide to the Study, Practice, and Tools of Modern Mathematics*.CRC Press, Taylor & Francis Group, LLC.

2. **Lamport, Leslie** (1994). *LaTeX*: *A Document Preparation System*, User's Guide and Reference Manual (2nd ed.). Pearson Education.Indian Reprint.

Teaching Plan {SEC45MAT101(T)25 : La*TeX* (Theory)}:

Weeks 1 to 3: Introduction to TeX and LaTeX, Typesetting a simple document, Adding basic information to a document, Environments, Footnotes, Sectioning and displayed material.
[1] Chapter 9 (9.1 to 9.5)[2] Chapter 2 (2.1 to 2.5)

Weeks 4 to 6: Accents of symbols, Mathematical typesetting (elementary and advanced): subscript/superscript, Fractions, Roots, Ellipsis, Mathematical symbols..[1] Chapter 9 (9.6 and 9.7)

Weeks 7 to 9: Arrays, Delimiters, Multiline formulas, Spacing and changing style in math mode [2] Chapter 3 (3.1 to 3.3)

Weeks 10 to 12: Graphics in LaTeX, Simple pictures using PS Tricks, Plotting of functions.
[1] Chapter 9 (Section 9.8)[1] Chapter 10 (10.1 to 10.3)[2] Chapter 7 (7.1 and 7.2)

Weeks 13 to 15: Beamer presentation.
[1] Chapter 11 (Sections 11.1 to 11.4)

List of Essential Major Equipments

- **Computer Laboratory**

Essential Software (Open-source)

- **La*TeX***

Student Activities

- Practical assignments and laboratory reports,
- Interactive sessions,

Academic level 4.5 and Semester – II
MJC45MAT102(T)25: Differential Calculus

Nature of the course	**Major**			
Course code	**MJC45MAT102(T)25**			
Course Title	**Differential Calculus**			
Course Level	**100**			
Credit Details	**Total credit**	**Lecture/week**	**Tutorial/week**	**Total Hour/week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Second Semester**			
Proposed by	**Board of Under Graduate Studies of Department of Mathematics, Manipur University**			
Pre-Requisites	**Function, limit, continuity, differentiation**			
Pre-Requisite Course required	**10+2 Mathematics**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: The primary objective of this course is to introduce the basic concepts of limit including indeterminate forms, continuity and differentiation and their application on finding tangents, normals, curvature, asymptotes etc., partial differentiation and mean value theorems.

Course learning outcomes: After completion of the course, a student will be able to

1	understand concept of the limit of a function, evaluate limit of a function, and differentiate the various types of discontinuity.
2	calculate the derivatives of hyperbolic functions, evaluate the successive derivatives, apply Leibnitz's theorem , and evaluate limits of indeterminate forms (e.g., 0/0, ∞/∞) using techniques like L'Hopital's Rule.
3	understand and apply Rolle's Theorem, the Mean Value theorem, Taylor's Series and Maclaurin's Series.
4	Determine the equations of tangents and normals to a curve, and analyse the concavity and convexity of functions and locate points of inflexion, calculate the curvature and center of curvature of a given curve.
5	calculate the partial derivatives of functions with multiple variables, apply Euler's theorem on homogeneous functions, differentiate implicit functions and calculate total differential coefficients, and understand the concept of an exact differential and its applications.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Limit and Continuity	Limit and continuity, different types of discontinuity	9	3	-	12
II	Differentiation	Derivatives of hyperbolic functions, successive differentiation, Leibnitz theorem, indeterminate forms	9	3	-	12
III	Expansion of Function	Roll's Theorem, Mean Value Theorem, Taylor's Series, Maclaurin's Series and Cauchy's Series in finite form, expansion of functions in infinite power series	9	3	-	12
IV	Application of Derivatives	Tangent and normal, curvature, centre of curvature, asymptotes, concavity and convexity of inflexion, singular points	9	3	-	12

V	Partial Differentiation	Partial differentiation, homogeneous functions, Eulers theorem on homogenous functions, differentiation of implicit functions, total differential coefficients, exact differential, partial derivatives of two functions, converse of Eulers theorem	9	3	-	12

Suggested Readings

1. **Thomas, Jr. George B., Weir, Maurice D., & Hass, Joel (2014)**. *Thomas' Calculus* (14th Edition, 2021), Pearson Education, Delhi. Indian Reprint.
2. **B. C. Das, B. N. Mukherjee**. *Differential Calculus* (59th Edition), U.N. Dhur & Sons Private Ltd., Kolkata (2024).

Teaching Plan (MJC45MAT102(T)25 : Differential Calculus):

Unit I: Limit of a function and limit laws, ε-δ definition of limit and one-sided limits [1] Chapter 2(Section 2.2 - 2.4);
Continuity [1] Chapter 2(Section 2.5); Different types of discontinuity [2] Chapter 4(Section 4.3);
Limits involving infinity and Asymptotes of graphs [1] Chapter 2(Section 2.6)

Unit II: Differentiation

Derivatives of a function and Rules of differentiation [1] Chapter 3(Section 3.2 - 3.3);
Derivative of Trigonometric hyperbolic functions [2] Chapter 7(Section 7.9);
Derivative of implicit functions [1] Chapter 3(Section 3.7);
Successive differentiation [2] Chapter 8(Section 8.1 – 8.3);
Leibnitz's Theorem [2] Chapter 8(Section 8.5);
Indeterminate forms and L'Hospital's Rule [2] Chapter 11

Unit III: Expansion of Function

Roll's Theorem and its geometrical interpretation [2] Chapter 9(Section 9.1 - 9.2);
Mean Value Theorem and its geometrical interpretation [2] Chapter 9(Section 9.3 - 9.4);
Taylor Series, Maclaurin's Series and Cauchy's Series in finite form [2] Chapter 9 (Section 9.5 - 9.7);
Expansion of functions in infinite power series [2]Chapter 9(Section 9.9)

Unit IV: Application of Derivatives

Tangent and normal [2] Chapter 14 (Section 14.2 - 14.6, 14.12 - 14.17);
Curvature and Center of curvature [2] Chapter 15 (Section 15.1 - 15.4, 15.7 - 15.8);
Asymptotes [2] Chapter 16(Section 16.2 - 16.7);
Concavity and Convexity of inflexion [2] Chapter 19 (Section 19.1 - 19.5)

Unit V: Partial Differentiation

Functions of two or more variables, partial differentiation, homogeneous functions, Eulers Theorem on homogenous functions, differentiation of implicit functions, total differential coefficients, exact differential, partial derivatives of two functions, converse of Eulers Theorem [2] Chapter 12 (Section 12.1 - 12.3, 12.5 - 12.13)

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	✓		✓		✓		✓
CO2	✓		✓		✓		✓
CO3	✓		✓		✓		✓
CO4	✓		✓		✓		✓
CO5	✓		✓		✓		✓

Assessment Methods

- Oral and written examination
- Closed book and open book tests
- Problem solving exercises
- Seminar and presentations
- Interactive sessions

Academic level 4.5 and Semester – II
MNC45MAT102(T)25: Differential Calculus

Nature of the course	**Minor**			
Course code	**MNC45MAT102(T)25**			
Course Title	**Differential Calculus**			
Course Level	**100**			
Credit Details	**Total credit**	**Lecture/week**	**Tutorial/week**	**Total Hour/week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Second Semester**			
Proposed by	**Board of Under Graduate Studies of Department of Mathematics, Manipur University**			
Pre-Requisites	**Function, limit, continuity, differentiation**			
Pre-Requisite Course required	**10+2 Mathematics**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: The primary objective of this course is to introduce the basic concepts of limit including indeterminate forms, continuity and differentiation and their application on finding tangents, normals, curvature, asymptotes etc., partial differentiation and mean value theorems.

Course learning outcomes: After completion of the course, a student will be able to

1	understand concept of the limit of a function, evaluate limit of a function, and differentiate the various types of discontinuity.
2	calculate the derivatives of hyperbolic functions, evaluate the successive derivatives, apply Leibnitz's theorem, and evaluate limits of indeterminate forms (e.g., 0/0, ∞/∞) using techniques like L'Hopital's Rule.
3	understand and apply Rolle's Theorem, the Mean Value theorem, Taylor's Series and Maclaurin's Series.
4	determine the equations of tangents and normals to a curve, and analyse the concavity and convexity of functions and locate points of inflexion, calculate the curvature and center of curvature of a given curve.
5	calculate the partial derivatives of functions with multiple variables, apply Euler's theorem on homogeneous functions, differentiate implicit functions and calculate total differential coefficients, and understand the concept of an exact differential and its applications.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Limit and Continuity	Limit and continuity, different types of discontinuity	9	3	-	12

II	Differentiation	Derivatives of hyperbolic functions, successive differentiation, Leibnitz theorem, indeterminate forms	9	3	-	12
III	Expansion of Function	Roll's Theorem, Mean Value Theorem, Taylor's Series, Maclaurin's Series and Cauchy's Series in finite form, expansion of functions in infinite power series	9	3	-	12
IV	Application of Derivatives	Tangent and normal, curvature, centre of curvature, asymptotes, concavity and convexity of inflexion, singular points	9	3	-	12
V	Partial Differentiation	Partial differentiation, homogeneous functions, Eulers theorem on homogenous functions, differentiation of implicit functions, total differential coefficients, exact differential, partial derivatives of two functions, converse of Eulers theorem	9	3	-	12

Suggested Readings

1. **Thomas, Jr. George B., Weir, Maurice D., & Hass, Joel** (2014). *Thomas' Calculus* (14th Edition, 2021), Pearson Education, Delhi. Indian Reprint.

2. **B. C. Das, B. N. Mukherjee**. *Differential Calculus* (59th Edition), U.N. Dhur & Sons Private Ltd., Kolkata (2024).

Teaching Plan (MNC45MAT102(T)25 : Differential Calculus):

Unit I: Limit of a function and limit laws, ε-δ definition of limit and one-sided limits [1] Chapter 2(Section 2.2 - 2.4);
Continuity [1] Chapter 2(Section 2.5); Different types of discontinuity [2] Chapter 4(Section 4.3);
Limits involving infinity and Asymptotes of graphs [1] Chapter 2(Section 2.6)

Unit II: Differentiation

Derivatives of a function and Rules of differentiation [1] Chapter 3(Section 3.2 - 3.3);
Derivative of Trigonometric hyperbolic functions [2] Chapter 7(Section 7.9);
Derivative of implicit functions [1] Chapter 3(Section 3.7);
Successive differentiation [2] Chapter 8(Section 8.1 – 8.3);
Leibnitz's Theorem [2] Chapter 8(Section 8.5);
Indeterminate forms and L'Hospital's Rule [2] Chapter 11

Unit III: Expansion of Function

Roll's Theorem and its geometrical interpretation [2] Chapter 9(Section 9.1 - 9.2);
Mean Value Theorem and its geometrical interpretation [2] Chapter 9(Section 9.3 - 9.4);
Taylor Series, Maclaurin's Series and Cauchy's Series in finite form [2] Chapter 9 (Section 9.5 - 9.7);
Expansion of functions in infinite power series [2]Chapter 9(Section 9.9)

Unit IV: Application of Derivatives

Tangent and normal [2]Chapter 14(Section 14.2 - 14.6, 14.12 - 14.17);
Curvature and Centre of curvature [2]Chapter 15(Section 15.1 - 15.4, 15.7 - 15.8);
Asymptotes [2]Chapter 16(Section 16.2 - 16.7);
Concavity and Convexity of inflexion [2]Chapter 19(Section 19.1 - 19.5)

Unit V: Partial Differentiation

Functions of two or more variables, partial differentiation, homogeneous functions, Eulers Theorem on homogenous functions, differentiation of implicit functions, total differential coefficients, exact differential, partial derivatives of two functions, converse of Eulers Theorem [2] Chapter 12 (Section 12.1 - 12.3, 12.5 - 12.13)

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	✓		✓		✓		✓
CO2	✓		✓		✓		✓
CO3	✓		✓		✓		✓
CO4	✓		✓		✓		✓
CO5	✓		✓		✓		✓

Assessment Methods

- Oral and written examination
- Closed book and open book tests
- Problem solving exercises
- Seminar and presentations
- Interactive sessions

Academic level 4.5 and Semester – II
MDC45MAT102(T)25 : Elementary Mathematics-I

Nature of Course	**MDC**			
Course Code	**MDC45MAT102(T)25**			
Course Title	**Elementary Mathematics-I**			
Course level	**100**			
Credit details	**Total Credit**	**Lecture/Week**	**Tutorial/week**	**Total Hour/Week**
	3	**3**	**0**	**3**
Course Audience	**BA/BSc Second Semester**			
Proposed by	**Board of Under-Graduate of Department of Mathematics, Manipur University**			
Pre Requisites	**Concept of numbers, counting, equations**			
Pre Requisite Course Required	**10 Mathematics**			
Faculty Eligibility and Specialization	**Not Required**			

Course Objectives: The course is aimed at imparting concepts frequently used in Mathematics at a primary level and also required in other disciplines. It aims at giving basic knowledge of the subject to students from any background which is often required for a student preparing for various competitive examinations.

Course learning outcomes: After completion of the course, a student will be able to

1.	define and identify various types of sets, understand various set operations like union, intersection, difference, and complement to sets, and use Venn diagrams to visualize these operations.
2.	understand the concepts of relations and functions, visualize various special functions graphically, and identify the domain and range of functions, particularly trigonometric functions.
3.	use PMI to prove mathematical statements and theorems, understand and apply the fundamental principle of counting, and solve problems involving the arrangement (permutations) and selection (combinations) of objects.
4.	**u**nderstand the basic algebra of complex numbers, including calculating the modulus and conjugates, represent complex numbers graphically, find solutions to quadratic equations, including the calculation of square roots for complex numbers.
5	identify and negate of statements, and understand the construction of compound statements using logical connectors like "Or" and "And", interpret logical implications ("If then", "Only if", "If and only if") and use quantifiers ("there exists", "for all"), construct truth tables to determine the validity and equivalence of statements, including the converse and contrapositive, apply principles of mathematical reasoning to validate statements and arguments.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Sets	Introduction with historical notes, Sets and their representations, Finite and Infinite sets, Equal sets, Subsets, power sets, Universal sets, Venn diagram, Operations on set, Union, Intersection, Difference of sets, Complement of sets, Practical problems on union and intersection	9	-	-	9
II	Relation, function	Introduction, Cartesian product, Relations, Functions, Graphs of some special functions, graphical representation of linear inequalities in one and two variables and their solutions, trigonometric functions, domain and range of such functions	9	-	-	9
III	Principle of Mathematical Induction, Permutation, Combination	Introduction of PMI, Motivation, PMI, Fundamental Principle of Counting, Permutations, Combinations	9	-	-	9
IV	Complex numbers and quadratic equations	Introduction, Algebra of complex numbers, the Modulus and the Conjugates of a Complex number, Argand plane and Polar Representation, Quadratic equations, Square roots	9	-	-	9
V	Mathematical reasoning	Introduction, Statements, Negation of a statement, Compound statement, Special words “Or”, “And”, Implications If then, Only if, If and only if, Quantifiers, there exists, for all, truth table, equivalence of statements, Converse, Contrapositive, validating statements	9	-	-	9

Suggested Readings:

NCERT Mathematics Text Book for Standard XI

Additional Readings:

B S Vatssa, *Discrete Mathematics*, 3rd Edition, Vishwa Prakashan

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- Class lectures
- Seminars
- Tutorials
- Group discussions and Workshops
- Short answer type questions
- Long answer type questions
- Objective type questions
- Multiple choice questions
- Statement, reasoning and explanation

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CO1		√	√				√		
CO2		√	√	√					
CO3		√	√	√		√			
CO4		√	√				√		

Assessment methods

- Oral and written examination
- Closed book and open book tests
- Problem solving exercises
- Seminar and presentations
- Interactive sessions

Academic level 4.5 and Semester – II
SEC45MAT102(T)25 : Python Programming

Nature of Course	**SEC**			
Course Code	**SEC45MAT102(T)25**			
Course Title	**Python Programming (Theory)**			
Course level	**100**			
Credit details	**Total Credit**	**Lecture/Week**	**Tutorial/week**	**Total Hour/Week**
	2	**2**	**0**	**2**
Course Audience	**BA/BSc Second Semester**			
Proposed by	**Board of Under-Graduate of Department of Mathematics, Manipur University**			
Pre Requisites	**Basic Computer Literacy**			
Pre Requisite Course Required	**10+2 Mathematics**			
Faculty Eligibility and Specialization				

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Introduction to Python	Python Identifiers, keywords, and Indentation, data types: Int, float, Boolean, string, and list; variables, Operators, precedence of operators, expressions, statements, comments; modules, functions and	6	-	-	6

		their use, flow of execution, parameters and arguments				
II	Control Statements	Branching, looping, break, continue, and pass, mutable and immutable structures. Testing and debugging a program	6	-	-	6
III	Functions	return values, parameters, local and global scope, exit function, function composition, and recursion	6	-	-	6
IV	Visualization using 2D and 3D graphics	Visualization using graphical objects like Point, Line, Histogram, Sine and Cosine Curve, and 3D objects	5	-	-	5
V	Data Structures	Built-in data structures: Strings, lists, Sets, Tuples, and dictionaries, and associated operations. Basic searching and sorting methods using iteration and recursion	5	-	-	5

Academic level 4.5 and Semester – II
SEC45MAT102(P)25 : Python Programming

Nature of Course	**SEC**			
Course Code	**SEC45MAT102(P)25**			
Course Title	**Python Programming (Practical)**			
Course Level	**100**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	1	**1**	**0**	**2**
Course Audience	**BA/BSc First Semester**			
Proposed by	**Board of Under-Graduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Basic Computer Literacy**			
Pre Requisite Course Required	**10+2 Mathematics**			
Faculty Eligibility and Specialization	**Master in Mathematics with Computer Programming knowledge**			

Course Objectives: This course is designed to introduce the student to the basics of programming using Python. The course covers the topics essential for developing well documented modular programs using different instructions and built-in data structures available in Python.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	develop, document, and debug modular python programs to solve computational problems
2.	select a suitable programming construct and data structure for a situation
3.	use built-in strings, lists, sets, tuples and dictionary in applications
4.	define classes and use them in applications
5.	use files for I/O operations

Detailed Syllabus Content

Unit	Unit Name	List of Practical	L	T	P	Total
I	**Introduction to Python:**	1. Execution of expressions involving arithmetic, relational, logical, and bitwise operators in the shell window of Python IDLE. 2. Write a Python function to produce the outputs such as:	-	-	3	3

		a) * * * * * * * * * * * * * (b) 1 232 34543 4567654 567898765 3. Write a Python program to illustrate the various functions of the "Math" module. 4. Write a function that takes the lengths of three sides: **side1**, **side2** and **side3** of the triangle as the input from the user using the **input** function and return the area of the triangle as the output. Also, assert that the sum of the length of any two sides is greater than the third side.				
II	Control Statements	5. Write a program to check whether a given number is positive, negative, or zero. 6. Write a program to check whether a person is eligible to vote. 7. Write a program to print even numbers from 1 to 50 using for loop. 8. Write a program to print numbers from 20 to 1 using for loop. 9. Write a program to count the vowels in a string given by user. 10. Write a program to find factorial of a number using While loop. 11. Write a program to calculate the GCD/LCM for two given number. 12. Write a program to calculate the sum of the first n natural numbers using for loop. 13. Write a program that calculates and prints the sum of cubes of even numbers up to a specified limit (e.g., 20) using a while loop 14. Write a program to print the sequence 1,2,3…n using do while loop	-	-	3	3
III	**Functions:**	15. Write a Python function that takes a number as an input from the user and computes its factorial. 16. Write a Python function to return nth terms of the Fibonacci sequence 17. Write a function that takes a number with two or more digits as an input and finds its reverse and computes the sum of its digits. 18. Write a function that takes two numbers as input parameters and returns their least common multiple and highest common factor.	-	-	3	3

		19. Write a function that takes a number as an input and determines whether it is prime or not. 20. Write a function that finds the sum of the terms of the following series: a) $1 - x^2/2! + x^4/4! - x^6/6! + \ldots x^n/n!$ b) $1 + x^2/2! + x^4/4! + x^6/6! + \ldots x^n/n!$ 21. Write a Python function that takes two strings as an input from the user and counts the number of MAThing characters in the given pair of strings. 22. Write a Python function that takes a string as an input from the user and displays its reverse. 23. Write a Python function that takes a string as an input from the user and determines whether it is palindrome or not. 24. Write a Python function to calculate the sum and product of two compatible matrices 25. Write a function that takes a list of numbers as input from the user and produces the corresponding cumulative list where each element in the list present at index i is the sum of elements at index j <=i. 26. Write a function that takes **n** as an input and creates a list of n lists such that i^{th} list contains first five multiples of i. 27. Write a function that takes a sentence as input from the user and calculates the frequency of each letter. Use a variable of dictionary type to maintain the count. 28. Write a Python function that takes a dictionary of *word*:*meaning*pairs as an input from the user and creates an inverted dictionary of the form meaning: list-of-words.				
IV	Visualization using 2D and 3D graphics	29. Write a menu-driven program to create mathematical 3D objects Curve, Sphere, Cone, Arrow, Ring, and Cylinder. 30. Write a program that makes use of a function to accept a list of n integers and displays a histogram. 31. Write a program that makes use of a function to display sine, cosine, polynomial and exponential curves.			3	3
V	Data Structures	32. Write a function that reads a file **file1** and displays the number of words and the number of vowels in the file. 33. Write a Python function that copies the content of one file to another. 34. Write a function that reads a file **file1** and copies only alternative lines to another file **file2**. Alternative lines copied should be the odd numbered lines.			2	2

Suggested Readings:

1. **Downey, A.B.,** (2015), *Think Python–How to think like a Computer Scientist*, 3rd edition. O'Reilly Media.
2. **Taneja, S. & Kumar, N.,** (2017), *Python Programming-A Modular Approach*. Pearson Education.

Additional Readings:

1. **Brown, M. C.** (2001).*The Complete Reference: Python*, McGraw Hill Education.
2. **Dromey, R. G.** (2006), *How to Solve it by Computer*, Pearson Education.
3. **Guttag, J.V.** (2016), *Introduction to computation and programming using Python*. MIT Press.
4. **Liang,Y.D.** (2013), *Introduction to programming using Python*. Pearson Education.

Teaching Plan (SEC45MAT102(T)25: Python Programming-Theory)

Lecture 1: Python Identifiers, keywords, and Indentation, data types: Int, float,
Lecture 2: Boolean, string, and list; variables
Lecture 3: Operators, precedence of operators,
Lecture 4: expressions, statements
Lecture 5: comments; modules, functions, and their use
Lecture 6: flow of execution, parameters, and arguments
Lecture 7: if Statements with examples
Lecture 8: switch Statements with examples
Lecture 9: while loop with examples
Lecture 10: do while loop with examples
Lecture 11: for loop with examples
Lecture 12: break, continue, and pass, mutable and immutable structures.
Lecture 13: Functions: return values,
Lecture 14: Functions: parameters
Lecture 15: Local Scope with examples
Lecture 16: Global scope with examples
Lecture 17: exit function, function composition
Lecture 18: function recursion with examples
Lecture 19: Visualization using graphical objects like Point
Lecture 20: Visualization using line
Lecture 21: Visualization using histogram
Lecture 22: Sine and cosine curve
Lecture 23: Potting of 3D graph
Lecture 24: Built-in data structures: Strings, lists
Lecture 25: Concepts of Sets, Tuples with examples
Lecture 26: Concept of dictionaries, and associated operations
Lecture 27: Basic searching and sorting methods using iteration
Lecture 28: Basic searching and sorting methods using recursion

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- Class lectures
- Seminars
- Tutorials
- Group discussions and Workshops
- Short answer type questions
- Long answer type questions
- Objective type questions
- Multiple choice questions
- Statement, reasoning and explanation

Linkage between POs and COs

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CO1		√	√				√		
CO2		√	√	√					
CO3		√	√	√		√			
CO4		√	√				√		

Assessment methods

- Oral and written examination
- Closed book and open book tests
- Problem solving exercises
- Seminar and presentations
- Interactive sessions

Academic level 5.0 and Semester – III
MJC50MAT203(T)25: Coordinate Geometry

Nature of Course	**Major**			
Course Code	**MJC50MAT203(T)25**			
Course Title	**Coordinate Geometry**			
Course Level	**200**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Third Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur university**			
Pre Requisites	**Straight lines, Circle, Conic section, Coordinate axes in three dimensions**			
Pre Requisite Course Required	**Class XII with Mathematics**			
Faculty Eligibility and Specialization	**Not Required**			

Course Objectives: The primary objective of the course is to introduce transformation of coordinates in two dimensions, pair of straight lines, general equation of second degree in two variables, transformation of axes in three dimensions, sphere, cone, cylinder, conicoids etc.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	learn about the transformation of coordinates in two dimensions and pair of straight lines
2.	learn about the general equation of the second degree in two variables and classification of conics
3.	understand the transformation of axes in three dimensions and learn the equations of sphere, cone and cylinder
4.	understand conicoids and also generating lines of conicoids

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	**Transformation of Coordinates and Pair of Straight Lines**	*Transformation of Co-ordinates*: Change of origin without changing the direction of axes: Translation of axes, Transformation from one pair of rectangular axes to another with the same origin: Rotation of axes, Invariants, Removal of the xy-term	9	3		12

		Pair of Straight Lines: Pair of straight lines, Homogeneous equation of second degree, Angle between the pair of lines given by the homogeneous equation, Bisectors of the angles between the pair of lines, Condition for the general equation of second degree to represent a pair of straight lines, Pair of intersecting straight lines, Pair of parallel straight lines, Equation of the pair of lines joining the origin to the points of intersection of a line and a curve.				
II	**General Equation of the Second Degree**	*General Equation of the Second Degree*: Every cartesian equation of the second degree represents a conic, Centre of a conic, Reduction of the equation of a central conic and a non-central conic, Condition that a line is a tangent to a conic, Chord of contact, Pole and polar, Diameter, Conjugate diameters, Intersection of two conics, Pair of tangents, Director circle, Asymptotes. *Polar equation of Conics*: Polar equation of a conic with respect to focus as pole, Equation of a chord, Tangent and normal, Chord of contact, Director circle	12	4		16
III	**Sphere, Cone and Cylinder**	*Transformation of Axes:* Change of origin with parallel axes, Three mutually perpendicular straight lines, Transformation of rectangular axes, Invariant. *Sphere:* Equation of a sphere, Condition for the general equation of second degree to represent a sphere, Section of a sphere by a plane, Intersection of two spheres, Tangent and tangent plane, Condition for a plane to be a tangent plane to a sphere. *Cone:* Equation of a cone with its vertex as origin, Right circular cone, Tangent plane, Condition for a plane to be a tangent plane, Reciprocal cone, Three mutually perpendicular generators. *Cylinder:* Equation of a cylinder, Right circular cylinder.	12	4		16
IV	**Conicoids**	*Central Conicoids*: Ellipsoid, Hyperboloid of one sheet, Hyperboloid of two sheets, Intersection of a line with a conicoid, Tangent lines and tangent planes, Normal, Number of normals through a given point, Polar plane, Polar lines, Diametral plane, Enveloping cone, Enveloping cylinder, Conjugate diameters. *Paraboloids:* Elliptic Paraboloid, Hyperbolic Paraboloid, Tangent Plane, Condition for tangent plane.	9	3		12
V	**Generating Lines**	*Generating Lines:* Ruled Surface, Generators of a Hyperboloid of one sheet, Generators of a Hyperbolic Paraboloid, Section by a tangent	3	1		4

		plane, Properties of generators, Perpendicular generators, Locus of the point of intersection of the perpendicular generators of a Hyperbolic Paraboloid, Condition for generator.				

Suggested Readings:

1. **Prof. B. Das** (2012). *Analytical Geometry with Vector Analysis*. Orient Book Company, Kolkata.

2. **J.G. Chakravorty and P.R. Ghosh** (2014). *Analytical Geometry and Vector Analysis*. U.N. Dhur & Sons Private Ltd., Kolkata.

Additional Readings:

1. **S.L. Loney** (2016). *The Elements of Coordinate Geometry.* McMillan and Company, London.

2. **R.J.T. Bell** (1994). *Elementary Treatise on Coordinate Geometry of Three Dimensions.* McMillan India Ltd.

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Teaching Plan (MJC50MAT203(T)25: Coordinate Geometry):

Week 1, 2 and 3: Transformation of Co-ordinates, Pair of straight lines
[1] Chapter 5, Chapter 6

Week 4, 5, 6 and 7: General Equation of the Second Degree, Polar equation of Conics
[1] Chapter 11, Chapter 12

Week 8, 9, 10 and 11: Transformation of Axes, Sphere, Cone and Cylinder
[2] Chapter 4, [1] Chapter 6, Chapter 7, Chapter 8

Week 12, 13 and 14: Central Conicoids, Paraboloids
[1] Chapter 9, Chapter 10

Week 15: Generating Lines [1] Chapter 11

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√		√	√	√		√
CO4	√			√	√		√

Academic level 5.0 and Semester – III
MJC50MAT204(T)25: Real Analysis

Nature of Course	**Major**			
Course Code	**MJC50MAT204(T)25**			
Course Title	**Real Analysis**			
Course Level	**200**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Third Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur university**			
Pre Requisites	**Nil**			
Pre Requisite Course Required	**Class XII with Mathematics**			
Faculty Eligibility and Specialization	**Not Required**			

Course Objectives: The primary objective of the course is to develop a deep and rigorous understanding of real lines of defining terms to prove the results of convergence and divergence of sequences and series of real numbers. These concepts have wide range of applications in real-life scenario.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	understand many properties of the real line R and learn to define sequence in terms of functions from to a subset of R.
2.	recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate their limit superior, limit inferior, and the limit of a bounded sequence.
3.	apply the ratio, root, alternating series and limit comparison tests for convergence and absolute convergence of an infinite series of real numbers.
4.	understand sequential criteria for continuity and learn the properties of continuous functions defined on closed intervals and the concept of uniform continuity

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	**Properties of Real Numbers**	Algebraic and order properties of R, Absolute value of a real number; Bounded above and bounded below sets, Supremum and infimum of a nonempty subset of R, the completeness property of R, Archimedean property, Density of rational numbers in R; Definition and types of intervals, Nested intervals property.	6	2		8
II	**Open Sets and Closed Sets**	Neighbourhood of a point in R, Interior point, Open sets, Limit point, Derived set, Bolzano-Weierstrass Theorem, Closed sets, Closure, Dense sets, Countable and uncountable sets.	9	3		12
III	**Sequences in** R	Convergent sequence, Limit of a sequence, Bounded sequence, Limit theorems, Monotone sequences, Monotone convergence theorem, Sub-sequences, Bolzano-Weierstrass theorem for sequences, Limit superior and limit inferior for bounded sequence, Cauchy sequence, Cauchy's convergence criterion.	12		4	16

IV	**Infinite Series**	Convergence and divergence of infinite series of real numbers, Necessary condition for convergence, Cauchy criterion for convergence; Tests for convergence of positive term series: Integral test, Basic comparison test, Limit comparison test, D'Alembert's ratio test, Cauchy's n^{th} root test; Alternating series, Leibniz test, Absolute and conditional convergence.	12	4		16
V	**Uniform Continuity**	Sequential criterion for continuity and discontinuity, Properties of continuous functions on closed intervals; Uniform continuity.	6	2		8

Suggested Readings:

1. **Bartle, Robert G., & Sherbert, Donald R.** (2015). *Introduction to Real Analysis* (4th ed.). Wiley India Edition. New Delhi.
2. **Ross, Kenneth A.** (2013). *Elementary Analysis*: *The theory of calculus* (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian Reprint.
3. **Denlinger, Charles G.** (2011). *Elements of Real Analysis*. Jones and Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.
4. **S.C. Malik and Savita Arora** (2010), Mathematical Analysis. New Age International (P) Ltd., New Delhi.

Additional Readings:

1. **Bilodeau, Gerald G., Thie, Paul R., & Keough, G. E.** (2010). *An Introduction to Analysis* (2nd ed.). Jones and Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

2. **Thomson, Brian S., Bruckner, Andrew. M., & Bruckner, Judith B.** (2001). *Elementary Real Analysis.* Prentice Hall.

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Teaching Plan (MJC50MAT204(T)25: Real Analysis):

Week 1 and 2: Algebraic and order properties of R**.** Absolute value of a real number; Bounded above and bounded below sets, Supremum and infimum of a nonempty subset of R.

[1] Chapter 2 [Sections 2.1, 2.2 (2.2.1 to 2.2.6), and 2.3 (2.3.1 to 2.3.5)]

Week 3 and 4: The completeness property of R, Archimedean property, Density of rational number sin R; Definition and types of intervals, Nested intervals property; Neighbourhood of a point in R,

Interior point, Open sets, Limit point, Derived set, Bolzano-Weierstrass Theorem, Closed sets, Closure, Dense sets, Countable and uncountable sets.
[1] Chapter 2 [Sections 2.3 (2.3.6), 2.4 (2.4.3 to 2.4.9), and 2.5 up to Theorem 2.5.3]
[1] Chapter 11 [Section 11.1 (11.1.1 to 11.1.3)] [4] Chapter 2

Week 5 and 6: Convergent sequence, Sequences and their limits, Bounded sequence, Limit theorems.
[1] Chapter 3 (Sections 3.1 and 3.2)

Week 7: Monotone sequences, Monotone convergence theorem and applications.
[1] Chapter 3 (Section 3.3)

Week 8: Subsequences and statement of the Bolzano-Weierstrass theorem, Limit superior and limit inferior for bounded sequence of real numbers with illustrations only.
[1] Chapter 3 [Section 3.4 (3.4.1 to 3.4.12), except 3.4.4, 3.4.7, 3.4.9 and 3.4.11]

Week 9: Cauchy sequences of real numbers and Cauchy's convergence criterion.
[1] Chapter 3 [Section 3.5 (3.5.1 to 3.5.6)]

Week 10: Convergence and divergence of infinite series, Sequence of partial sums of infinite series, Necessary condition for convergence, Cauchy criterion for convergence of series.
[3] Chapter 8 (Section 8.1)

Week 11 and 12: Tests for convergence of positive term series**:** Integral test statement and convergence of *p*-series, Basic comparison test, Limit comparison test with applications, D'Alembert's ratio test and Cauchy's *n*th root test.
[3] Chapter 8 [Section 8.2 up to 8.2.19]

Week 13 and 14: Alternating series, Leibniz test, Absolute and conditional convergence.
[3] Chapter 8[Section 8.3 (8.3.1 to 8.3.7)]

Week 15: Sequential criterion for continuity and discontinuity, Properties of continuous functions on closed intervals; Uniform continuity. [4] Chapter 2 [Section 2 Subsection 2.4 (Theorem 4 & examples related to sequential criteria for continuity, Section 3, Section 4]

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√		√	√	√		√
CO4	√		√	√	√		√

Academic level 5.0 and Semester – III
MNC50MAT203(T)25: Coordinate Geometry

Nature of Course	**Minor**			
Course Code	**MNC50MAT203(T)25**			
Course Title	**Coordinate Geometry**			
Course Level	**200**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Third Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur university**			
Pre Requisites	**Straight lines, Circle, Conic section, Coordinate axes in three dimensions**			
Pre Requisite Course Required	**Class XII with Mathematics**			
Faculty Eligibility and Specialization	**Not Required**			

Course Objectives: The primary objective of the course is to introduce transformation of coordinates in two dimensions, pair of straight lines, general equation of second degree in two variables, transformation of axes in three dimensions, sphere, cone, cylinder, conicoids etc.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	learn about the transformation of coordinates in two dimensions and pair of straight lines
2.	learn about the general equation of the second degree in two variables and classification of conics
3.	understand the transformation of axes in three dimensions and learn the equations of sphere, cone and cylinder
4.	understand conicoids and also generating lines of conicoids

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	**Transformation of Coordinates and Pair of Straight Lines**	*Transformation of Co-ordinates*: Change of origin without changing the direction of axes: Translation of axes, Transformation from one pair of rectangular axes to another with the same origin: Rotation of axes, Invariants, Removal of the xy-term *Pair of Straight Lines*: Pair of straight lines, Homogeneous equation of second degree, Angle between the pair of lines given by the homogeneous equation, Bisectors of the angles between the pair of lines, Condition for the general equation of second degree to represent a pair of straight lines, Pair of intersecting straight lines, Pair of parallel straight lines, Equation of the pair of lines joining the origin to the points of intersection of a line and a curve.	9	3		12
II	**General Equation of the Second Degree**	*General Equation of the Second Degree*: Every cartesian equation of the second degree represents a conic, Centre of a conic, Reduction of the equation of a central conic and a non-central conic, Condition that a line is a tangent to a conic, Chord of contact, Pole and polar, Diameter, Conjugate diameters, Intersection of two conics, Pair of tangents, Director circle, Asymptotes. *Polar equation of Conics*: Polar equation of a conic with respect to focus as pole, Equation of a chord, Tangent and normal, Chord of contact, Director circle	12	4		16
III	**Sphere, Cone and Cylinder**	*Transformation of Axes:* Change of origin with parallel axes, Three mutually perpendicular straight lines, Transformation of rectangular axes, Invariant. *Sphere:* Equation of a sphere, Condition for the general equation of second degree to represent a sphere, Section of a sphere by a plane, Intersection of two spheres, Tangent and tangent plane, Condition for a plane to be a tangent plane to a sphere.	12	4		16

		Cone: Equation of a cone with its vertex as origin, Right circular cone, Tangent plane, Condition for a plane to be a tangent plane, Reciprocal cone, Three mutually perpendicular generators. *Cylinder:* Equation of a cylinder, Right circular cylinder.				
IV	**Conicoids**	*Central Conicoids*: Ellipsoid, Hyperboloid of one sheet, Hyperboloid of two sheets, Intersection of a line with a conicoid, Tangent lines and tangent planes, Normal, Number of normals through a given point, Polar plane, Polar lines, Diametral plane, Enveloping cone, Enveloping cylinder, Conjugate diameters. *Paraboloids:* Elliptic Paraboloid, Hyperbolic Paraboloid, Tangent Plane, Condition for tangent plane.	9	3		12
V	**Generating Lines**	*Generating Lines:* Ruled Surface, Generators of a Hyperboloid of one sheet, Generators of a Hyperbolic Paraboloid, Section by a tangent plane, Properties of generators, Perpendicular generators, Locus of the point of intersection of the perpendicular generators of a Hyperbolic Paraboloid, Condition for generator.	3	1		4

Suggested Readings:

1. **Prof. B. Das** (2012). *Analytical Geometry with Vector Analysis*. Orient Book Company, Kolkata.

2. **J.G. Chakravorty and P.R. Ghosh** (2014). *Analytical Geometry and Vector Analysis*. U.N. Dhur & Sons Private Ltd., Kolkata.

Additional Readings:

1. **S.L. Loney** (2016). *The Elements of Coordinate Geometry.* McMillan and Company, London.

2. **R.J.T. Bell** (1994). *Elementary Treatise on Coordinate Geometry of Three Dimensions.* McMillan India Ltd.

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Teaching Plan (MNC50MAT203(T)25: Coordinate Geometry):

Week 1, 2 and 3: Transformation of Co-ordinates, Pair of straight lines
[1] Chapter 5, Chapter 6

Week 4, 5, 6 and 7: General Equation of the Second Degree, Polar equation of Conics
[1] Chapter 11, Chapter 12

Week 8, 9, 10 and 11: Transformation of Axes, Sphere, Cone and Cylinder
[2] Chapter 4, [1] Chapter 6, Chapter 7, Chapter 8

Week 12, 13 and 14: Central Conicoids, Paraboloids
[1] Chapter 9, Chapter 10

Week 15: Generating Lines
[1] Chapter 11

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√		√	√	√		√
CO4	√			√	√		√

Academic level 5.0 and Semester – III
MDC50MAT203(T)25 : Elementary Mathematics-II

Nature of Course	**MDC**			
Course Code	**MDC50MAT203(T)25**			
Course Title	**Elementary Mathematics-II**			
Course level	**100**			
Credit details	**Total Credit**	**Lecture/Week**	**Tutorial/week**	**Total Hour/Week**
	3	**3**	**0**	**3**
Course Audience	**BA/BSc Third Semester**			
Proposed by	**Board of Under-Graduate of Department of Mathematics, Manipur University**			
Pre Requisites	**Concept of numbers, counting, equations, geometry**			
Pre Requisite Course Required	**10 Mathematics**			
Faculty Eligibility and Specialization	**Not Required**			

Course Objectives: The course is to impart concepts frequently used in Mathematics at a primary level and also required in other disciplines to the students from any background. It will make them aware about many natural situations in a precise form of mathematical tools.

Course Learning Outcomes: This course will enable the students to:

1.	Gain sufficient knowledge of basics of mathematical tools used daily
2.	Get the idea of shortest distance, different geometrical objects in two and three dimensions
3.	Understand many physical phenomena by modeling using the methods of LPP
4.	Analyze the information available in the surroundings with statistical tools

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Binomial theorem, Sequence, Series	Permutation, Combinations, Pascal triangle, Binomial theorem of for positive integral index, general term, Middle term; Sequences and Series, Arithmetic Progression (AP), Arithmetic means (AM's), Sum of n terms, Geometric Progression (GP) , Sum of n terms of a G P, Geometric mean (GM), Sum to n terms of special series	9	-	-	9
II	Straight lines	Slope of a line, Condition of parallelism, Condition of perpendicularity, Collinearity of three points, Various forms of equation of a line, Distance of a point from a line	9	-	-	9
III	Conic Sections and three dimensional geometry	Conic Sections; Sections of a cone, Circle, Parabola, Hyperbola, Ellipse, Three demensional geometry; Coordinate axes and Coordinate planes, Distance between two points, Section formula, position vector	9	-	-	9
IV	Matrices and Mathematical Modelling	Matrix, Types of matrix, Operations on matrices, Symmetric and Skew Symmetric matrices, Determinants, Minors and Cofactors, Adjoint and Inverse of a matrix, Application of Determinants and matrices to solve system of linear equations, Principles of mathematical modeling, Model formulation using matrices, linear programming problem and mathematical formulation, solution of LPP graphically	9	-	-	9
V	Statistics and Probability	Measures of Dispersion, Range, Mean Deviation, Variance and Standard Deviation, Analysis of frequency Distribution, Probabilty; Random experiments, Event, Axiomatic Approach to probability, Conditional probability and its properties, Multiplication theorem on conditional probability, Independent events	9	-	-	9

Suggested readings:

NCERT Mathematics Text Book for Standard XI, XII

Additional Readings:

B S Vatssa, Discrete Mathematics, 3rd Edition Vishwa Prakashan

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- Class lectures
- Seminars
- Tutorials
- Group discussions and Workshops
- Short answer type questions
- Long answer type questions
- Objective type questions
- Multiple choice questions
- Statement, reasoning and explanation

Linkage between POs and COs

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CO1		√	√	√					
CO2		√							
CO3				√			√		
CO4		√				√			

Assessment methods

- Oral and written examination
- Closed book and open book tests
- Problem solving exercises
- Seminar and presentations
- Interactive sessions

Academic level 5.0 and Semester – III
SEC50MAT203(T)25 : Microsoft Excel

Nature of Course	**SEC**			
Course Code	**SEC50MAT203(T)25**			
Course Title	**Microsoft Excel (Theory)**			
Course level	**200**			
Credit details	**Total Credit**	**Lecture/Week**	**Tutorial/week**	**Total Hour/Week**
	2	**2**	**0**	**2**
Course Audience	**BA/BSc Third Semester**			
Proposed by	**Board of Under-Graduate of Department of Mathematics, Manipur University**			
Pre Requisites	**Basic Computer Literacy**			
Pre Requisite Course Required	**10+2 Mathematics**			
Faculty Eligibility and Specialization	**Master's in Mathematics with Knowledge of Computer Applications**			

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Introduction to Spreadsheets	Introduction to MS Excel, Features and Applications of Excel, Excel interface: Title bar, Quick access toolbar, Formatting toolbar, Ribbon, Formula bar, Worksheet tabs, and Status bar, working with spreadsheet cells, and ranges.	6	-	-	6
II	Data Entry and Formatting	Enter and revise data, manage data using Flash Fill, move data within a workbook, find and replace data, Correct and expand upon data, and define Excel tables. Format cells: define styles, apply workbook themes and table styles, add images, and change font, color, and alignment of the cells and data entered.	6	-	-	6

III	Formulas and Functions	Operators, precedence, and basics of writing formulas, operation using built-in functions, inserting functions into formulas, editing formulas, using cell references in formulas, using formulas in tables, and within tables.	6	-	-	6
IV	Data Analysis Tools	Filtering data, summarizing filtered data, defining a valid set of values for a range of cells, sorting data using a custom list, creating a pivot table automatically or manually, formatting a pivot table, grouping pivotable items, and using a pivot table to create a frequency distribution.	6	-	-	6
V	Charts & Advanced Features	Charts in Excel, embedded charts, limitations of charts, basic steps for creating charts, modifying and customizing charts, chart types, create forecast worksheets, define and manage measures, create 3D maps.	6	-	-	6

Academic level 5.0 and Semester – III
SEC50MAT203(P)25 : Microsoft Excel

Nature of Course	**SEC**			
Course Code	**SEC50MAT203(P)25**			
Course Title	**Microsoft Excel (Practical)**			
Course Level	**200**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	1	**1**	**0**	**2**
Course Audience	**BA/BSc First Semester**			
Proposed by	**Board of Under-Graduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Basic Computer Literacy**			
Pre Requisite Course Required	**10+2 Mathematics**			
Faculty Eligibility and Specialization	**Master in Mathematics with Knowledge of Computer Applications**			

Course Objectives: This course provides students with a comprehensive foundation in Microsoft Excel for academic, business, and data handling applications. The primary objective is to develop practical proficiency in using spreadsheets for data entry, formatting, computation, analysis, and visualization. By the end of the course, students will be able to independently create, manage, and interpret spreadsheets using core and intermediate Excel features to solve real-world problems efficiently.

Course Learning Outcomes: This course will enable the students to:

1.	Demonstrate competency in using Microsoft Excel for data entry, management, analysis, and visualization.
2.	Apply Excel tools and functions to solve real-world problems in business, education, and research contexts.
3.	Create professional spreadsheets with formatted data, formulas, PivotTables, and charts for reporting purposes.

4.	Perform data analysis tasks, including filtering, sorting, validation, and PivotTable-based summarization.
5.	Build confidence in using Excel for academic, professional, and personal productivity applications.

Detailed Syllabus Content

Unit	Unit Name	List of Practical	L	T	P	Total
I	Introduction to Spreadsheets	1. Create workbooks, modify workbooks, merge and unmerge cells.	-	-	3	3
II	Data Entry and Formatting	2. Enter data in spreadsheets and perform the following operation (i) manage data by using splash fill (ii) move data within a workbook (iii) find and replace data in the worksheet. 3. Create tables from the data entered in the spreadsheet. 4. Use font size, color, alignment and format the cells and data entered in the table.	-	-	3	3
III	Formulas and Functions	5. Use relative, absolute and mixed references in the tables for computation. 6. Use formulas for summarizing data in a table. 7. Use formulas within a table to perform calculations that use other columns in the table.	-	-	3	3
IV	Data Analysis Tools	8. Open the LimitData workbook in Excel, and then perform filtering. 9. Using the create table dialog box, create a pivot table. 10. After the pivot table is created, perform formatting in the pivot table. 11. Use a pivot table and create a frequency distribution.			3	3
V	Charts & Advanced Features	12. Create a table and create all types of charts available in Excel. 13. Enter business data and create a linear forecast by using the FORECAST.LINEAR() function. 14. Plot data on 3D maps by using the built-in power maps facilities.			3	3

Suggested Readings:

1. **Curtis Frye** (2015), *Microsoft Excel 2016 Step by Step*, Microsoft Press.
2. **Michael Alexander, Richard Kusleika , John Walkenbach**, (2017), *Excel 2019 Bible*. Wiley.

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- Class lectures
- Seminars
- Tutorials
- Group discussions and Workshops
- Short answer type questions
- Long answer type questions

- Objective type questions
- Multiple choice questions
- Statement, reasoning and explanation

Assessment methods

- Oral and written examination
- Closed book and open book tests
- Problem solving exercises
- Seminar and presentations
- Interactive sessions

Academic level 5.0 and Semester – IV
MJC50MAT205(T)25: Abstract Algebra

Nature of Course	**Major**			
Course Code	**MJC50MAT205(T)25**			
Course Title	**Abstract Algebra**			
Course Level	**200**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Fourth Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Sets, functions, binary operations, equivalence class, congruence**			
Pre Requisite Course Required	**Bachelor certificate with Mathematics as one subject(minor/major)**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: The primary objective of the course is to introduce the fundamental theory of groups and their homomorphisms so as to determine the structure of the group upto isomorphism. The concept of rings will be given along with ideas on specific rings such as Integral domain, PID, UFD.

Course Learning Outcomes: After the completion of the course, a student will be able to

1.	Understand the basic concepts of groups and links with permutations
2.	Learn normal subgroups, cosets, quotient groups, homomorphisms, isomorphisms
3.	Gain knowledge about rings, integral domains, fields, prime and irreducible elements

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Groups	Definition and examples of groups, semigroup, monoid, elementary properties of groups (identity, inverse, cancellation), order of an element, order of a group, abelian groups, permutation group, even and odd permutation	9	3		12

II	Subgroups	Definition and examples of subgroups, Centre of a group, centralizer, cyclic groups, Cosets, Lagrange's theorem and its application, normal subgroups and factor groups	9	3		12
III	Homomorphisms	Definition and examples, types of homomorphisms, properties, kernels, Isomorphism theorems, Caley's Theorem	6	2		8
IV	Rings	Definition and examples of rings, properties of rings, subrings, Integral domain, Fields, Characteristic of a ring, ideals, operation on ideals, quotient ring, prime ideal, maximal ideal, Ring homomorphism, Isomorphism theorems, kernels, field of quotients	9	3		12
V	Factorization domains	Divisibility in integral domain, associate, units, greatest common divisor, irreducible element, prime element, Euclidean domain, Principal ideal domain, polynomial ring, Unique factorization domain, Gauss lemma, Eisenstein's criteria	12	4		16

Suggested Readings

1. **Gallian, Joseph A** (2013), Contemporary Abstract Algebra (8th Edn) Cengage Learning India Pvt Ltd, Delhi
2. **I.N. Herstein** (2006), Topics in Algebra (Second Edn), Wiley India Pvt Ltd.

Additional Readings:

1. **V K Khanna, SK Bhambri** (2017), A Course in Abstract Algebra (5th Edn), Vikas Pub. House Pvt. Ltd
2. **Rotman, Joseph J (**1995), An introduction to the Theory of Groups(4th Edn), Springer Verlag, NY.
3. **David S Dummit, Richard M Foote** (2004), Abstract Algebra (3rd Edn)Wiley Student Edition
4. **Michael Artin** (2014), Algebra (2nd Edn), Pearson
5. **J B Fraleigh** (2007), A first course in Abstract Algebra(7th Edn) Pearson
6. **Nathan Jacobson** (2009), Basic Algebra I (2nd Edn), Dover Publication
7. **I S Luther IBS Passi** (2013), Algebra Volume I Group, Narosa

Teaching Plan **MJC50MAT205(T)25: Abstract Algebra**

Week 1: Definition and examples of groups, semigroup, monoid, elementary properties of groups (identity, inverse, cancellation) [1] chapter 2

Week 2-3: order of an element, order of a group, abelian groups, permutation group, even and odd permutation [1] chapter 5

Week 4: Definition and examples of subgroups, Centre of a group, centralizer, cyclic groups [1] chapter 3,4

Week 5: Cosets, Lagrange's theorem and its application [1] chapter 7

Week 6: Normal subgroups and factor groups [1] chapter 9

Week 7-8: Definition and examples, types of homomorphisms, properties, kernels, Isomorphism theorems, Caley's Theorem [1] chapter 10, 6

Week 9: Definition and examples of rings, properties of rings, subrings [1] chapter 12

Week 10: Integral domain, Fields, Characteristic of a ring, ideals, operation on ideals, Quotient ring, prime ideal, maximal ideal [1] chapter 13, 14

Week 11: Ring homomorphism, Isomorphism theorems, kernels, field of quotient [1] chapter 15

Week 12: Divisibility in integral domain, associate, units, greatest common divisor, irreducible element, prime element [1] chapter 18, Additional reading [1] chapter 9
Week 13: Euclidean domain, Principal ideal domain, polynomial ring [1] chapter 18, Additional reading [1] chapter 9
Week 14-15: Unique factorization domain, Gauss lemma, Eisenstein's criteria [1] chapter 18, Additional reading [1] chapter 9

Course Teaching-Learning Process
The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√		√	√	√		√

Academic level 5.0 and Semester – IV
MJC50MAT206(T)25: Ordinary Differential Equations

Nature of Course	**Major**			
Course Code	MJC50MAT206(T)25			
Course Title	**Ordinary Differential Equations**			
Course Level	**200**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience				
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Real Analysis and Multivariate Calculus**			
Pre Requisite Course Required	**Real Analysis and Multivariate Calculus**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: The main objectives of this course are to introduce the students to the exciting world of Differential Equations, Mathematical Modelling and their applications.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	Formulate Differential Equations for various Mathematical models.
2.	Solve first order non-linear differential equation and linear differential equations of higher order using various techniques
3.	Apply these techniques to solve and analyse various mathematical models.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Equation of first order and first degree	Differential equations and mathematical models, Order and degree of a differential equations, Integrals as general and particular solutions, Exact differential equations and integrating factors of first order differential equations, Separable Equations	9	3		12
II	Linear Equation with constant coefficients	Homogeneous Equations, Reduction to homogeneous equations, Linear equations and Bernoulli Equation, Clairaut's Equation, Existence and Uniqueness of solution of initial and boundary value problems of first order ODE, singular solution of first order ODE.	9	3		12
III	Homogeneous Linear Equations	General solution of homogeneous equation of second order, Principle of superposition for a homogeneous equation, Wronskian, its properties and applications, Linear homogeneous and non- homogeneous equations of higher order with constant coefficients	9	3		12
IV	Method of variation parameter	Euler's equation, Method of undetermined coefficients, Method of variation of parameters, Applications of second order differential equations to mechanical vibration.	9	3		12
V	Analysis of Mathematical Models	Application of first order differential equations to acceleration-velocity model, Growth and Decay model. Introduction to compartmental models, Lake pollution model (with case study of Lake Burley Griffin), Drug Assimilation models, population models (with limited growth, exponential growth), Epidemic models.	9	3		12

Suggested Readings:

1. **Barnes, Belinda &Fulford, Glenn R.** (2015). *Mathematical Modelling with Case Studies, Using* Maple *and* MATLAB (3rd ed.). CRC Press, Taylor & Francis Group.
2. **Edwards, C. Henry, Penney, David E., & Calvis, David T.** (2015). *Differential Equation and Boundary Value Problems*: *Computing and Modeling* (5th ed.). Pearson Education.
3. **Ross, Shepley L.** (2004). *Differential Equations* (3rd ed.). John Wiley & Sons. India.

Additional Reading:

1. M.D. Raisinghania (2008). Advanced Differential Equations S. Chand & Company PVT. LTD, India

Teaching plan (MJC50MAT206(T)25: Ordinary Differential Equations)

Week 1: Differential equations and mathematical models; [2] Chapter 1 (Section 1.1), Order and degree of a differential equations; [3] Chapter 1 (Section 1.1)
Week 2: Integrals as general and particular solutions; [2] Chapter 1 (Section 1.2), Exact differential equations and integrating factors of first order differential equations; [3] Chapter 2 (Section 2.1)
Week 3: Separable equations, Homogeneous equations, Reduction to homogeneous equations; [3] Chapter 2 (Section 2.2).
Week 4: Linear equations and Bernoulli equation Clairaut'sequation ; [3] Chapter 2 (Section 2.3)
Week 5: Existence and Uniqueness of solution of initial and boundary value problems of first order ODE; singular solution of the first order ODE [3] Chapter 1 (Section 1.3),
Week 6& 7: General solution of homogeneous equation of second order, Principle of superposition for a homogeneous equation, Wronskian, its properties and applications; [2] Chapter 3 (Section 3.1).
Week8: Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation; [2] Chapter 3 (Section 3.3).
Week 9: Method of undetermined coefficients, Method of variation of parameters; [2] Chapter 3 (Section 3.5).
Week 10: Applications of second order differential equations to mechanical vibration; [2] Chapter 3 (Section 3.6).
Week 11& 12: Application of first order differential equations to acceleration-velocity model; [2] Chapter 2 (Section 2.3), Growth and Decay model; [1] Chapter 2 (Section 2.2).
Week 13: Introduction to compartmental models; [1] Chapter 2 (Section 2.1), Lake pollution model (with case study of Lake Burley Griffin);
Week 14: [1] Chapter 2 (Section 2.5 & 2.6), Drug Assimilation models; [1] Chapter 2 (Section 2.7).
Week 15: Population models (with limited growth, exponential growth) Epidemic models; [2] Chapter 2 (Section 2.1) or [1] Chapter 3 (Section 3.1)

Assessment Methods

Course Teaching-Learning Process
The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**
- **Project**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√	√	√	√	√		√
CO4	√	√	√	√	√		√

Academic level 5.0 and Semester – IV
MJC50MAT207(T)25: Multivariate Calculus

Nature of Course	**Major**			
Course Code	**MJC50MAT207(T)25**			
Course Title	**Multivariate Calculus**			
Course Level	**200**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Fourth Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Single variable calculus, Elementary vector algebra and analytic geometry**			
Pre Requisite Course Required	**Differential Calculus, Integral Calculus and Analytic geometry**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: The primary objective of the course is to develop an understanding of the extension of the studies of single variable differential and integral calculus to functions of two or more independent variables, and to introduce vector valued functions and vector fields. It also aims to develop application skills in using multivariable calculus methods to solve optimization, geometric, and physical problems.

Course Learning Outcomes: This course will enable the students to:

1.	describe and explain the fundamental concepts of multivariate calculus, including limits continuity, partial derivatives, and vector fields.
2.	compute limits, partial derivatives, higher-order derivatives, and directional derivatives of multivariable functions.
3.	analyse multivariable functions using gradients, tangent planes, divergence, and curl.
4.	apply optimization techniques and multiple integrals to solve geometric and physical problems.
5	Evaluate line and surface integrals and apply Green's, Stokes', and Divergence theorems to solve problems.

Detailed Syllabus-Content:

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Functions of several variables and partial derivatives	Functions of several variables, Level curves and surfaces, Limits and continuity, Partial differentiation, Higher order partial derivative, Tangent planes, Total differential and differentiability, Chain rule	9	3		12

II	Vector Fields and Applications	Vector field, Divergence and Curl, Del Operator Forms for divergence and Curl, Gradient vector field, Basic properties of the gradient, Directional derivatives, Maximal and normal property of the gradient, Tangent planes and normal lines, Extrema of functions of two variables, Method of Lagrange multipliers, Constrained optimization problems	9	3		12
III	Double Integrals	Double integration over rectangular and nonrectangular regions, Double integrals in polar co-ordinates, Jacobians (Without Proof), Change of variables in double integrals	9	3		12
IV	Triple Integrals	Triple integral over a parallelepiped and solid regions, Volume by triple integrals, triple integration in cylindrical and spherical coordinates, Change of variables in triple integrals.	6	2		8
V	Green's, Stokes' and Gauss Divergence Theorem	Line integrals, Applications of line integrals**:** Mass and Work, Fundamental theorem for line integrals, Conservative vector fields, Green's theorem, Area as a line integral; Orientable and non-orientable surface-Mobius strip, Surface integrals, Stokes' theorem, Gauss divergence theorem.	12	4		16

Suggested Readings:

1. **Strauss, Monty J., Bradley, Gerald L., & Smith, Karl J.** (2007). *Calculus* (3rd ed.). Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). Delhi. Indian Reprint 2011.
2. **Marsden, J. E., Tromba, A., & Weinstein, A.** (2004). *Basic Multivariable Calculus*. Springer (SIE).First Indian Reprint.

Additional Reading:

1. **Steward James** (2012). *Multivariable Calculus* (7th Edn.), Books/Cole, Cengage.

2. **George B, Thomas Jr., Joel Hass, Christopher Heil & Maurice D. Weir** (2018). *Thomas' Calculus* (14th Edn.) Pearson.

Teaching Plan [MJC50MAT207(T)25: Multivariate Calculus]

Week 1: Definition of functions of several variables, Graphs of functions of two variables-Level curves and surfaces, limits and continuity of functions of two variables.
[1] Chapter 11(Sections 11.1 and 11.2)
Week 2: Partial differentiation, and partial derivative as slope and rate, Higher order partial derivatives, Tangent Planes, incremental approximation, Total differential.
[1] Chater 11 (Sections 11.3 and 11.4)
Week 3: Differentiability, Chain rule for one parameter, Two and three independent parameters.
[1] Chapter 11 (Section 11.4 and 11.5)
Weeks 4 and 5: Definition of vector field, Divergence and curl. The gradient, Basic properties of the gradient, Directional derivatives, Maximal and normal property of the gradient, Tangent planes and normal lines. [1] Chapter 13 (section 13.1), Chapter 11 (Section 11.6)
Week 6: First and second partial derivative tests for relative extrema of functions of two variables, and absolute extrema of continuous functions.[1] Chapter 11 (Section 11.7)
Week 7: Lagrange multipliers method for optimization problems with one constraint,
[1] Chapter 11 [Section 11.8 (pages 610-714C)
Week 8: Double integration over rectangular and nonrectangular regions.
[1] Chapter 12(Sections 12.3 and 12.4)
Week 9: Double integrals in polar coordinates, and triple integral over a parallelopiped.
[1] Chapter 12 (Sections 12.3 and 12.4)

Week 10: Triple integral over solid regions, Volume by triple integral, and triple integration in cylindrical coordinates.
[1] chapter 12 (Sections 12.4 and 12.5)
Week 11: Triple integration in spherical coordinates, Jacobian (Without Proof), Change of variables in double and triple integrals.
[1] Chapter 12(Sections 12.7 and 12.8 up to page 849)
Week 12: Line integrals and its properties, applications of line integrals: mass and work.
[1] Chapter 13 (Section 13.2)
Week 13: Fundamental theorem for line integrals, Conservative vector fields and path independence.
[1] Chapter 13 (Section 13.3)
Week 14: Green's theorem for simply connected region, area as a line integral, Orientable and non-orientable surface-Mobius strip and definition of surface integrals.
[1] Chapter 13(section 13.4 and 13.5)
Week 15: Stokes' theorem and the divergence theorem. [1] Chapter 13 (Sections 13.6 and 13.7)

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√	√	√	√	√		√
CO2	√	√	√	√	√		√
CO3	√	√	√	√	√		√
CO4	√	√	√	√	√		√
CO5	√	√	√	√	√		√

Academic level 5.0 and Semester – IV
MJC50MAT208(T)25: Numerical Analysis

Nature of Course	**Major**			
Course Code	**MJC50MAT208(T)25**			
Course Title	**Numerical Analysis**			
Course Level	**200**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA / BSc fourth semester**			
Proposed by	**Board of Undergraduate Studies of the Department of Mathematics, Manipur University**			
Pre Requisites	To learn this course effectively, students should have knowledge of Calculus, Linear Algebra, and ODEs			
Pre Requisite Course Required				
Faculty Eligibility and Specialization	**Not Required**			

Course Objectives: This course introduces numerical methods for solving mathematical problems. Students will learn to analyze errors, derive and implement numerical techniques for solving algebraic and transcendental equations, systems of linear equations, interpolation, numerical differentiation and integration, and ordinary differential equations. Emphasis is placed on understanding the accuracy, convergence, and stability.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	Analyze and quantify numerical errors and solve nonlinear equations numerically.
2.	Solve systems of linear equations.
3.	Construct interpolating functions for data approximation and perform numerical differentiation and integration.
4.	Solve ordinary differential equations numerically.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	**Errors, Solution of Algebraic & Transcendental Equations**	Error analysis: Absolute, relative, and percentage error. Round-off, truncation error, Significant digits, condition number: Well-conditioned vs ill-conditioned problems, Solution of Algebraic & Transcendental Equations: Bisection method, Regula-Falsi method, Fixed-point iteration, Newton-Raphson, Secant method, (order of convergence and error bound).	9	3	-	12
II	**System of Linear Equations**	Direct methods: Gauss elimination with partial pivoting, LU decomposition: Doolittle, Crout, Cholesky for symmetric positive definite, Matrix inversion, Iterative methods: Jacobi method, Gauss-Seidel method, Convergence, error estimates and conditioning.	9	3	-	12

III	**Interpolation**	Finite differences: Forward Δ, backward ∇, central difference (definition), shift operator, Newton forward/backward interpolation for equal intervals, Lagrange interpolation for unequal intervals, Divided differences, Spline interpolation: Cubic splines, natural/end conditions, Hermite Interpolation.	9	3	-	12
IV	**Numerical Differentiation & Integration**	Numerical differentiation: Forward and Central difference, Numerical integration: Newton- Cotes Formula, Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule, convergence and error analysis.	9	3	-	12
V	**Numerical Solution of ODEs**	Euler method, Modified Euler, Runge-Kutta methods 2^{nd} and 4^{th} order, Multi-step methods: Predictor-Corrector, Adam-Bashforth, Convergence and Stability Analysis.	9	3	-	12

Suggested Readings:

1. **Brian Bradie**, (2007) A Friendly Introduction to Numerical Analysis. (First Impression), Pearson Prentice Hall.
2. **Jain, M. K., Iyengar, S. R. K., & Jain, R. K.** (2012). *Numerical Methods for Scientific and Engineering Computation*. (6th ed.). New Age International Publisher, India, 2016.

Additional Readings:

1. Gerald, C. F., & Wheatley, P. O. (2008). *Applied Numerical Analysis* (7th ed.). Pearson Education. India.

2. **Hildebrand F.B.** (2013). *Introduction to Numerical Analysis* (2^{nd} Edn.) Dover publication.

3. **Schilling J. Robert, Harris I. Sandra** (1999). *Applied Numerical Methods for Engineering using MATLAB and C.* Books/Cole

Teaching plan (MJC50MAT208(T)25: Numerical Analysis):

Week 1: Error analysis: Absolute, relative, and percentage error. Round-off, truncation error, Significant digits, conditioning, Solution of Algebraic & Transcendental Equations: Bisection method, Regula-Falsi method. [1] Chap. 1 (1.1) Chap. 2 (2.1-2.2), [2] Chap. 1 (1.3),

Week 2: Fixed-point iteration, Newton-Raphson, [1] Chap. 2 (2.3-2.5)

Week 3: Secant method (order of convergence and error bound). [1] Chap. 2 (2.3-2.5,2.7)

Week 4: Direct methods: Gauss elimination with partial pivoting, LU decomposition. [2] Chap. 3 (3.2)

Week 5: Doolittle, Crout, Cholesky for symmetric positive definite, Matrix inversion. [2] Chap. 3 (3.2)

Week 6: Iterative methods: Jacobi method, Gauss-Seidel method, Convergence, error estimates and conditioned number. [2] Chap. 3 (3.4), [1] Chap. 3 (3.4)

Week 7: Finite differences: Forward Δ, backward ∇, central difference (definition), shift operator, Newton forward/backward interpolation for equal intervals. [2] Chap. 4 (4.1, 4.3)

Week 8: Lagrange interpolation for unequal intervals, Divided differences, Spline interpolation: Cubic splines. [2] Chap. 4 (4.2, 4.6)

Week 9: Natural/end conditions, Hermite Interpolation. [2] Chap. 4 (4.5-4.6)

Week 10: Numerical differentiation: Forward and Central difference, Numerical integration: Newton- Cotes Formula. [1] Chap 6 (6.2, 6.4)

Week 11: Trapezoidal rule, Simpson's 1/3 rule[1] Chap 6 (6.5-6.6) [2] Chap. 5 (5.8)
Week 12: Simpson's 3/8 rule, convergence and error analysis [1] Chap 6 (6.5-6.6) [2] Chap. 5 (5.8). [1] Chap 6 (6.5-6.6) [2] Chap. 5 (5.8)
Week 13: Euler method, Modified Euler, Runge-Kutta 2^{nd} and 4^{th} order. [1] Chap 7 (7.2, 7.4) [2] Chap. 6 (6.3)
Week 14: Multi-step methods: Predictor-Corrector, Adam-Bashforth. [1] Chap. 7 (7.5) [2] Chap. 6 (6.6-6.7)
Week 15: Convergence and Stability .Analysis. [1] Chap 7 (7.6)

Course Teaching-Learning Process
The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between PLOs and COs

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CO1	√	√		√		√			√
CO2	√			√	√	√	√		
CO3	√	√	√	√	√	√	√	√	√
CO4	√	√	√	√	√	√	√		√

Academic level 5.0 and Semester – IV
MNC50MAT204(T)25: Abstract Algebra

Nature of Course	**Minor**			
Course Code	**MNC50MAT204(T)25**			
Course Title	**Abstract Algebra**			
Course Level	**200**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Fourth Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Sets, functions, binary operations, equivalence class, congruence**			
Pre Requisite Course Required	**Bachelor certificate with Mathematics as one subject(minor/major)**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: The primary objective of the course is to introduce the fundamental theory of groups and their homomorphisms so as to determine the structure of the group upto isomorphism. The concept of rings will be given along with ideas on specific rings such as Integral domain, PID, UFD.

Course Learning Outcomes: After the completion of the course, a student will be able to

1.	Understand the basic concepts of groups and links with permutations
2.	Learn normal subgroups, cosets, quotient groups, homomorphisms, isomorphisms
3.	Gain knowledge about rings, integral domains, fields, prime and irreducible elements

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Groups	Definition and examples of groups, semigroup, monoid, elementary properties of groups (identity, inverse, cancellation), order of an element, order of a group, abelian groups, permutation group, even and odd permutation	9	3		12
II	Subgroups	Definition and examples of subgroups, Centre of a group, centralizer, cyclic groups, Cosets, Lagrange's theorem and its application, normal subgroups and factor groups	9	3		12
III	Homomorphisms	Definition and examples, types of homomorphisms, properties, kernels, Isomorphism theorems, Caley's Theorem	6	2		8
IV	Rings	Definition and examples of rings, properties of rings, subrings, Integral domain, Fields, Characteristic of a ring, ideals, operation on ideals, quotient ring, prime ideal, maximal ideal, Ring homomorphism, Isomorphism theorems, kernels, field of quotients	9	3		12
V	Factorization domains	Divisibility in integral domain, associate, units, greatest common divisor, irreducible element, prime element, Euclidean domain, Principal ideal domain, polynomial ring, Unique factorization domain, Gauss lemma, Eisenstein's criteria	12	4		16

Suggested Readings

1. **Gallian, Joseph A** (2013), Contemporary Abstract Algebra (8th Edn) Cengage Learning India Pvt Ltd, Delhi
2. **I.N. Herstein** (2006), Topics in Algebra (Second Edn), Wiley India Pvt Ltd.

Additional Readings:

1. **V K Khanna, SK Bhambri** (2017), A Course in Abstract Algebra (5th Edn), Vikas Pub. House Pvt. Ltd
2. **Rotman, Joseph J (**1995), An introduction to the Theory of Groups(4th Edn), Springer Verlag, NY.
3. **David S Dummit, Richard M Foote** (2004), Abstract Algebra (3rd Edn)Wiley Student Edition
4. **Michael Artin** (2014), Algebra (2nd Edn), Pearson
5. **J B Fraleigh** (2007), A first course in Abstract Algebra(7th Edn) Pearson
6. **Nathan Jacobson** (2009), Basic Algebra I (2nd Edn), Dover Publication
7. **I S Luther IBS Passi** (2013), Algebra Volume I Group, Narosa

Teaching Plan **MNC50MAT204(T)25: Abstract Algebra**

Week 1: Definition and examples of groups, semigroup, monoid, elementary properties of groups (identity, inverse, cancellation) [1] chapter 2

Week 2-3: order of an element, order of a group, abelian groups, permutation group, even and odd permutation [1] chapter 5

Week 4: Definition and examples of subgroups, Centre of a group, centralizer, cyclic groups [1] chapter 3,4

Week 5: Cosets, Lagrange's theorem and its application [1] chapter 7

Week 6: Normal subgroups and factor groups [1] chapter 9

Week 7-8: Definition and examples, types of homomorphisms, properties, kernels, Isomorphism theorems, Caley's Theorem [1] chapter 10, 6

Week 9: Definition and examples of rings, properties of rings, subrings [1] chapter 12

Week 10: Integral domain, Fields, Characteristic of a ring, ideals, operation on ideals, Quotient ring, prime ideal, maximal ideal [1] chapter 13, 14

Week 11: Ring homomorphism, Isomorphism theorems, kernels, field of quotient [1] chapter 15

Week 12: Divisibility in integral domain, associate, units, greatest common divisor, irreducible element, prime element [1] chapter 18, Additional reading [1] chapter 9

Week 13: Euclidean domain, Principal ideal domain, polynomial ring [1] chapter 18, Additional reading [1] chapter 9

Week 14-15: Unique factorization domain, Gauss lemma, Eisenstein's criteria [1] chapter 18, Additional reading [1] chapter 9

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√		√	√	√		√

Academic level 5.5 and Semester – V
MJC55MAT309(T)25: Linear Algebra

Nature of Course	**Major**			
Course Code	**MJC55MAT309(T)25**			
Course Title	**Linear Algebra**			
Course Level	**300**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Fifth Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Set, functions, binary operations, groups, rings, fields, matrices**			
Pre Requisite Course Required	**Bachelor Diploma in Mathematics**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: The primary objective of the course is to introduce the fundamental theory of vector spaces and the corresponding homomorphisms. It also aims to discuss thoroughly about inner product spaces and linear operators.

Course Learning Outcomes: After the completion of the course, a student will be able to

1.	know the concept of linear independence of vectors over a field, basis and dimension of a vecto space
2.	understand basic concepts of linear transformations and its connection with the matrices, Rank – Nullity theorem, Eigen values and Eigen vectors
3.	know Inner product space, Orthonormal sets in an inner product space, normal operators, unitary and orthogonal operators.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Vector spaces	Definition and examples of vector spaces over a field, Subspaces, Algebra of subspaces, Coset of a subspace, Quotient space, Linear combination of vectors, linear span, Linear dependence and Linear independence, Basis and dimension with related theorems, Existence theorem of basis	9	3		12
II	Linear transformations	Linear transformations, Null spaces, Ranges, Rank Nullity theorem, Matrix representation of linear transformations, Algebra of linear transformations, Isomorphisms, Change of coordinates, Dual spaces, Double dual	9	3		12
III	Eigen vectors	Eigen values and Eigen vectors, Characteristic polynomial, Diagonalizability, Eigen spaces, Direct sum of vector subspaces, Invariant Subspaces and Cayley Hamilton Theorem, Minimal polynomial	9	3		12
IV	Inner product spaces	Inner products and norms, Orthogonal and orthonormal sets, Gram-Scmidt Orthogonalization process, orthogonal complement, Bessel's Inequality	6	2		8
V	Adjoint of linear operator	Adjoint, Least square Approximation, Normal and self-adjoint operator, positive definite operator, Unitary and orthogonal operator, rigid motions, orthogonal operator on $\mathbb{R}^2$, Bilinear forms, Quadratic forms, Sylvester law of inertia	12	4		16

Suggested Readings

1. **Hoffman, Kenneth, Kunze, Ray Alden** (1978), Linear Algebra (2nd Edn) Prentice Hall of India Pvt. Ltd
2. **Friedberg, StephenH, Insel, Arnold J & Spence Lawrence E.** (2003), Linear Algebra (4th Edn), Prentice Hall of India Pvt. Ltd. New Delhi

Additional Readings:

1. **V K Khanna, SK Bhambri** (2017), A Course in Abstract Algebra (5th Edn), Vikas Pub. House Pvt. Ltd
2. **David S Dummit, Richard M Foote** (2004), Abstract Algebra (3rd Edn)Wiley Student Edition
3. **J B Fraleigh** (2007), A first course in Abstract Algebra(7th Edn) Pearson
4. **I.N. Herstein** (2006), Topics in Algebra (Second Edn), Wiley India Pvt Ltd.
5. **Michael Artin** (2014), Algebra (2nd Edn), Pearson
6. **Gilbert Strang** (2014), Linear Algebra and its Applications (second Edn) Elsevier

Teaching Plan[**MJC55MAT309(T)25: Linear Algebra]**

Week 1: Definition and examples of vector spaces over a field, Subspaces, Algebra of subspaces, Coset of a subspace, Quotient space [2] Chapter 1(section 1.2, 1.3)

Week 2: Linear combination of vectors, linear span, Linear dependence and Linear independence [2] Chapter 1(section 1.4, 1.5)

Week 3: Basis and dimension with related theorems, Existence theorem of basis [2] Chapter 1 (section 1.6, 1.7)

Week 4: Linear transformations, Null spaces, Ranges, Rank Nullity theorem [2] Chapter 2 (section 2.1)

Week 5: Matrix representation of linear transformations, Algebra of linear transformations [2] Chapter 2(section 2.2, 2.3)

Week 6: Isomorphisms, Change of coordinates, Dual spaces, Double dual [2] Chapter 2 (section 2.4, 2.5, 2.6)

Week 7: Eigen values and Eigen vectors, Characteristic polynomial [2] Chapter 5(section 5.1)

Week 8: Diagonalizability, Eigen spaces, Direct sum of vector subspaces [2] Chapter 5 (section 5.2)

Week 9: Invariant Subspaces and Cayley Hamilton Theorem, Minimal polynomial [2]Chapter 5(section 5.4) Chapter 7(section 7.3)

Week 10, 11: Inner products and norms, Orthogonal and orthonormal sets, Gram-Scmidt Orthogonalization process, orthogonal complement, Bessel's Inequality [2]Chapter 6 (section 6.1, 6.2)

Week 12: Adjoint, Least square Approximation [2]Chapter 6(section 6.3)

Week 13: Normal and self-adjoint operator, positive definite operator [2]Chapter 6(section 6.4)

Week 14: Unitary and orthogonal operator, rigid motions, orthogonal operator on $\mathbb{R}^2$ [2] Chapter 6(section 6.5)

Week 15: Bilinear forms, Quadratic forms, Sylvester law of inertia [2]Chapter 6(section 6.8)

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- Class lectures
- Seminars
- Tutorials
- Group discussions and Workshops
- Short answer type questions
- Long answer type questions
- Objective type questions
- Multiple choice questions
- Statement, reasoning and explanation

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√		√	√	√		√

Academic level 5.5 and Semester – V
MJC55MAT310(T)25: Partial Differential Equations

Nature of Course	**Major**			
Course Code	**MJC55MAT310(T)25**			
Course Title	**Partial Differential Equations**			
Course Level	**300**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Fifth Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**ODE, Real Analysis and Multivariate Calculus**			
Pre Requisite Course Required	**FYUP upto Fourth Semester**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives

The primary objectives of this course are:

1. To introduce the theory and classification of first- and second-order partial differential equations.
2. To develop analytical techniques for solving partial differential equations and related boundary value problems.
3. To demonstrate the role of partial differential equations in modelling and solving physical problems involving heat transfer and wave motion.

Course Learning Outcomes: After the completion of the course, a student will be able to

1.	classify and transform first- and second-order partial differential equations into suitable forms for analysis and solution.
2.	solve first-order partial differential equations using standard methods such as Lagrange's and Charpit's methods.

3.	solve boundary and initial value problems involving second-order partial differential equations using method of characteristics and separation of variables.
4	formulate and solve mathematical models involving the wave equation and heat equation arising in physical and engineering problems.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	First order PDE and their classification	Definitions & Basic concepts, Formation of PDE, classification and geometrical interpretation of first order partial differential equations (PDE), Complete integral, General solution, Particular solution, Envelope, Weak solution, Canonical form of first order PDE and General solution.	9	3		12
II	Solution Methods for first order Partial Differential Equations	Method of characteristics and general solution of first order PDE, Lagrange method, Charpit's method- Special types of First-order PDE, Cauchy's problems for first order PDE, Method of separation of variables.	9	3		12
III	Classification of second order Linear PDE	Classification of second order PDE, Reduction to canonical forms, Equations with constant coefficients, General solutions, Cauchy's Problem for second order PDE.	9	3		12
IV	Wave Equation	Mathematical Modelling of vibrating string, vibrating membrane, Homogeneous wave equation, Initial boundary value problems, non-homogenous boundary conditions, Finite string with fixed ends, non-homogeneous wave equation.	9	3		12
V	Heat Equation	Conduction of heat in solids, Method of Separation of variables, Heat conduction problems, Heat conduction problem, Existence and uniqueness of solution of Heat conduction problems.	9	3		12

Suggested Readings:

1. **Myint-U, Tyn and Debnath, Lokenath.** (2007). *Linear Partial Differential Equation for Scientists and Engineers* (4thed). Springer, Third Indian Reprint.
1. **Sneddon, I. N.** (1957). *Elements of Partial Differential Equations*, McGraw-Hill International Editions.

Additional Readings:

1. **Stavroulakis, Ioannis P & Tersian, Stepan A**. (2004). *Partial Differential Equations*: *An Introduction with Mathematica and MAPLE* (2nd ed.). World Scientific.
2. **Kreyszig E.** (2011). *Advanced Engineering Mathematics* (10th Edn.) Wiley.
3. **Piaggio H.T.H** (2004). *An Elementary Treatise on Differential Equations and its application*, CBS Publication.

Teaching Plan [**MJC55MAT310(T)25:** Partial Differential Equations]

Week 1 and 2: Introduction, Classification, Construction of first order partial differential equations (PDE). Complete integral, General solution, Particular solution, Envelope, Weak solution, Canonical form of first order PDE. [1] Chapter 2 (Sections 2.1 to 2.3, 2.6)
Week 3 and 4: Method of characteristics-Lagrange method and Charpit's method and general solution of first order PDE, Method of separation of variables for first order PDE.
[1] Chapter 2 (Sections 2.4. 2.5 and 2.7) [1], [2] Chapter 2(Section 10)
Weeks 5 and 6: Reduction to canonical forms, Equations with constant coefficients, General solution. [1] Chapter 4 (Sections 4.1 to 4.5)
Week 7 and 8: Modelling of vibrating string, Vibrating membrane, [1] Chapter 3 (Sections 3.1 to 3.3) , The Cauchy problem for second order PDE, Homogeneous wave equation, Initial boundary value problem.[1] Chapter 5 (Section 5.1, 5.3)
Weeks 9 and 10: Initial boundary value problem, non-homogeneous boundary conditions, Finite string with fixed ends,
[1] Chapter 5 (Sections 5.4, 5.5 and 5.6)
Weeks 11 and 12: non – homogeneous wave equation and problems, Goursat problem. [1] Chapter 5 (Sections 5.7 and 5.9)
Weeks 13 and 14: Conduction of heat in solids, Method of separation of variables for second order PDE
[1] Chapter 3(Section 3.5) Chapter 7 (Sections 7.1 to 7.2)
Week 15: Heat conduction problem. Existence (omit proof) and uniqueness of the solution of heat conduction problem, non-homogeneous problems.
Chapter 7 (Sections 7.5, 7.6 and 7.8)

Course Teaching-Learning Process
The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**
- **Project**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√	√	√	√	√		√
CO4	√	√	√	√	√		√

Academic level 5.5 and Semester – V
MJC55MAT311(T)25: Riemann Integration

Nature of Course	**Major**			
Course Code	**MJC55MAT311(T)25**			
Course Title	**Riemann Integration**			
Course Level	**300**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Fifth Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur university**			
Pre Requisites	**Elementary Real Analysis, Calculus**			
Pre Requisite Course Required	**FYUP upto the fourth semester**			
Faculty Eligibility and Specialization	**Not Required**			

Course Objectives: The objective of the course is to introduce more topics on indefinite and definite integrals (after Class XII level integral calculus). The course introduces Riemann integral, integrability criteria, and the fundamental and mean value theorems of integral calculus. Students will also study improper integrals, Beta and Gamma functions and their properties.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	learn integration of irrational functions, integration by successive reduction and express definite integral as the limit of a sum and also find areas of plane curves, lengths of plane curves and volumes and surface areas of revolution using integrals
2.	learn some of the families and properties of Riemann integrable functions, and the applications of the fundamental theorems of integration.
3.	learn about improper integrals, Beta and Gamma functions and their properties.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	**Indefinite and Definite Integrals**	Integrals of irrational functions, Integration by successive reduction, Definite integral as the limit of a sum	6	2		8
II	**Applications of Integrals**	Areas of plane curves, Lengths of plane curves, Volumes and surface areas of revolution	9	3		12
III	**Riemann Integral**	Definition of Riemann integration, (Algebraic and order properties of Riemann Integrals) Boundedness theorem, Riemann integrability, Cauchy's criterion, Squeeze Theorem, Integration by parts, Darboux sums, Darboux integrals, Darboux integrability criteria, equivalence of Riemann integral and Darboux integral.	12	4		16
IV	**Properties of Riemann Integral**	Riemann integrability of step, continuous, and monotone functions, Additivity theorem, Fundamental theorems (First and Second forms), substitution theorem, Lebesgue's integrability criteria, composition theorem, product theorem,	12	4		16

V	**Improper Integrals**	Improper integrals of Type-I, Type-II and mixed type, Convergence of Beta and Gamma functions, and their properties.	6	2		8

Suggested Readings:

1. **Bartle, Robert G., & Sherbert, Donald R.** (2015). *Introduction to Real Analysis* (4th ed.). Wiley India Edition. Delhi.
2. **Denlinger, Charles G.** (2011). *Elements of Real Analysis*. Jones and Bartlett (Student Edition). First Indian Edition. Reprinted 2015.
3. **Ghorpade, Sudhir R. & Limaye, B. V.** (2006). *A Course in Calculus and Real Analysis*. Undergraduate Texts in Mathematics, Springer (SIE). First Indian reprint.
4. **B.C. Das and B.N. Mukherjee** (2012). *Integral Calculus*. U.N. Dhur & Sons Private Ltd., Kolkata.

Additional Readings:

1. **S.C. Malik and Savita Arora** (2010), *Mathematical Analysis*. New Age International (P) Ltd., New Delhi.
2. **Ross, Kenneth A.** (2013). *Elementary Analysis*: *The Theory of Calculus* (2nd ed.). Undergraduate Texts in Mathematics, Springer.

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Teaching Plan (MJC55MAT311(T)25: Riemann Integration):

Week 1 and 2: Integrals of irrational functions, Integration by successive reduction, Definite integral as the limit of a sum.

[4] Chapter 6, Chapter 7, Chapter 8 Section 8.2, 8.3, 8.11 and relevant exercises

Week 3, 4 and 5: Areas of plane curves, Lengths of plane curves, Volumes and surface areas of revolution

[4] Chapter 11, Chapter 12, Chapter 13

Week 6: Definition of Riemann integration.

[1] Chapter 7 [Section (7.1.1 to 7.1.4)]

Week 7: Some properties of Riemann integral, Boundedness theorem,

[1] Chapter 7 [Section (7.1.5 to 7.1.7), Exercises of section 7 (1, 2, 7, 8)]

Week 8 and 9: Riemann integrable function, Cauchy criterion, Squeeze theorem, Riemann integrability of step, continuous, and monotone functions, additive theorem

[1] Chapter 7 [Section (7.2.1 to 7.2.13)]

Week 10 and 11: Fundamental theorems (First and Second forms), substitution theorem, Lebesgue's integrability criteria, product theorem, Integration by parts

[1] Chapter 7 [Section (7.3.1 to 7.3.17)]

Week 12 and 13: Darboux sums, Darboux integrals, Darboux integrability criteria, equivalence of Riemann integral and Darboux integral.

[1] Chapter 7 [Section (7.4.1 to 7.4.11)]

Week 14: Improper integrals of Type-I, Type-II and mixed type.

[2] Chapter 7 [Section 7.8 (7.8.1 to 7.8.18)]

Week 15: Convergence of Beta and Gamma functions, and their properties.

[3] Pages 405 - 608C

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√		√	√	√		√

Academic level 5.5 and Semester – V
MNC55MAT205(T)25: Ordinary Differential Equations

Nature of Course	**Minor**			
Course Code	**MNC55MAT205(T)25**			
Course Title	**Ordinary Differential Equations**			
Course Level	**200**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Fifth Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Real Analysis and Calculus**			
Pre Requisite Course Required	**FYUP upto Fourth Semester**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: The main objectives of this course are to introduce the students to the exciting world of Differential Equations, Mathematical Modelling and their applications.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	formulate Differential Equations for various Mathematical models.
2.	solve first order non-linear differential equation and linear differential equations of higher order using various techniques
3.	apply these techniques to solve and analyse various mathematical models.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Equation of first order and first degree	Differential equations and mathematical models, Order and degree of a differential equations, Integrals as general and particular solutions, Exact differential equations and integrating factors of first order differential equations, Separable Equations	9	3		12
II	Linear Equation with constant coefficients	Homogeneous Equations, Reduction to homogeneous equations, Linear equations and Bernoulli Equation, Clairaut's Equation, Existence and Uniqueness of solution of initial and boundary value problems of first order ODE, singular solution of first order ODE.	9	3		12
III	Homogeneous Linear Equations	General solution of homogeneous equation of second order, Principle of superposition for a homogeneous equation, Wronskian, its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients	9	3		12
IV	Method of variation parameter	Euler's equation, Method of undetermined coefficients, Method of variation of parameters, Applications of second order differential equations to mechanical vibration.	9	3		12
V	Analysis of Mathematical Models	Application of first order differential equations to acceleration-velocity model, Growth and Decay model. Introduction to compartmental models, Lake pollution model (with case study of Lake Burley Griffin), Drug Assimilation models, population models (with limited growth, exponential growth), Epidemic models.	9	3		12

Suggested Readings:

1. **Barnes, Belinda &Fulford, Glenn R.** (2015). *Mathematical Modelling with Case Studies, Using* Maple *and* MATLAB (3rd ed.). CRC Press, Taylor & Francis Group.
2. **Edwards, C. Henry, Penney, David E., & Calvis, David T.** (2015). *Differential Equation and Boundary Value Problems*: *Computing and Modeling* (5th ed.). Pearson Education.
3. **Ross, Shepley L.** (2004). *Differential Equations* (3rd ed.). John Wiley & Sons. India.

Additional Reading:

1. M.D. Raisinghania (2008). Advanced Differential Equations S. Chand & Company PVT. LTD, India

Teaching plan (MNC55MAT205(T)25: Ordinary Differential Equations)

Week 1: Differential equations and mathematical models; [2] Chapter 1 (Section 1.1), Order and degree of a differential equations; [3] Chapter 1 (Section 1.1)

Week 2: Integrals as general and particular solutions; [2] Chapter 1 (Section 1.2), Exact differential equations and integrating factors of first order differential equations; [3] Chapter 2 (Section 2.1)

Week 3: Separable equations, Homogeneous equations, Reduction to homogeneous equations; [3] Chapter 2 (Section 2.2).
Week 4: Linear equations and Bernoulli equation Clairaut'sequation ; [3] Chapter 2 (Section 2.3)
Week 5: Existence and Uniqueness of solution of initial and boundary value problems of first order ODE; singular solution of the first order ODE [3] Chapter 1 (Section 1.3),
Week 6& 7: General solution of homogeneous equation of second order, Principle of superposition for a homogeneous equation, Wronskian, its properties and applications; [2] Chapter 3 (Section 3.1).
Week8: Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation; [2] Chapter 3 (Section 3.3).
Week 9: Method of undetermined coefficients, Method of variation of parameters; [2] Chapter 3 (Section 3.5).
Week 10: Applications of second order differential equations to mechanical vibration; [2] Chapter 3 (Section 3.6).
Week 11& 12: Application of first order differential equations to acceleration-velocity model; [2] Chapter 2 (Section 2.3), Growth and Decay model; [1] Chapter 2 (Section 2.2).
Week 13: Introduction to compartmental models; [1] Chapter 2 (Section 2.1), Lake pollution model (with case study of Lake Burley Griffin);
Week 14: [1] Chapter 2 (Section 2.5 & 2.6), Drug Assimilation models; [1] Chapter 2 (Section 2.7).
Week 15: Population models (with limited growth, exponential growth) Epidemic models; [2] Chapter 2 (Section 2.1) or [1] Chapter 3 (Section 3.1)

Assessment Methods

Course Teaching-Learning Process
The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**
- **Project**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√	√	√	√	√		√
CO4	√	√	√	√	√		√

Academic level 5.5 and Semester – VI
MJC55MAT312(T)25: Complex Analysis

Nature of Course	**Major**			
Course Code	**MJC55MAT312(T)25**			
Course Title	Complex Analysis			
Course Level	**300**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA / BSc sixth semester**			
Proposed by	**Board of Undergraduate Studies of the Department of Mathematics, Manipur University**			
Pre Requisites	Algebra of complex numbers, Differential Calculus, Integral Calculus and Multivariate Calculus			
Pre Requisite Course Required	**FYUP upto Fifth Semester**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: This course aims to provide students with a comprehensive understanding of complex variables and complex analysis, enabling them to Master the foundational theory of complex numbers, Develop proficiency in analytic functions, Acquire skills in complex integration, Understand series representations of complex functions, Apply residue theory to evaluate complex integrals, Bridge theoretical knowledge with applications by connecting complex analysis to fundamental results like Liouville's theorem and the fundamental theorem of algebra.

Course Learning Outcomes: After completion of the course, a student will be able to:

1.	understand complex-plane topology and basic functions, and apply Cauchy-Riemann equations and analyze analytic functions
2.	evaluate complex integrals using fundamental theorems including Cauchy's integral formula and its extensions
3.	develop power series, Taylor series and Laurent series representations of complex functions
4	determine singularities, residue, and evaluate contour integrals using the residue theorem

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Topology of the complex plane and functions of complex variables	Regions in the complex plane, open set, convex set, connected set, path, path-wise connected set, Domain, extended complex plane, Functions, Limits, Theorems on limits, Limits involving the point at infinity, Continuity, Derivatives, Differentiability.	9	3	-	12
II	Analytic Functions and Cauchy-Riemann Equations	Cauchy-Riemann equations, Sufficient conditions for differentiability; Polar forms of Cauchy-Riemann equations, Analytic functions, Trigonometric function, Multivalued Functions and its branches, Logarithmic functions, Complex exponents.	9	3	-	12

III	Complex Integrals	Definite integrals of complex functions over a real interval, Contours, Contour integrals, Antiderivatives, Proof of antiderivative theorem, Cauchy-Goursat theorem, Cauchy integral formula; An extension of Cauchy integral formula, Extension of Cauchy integral formula, Cauchy's inequality, Liouville's theorem, and the fundamental theorem of algebra.	9	3	-	12
IV	Power Series	Convergence of sequences and series, Power series, Absolute and uniform convergence of power series, Uniqueness of series representations, Taylor series and its examples	6	2	-	8
V	Laurent series and residue	Laurent series and its examples, Singular points, Isolated singular points, Residues, Cauchy's residue theorem, residue at infinity; Types of isolated singular points, Residues at poles and its examples.	12	4	-	16

Suggested Readings

1. **H.S. Kasana.** (2005). *Complex Variables, Theory and Applications*, (2nd ed.). Prentice Hall of India Learning Private Limited.
2. **Brown, James Ward, & Churchill, Ruel V.** (2009). *Complex Variables and Applications* (8th ed.). McGraw-Hill Education. New York

Additional Readings:

1. **Bak, Joseph & Newman, Donald J.** (2010). *Complex analysis* (3rd ed.). Undergraduate Texts in Mathematics, Springer. New York.
2. **Zills, Dennis G., & Shanahan, Patrick D.** (2003). *A First Course in Complex Analysis with Applications*. Jones & Bartlett Publishers, Inc.
3. **Mathews, John H., & Howell, Rusell W.** (2012). *Complex Analysis for Mathematics and Engineering* (6th ed.). Jones & Bartlett Learning. Narosa, Delhi. Indian Edition.
4. **John B. Conway** (1973). *Functions of One Complex Variables*. Springer-Verlag.
5. **H.A. Priestley** (2003). *Introduction to Complex Analysis*, Oxford University Press.
6. **L.V. Ahlfors** (2017). *Complex Analysis* (3rd Edn.). McGraw Hill Education.

Teaching Plan (MJC55MAT312(T)25: Complex Analysis

Week 1: Regions in the complex plane, open set, convex set, connected set, path, path-wise connected set, Domain, extended complex plane, [1] Chapter 1(1.5-1.6)
Week 2: Functions, Limits, theorems on limits, limits involving the point at infinity, [1] Chapter 2 (2.1-2.2)
Week 3: Continuity, differentiability, [1] Chapter 2 (2.3-2.4)
Week 4: Cauchy- Riemann Equation, sufficient condition for differentiability, Polar form of Cauchy- Riemann Equation [1] Chapter 2 (2.5-2.6)
Week 5: Analytic functions, Exponential, Trigonometric functions. [1] Chapter 2 (2.6), Chapter 3 (3.1, 3.2, 3.3)
Week 6: Multivalued Functions and its branches, Logarithmic functions, Complex Exponents. [1] Chapter 3 (3.5-3.7)
Week 7: Definite Integrals of complex functions over a real interval, Contours, Contours Integrals [2] Chapter 4 (40-43) , [1] Chapter 4 (4.1-4.2)
Week 8: Antiderivatives, Proof of antiderivative theorem, Cauchy-Goursat theorem, [2] Chapter 4 (44-46), [1] Chapter 4 (4.4-4.5)

Week 9: Cauchy Integral formula, Extension of Cauchy Integral formula, Consequences of Cauchy Integral formula. [2] Chapter 4 (50-52), [1] Chapter 4 (4.7-4.8)

Week 10: Cauchy's inequality, Liouville's theorem and fundamental theorem of algebra. [2] Chapter 4 (53), [1] Chapter 4 (4.8)

Week 11: Convergence of sequences and series, power series, Absolute and uniform convergence of power series [2] Chapter 5 (55-56), [1] Chapter 6(6.1-6.2)

Week 12: Uniqueness of series representations, Taylor series with examples, [2] Chapter 5 (57-58), Chapter 6 (66), [1] Chapter 6(6.3)

Week 13: Laurent series with examples, Singular points, Isolated singular points, Residues, Cauchy's Residue Theorem. [2] Chapter 5 (60), Chapter 6 (68-70)

Weeks 14 and 15: Residue at infinity, Types of isolated singular points, Residue at poles with examples. [2] Chapter 6 (71-74)

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√		√	√	√		√
CO4	√		√	√	√		√

Academic level 5.5 and Semester – VI
MJC55MAT313(T)25: Metric Spaces

Nature of Course	**Major**			
Course Code	**MJC55MAT313(T)25**			
Course Title	**Metric Spaces**			
Course Level	**300**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Sixth Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur university**			
Pre Requisites	**Real Analysis, Calculus**			
Pre Requisite Course Required	**FYUP upto Fifth Semester**			
Faculty Eligibility and Specialization	**Not Required**			

Course Objectives: The primary objective of the course is to introduce the basic idea of metric space, complete metric space, open and closed balls, neighbourhood, interior, closure, subspace, continuity, compactness, connectedness etc.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	understand the basic concepts of metric spaces and the concept such as open balls, closed balls
2.	learn concepts of convergence of sequences, Cauchy sequence, completeness, compactness, connectedness and their interrelations
3.	correlate the concepts of Metric Space with the Analytical concepts such as continuity and uniform continuity
4.	know about contraction mapping and Banach fixed point theorem

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	**Basic Concepts**	Metric spaces: Definition and examples, Open and closed ball, Neighbourhood, Open set, Interior, exterior, frontier and boundary points of a set, limit point of a set, derived set, closed set, closure of a set, diameter of a set, Dense set, Subspace of a metric space.	12	4		16
II	**Convergence of sequence**	Sequences in metric spaces, Cauchy and convergent sequences, Completeness of a metric space	6	2		8
III	**Continuity**	Continuous mappings, Criteria for Continuity, Uniform Continuity, Homeomorphism, Lipschitz Conditions, Contraction mapping, Banach fixed point theorem.	9	3		12
IV	**Connectedness**	Connectedness, Components, Connected subsets of R, Connectedness and continuity	6	2		8
V	**Compactness**	Compactness, Compactness and Continuity, Sequential compactness, Compactness and finite intersection property, Bolzano-Weierstrass property, Heine-Borel theorem, Totally bounded sets, Compact Subsets of Function Spaces.	12	4		16

Suggested Readings:

1. **E. T. Copson** (1988). *Metric Spaces*. Cambridge University Press.
2. **S. Kumaresan** (2014). *Topology of Metric Spaces* (2nd ed.). Narosa Publishing House. New Delhi.

3. **Satish Shirali & Harikishan L. Vasudeva** (2006). *Metric Spaces*. Springer-Verlag.
4. **Micheál O'Searcoid** (2009). *Metric Spaces*. Springer-Verlag.

Additional readings:

1. **P. K. Jain & Khalil Ahmad** (2019). *Metric Spaces*. Narosa Publishing House. New Delhi.
2. G.F. Simmons (2004). *Introduction to Topology and Modern Analysis*. Tata McGraw Hill. New Delhi.

Teaching plan (MJC55MAT313(T)25: Metric Spaces)

Week 1: Metric spaces: Definition and examples [1] Chapter 2, [3] Chapter 1 section 1.2

Week 2, 3 and 4: Open and closed ball, Neighbourhood, Open set, Interior, exterior, frontier and boundary points of a set limit point of a set, derived set, closed set, closure of a set, diameter of a set, Dense set, Subspace of a metric space. [1] Chapter 3

Week 5 and 6: Sequences in metric spaces, Cauchy and convergent sequences, Completeness of a metric space [1] Chapter 4, [2] Chapter 2

Week 7 and 8: Continuous mappings, Criteria for Continuity, Uniform Continuity, Homeomorphism [1] Chapter 7, [3] Chapter 3 section 3.1 – 3.5, [2] Chapter 3.

Week 9: Lipschitz conditions, Contraction mapping, Banach fixed point theorem. [1] Chapter 8, [2] Chapter 6 section 6.4, [3] Chapter 3 section 3.7, [5] Chapter 9.

Week 10 and 11: Connectedness, Components, Connected subsets of R, Connectedness and continuity [1] Chapter 5, [2] Chapter 5, [3] Chapter 4 section 4.1

Week 12, 13, 14 and 15: Compactness, Compactness and Continuity, Sequential compactness, Compactness and finite intersection property, Bolzano-Weierstrass property, Heine-Borel theorem, Totally bounded sets, Compact Subsets of Function Spaces. [1] Chapter 6, [2] Chapter 4, [4] Chapter 12 Section 12.8.

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√		√	√	√		√
CO4			√		√		

Academic level 5.5 and Semester – VI
MJC55MAT314(T)25: Mechanics

Nature of Course	**Major**			
Course Code	**MJC55MAT314(T)25**			
Course Title	**Mechanics**			
Course Level	**300**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience				
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Coordinate Geometry, Ordinary and Partial Differential Equations**			
Pre Requisite Course Required	**FYUP upto Fifth Semester**			
Faculty Eligibility and Specialization	**Not Required**			

Course Objectives: The course aims to provide basic knowledge of dynamics, including simple harmonic motion, particle dynamics, projectiles, Kepler's Laws, and the dynamics of rigid bodies. It also aims to study and impart knowledge on statics such as coplanar forces, catenary, stable and unstable equilibrium.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	Deal with the kinematics and kinetics of the rectilinear and planar motions of a particle including the constrained oscillatory motions of particles.
2.	Learn that a particle moving under a central force describes a plane curve and know the Kepler's laws of the planetary motions, which were deduced by him long before the mathematical theory given by Newton.
3.	Understand necessary conditions for the equilibrium of particles acted upon by various forces and learn the principle of virtual work for a system of coplanar forces acting on a rigid body.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	**Kinematics of a particle**	Velocity and acceleration, motion in a straight line, motion in a plane curve, components of velocities and accelerations along radial and transverse, tangential and normal accelerations, simple harmonic motions.	9	3		12
II	**Dynamics of a particle**	Motion on smooth and rough plane curves, constrained motion, Motion in resisting medium including projectile, motion of varying mass, central orbits and Kepler's laws of planetary motion.	9	3		12
III	**Statics:**	Equilibrium condition of coplanar forces, Equilibrium of strings and chains, common catenary, Catenary of uniform strength strings on smooth surfaces and rough curves.	9	3		12

IV	**Forces in 3-dimensions**	Central axis, Poinsot's central axis, Wrenches, Null lines and planes, stable and unstable equilibrium.	6	2		8
V	**Dynamics of rigid bodies**	Moments and products of inertia, momental ellipsoid, equimomental systems, principal axis, D' Alembert's principle, motion about fixed axis, compound pendulum, motion in two dimensions, conservation of momentum and energy.	12	4		16

Suggested Readings:

1 **S.L. Loney** (1988): *An elementary treatise on dynamics of particle and of rigid bodies*. Cambridge University Press 1956, reprinted by S. Chand & Company (P) Ltd.
2 **Das & Mukherjee** (2010): *Dynamics* published by S. Chand & company (p) Ltd. ISBN-81-85624-96-8.
3 **Das & Mukherjee** (2010): *Statics* published by S. Chand & company (p) Ltd., ISBN-81-85624-18-6.
4 **S.L. Loney** (2004): *An Elementary treatise on Statics*, published by A.I.T.B.S., New Delhi, 2004 ISBN-81-7473-123-7.
5 **A.S. Ramsey** (2009): *Statics*, Cambridge University Press

Additional Readings:

1 **M. Ray and G.C. Sharma** (2008): *A Textbook of dynamics*, published by S. Chand & Company (p) Ltd., (Chapter 1,2,6,8,9,11,12), ISBN-81-219-0342-4.
2 **R.S. Verma**: *A Text Book on Statics*, Pothishala Pvt Ltd., Allahabad.
3 **A.S. Ramsey** (2009): *Dynamics* , Cambridge University Press
4 **P. L. Srivastava** (1964). *Elementary Dynamics*. Ram Narin Lal, Beni Prasad Publishers Allahabad.
5 **J. L. Synge & B. A. Griffith** (1949). *Principles of Mechanics*. McGraw-Hill

Teaching plan (Paper Code MJC55MAT314(T)25 and Name):

Week 1 : Components of velocities and accelerations along, radial and transverse, along tangential and normal [1] Art 48. 49. 87, 88

Week 2: Simple Harmonic motions [1] Art 22-25, [2] Art 17.1 - 17.4. 17.6. 17.7

Week 3 : Dynamics of a particle, Motion on smooth and rough plane curves [1]Art 14.1, 14.2, 15.1, 15.2, 16.1, 16.2

Week 4: Motion in resisting medium including projectile, Motion of varying mass [1] Art 104-112

Week 5: Central orbit, Kepler's Law [1] Art 53-55, 57, 60, 64-67, 69-70)

Week 6 and 7: Equilibrium condition of coplanar forces [3]Art 81, 8.3, Equilibrium of strings, common catenary, catenary of uniform strength [3]Art 14.1-14.5 [5] Art 12.2, 12.21, 12.22, 12.5

Week 8 and 9 : Force in 3-dimension, Poinsots Central axis [1]Art 154-157, 162-165,[4] Art184-186, 188-190

Week 10: Wrenches Null lines and planes[4]Art 206-208, stable and unstable equilibrium [4] Art 158, [1]Art 11.5, 11.6, 11.62, 11.7

Week 11 and 12: Moments and products of inertia [1]Art 144-149, Momental Ellipsoid [1]Art 151, Equimomental systems, Principal Axis [1]Art 154, 155

Week 13: D'Alembert's Principle, Equations of motion of rigid bodies, Motion of centre of inertia,

Motion relative to centre of inertia [1]Art 162.
Week 14: Motion about a fixed axis[1]Art 168 -171, Compound Pendulum [1]Art 173-175. Motion in 2 dimension under finite and impulsive forces [1]Art 187-190.

Week 15: Conservation of momentum and Energy.[1]Art 235, 236, 238, 239, 242.

Assessment Methods: The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**
- **Project**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√	√	√	√	√		√
CO4	√	√	√	√	√		√

Academic level 5.5 and Semester – VI
MJC55MAT315(T)25: Linear Programming Problem

Nature of Course	**Major**			
Course Code	**MJC55MAT315(T)25**			
Course Title	**Linear Programming Problem**			
Course Level	**300**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA / BSc sixth semester**			
Proposed by	**Board of Undergraduate Studies of the Department of Mathematics, Manipur University**			
Pre Requisites	Coordinate Geometry, Linear Algebra, set theory & logical reasoning			
Pre Requisite Course Required	**FYUP upto Fifth Semester**			
Faculty Eligibility and Specialization	**Not Required**			

Course Objectives: This course develops the ideas underlying the Simplex Method for Linear Programming Problems, as an important branch of Operations Research. The course covers Linear Programming with applications to Transportation, Assignment, and Game Problems. Such problems arise in manufacturing resource planning and the financial sectors.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	analyze and solve linear programming models of real-life situations
2.	understand the graphical solution of LPP with only two variables, the concept of a convex set, extreme points and the theory of the simplex method.
3.	learn the relationships between the primal and dual problems and their solutions, with applications to transportation, assignment, and the two-person zero-sum game.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	**Introduction to Linear Programming**	The Linear Programming Problem: Standard, Canonical and matrix forms, Graphical solution, Convex sets and polyhedral sets, Hyperplanes, Extreme points and optimality, Basic Feasible Solutions.	9	3	-	12
II	**Simplex Method**	Introduction to the simplex method, Optimal solution, Termination criteria for optimal solution of the Linear Programming Problem, Simplex Algorithm and its Tableau Format; Artificial variables, Two-phase, Big-M method.	15	5	-	20
III	**Duality**	Formulation of the Dual problem, primal-dual relationship, the fundamental theorem of Duality, complementary slackness, and the Dual Simplex Method.	9	3		12
IV	**Transportation**	Transportation Problem**:** Definition and formulation, Methods of finding initial basic feasible solutions, North West corner rule, Least cost method, Vogel's Approximation method, Algorithm for solving the Transportation Problem.	6	2	-	8
V	**Assignment**	Assignment Problem: Mathematical formulation and Hungarian method of solving.	6	2	-	8

Suggested Readings:

1. **Bazaraa, Mokhtar S., Jarvis, John J., & Sherali, Hanif D. (2010).** *Linear Programming and Network Flows*. (4th ed.). John Wiley and Sons.
2. **Thie, Paul R., & Keough, G. E. (2014).** *An Introduction to Linear Programming and Game Theory*. (3rd ed.). Wiley India Pvt. Ltd.
3. **Taha, Hamdy A. (2010).** *Operations Research*: *An Introduction* (9th ed.). Pearson.

Additional Readings:

1. **Hillier, F. S. & Lieberman, G. J. (2010).** *Introduction to Operations Research- Concepts and Cases* (9th ed.). Tata McGraw-Hill.
2. **Hadley, G. (1997).** *Linear Programming*. Narosa Publishing House. New Delhi**.**

Teaching plan (MJC55MAT315(T)25 and Linear Programming Problem):

Week 1: The Linear Programming Problem: Standard, Canonical and matrix forms, Graphical solution. [1] chapter 1(1.1-1.3)
Week 2: Convex sets and polyhedral sets, Hyperplanes. [1] chapter 2 (2.4-2.5)
Week 3: Extreme points and optimality, Basic Feasible Solutions. [1] chapter 3 (3.1-3.2)
Week 4: Introduction to the simplex method, Optimal solution. [1] Chapter 3(3.3-3.4)
Week 5: Termination criteria for optimal solution of the Linear Programming Problem. [2] Chapter 3 (3.4)
Week 6: Simplex Algorithm and its Tableau Format; [2] Chapter 3 (3.5)
Week 7,8: Artificial variables, Two-phase method, Big-M method. [1] Chapter 4 (4.1-4.3)
Week 9: Formulation of the Dual problem. [1] Chapter 6 (6.1)
Week 10: primal-dual relationship, the fundamental theorem of Duality, complementary slackness. [1] Chapter 6 (6.2)
Week 11: Dual Simplex Method. [1] Chapter 6 (6.4)
Week 12: Transportation Problem**:** Definition and formulation, Methods of finding initial basic feasible solutions, North West corner rule, Least cost method. [2] Chapter 7 (7.1) [3] Chapter 5 (5.1-5.2)
Week 13: Vogel's Approximation method, Algorithm for solving the Transportation Problem. [3] Chapter 5 (5.1-5.3)
Week 14, 15: Assignment Problem: Mathematical formulation and Hungarian method of solving. [3] Chapter 5 (5.4)

Course Teaching-Learning Process
The important relevant teaching and learning processes involved in this course are:

- Class lectures
- Seminars
- Tutorials
- Group discussions and Workshops
- Short answer type questions
- Long answer type questions
- Objective type questions
- Multiple choice questions
- Statement, reasoning and explanation

Assessment methods

- Oral and written examination
- Closed book and open book tests
- Problem solving exercises
- Seminar and presentations
- Interactive sessions

Linkage between PLOs and COs

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CO1	√	√	√	√	√		√	√	√
CO2	√	√	√	√			√		√
CO3	√	√	√	√	√	√	√	√	√

Academic level 5.5 and Semester – VI
MNC55MAT206(T)25: Numerical Analysis

Nature of Course	**Minor**			
Course Code	**MNC55MAT206(T)25**			
Course Title	**Numerical Analysis**			
Course Level	**200**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA / BSc sixth semester**			
Proposed by	**Board of Undergraduate Studies of the Department of Mathematics, Manipur University**			
Pre Requisites	Calculus, Linear Algebra, and ODEs			
Pre Requisite Course Required	**FYUP upto Fifth Semester**			
Faculty Eligibility and Specialization	**Not Required**			

Course Objectives: This course introduces numerical methods for solving mathematical problems. Students will learn to analyze errors, derive and implement numerical techniques for solving algebraic and transcendental equations, systems of linear equations, interpolation, numerical differentiation and integration, and ordinary differential equations. Emphasis is placed on understanding the accuracy, convergence, and stability.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	analyze and quantify numerical errors and solve nonlinear equations numerically.
2.	solve systems of linear equations.
3.	construct interpolating functions for data approximation and perform numerical differentiation and integration.
4.	solve ordinary differential equations numerically.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	**Errors, Solution of Algebraic & Transcendental Equations**	Error analysis: Absolute, relative, and percentage error. Round-off, truncation error, Significant digits, condition number: Well-conditioned vs ill-conditioned problems, Solution of Algebraic & Transcendental Equations: Bisection method, Regula-Falsi method, Fixed-point iteration, Newton-Raphson, Secant method, (order of convergence and error bound).	9	3	-	12
II	**System of Linear Equations**	Direct methods: Gauss elimination with partial pivoting, LU decomposition: Doolittle, Crout, Cholesky for symmetric positive definite, Matrix inversion, Iterative methods: Jacobi method, Gauss-Seidel method, Convergence, error estimates and conditioning.	9	3	-	12
III	**Interpolation**	Finite differences: Forward Δ, backward ∇, central difference (definition), shift operator, Newton forward/backward interpolation for equal intervals, Lagrange interpolation for unequal intervals, Divided differences, Spline	9	3	-	12

		interpolation: Cubic splines, natural/end conditions, Hermite Interpolation.				
IV	**Numerical Differentiation & Integration**	Numerical differentiation: Forward and Central difference, Numerical integration: Newton- Cotes Formula, Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule, convergence and error analysis.	9	3	-	12
V	**Numerical Solution of ODEs**	Euler method, Modified Euler, Runge-Kutta methods 2^{nd} and 4^{th} order, Multi-step methods: Predictor-Corrector, Adam-Bashforth, Convergence and Stability Analysis.	9	3	-	12

Suggested Readings:

3. **Brian Bradie**, (2007) A Friendly Introduction to Numerical Analysis. (First Impression), Pearson Prentice Hall.
4. **Jain, M. K., Iyengar, S. R. K., & Jain, R. K.** (2012). *Numerical Methods for Scientific and Engineering Computation*. (6th ed.). New Age International Publisher, India, 2016.

Additional Readings:

1. Gerald, C. F., & Wheatley, P. O. (2008). *Applied Numerical Analysis* (7th ed.). Pearson Education. India.

2. **Hildebrand F.B.** (2013). *Introduction to Numerical Analysis* (2^{nd} Edn.) Dover publication.

3. **Schilling J. Robert, Harris I. Sandra** (1999). *Applied Numerical Methods for Engineering using MATLAB and C.* Books/Cole

Teaching plan (MNC55MAT206(T)25: Numerical Analysis):

Week 1: Error analysis: Absolute, relative, and percentage error. Round-off, truncation error, Significant digits, conditioning, Solution of Algebraic & Transcendental Equations: Bisection method, Regula-Falsi method. [1] Chap. 1 (1.1) Chap. 2 (2.1-2.2), [2] Chap. 1 (1.3),

Week 2: Fixed-point iteration, Newton-Raphson, [1] Chap. 2 (2.3-2.5)

Week 3: Secant method (order of convergence and error bound). [1] Chap. 2 (2.3-2.5,2.7)

Week 4: Direct methods: Gauss elimination with partial pivoting, LU decomposition. [2] Chap. 3 (3.2)

Week 5: Doolittle, Crout, Cholesky for symmetric positive definite, Matrix inversion. [2] Chap. 3 (3.2)

Week 6: Iterative methods: Jacobi method, Gauss-Seidel method, Convergence, error estimates and conditioned number. [2] Chap. 3 (3.4), [1] Chap. 3 (3.4)

Week 7: Finite differences: Forward Δ, backward ∇, central difference (definition), shift operator, Newton forward/backward interpolation for equal intervals. [2] Chap. 4 (4.1, 4.3)

Week 8: Lagrange interpolation for unequal intervals, Divided differences, Spline interpolation: Cubic splines. [2] Chap. 4 (4.2, 4.6)

Week 9: Natural/end conditions, Hermite Interpolation. [2] Chap. 4 (4.5-4.6)

Week 10: Numerical differentiation: Forward and Central difference, Numerical integration: Newton- Cotes Formula. [1] Chap 6 (6.2, 6.4)

Week 11: Trapezoidal rule, Simpson's 1/3 rule[1] Chap 6 (6.5-6.6) [2] Chap. 5 (5.8)

Week 12: Simpson's 3/8 rule, convergence and error analysis [1] Chap 6 (6.5-6.6) [2] Chap. 5 (5.8). [1] Chap 6 (6.5-6.6) [2] Chap. 5 (5.8)

Week 13: Euler method, Modified Euler, Runge-Kutta 2^{nd} and 4^{th} order. [1] Chap 7 (7.2, 7.4) [2] Chap. 6 (6.3)

Week 14: Multi-step methods: Predictor-Corrector, Adam-Bashforth. [1] Chap. 7 (7.5) [2] Chap. 6 (6.6-6.7)

Week 15: Convergence and Stability .Analysis. [1] Chap 7 (7.6)

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between PLOs and COs

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9
CO1	√	√		√		√			√
CO2	√			√	√	√	√		
CO3	√	√	√	√	√	√	√	√	√
CO4	√	√	√	√	√	√	√		√

Academic level 6.0 and Semester – VII
MJC60MAT416(T)25: Advanced Abstract Algebra

Nature of Course	**Major**			
Course Code	**MJC60MAT416(T)25**			
Course Title	**Advanced Abstract Algebra**			
Course Level	**400**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Seventh Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Functions, binary operations, groups, rings, fields, homomorphism**			
Pre Requisite Course Required	**Bachelor Degree in Mathematics**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: The primary objective of the course is to introduce the advanced topics on group theory such as automorphisms, series of groups, solvable groups. It also aims to discuss thoroughly about field extensions and finding the Galois groups.

Course Learning Outcomes: After the completion of the course, a student will be able to learn

1.	the Class Equation of finite groups and applications
2.	structure of groups through the idea of Sylow theorems
3.	different types of field extensions and fundamental theorem of Galois theory

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Group Actions	Definition and examples, group action and permutation representation, group action by left multiplication and conjugation, stabilizer and kernel of group action, orbit, transitive action, and consequence on Caley's theorem, Class equation, Applications of Class equation, Cauchy's theorem, Conjugacy in S_n, Simplicity of A_5	9	3	-	12
II	Automorphisms and Sylow theorems	Automorphism group, Inner Automorphism, Characteristic Subgroup, p-groups, Sylow p-subgroups, Sylow's theorems, Applications of Sylow's theorems, Simplicity of A_n , Non Simplicity test, Direct products, Fundamental theorem of finitely generated abelian group (only statement) and applications	9	3	-	12
III	Series of groups	Normal and subnormal series, Composition series, Zassenhaus Lemma, Schreier's refinement theorem, Jordan Holder theorem Commutator subgroups, Solvable groups, Nilpotent groups	9	3	-	12
IV	Field extensions	Algebraic and transcendental extension, algebraic closure, K-homomorphisms, Finite fields, Splitting fields, Normal extensions, algebraically closed field	9	3	-	12
V	Galois extension	Separable and inseparable extensions, perfect field, Automorphisms of field, fixed field, Galois group of f(x), Fundamental theorem of Galois theory	9	3	-	12

Suggested Readings

1. **David S Dummit, Richard M Foote** (2004), Abstract Algebra (3rd Edn) Wiley Student Edition
2. **Gallian, Joseph A** (2013), Contemporary Abstract Algebra (8th Edn) Cengage Learning India Pvt Ltd, Delhi
3. **Vivek Sahai, Vikas Bist (2008)**, Algebra, Prentice Hall of India

Additional Readings:

1. **P B Bhattacharya, S K Jain, S R Nagpaul (1997)** , Basic Abstract Algebra, CUP
2. **J B Fraleigh** (2007), A first course in Abstract Algebra(7th Edn) Pearson
3. **I.N. Herstein** (2006), Topics in Algebra (Second Edn), Wiley India Pvt Ltd.
4. **Michael Artin** (2014), Algebra (2nd Edn), Pearson

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√		√	√	√		√

Academic level 6.0 and Semester – VII
MJC60MAT417(T)25: Advanced Real Analysis

Nature of Course	**Major**			
Course Code	**MJC60MAT417(T)25**			
Course Title	**Advanced Real Analysis**			
Course Level	**400**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Seventh Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Real Analysis**			
Pre Requisite Course Required	**Bachelor Degree in Mathematics**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: The main objective of this course is to impart the various concepts of real numbers, sequences of functions with convergence and divergence, Riemann-Stieltjes Integration, functions in higher dimension.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	apply convergence tests, utilize the Weierstrass M-test, and analyze series behaviors, including rearrangements of terms and Riemann's theorem.
2.	differentiate between pointwise and uniform convergence. Evaluate how uniform convergence preserves continuity and differentiability, and apply the Weierstrass approximation theorem.
3.	define and evaluate the Riemann-Stieltjes integral. Understand integration of vector-valued functions and rectifiable curves.
4.	analyze linear transformations and derivatives in $\mathbb{R}^n$. Utilize the chain rule, partial derivatives, and higher-order derivatives for several variables.
5.	prove and apply the Inverse function theorem, the Implicit function theorem, and understand Jacobians and partitions of unity.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Sequence and Series functions	Rearrangements of terms of a series, Riemann's theorem. Sequence and series of functions, pointwise and uniform convergence, Cauchy criterion for uniform convergence, Weiestrass M-test	9	3	-	12
II	Uniform convergence	uniform convergence and continuity, uniform convergence and differentiation, Weierstrass approximation theorem, Power series, uniqueness theorem of power series	9	3	-	12
III	Riemann-Stieltjes Integral	Definition and existence of Riemann-Stieltjes integral, Properties of the Integral, Integration and differentiation, uniform convergence and Riemann-Stieltjesintegratjion, the fundamental theorem of Calculus, Integration of vector-valued functions, Rectifiable curves	9	3	-	12
IV	Functions of Several variables	Functions of several variables, linear transformations, Derivatives in an open subset of R^n , Chain rules, Partial derivatives, interchange of the order of differentiation	9	3	-	12
V	Inverse function Theorem	Derivatives of higher orders, Taylor's theorem, Inverse function theorem, Implicit function theorem, Jacobians, Partitions of unity	9	3	-	12

Suggested Readings

1. Walter Rudin, Principles of Mathematical Analysis (3rd edition) McGraw-Hill, Kogakusha, 1976, International Student edition.
2. T.M. Apostol, Mathematical Analysis, Narosa Publishing House, new Delhi, 1985.
3. H.L. Royden, Real Analysis, Macmillan Pub. Co. Inc. 4th Edition, New York, 1993.
4. S. C. Malik and Savita Arora, Mathematical Analysis, New Age International (P) Ltd., New Delhi, 2004.

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√		√	√
CO2	√	√		√		√	√
CO3	√	√		√	√		√

Academic level 6.0 and Semester – VII
MJC60MAT418(T)25: Research Methodology

Nature of Course	**Major**			
Course Code	**MJC60MAT418(T)25**			
Course Title	**Research Methodology**			
Course Level	**400**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Seventh Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites				
Pre Requisite Course Required	**Bachelor Degree in Mathematics**			
Faculty Eligibility and Specialization				

Course Objectives: The course aims to study about importance of research, its types, methods and characteristics. It also aims to study literature survey and preparation of research papers

Course Learning Outcomes: After completion of the course, a student will be able to

1.	differentiate between research methods and research methodologies, identifying the core characteristics of scientific research and the qualities of an effective researcher.
2.	distinguish between quantitative and qualitative approaches, determining the best methods to tackle specific research aims.
3.	apply mathematics, statistical techniques, and computational software effectively to analyze and interpret research data.
4.	conduct comprehensive literature surveys, critically review research papers, and identify gaps in existing scientific studies.
5.	define moral philosophy and critically evaluate the nature, structure, and emotive reactions involved in moral judgments. Articulate and apply the core principles of research integrity, intellectual honesty, and responsible conduct in scientific inquiries.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Meaning and Importance of Research	Research and its Importance, Research Methods and Research Methodology, Components of research methodology (Problem posing and problem solving)	9	3	-	12
II	Quantitative and Qualitative Methods	Quantitative and Qualitative Methods, Various stages of Research, Selection of Research topic and problem	9	3	-	12
III	Scientific methods and research process	Characteristics of scientific research, Role of mathematics and computers in scientific research, Criteria for excellence in Research, Qualities of Research Worker	9	3	-	12
IV	Review of literature and presentation	Literature survey and reviewing of research papers, Preparation of papers for journals and for presentation in the conferences and Seminars, Preparation of Project proposals, dissertation and thesis	9	3	-	12
V	Ethical research	Definition, moral philosophy, nature of moral judgments & reactions, Ethics with respect to science	9	3	-	12

		and research, Intellectual honesty and research integrity, Scientific misconducts: Falsification, Fabrication and Plagiarism (FFP), Selective reporting and misrepresentation of data, Redundant publication: duplicate and overlapping publication, salami slicing				

Suggested Readings

1. J.N. Kapur : Research Methodology: Wiley Eastern Ltd.
2. G. Polya: Mathematics & Plausible Reasoning Princeton University Press, USA.
3. Bird, A. (2006): Philosophy of Science, Routledge.
4. MacIntyre, Alasdair (1967): A Short History of Ethics, London.
5. P. Chaddah, (2018): Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN: 9789387480865.
6. National Academy of Sciences, National Academy of engineering and Institute of Medicine, (2009): On Being a Scientist: A Guide to Responsible Conduct in Research: Third Edition, National Academies Press.
7. Beall, J. (2012). Predatory publishers are corruption open access. Nature, 489(7415), 179179.https://doi.org/10.1038/489179a
8. Indian National Science Academy (INSA), Ethics in Science Education, Research & Governance (2019), ISBN: 978-81-939482-1-7. http://www.insaindia.res.in/pdf/Ethics_Book.pdf

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√	√		√		√	√
CO2	√	√		√		√	√
CO3	√	√		√		√	√

Academic level 6.0 and Semester – VII
MNC60MAT307(T)25: Linear Algebra

Nature of Course	**Minor**			
Course Code	**MNC60MAT307(T)25**			
Course Title	**Linear Algebra**			
Course Level	**300**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Sixth Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Set, functions, binary operations, groups, rings, fields, matrices**			
Pre Requisite Course Required	**Bachelor Degree**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: The primary objective of the course is to introduce the fundamental theory of vector spaces and the corresponding homomorphisms. It also aims to discuss thoroughly about inner product spaces and linear operators.

Course Learning Outcomes: After the completion of the course, a student will be able to

1.	understand the concept of linear independence of vectors over a field, basis and dimension of a vector space
2.	know basic concepts of linear transformations and its connection with the matrices, Rank –Nullity theorem, Eigen values and Eigen vectors
3.	understand Inner product space, Orthonormal sets in an inner product space, normal operators, unitary and orthogonal operators.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Vector spaces	Definition and examples of vector spaces over a field, Subspaces, Algebra of subspaces, Coset of a subspace, Quotient space, Linear combination of vectors, linear span, Linear dependence and Linear independence, Basis and dimension with related theorems, Existence theorem of basis	9	3		12
II	Linear transformations	Linear transformations, Null spaces, Ranges, Rank Nullity theorem, Matrix representation of linear transformations, Algebra of linear transformations, Isomorphisms, Change of coordinates, Dual spaces, Double dual	9	3		12
III	Eigen vectors	Eigen values and Eigen vectors, Characteristic polynomial, Diagonalizability, Eigen spaces, Direct sum of vector subspaces, Invariant Subspaces and Cayley Hamilton Theorem, Minimal polynomial	9	3		12
IV	Inner product spaces	Inner products and norms, Orthogonal and orthonormal sets, Gram-Scmidt Orthogonalization process, orthogonal complement, Bessel's Inequality	6	2		8
V	Adjoint of linear operator	Adjoint, Least square Approximation, Normal and self-adjoint operator, positive definite operator, Unitary and orthogonal operator, rigid motions, orthogonal operator on $\mathbb{R}^2$, Bilinear forms, Quadratic forms, Sylvester law of inertia	12	4		16

Suggested Readings

1. **Hoffman, Kenneth, Kunze, Ray Alden** (1978), Linear Algebra (2nd Edn) Prentice Hall of India Pvt. Ltd

2. **Friedberg, StephenH, Insel, Arnold J & Spence Lawrence E.** (2003), Linear Algebra (4th Edn), Prentice Hall of India Pvt. Ltd. New Delhi

Additional Readings:

1. **V K Khanna, SK Bhambri** (2017), A Course in Abstract Algebra (5th Edn), Vikas Pub. House Pvt. Ltd
2. **David S Dummit, Richard M Foote** (2004), Abstract Algebra (3rd Edn)Wiley Student Edition
3. **J B Fraleigh** (2007), A first course in Abstract Algebra(7th Edn) Pearson
4. **I.N. Herstein** (2006), Topics in Algebra (Second Edn), Wiley India Pvt Ltd.
5. **Michael Artin** (2014), Algebra (2nd Edn), Pearson
6. **Gilbert Strang** (2014), Linear Algebra and its Applications (second Edn) Elsevier

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√		√	√	√		√

Academic level 6.0 and Semester – VII
DSE60MAT401(T)25: Advanced Complex Analysis

Nature of Course	**DSE**			
Course Code	**DSE60MAT401(T)25**			
Course Title	**Advanced Complex Analysis**			
Course Level	**400**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BSc seventh semester**			
Proposed by	**Board of Postgraduate Studies of the Department of Mathematics, Manipur University**			
Pre Requisites	**Background in Real Analysis, basic differential Topology and a first course in Complex Analysis**			
Pre Requisite Course Required	**Three year Undergraduate**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: This course aims to introduce the basic ideas of analysis for complex integration and meromorphic functions as well as bilinear transformations.

Course Learning Outcomes: After completion of the course, a student will be able to:

1.	get equipped with the understanding of the fundamental concepts of functions of a complex variable along with the concepts of analyticity, Cauchy-Riemann relations and harmonic functions.
2.	evaluate complex contour integrals applying the Cauchy's integral theorem and Cauchy's integral formula.
3.	acquire the skill of evaluating contour integrals using Cauchy's integral formula and Cauchy's integral theorem.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Complex integration	Cauchy-Goursat Theorem for simple closed contour, simply and multiply connected domain, Cauchy's integral formula and higher order derivatives, theorems of Morera and Liouville, Maximum modulus principle, Schwarz lemma, Counting zeros; the open mapping theorem.	12	4	-	16
II	Power series	Taylor's theorem, zeros of Analytic Functions, Identity/Uniqueness theorem, Uniqueness theorem for Power series, Laurent series, Laurent's theorem	6	2	-	8
III	Residue Theory	Residues and poles, Cauchy's residue theorem, zeros of analytic functions, Evaluation of improper integrals, Meromorphic functions; The argument principle, Rouch's theorem, Inverse Laplace Transform and examples.	9	3	-	12
IV	Conformal Mappings	Branches of many valued functions with special reference to arg z, log z and zn, Definitions and examples of Conformal mapping, Bilinear transformations, their properties and classifications.	9	3	-	12
V	Harmonic Function and Entire Function	Basic properties of Harmonic functions, Harmonic functions on a disk, Harnack's inequality, Jensen's formula, Poisson-Jensen formula, Canonical products, Hadamard's three circles theorem.	9	3	-	12

Suggested Readings

1. **J.B. Conway** (2002), *Functions of One Complex Variable*, Narosa Publishing House.
2. **H.A. Priestly** (1990), *Introduction to Complex Analysis*, Clarendon Press, Oxford.
3. **S. Ponnusamy** (1997), *Foundation of Complex Analysis*, Narosa Pub. House.

Additional Readings:

1. **James W Brown, R V Churchill** (2004), *Complex variables and Applications*, McGraw Hill.
2. **Liang-Shin Hahn and Bernard Epstein** (1996), *Classical Complex Analysis*, Jones and Bertlett Pub. International, London.
3. **Walter Rudin** (1987), *Real & Complex Analysis*, 3rd Edn. McGraw-Hill Book Co.
4. **H.S. Kasana** (2005), *Complex Variables; Theory and Applications*, Prentice-Hall of India, New Delhi.

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- Class lectures
- Seminars
- Tutorials
- Group discussions and Workshops
- Short answer type questions
- Long answer type questions
- Objective type questions
- Multiple choice questions
- Statement, reasoning and explanation

Assessment methods

- Oral and written examination
- Closed book and open book tests
- Problem solving exercises
- Seminar and presentations
- Interactive sessions

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√	√	√	√	√		
CO2	√		√		√		
CO3	√	√	√	√	√	√	√

Academic level 6.0 and Semester – VII
DSE60MAT402(T)25: Functional Analysis

Nature of Course	**DSE**			
Course Code	**DSE60MAT402(T)25**			
Course Title	**Functional Analysis**			
Course Level	**400**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Sixth Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Real Analysis, Linear Algebra**			
Pre Requisite Course Required	**Three Year Undergraduate**			

Course Objectives: This course aims at imparting concepts on a normed space in particular Banach and Hilbert spaces. The equivalence of various norms and various results on Banach spaces will be studied.

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

1.	define and analyse the structure of **normed and Banach spaces**, including quotient spaces, equivalent norms, and the properties of bounded linear transformations and dual spaces
2.	apply foundational results of functional analysis, such as the **Hahn-Banach**, **Open Mapping**, and **Closed Graph** theorems, to solve problems involving reflexive spaces and bounded operators
3.	master the geometric and analytical properties of **Hilbert spaces**, utilizing orthonormal sets, projection theorems, and the **Riesz representation theorem** to represent linear functionals

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Normed Spaces	Normed linear spaces, Banach spaces and examples, Quotient space of normed linear spaces and its completeness, equivalent norms, Riesz Lemma	9	3		12
II	Finite Dimensional Normed Spaces	Basis properties of finite dimensional normed linear spaces and compactness, Weak convergence and bounded linear transformations, normed linear spaces of bounded linear transformations, dual spaces with examples.	12	4		16
III	Hahn Banach Theorem	Uniform boundedness theorem and some of its consequences, Open mapping and closed graph theorems, Hahn-Banach theorem for real linear spaces, complex linear spaces and normed linear spaces.	12	4		16
IV	Hilbert Spaces	Reflexive spaces, Inner product spaces, Hilbert spaces, Orthonormal Set, Bessel's inequality	6	2		8
V	Riesz Representation Theorem	Complete orthonormal sets and Parseval's identity, Structure of Hilbert spaces, Projection theorem, Riesz representation theorem.	6	2		8

Suggested Readings

1. **D. Kreyszig** (1978), *Introductory Functional Analysis with Applications*, John Wiley & Sons, New York, 1978.
2. **H.L. Royden** (1993), *Real Analysis*, Macmillan Pub. Co. Inc. New York, 4th Edition.

Additional Readings:

1. **C. Goffman and G. Pedrick** (1987): *First Course in Functional Analysis*, Prentice Hall of India, New Delhi.
2. **P.K. Jain**, **O.P. Ahuja and Khalil Ahmad** (1997), *Functional Analysis*, New Age International (P) Ltd. & Wiley Eastern Ltd. New Delhi.
3. **R.B. Holmes** (1975), *Geometric Functional Analysis and its Applications*, Springer-Verlag.
4. **K.K. Jha** (1982), *Functional Analysis*, Students' Friends.
5. **L.V. Kantorovich and G.P. Akilov** (1982), *Functional Analysis*, Pergamon Press.

Assessment Methods

- Oral and written examinations,
- Closed-book and open-book tests,
- Problem-solving exercises,
- Individual and group project reports,
- Seminar and presentations,
- Interactive sessions,

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√	√	√	√			
CO2	√	√	√				
CO3	√	√	√	√	√		

Academic level 6.0 and Semester – VII
DSE60MAT403(T)25: Graph Theory

Nature of Course	**DSE**			
Course Code	**DSE60MAT403(T)25**			
Course Title	**Graph Theory**			
Course Level	**400**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Seventh Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Geometry, Set theory, Logical Reasoning, Abstract Algebra**			
Pre Requisite Course Required	**Bachelor Degree in Mathematics**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: This course aims to introduce the basic ideas of graph theory with applications to Networks. This course will enhance the problem-solving skills and research related skills.

Course Learning Outcomes: After the completion of the course, a student will be able to

1.	define graphs, subgraphs, walks, paths, circuits, and connected components. Identify Euler and Hamiltonian graphs and test for graph isomorphisms. Represent graphs using adjacency and incidence matrices, and analyze directed graphs.
2.	explain properties of trees, rooted trees, binary trees, and Cayley's theorem. Find spanning trees, fundamental circuits, and minimal spanning trees. Analyze cut-sets, cut-vertices, network flows, and 1- or 2-isomorphisms.
3.	test and detect planarity using Euler's theorem and Kuratowski's theorem. Construct dual graphs and various planar representations. Calculate chromatic numbers, chromatic polynomials, and evaluate the four-color problem.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Path, Circuits and Graph	Paths, Circuits and Graph Isomorphisms Definition and examples of a graph, Subgraph, Walks, Paths and circuits; Connected graphs, disconnected graphs and components of a graph;	9	3		12
II	Adjacency Adjacency and Incidence Matrix	Euler and Hamiltonian graphs, Graph isomorphisms, Adjacency matrix and incidence matrix of a graph, Directed graphs and their elementary properties.	9	3		12

III	Trees and Fundamental Circuits	Trees and Fundamental Circuits Definition and properties of trees, Rooted and binary trees, Cayley's theorem on a counting tree, Spanning tree, Fundamental circuits, Minimal spanning trees in a connected graph.	9	3		12
IV	Cut-set, Connectivity and separability	Cut-set of a graph and its properties, Fundamental circuits and cut-sets, Cut-vertices, Connectivity and separability, Network flows, 1- isomorphism and 2- isomorphism.	6	2		8
V	Planar Graph	Planar Graphs and Coloring Planar graph, Euler theorem for a planar graph, Various representations of a planar graph, Dual of a planar graph, Detection of planarity, Kuratowski's theorem. Chromatic number of a graph, Chromatic partition, Chromatic polynomial, Matching and coverings, Fourcolor problem.	12	4		16

Suggested Readings

1. R. Balakrishnan & K. Ranganathan (2012). A Textbook of Graph Theory. Springer.
2. C.L. Liu, Elements of Discrete Mathematics, Mc-Graw-Hill Book Co.

Additional Readings:

1. N. Deo (2016), Graph Theory with Applications to Engineering and Computer Sciences, Dover Publicaton.
2. F Harary (1969), Graph Theory, Addison Wesley Publishing Company Reprinted Narosa Publishing House
3. J.P. Tremblay & R. Manohar (1997), Discrete Mathematical Structures with Applications to Computer Science, McGraw-Hill Book Co.
4. J.L. Gersing (2014), Mathematical Structures for Computer Science, W H Freeman nad Co.
5. Seymour Lipschutz (1983), Finite Mathematics, McGraw-Hill Book Company, New York.
6. S. Wiitala (1987), Discrete Mathematics – A Unified Approach, McGraw-Hill Book Co.
7. Kolman, Busby, Ross (2004), Discrete Mathematical Structures, Prentice Hall of India (reprint)

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√	√		√	√		√
CO2	√		√	√		√	√
CO3	√		√	√	√		√

Academic level 6.0 and Semester – VIII
MJC60MAT419(T)25 : Topology

Nature of Course	**Major**			
Course Code	**MJC60MAT419(T)25**			
Course Title	**Topology**			
Course Level	**400**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Eighth Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Set Theory and Real Analysis**			
Pre Requisite Course Required	**Bachelor Degree in Mathematics**			
Faculty Eligibility and Specialization				

Course Objectives: The course aims to understand clearly about the metric spaces, topological spaces, compactness of a general topological space so as to visualize many spaces with the concepts of countability

Course Learning Outcomes: After completion of the course, a student will be able to

1.	understand Basic topological structures, such as open/closed sets, accumulation points neighborhoods, and denser subsets.
2.	distinguish between coarser and finer topologies, as well as the alternate formulations using Kuratowski closure operators and neighborhood systems. analyze metric properties, including metric products, completeness, and incompleteness.
3.	formulate proofs and characterizations utilizing separation axioms
4.	demonstrate comprehension of compactness, countable compactness, and sequential compactness, particularly exploring their equivalence in metric spaces. Analyze continuous functions, compact sets, and their properties such as the finite intersection property, local compactness, and one-point compactification.
5.	evaluate concepts of connectedness, topological components, and locally connected spaces.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Metric and Topological Spaces	Metric and topological spaces: Definitions, Examples and Theorems – Open sets, Accumulation points, Derived Set, Closed sets, Closure. Dense subsets. Neighborhoods. Interior, exterior and boundary.	9	3	-	12

		Points, Convergent sequences, Coarser and finer topologies				
II	Complete spaces, bases and relative topology	Metrics on Products, Incomplete and Complete Metric Spaces, Bases and sub-bases. Topology generated by classes of sets, Subspaces and relative topology. Alternate methods of defining a topology in terms of Kuratowski Closure Operator and Neighbourhood Systems	9	3	-	12
III	Separability axioms	Continuous functions and homeomorphism (Metric space / topological space continued). First and Second Countable spaces. Lindelof's theorems. Separable spaces. Second Countability and Separability. Separation axioms T0, T1, T3 ½, T4; their Characterizations and basic properties. Urysohn's lemma. Tietze extension theorem	9	3	-	12
IV	Compactness	Compactness. Continuous functions and compact sets. Basic properties of compactness. Compactness and finite intersection property. Sequentially and countably compact sets. Local compactness and one point compactification. Compactness in metric spaces. Equivalence of comptactness, countable compactness and sequential compactness in metric spaces	9	3	-	12
V	Connectedness	Connectedness, Components, Locally connected spaces, Tychonoff product topology in terms of standard sub-base and its characterizations, Projection maps, Separation axioms and product spaces. Connectedness and product spaces, Compactness and product spaces (Tychonoff's theorem), Countability and product spaces	9	3	-	12

Suggested Readings

1. James R. Munkres (2002), Topology, Pearson Education Asia.

Additional Readings:

1. J. Dugundji (1966), Topology, Allyn and Bacon (Reprinted in India by Prentice Hall of India Pvt. Ltd.).
2. George F. Simmons (1963), Introduction to Topology and Modern Analysis, McGraw-Hall Book Company,.
3. K.D. Joshi (1983), Introduction to General Topology, Wiley Eastern Ltd.
4. J.A. Kelley (1995), General Topology, Van Nostrand, Reinhold Co., New York,.
5. L. A. Steen and J.A. Seebach (Jr.) (1970), Counter examples in Topology, Holt, Rinehart and Winston, New York.
6. Crump W. Baker (1991), Introduction to Topology, Wm C. Brown Publisher.
7. M.J. Mansfield (1963), Introduction to Topology, D. Van Nostrand Co. Inc. Princeton, N.J..
8. B. Mendelson (1962), Introduction to Topology, Allyn & Bacon Inc..
9. B.K. Lahiri (2000), A First Course in Algebraic Topology, Narosa.
10. C.Wayne Patty (2010), Foundations of Topology, Jones & Bartlet Student edition.
11. P.K.Jain, Khalil Ahmad (2019), Metric Spaces, Narosa, Third Edition.
12. Michael O Searcold (2008), Metric Spaces, Springer.

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**

- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1		√	√	√		√	√
CO2		√	√	√		√	√
CO3	√	√		√		√	√

Academic level 6.0 and Semester – VIII
MJC60MAT420(T)25 : Measure Theory and Integration

Nature of Course	**Major**			
Course Code	**MJC60MAT420(T)25**			
Course Title	**Measure Theory and Integration**			
Course Level	**400**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Eighth Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Real Analysis**			
Pre Requisite Course Required	**Bachelor Degree in Mathematics**			
Faculty Eligibility and Specialization				

Course Objectives: This course aims to understand clearly about the measurable set, integration with respect to measure and difference of Lebesgue integration with Riemann integration, to extend the results in abstract spaces.

Course Learning Outcomes: After completion of the course, a student will be able to

1.	define and evaluate Lebesgue outer measure and establish the outer measure of intervals. Students will understand the foundations of σ-algebras and Borel sets, and be able to analyze the limit properties of sequence of sets. Students will master the Carathéodory extension theorem and distinguish between Lebesgue measurable and non-measurable sets.
2.	demonstrate the ability to verify the measurability of functions, identifying the properties of constant and continuous functions. Students will prove closure properties of measurable functions, specifically regarding sums, differences, and products.

3.	understand the construction of the Lebesgue integral for non-negative functions and use tools like Fatou's Lemma to evaluate the general integral. Students will apply limit theorems for integration and compare the scopes and results of Riemann versus Lebesgue integrals.
4.	generalize from Lebesgue measure to abstract measure and outer measure spaces, understanding the completion of measures and the uniqueness of extensions. Students will successfully perform integrations with respect to an abstract measure.
5.	analyze signed measures and demonstrate Hahn decomposition and the classification of mutually singular measures. Students will apply advanced integral representation theorems, including the Radon-Nikodym theorem and Lebesgue Decomposition theorem. Students will understand and use the Riesz Representation theorem to link measures with bounded linear functionals.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Lebesgue's Outer Measure	Lebesgue outer measure, Outer Measure of Intervals, σ-algebra, Borel sets, limit of sequence of sets Measurable sets, Non-measurable sets	9	3	-	12
II	Measurable Function	Measurable functions, measurability of constant functions, measurability of continuous functions and measurability of sum, difference and product of measurable functions	9	3	-	12
III	Riemann Integration	Integration of Non negative function, Fatou Lemma, the general integral, integration of series, Riemann and Lebesgue integrals	9	3	-	12
IV	Abstract Measure	Abstract Measure and outer measure, extension of a measure, uniqueness of extension, completion of measure, integration with respect to a measure	9	3	-	12
V	Signed Measures	Signed measures, Hahn decomposition theorem, mutually singular measures, Radon-Nikodym theorem, Lebesgue Decomposition theorem, Riesz representation theorem	9	3	-	12

Suggested Readings

1. Walter Rudin, Principles of Mathematical Analysis (3rd edition) McGraw-Hill, Kogakusha, 1976, International Student edition.
2. T.M. Apostol, Mathematical Analysis, Narosa Publishing House, new Delhi, 1985.
3. H.L. Royden, Real Analysis, Macmillan Pub. Co. Inc. 4th Edition, New York, 1993.
4. G. De Barra, Measure Theory and integration, Wiley Eastern ltd., 1981.
5. P.R. Halmos, Measure Theory, Van Nostrand, Princeton, 1950.
6. T.G. Hawkins, Lebesgue's Theory of Integration: Its Origins and Development, Chelsea, New York, 1979.
7. J.H. Williamson, Lebesgue Integration, Holt Rinehart and Winston, Inc., New York, 1962

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**

- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1		√	√		√	√	√
CO2		√	√		√	√	√
CO3	√	√			√	√	√

Academic level 6.0 and Semester – VIII
MNC60MAT308(T)25: Partial Differential Equations

Nature of Course	**Minor**			
Course Code	**MNC60MAT308(T)25**			
Course Title	**Partial Differential Equations**			
Course Level	**300**			
Credit Details	Total Credit	Lecture/Week	Tutorial/Week	Total Hour/Week
	4	3	1	4
Course Audience	BA/BSc Eighth Semester			
Proposed by	Board of Undergraduate Studies of Department of Mathematics, Manipur University			
Pre Requisites	ODE, Real Analysis and Multivariate Calculus			
Pre Requisite Course Required	ODE, Real Analysis and Multivariate Calculus			
Faculty Eligibility and Specialization	Not required			

Course Objectives

The primary objectives of this course are:

1. To introduce the theory and classification of first- and second-order partial differential equations.
2. To develop analytical techniques for solving partial differential equations and related boundary value problems.
3. To demonstrate the role of partial differential equations in modelling and solving physical problems involving heat transfer and wave motion.

Course Learning Outcomes: After the completion of the course, a student will be able to

1.	classify and transform first- and second-order partial differential equations into suitable forms for analysis and solution.
2.	solve first-order partial differential equations using standard methods such as Lagrange's and Charpit's methods.
3.	solve boundary and initial value problems involving second-order partial differential equations using method of characteristics and separation of variables.
4	formulate and solve mathematical models involving the wave equation and heat equation arising in physical and engineering problems.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	First order PDE and their classification	Definitions & Basic concepts, Formation of PDE, classification and geometrical interpretation of first order partial differential equations (PDE), Complete integral, General solution, Particular solution, Envelope, Weak solution, Canonical form of first order PDE and General solution.	9	3		12
II	Solution Methods for first order Partial Differential Equations	Method of characteristics and general solution of first order PDE, Lagrange method, Charpit's method- Special types of First-order PDE, Cauchy's problems for first order PDE, Method of separation of variables.	9	3		12
III	Classification of second order Linear PDE	Classification of second order PDE, Reduction to canonical forms, Equations with constant coefficients, General solutions, Cauchy's Problem for second order PDE.	9	3		12
IV	Wave Equation	Mathematical Modelling of vibrating string, vibrating membrane, Homogeneous wave equation, Initial boundary value problems, non-homogenous boundary conditions, Finite string with fixed ends, non-homogeneous wave equation.	9	3		12
V	Heat Equation	Conduction of heat in solids, Method of Separation of variables, Heat conduction problems, Heat conduction problem, Existence and uniqueness of solution of Heat conduction problems.	9	3		12

Suggested Readings:

1. **Myint-U, Tyn and Debnath, Lokenath.** (2007). *Linear Partial Differential Equation for Scientists and Engineers* (4thed). Springer, Third Indian Reprint.
2. **Sneddon, I. N.** (1957). *Elements of Partial Differential Equations*, McGraw-Hill International Editions.

Additional Readings:

1. **Stavroulakis, Ioannis P & Tersian, Stepan A**. (2004). *Partial Differential Equations*: *An Introduction with Mathematica and MAPLE* (2nd ed.). World Scientific.
2. **Kreyszig E.** (2011). *Advanced Engineering Mathematics* (10th Edn.) Wiley.
3. **Piaggio H.T.H** (2004). *An Elementary Treatise on Differential Equations and its application*, CBS Publication.

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**

- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**
- **Project**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√		√	√	√		√
CO2	√		√	√	√		√
CO3	√	√	√	√	√		√
CO4	√	√	√	√	√		√

Academic level 6.0 and Semester – VIII
DSE60MAT404(T)25: Advanced Partial Differential Equations

Nature of Course	**DSE**			
Course Code	**DSE60MAT404(T)25**			
Course Title	**Advanced Partial Differential Equations**			
Course Level	**400**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Eighth Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**ODE**			
Pre Requisite Course Required	**Bachelor Degree in Mathematics**			

Course Objectives: This course aims to give knowledge of PDEs which are used to mathematically formulate physical and other problems involving functions of several variables, such as the propagation of heat or sound, fluid flow, elasticity, electrostatics, electrodynamics such as propagation of light and sound in the atmosphere, and waves on the surface of pond.

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

1.	Differentiate between linear, quasi-linear, and fully nonlinear partial differential equations, and determine their appropriate analytical frameworks (elliptic, parabolic, or hyperbolic).
2.	Apply the Method of Characteristics, Legendre transforms, and Hamilton-Jacobi equations to construct complete integrals and analyze geometric solutions.
3.	Construct entropy-satisfying weak solutions for conservation laws to accurately model shocks, discontinuities, and physical transport phenomena using the Hopf-Lax and Lax-Oleinik formulas.
4.	Map complex differential systems into solvable forms using linear transforms (Fourier, Laplace) and nonlinear integral transforms (Hopf-Cole, Hodograph).

5.	Evaluate the fundamental properties of Laplace, Heat, and Wave equations using specialized analytical tools, including Green's functions, spherical means, and energy methods.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Examples and Classification of PDE	Examples of PDE. Classification, Nonlinear First Order PDE – Complete Integrals, Envelopes, Characteristics, Hamilton-Jacobi Equations (Calculus of Variations, Hamilton's ODE, Legendre Transform, Hopt-Lax Formula, Weak Solutions, Uniqueness)	12	4		16
II	Separation of Variables	Conservation Laws (Lax-Oleinik formula, Weak Solutions), Representation of Solutions – Separation of Variables, Similarity Solutions (Plane and Travelling Waves, Similarity under Scaling)	6	2		8
III	Integral Transform	Fourier and Laplace Transform, Hopf-Cole Transform, Hodograph and Legendre Transforms, Potential Functions, Power Series (Non-characteristics Surfaces, Real Analytic Functions, Cauchy-Kovalevskaya Theorem).	9	3		12
IV	Transport, Homogeneous and Laplace Equations	Transport Equation – Initial value Problem. Non-homogeneous Equation. Laplace's Equation – Fundamental Solution, Mean and Formulas, Properties of Harmonic Functions, Green's Function, Energy Methods.	9	3		12
V	Heat and Wave Equations	Heat Equation – Fundamental Solution, Mean Value Formulation, Properties of Solutions, Energy Methods. Wave Equation – Solution by Spherical Means, Non-homogeneous Equations, Energy Methods.	9	3		12

Suggested Readings

1. L.C. Evans (1998), Partial Differential Equations, Graduate Studies in Mathematics, Volume 19, AMS.

Additional Readings:

1. I.N. Sneddon (2006), Elements of Partial Differential Equations, Dover Publications.
2. F. John (1991). Partial Differential Equations, Springer
3. P. Prasad, R. Ravindran (1984). Partial Differential Equations, John Wiley.
4. I.M. Gelfand and S.V. Fomin, Calculus of Variations, Prentice Hall.
5. http://archive.nptel.ac.in/courses/111/103/111103021/

Assessment Methods

- Oral and written examinations,
- Closed-book and open-book tests,
- Problem-solving exercises,
- Individual and group project reports,
- Seminar and presentations,
- Interactive sessions,

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√	√	√	√		√	√
CO2	√	√	√				√
CO3	√	√	√	√	√	√	√

Academic level 6.0 and Semester – VIII
DSE60MAT405(T)25: Fixed Point Theory

Nature of Course	**DSE**			
Course Code	**DSE60MAT405(T)25**			
Course Title	**Fixed Point Theory**			
Course Level	**400**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Eighth Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Metric Spaces and Functional Analysis**			
Pre Requisite Course Required	**Bachelor Degree in Mathematics**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: This course aims at imparting the problem solving and research related skills using the concepts of contraction principles and fixed point theory.

Course Learning Outcomes: After the completion of the course, a student will be able to learn

1.	Define metric spaces, complete metric spaces, normed linear spaces, and Banach spaces with their core properties. Understand bounded linear operators and how they act within these spaces.
2.	Apply the principle of contraction mapping and approximate iteration techniques.
3.	Explore generalizations and the converse of the contraction principle for advanced problem-solving.
4.	State and prove the Banach fixed point theorem in metric spaces.
5.	Utilize fixed point theorems and their extensions to solve real mathematical and analytical problems.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Basic Notions of Metric Spaces	Review the concept of metric space and Banach space-definition and properties of metric space, complete metric space, definitions and properties of normed and Banach spaces.	12	4		16
II	Contraction Mappings	Contraction Principle, principle of contraction mapping, linear operators, generalization of contraction mappings	9	3		12
III	Converse of contraction and applications	Approximate iteration, converse of the contraction principle, applications of contraction principle.	6	2		8
IV	Banach Fixed theorem	Fixed point theory in metric spaces-introduction of fixed point theory, Banach fixed point theorem	9	3		12
V	Application of Banach Fixed point Theorem	Applications of the Banach fixed point theorem, generalizations of the Banach fixed point theorem.	9	3		12

Suggested Readings

1. M. A. Khamsi and W. A. Kirk (2001), An introduction to Metric Spaces and Fixed Point Theory, Wiley-Inter Sci., New York.
2. W. A. Kirk and B. Sims (2001), Hand Book of Metric Fixed Point Theory, Springer, Netherlands, 2001.

Additional reading:
1. K. C. Border, Fixed point theorems with applications to economics and game theory, Cambridge University Press, Cambridge, 1985.
2. S. Singh, B. Watson and P. Srivastava, Fixed Point Theory and Best Approximation: The KKM - map Principle, Kluwer Academic Publishers, Dordrecht, 1997.
3. M. C. Joshi and R. K. Bose, Some topics in nonlinear functional analysis, Wiley Eastern Ltd, 1985.
4. Erwin Kreyszig, Introductory Functional Analysis with Applications, John Wiley & Sons, NY, 1978.
5. Vasile I. Istratescu, Fixed point Theory (An Introduction), D. Reidel Publishing Co., 1981.

Course Teaching-Learning Process
The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√	√	√		√		√
CO2	√	√	√		√		√
CO3	√	√	√		√		√

Academic level 6.0 and Semester – VIII
DSE60MAT406(T)25: Cryptography

Nature of Course	**DSE**			
Course Code	**DSE60MAT406(T)25**			
Course Title	**Cryptography**			
Course Level	**400**			
Credit Details	**Total Credit**	**Lecture/Week**	**Tutorial/Week**	**Total Hour/Week**
	4	**3**	**1**	**4**
Course Audience	**BA/BSc Eighth Semester**			
Proposed by	**Board of Undergraduate Studies of Department of Mathematics, Manipur University**			
Pre Requisites	**Number Theory, Field Theory**			
Pre Requisite Course Required	**Bachelor Degree in Mathematics**			
Faculty Eligibility and Specialization	**Not required**			

Course Objectives: This course aims at providing knowledge of the important aspects and application of cryptography and aspects of number theory in the present times.

Course Learning Outcomes: After the completion of the course, a student will be able to

1.	break shift, substitution, affine, Vigenère, Hill, and LFSR stream ciphers using fundamental cryptanalysis. explain Shannon's theory, perfect secrecy, entropy, and unicity distance.
2.	describe and analyze substitution-permutation networks, Data Encryption Standard (DES), Advanced Encryption Standard (AES), and Trivium stream ciphers.
3.	examine bit generators and the security metrics of pseudorandom bit sequences.
4.	use finite fields, primality testing (Miller-Rabin, Solovay-Strassen), and quadratic residues. Operate and secure RSA, Rabin, and El-Gamal cryptosystems alongside discrete logarithm algorithms (Shanks, Pollard rho, Pohlig-Hellman).
5.	utilize message authentication codes, hash functions, digital signatures, certificates, and nonrepudiation protocols.

Detailed Syllabus Content

Unit	Unit Name	Detailed Syllabus	L	T	P	Total
I	Introduction to Cryptography	Introduction to Cryptography and Classical Cryptography Cryptosystems and basic cryptographic tools: Secret-key cryptosystems, Public-key cryptosystems, Block and stream ciphers, Hybrid cryptography, Message integrity: Message authentication codes, Signature schemes, Nonrepudiation, Certificates, Hash functions	9	3		12
II	Ciphers	Cryptographic protocols, Security; Hybrid cryptography: Message integrity, Cryptographic protocols, Security, Some simple cryptosystems, Shift cipher, Substitution cipher, Affine cipher, Vigenère cipher, Hill cipher, Permutation cipher, Stream ciphers, Cryptanalysis of affine, substitution, Vigenère, Hill and LFSR stream ciphers.	9	3		12
III	Cryptographic Security	Cryptographic Security, Pseudo Randomness and Symmetric Key Ciphers Shannon's theory, Perfect secrecy, Entropy, Spurious keys and unicity distance; Bit generators, Security of pseudorandom bit generators. Substitution-permutation networks, Data encryption standard (DES), Description and analysis of DES; Advanced encryption standard (AES), Description and analysis of AES; Stream ciphers, Trivium.	12	4		16
IV	Number Theory and Cryptography	Basics of Number Theory and Public-Key Cryptography Basics of number theory; Introduction to public-key cryptography, RSA cryptosystem, Implementing RSA; Primality testing, Legendre and Jacobi symbols, Solovay-Strassen algorithm, Miller-Rabin algorithm; Square roots modulo n, Factoring algorithms, Pollard p - 1 algorithm, Pollard rho algorithm, Dixon's random squares algorithm, Factoring algorithms in practice; Rabin cryptosystem and its security.	9	3		12
V	Finite Fields and Cryptography	Basics of finite fields; ElGamal cryptosystem, Algorithms for the discrete logarithm problem, Shanks' algorithm, Pollard rho discrete logarithm algorithm, Pohlig-Hellman64 algorithm; Discrete	6	2		8

		logarithm algorithms in practice, Security of ElGamal systems, Bit security of discrete logarithms.				

Suggested Readings:

1. Jeffrey Hoffstein, Jill Pipher & Joseph H. Silverman (2014). An Introduction to Mathematical Cryptography (2nd edition). Springer.

Additional reading:

1. Neal Koblitz (1994). A Course in Number Theory and Cryptography (2nd edn). Springer-Verlag.
2. Christof Paar & Jan Pelzl (2014). Understanding Cryptography. Springer.
3. Simon Rubinstein-Salzedo (2018). Cryptography. Springer.
4. Douglas R. Stinson & Maura B. Paterson (2019). Cryptography Theory and Practice (4th edition). Chapman & Hall/CRC Press, Taylor & Francis.

Course Teaching-Learning Process

The important relevant teaching and learning processes involved in this course are:

- **Class lectures**
- **Seminars**
- **Tutorials**
- **Group discussions and Workshops**
- **Short answer type questions**
- **Long answer type questions**
- **Objective type questions**
- **Multiple choice questions**
- **Statement, reasoning and explanation**

Assessment methods

- **Oral and written examination**
- **Closed book and open book tests**
- **Problem solving exercises**
- **Seminar and presentations**
- **Interactive sessions**

Linkage between Programme Outcomes (POs) and Course Learning Outcomes (COs)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	√	√		√	√		√
CO2	√	√	√		√		√
CO3	√	√		√	√		√