Learning Outcome Based Curriculum Framework (LOCF)

SYLLABUS

FOR

M.SC. IN MATHEMATICS

Under Choice Based Credit System
(CBCS)

Effective from the academic session 2022-2023

KAZI NAZRUL UNIVERSITY

ASANSOL-713 340

WEST BENGAL

Preamble

The purpose of a Learning Outcome-based Curriculum Framework (LOCF) is to change the paradigm of higher education from a teacher-centric to learner-centric curriculum. It is hoped that this paradigmatic change will bring about a significant improvement in the quality of higher education and make the learners both competent and confident to face the challenges of a modern competitive world. The philosophy of this new curriculum framework is pragmatism, to realise that it is not enough for institutions of higher learning to produce good humans and responsible citizens of the country but also to produce employed graduates and postgraduates. After all, it is not prudent to expect an unemployed youth to cherish values like humanity and responsibility towards the nation; he/she first needs to have a productive employment to nourish such values.

LOCF seeks to make higher education in India learner-centric so that graduates and postgraduates not only have a more holistic understanding of their subject but also be able to better serve the humanity with dignity and honour, which can be expected only if they are able to secure productive employment after completing their higher education degrees.

Introduction to Learning Outcome Based Curriculum Framework (LOCF) in Kazi Nazrul University:

Two-year Post-Graduate programs in Kazi Nazrul University have been designed as a base for research and application of knowledge. The syllabus and curricula of the post graduate programme have been developed following the UGC LOCF guidelines and through rigorous academic exercises after consulting eminent academic experts and feedback received from various stakeholders of the University. These two-year programs will enable the students to enhance their learning after under-graduate course and to join the workforce in their respective fields. Kazi Nazrul University has an aim to develop the future generation learners sensitive towards the developmental challenges of the nation with special emphasis on the local developmental needs. The University also aims to foster this future generation of learners with a systematic understanding of global development need. The learning outcome-based curricula of different disciplines reflect the national as well as global sustainable needs listed below in the respective programme and course specific outcomes:

National needs:

- Promote Right to education
- Inculcate ethical and professional values
- Increase national and international visibility
- Leverage institutional strengths through strategic partnerships
- Enlarge the academic community within which to benchmark their activities
- Mobilise internal intellectual resources
- Add important, contemporary learning outcomes to student experience
- Develop stronger research groups
- Encourage multidisciplinary
- Promote cross cultural exchanges
- Preservation of traditional knowledge
- Creating human resource for Economic growth
- Promotion of scientific mind-set and critical thinking

Sustainable development needs:

- Help to eradicate poverty
- Ensuring meal for all

- Promoting good health and well being
- Promoting quality education
- Promoting gender equality
- Initiatives for clean water and sanitization
- Programmes to reduce inequalities
- Develop sustainable cities and communities
- Promote decent work and economic growth
- Initiate industry-academia collaboration for innovative research
- Encourage responsible consumer behaviour
- Encourage pro-environment awareness

Program Outcomes (PO)s:

The overall program outcomes of the LOCF at PG level are to:

- help formulate postgraduate attributes, qualification descriptors, programme learning outcomes and course learning outcomes that are expected to be demonstrated by the holder of a Master's degree;
- enable prospective students, parents, employers and others to understand the nature and level of learning outcomes (knowledge, skills, attitudes and values) or attributes a graduate/postgraduate should be capable of demonstrating on successful completion of M.A./M.Sc./ M.Com/ MBA
- maintain national standards and international comparability of standards to ensure global competitiveness, and to facilitate postgraduate mobility; and
- provide higher education institutions and their stake holders an important point of reference for setting and assessing standards.

Postgraduate Attributes:

The postgraduate attributes reflect the particular quality and feature or characteristics of an individual, including the knowledge, skills, attitudes and values that are expected to be acquired by a postgraduate through studies at the higher education institution (HEI) such as a college or university. Such attributes include capabilities that help strengthen one's abilities for widening current knowledge base and skills, gaining new knowledge and skills, undertaking future studies and performing well in a chosen career and playing a constructive role as responsible citizen of the country. The Attributes define the characteristics of a student's university degree programme(s), and describe a set of characteristics/competencies that are designed to be transferable beyond the particular disciplinary area and programme contexts in which they have been developed. Such attributes are fostered through meaningful learning experiences made available through the curriculum, the total college/university experiences and a process of critical and reflective thinking.

The learning outcomes-based curriculum framework is based on the premise that every student is unique. Each student has his/her own characteristics in terms of previous learning levels and experiences, life experiences, learning styles and approaches to future career-related actions. The quality, depth and breadth of the learning experiences made available to the students while at the college/University help develop their characteristic attributes. The postgraduate attributes reflect both disciplinary knowledge and understanding and generic/global skills and competencies that all students in different academic fields of study should acquire/attain and demonstrate. Some of the desirable attributes which a postgraduate student should demonstrate will include the following:

- ***Disciplinary Knowledge:*** Demonstrate comprehensive knowledge and understanding of one or more disciplines that form a part of a programme of study, and knowledge and skills acquired from interaction with educators and peer group throughout the programme of study.
- ***Communication Skills:*** Express thoughts and ideas effectively in writing and orally, communicate with others using appropriate media, confidently share one's views and express herself/himself, demonstrate the ability to listen carefully, read and write analytically, and present complex information in a clear and concise manner to different groups.
- ***Critical Thinking:*** Apply analytic thought to a body of knowledge, analyse and evaluate evidence, arguments, claims, beliefs on the basis of empirical evidence, identify relevant assumptions or implications, formulate coherent arguments, critically evaluate practices, policies and theories by following scientific approach to knowledge development.
- ***Problem Solving:*** Demonstrate capacity to extrapolate from what one has learned and apply their competencies to solve different kinds of non-familiar problems, rather than replicate curriculum content knowledge and apply one's learning to real life situations.
- ***Analytical Reasoning****:* Demonstrate the ability to evaluate the reliability and relevance of evidence, identify logical flaws and holes in the arguments of others, analyse and synthesise data from a variety of sources, draw valid conclusions and support them with evidence and examples, and addressing opposing viewpoints.
- ***Research-related Skills****:* Demonstrate a sense of inquiry and capability for asking relevant/appropriate questions, problematising, synthesising and articulating, demonstrate the ability to recognise cause-and-effect relationships, define problems, formulate hypotheses, test hypotheses, analyse, interpret and draw conclusions from data, establish hypotheses, predict cause-and-effect relationships, plan, execute and report the results of an experiment or investigation.
- ***Collaboration/Cooperation/Team work****:* Demonstrate ability to work effectively and respectfully with diverse teams, facilitate cooperative or coordinated effort on the part of a group, and act together as a group or a team in the interests of a common cause and work efficiently as a member of a team.
- ***Scientific Reasoning using Quantitative/Qualitative Data****:* Demonstrate the ability to understand cause-and-effect relationships, define problems, apply scientific principles, analyse, interpret and draw conclusions from quantitative/qualitative data, and critically evaluate ideas, evidence and experiences from an open-minded and reasoned perspective.
- ***Reflective Thinking:*** Demonstrate critical sensibility to lived experiences, with self-awareness and reflexivity of both self and society.
- ***Information/Digital Literacy:*** Demonstrate capability to use ICT in a variety of learning situations, demonstrate ability to access, evaluate, and use a variety of relevant information sources and to use appropriate software for analysis of data.
- ***Self-Directed Learning:*** Demonstrate ability to work independently, identify appropriate resources required for a project, and manage a project through to completion.
- ***Multicultural Competence:*** Demonstrate knowledge of the values and beliefs of multiple cultures and a global perspective, effectively engage in a multicultural society, interact respectfully with diverse groups.
- ***Moral and Ethical Awareness/Reasoning****:* Demonstrate the ability to embrace moral/ethical values in conducting one's life, formulate a position/argument about an ethical issue from multiple perspectives, and use ethical practices in all work. Demonstrate the ability to identify ethical issues related to one's work, avoid unethical behaviour such as fabrication, falsification or misrepresentation of data or

committing plagiarism, not adhering to intellectual property rights, appreciate environmental and sustainability issues, and adopt objective, unbiased and truthful actions in all aspects of work.

- ***Community Engagement:*** Demonstrate responsible behaviour and ability to engage in the intellectual life of the educational institution, and participate in community and civic affairs.

- ***Leadership Readiness/Qualities**:* Demonstrate capability for mapping out where one needs to go to "win" as a team or an organization, and set direction, formulate an inspiring vision, build a team who can help achieve the vision, motivate and inspire team members to engage with that vision, and use management skills to guide people to the right destination, in a smooth and efficient way.

- ***Lifelong Learning**:* Demonstrate the ability to acquire knowledge and skills, including 'learning how to learn' that are necessary for participating in learning activities throughout life, through self-paced and self-directed learning aimed at personal development, meeting economic, social and cultural objectives, and adapting to changing trades and demands of work place through knowledge/skill development/reskilling.

Program Specific outcomes (PSO)s:

Two-year post graduate programme in Mathematics is the culmination of in-depth knowledge of algebra, analysis, geometry, differential equations, mechanics and several other branches of mathematics. This programme helps learners in building a solid foundation for higher studies in mathematics.

- Students undergoing this programme learn to logically question assertions, to recognize patterns and to distinguish between essential and irrelevant aspects of problems. They also share ideas and insights while seeking and benefitting from knowledge and insight of others. This helps them to learn inculcate ethical and professional values in a rapidly changing interdependent society.

- Students completing this programme will be able to present mathematics clearly and precisely, make vague ideas precise by formulating them in the language of mathematics. This helps in promoting quality education.

- This programme will also help students to enhance their employability for teaching profession in Schools/colleges/ universities/institutes, government jobs, jobs in banking, insurance and investment sectors, data analyst jobs and jobs in various other public and private enterprises. Thus this programme will create human resources for Economic growth.

- After completing this programme the students can demonstrate fundamental systematic knowledge of mathematics and its applications in engineering, science, technology and mathematical sciences. Therefore, this programme encourages multidisciplinary aspects.

- After completing this programme the students can demonstrate educational skills in areas of analysis, geometry, algebra, mechanics, differential equations, etc. These help them to preserve traditional knowledge.

- Students can apply knowledge and skills to identify the difficult/unsolved problems in mathematics and to collect the required information in possible range of sources and try to analyse and evaluate these problems using appropriate methodologies. These help to develop strong research groups.

CORE COURSES (16)																
Programme outcomes	Real Analysis	Functional Analysis	Algebra	Numerical Analysis	Computational Techniques Using MATLAB	Complex Analysis	Topology	Classical Mechanics and Variational Calculus	Computer Aided Numerical Practical	Multivariate Calculus	Ordinary Differential Equations and Special Functions	Integral Equations and Integral Transforms	Partial Differential Equations and Generalized Functions	Measure and Integration	Geometry of Curves and Surfaces	Project Work
Disciplinary knowledge	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Communication skills	√	√	√		√	√	√		√	√				√	√	√
Critical thinking competency	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Analytical thinking	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Transdisciplinary collaboration competency	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Normative competency				√	√			√	√		√		√			√
Strategic competency				√	√	√		√	√				√			√
Problem Solving Skills	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Research related skills	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Information literacy	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Digital literacy	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Self-directed learning	√	√	√	√		√		√		√	√	√	√	√	√	
Lifelong learning	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
Professional skills			√	√	√			√	√	√	√	√	√			√
Applicational skills	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Employability options	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

ELECTIVE COURSES																			
Programme outcomes	Introduction to Operations Research	Mathematical Logic and Set Theory	Graph Theory	Advanced Complex Analysis I	Advanced Functional Analysis I	Advanced Topology I	Operator Theory I	Advanced Optimization Techniques I	Biomathematics I	Fluid Mechanics I	Operations Research I	Advanced Complex Analysis II	Advanced Functional Analysis II	Advanced Topology II	Operator Theory II	Advanced Optimization Techniques II	Biomathematics II	Fluid Mechanics II	Operations Research II
Disciplinary knowledge	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Communication skills	√	√	√					√	√	√	√					√	√	√	√
Critical thinking competency	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Analytical thinking	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Transdisciplinary collaboration competency	√	√	√					√	√	√	√					√	√	√	√
Normative competency		√	√					√	√	√	√					√	√	√	√
Strategic competency	√	√	√					√	√	√	√					√	√	√	√
Problem Solving Skills	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Research related skills	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Information literacy	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Digital literacy	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Self-directed learning	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Lifelong learning	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Professional skills	√	√	√					√	√	√	√					√	√	√	√
Applicational skills	√	√	√	√	√		√	√	√	√	√	√	√		√	√	√	√	√
Employability options	√	√	√					√	√	√	√					√	√	√	√

Course Structure

Semester	Course Code	Course Name	Credit	Marks
Semester I	MSCMATHC101	Real Analysis	4	50
	MSCMATHC102	Functional Analysis	4	50
	MSCMATHC103	Algebra	4	50
	MSCMATHC104	Numerical Analysis	4	50
	MSCMATHC105	Computational Techniques Using MATLAB	2	50
		Total	**18**	**250**
Semester II	MSCMATHC201	Complex Analysis	4	50
	MSCMATHC202	Topology	4	50
	MSCMATHC203	Classical Mechanics and Variational Calculas	4	50
	MSCMATHC204	Computer Aided Numerical Practical	2	50
		Minor Elective 1 (Any One)		
	MSCMATHMIE201	Introduction to Operations Research	4	50
	MSCMATHMIE202	Mathematical Logic and Set Theory		
		Total	**18**	**250**
Semester III	MSCMATHC301	Multivariate Calculus	4	50
	MSCMATHC302	Ordinary Differential Equations and Special Functions	4	50
	MSCMATHC303	Integral Equations and Integral Transforms	4	50
		Major Elective 1 & 2 (Any two)		
	MSCMATHMJE301	Advanced Complex Analysis I	5×2=10	50×2 =100
	MSCMATHMJE302	Advanced Functional Analysis I		
	MSCMATHMJE303	Advanced Topology I		
	MSCMATHMJE304	Operator Theory I		
	MSCMATHMJE305	Advanced Optimization Techniques I		
	MSCMATHMJE306	Biomathematics I		
	MSCMATHMJE307	Fluid Mechanics I		
	MSCMATHMJE308	Operations Research I		
		Minor Elective 2		
	MSCMATHMIE301	Graph Theory	4	50
		Total	**26**	**300**
Semester IV	MSCMATHC401	Partial Differential Equations and Generalized Functions	4	50
	MSCMATHC402	Measure and Integration	4	50
	MSCMATHC403	Geometry of Curves and Surfaces	4	50
	MSCMATHC404	Project Work	4	50
		Major Elective 3 & 4 (Any two)		
	MSCMATHMJE401	Advanced Complex Analysis II	5×2=10	50×2 =100
	MSCMATHMJE402	Advanced Functional Analysis II		
	MSCMATHMJE403	Advanced Topology II		
	MSCMATHMJE404	Operator Theory II		
	MSCMATHMJE405	Advanced Optimization Techniques II		
	MSCMATHMJE406	Biomathematics II		
	MSCMATHMJE407	Fluid Mechanics II		
	MSCMATHMJE408	Operations Research II		
		Total	**26**	**300**
		Grand Total	**88**	**1100**

Detailed Syllabus

SEMESTER-I

CORE COURSE-1

Course Code: MSCMATHC101

Course Name: Real Analysis

Course Structure

Course Type: **Core (Theoretical)**	Course Details: **CC-1**			L-T-P: 4-**0-0**	
Credit: **4**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To familiarize with functions of bounded variations, measure theory, double Series, Fourier series, etc.
- To understand the relation between function of bounded variation and absolutely continuous functions, outer measure and general measure, Riemann integral and Riemann-Stieltjes integral, etc.
- To explain the situation where the above concepts are applied in other branch of mathematics and higher studies.
- To extend the concept of outer measure in an abstract space and almost everywhere property of functions and its application

Course Learning Outcomes: After successful completion of the course the student would be able

- to verify whether a given subset of R is measurable or to examine whether a real valued function is a function of bounded variation, absolutely continuous, measurable, Riemann-Stieltjes integrable etc.
- to understand the requirement and the concept of the Bounded variation, Double series, measurable sets, measurable function along with its properties
- to apply the knowledge of Fourier series in solving complex differential equations
- to demonstrate understanding of the statement and proofs of the different theorems and their applications.

Course content

Set Theory: Concept of Cardinal number of an infinite set, order relation of Cardinal numbers, Schroeder-Bernstein theorem, Cantor's Theorem, Cardinal numbers and Cardinal arithmetic, Continuum Hypothesis, Zorn's Lemma, Axioms of Choice, Well-Ordered Sets, Maximum Principle, Ordinal numbers, Cantor set and cantor-like sets. [5H]

Bounded Variation. Monotone functions and their discontinuities, Functions of Bounded Variation and their properties, Differentiation of a function of bounded variation, characterization of a function of bounded variation, Absolutely Continuous Function, Representation of an absolutely continuous function by an integral. Everywhere Continuous but nowhere differentiable function.

[10H]

Riemann-Stieltjes integral: Definition, Necessary and sufficient condition for existence of Riemann-Stieltjes integral, Integration by parts, Change of variables in integral, Integral of step functions, First mean value theorem and Second mean value theorem for Riemann-Stieltjes integrals.

[6H]

Double sequences, double series, Stolz's theorem, double series of positive terms, absolute convergence of double series. [4H]

Measure Theory: Outer measure, Lebesgue measure, Measurable sets and their properties, F_σ sets, G_δ sets, Borel sets, Existence of non measurable sets. [8H]

Measurable functions and its operations, sequence of measurable functions and their properties, simple functions, almost everywhere property and its application. [7H]

Fourier Series: Periodic functions. Definition of Fourier Series. Dirichlet's conditions of convergence and statement for sufficient condition for a trigonometric series to be a Fourier series.Derivation of Fourier Coefficients.Examples of Fourier expansions and summation results for series. Gibbs phenomenon. Use of odd & even functions in evaluating Fourier coefficients– Half range sine & cosine series, Differentiation and integration of Fourier series. Absolute and uniform convergence of Fourier series, Riemann- Lebesgue lemma, Bessel's inequality and Parseval's identity.The complex form of Fourier series.

[10H]

References:

1. Royden, H.L., Real Analysis, Pearson
2. Apostol T. M., Mathematical Analysis, Addison Wesley Publishing Company.
3. Aliprantis, C.D., Burkinshaw, O., Principles of Real Analysis, Harcourt Asia Pvt Ltd.
4. Halmos, P.R., Measure Theory , Van Nostrand, New York, 1950.
5. Rudin, W., Real and Complex Analysis, McGraw Hill Book Co., 1966.
6. Kolmogorov, A.N., Fomin, S.V., Measures, Lebesgue Integrals and Hilbert Space, Academic Press, New York and London, 1961.
7. Robert R. Stoll, Set Theory and Logic, Dover Publications, Inc, New York, 1963.

CORE COURSE-2

Course Code: MSCMATHC102

Course Name: Functional Analysis

Course Structure

Course Type: **Core (Theoretical)**	Course Details: **CC-2**		L-T-P: 4-**0-0**		
Credit: **4**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To develop a deeper and rigorous understanding of fundamental concepts of functional analysis involving normed spaces, Banach spaces and Hilbert spaces, their properties dependent on the dimension and the bounded linear operators from one space to another**.**
- To acquire knowledge about some important features of metric spaces such as completion of a metric space, Baire Category theorem, equicontinuous family of functions, Arzela-Ascoli's theorem,Weierstrass approximation theorem, The Stone-Weierstrass theorem etc.

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

- Realize the importance of Baire category theorem, Weierstrass approximation theorem, The Arzela-Ascoli theorem etc. and apply them in other related areas.
- Realize the concepts of bounded operators, normed spaces, Hilbert spaces and utilize them in science and engineering.
- Distinguish between Banach spaces and Hilbert spaces
- Apply the Hahn-Banach theorem, the open mapping theorem, the closed graph theorem and uniform boundedness theorem to different related fields.

Course content

Metric spaces: Completion of Metric space. Equicontinuous family of Functions. Compactness in C[0,1] (Arzela-Ascoli's Theorem), Baire category theorem. [8H]

Normed linear spaces: Norm, continuity of norm function, Banach spaces with examples, quotient space.
Linear operator, boundedness and continuity, examples of bounded and unbounded linear operators.
Properties of normed linear spaces, Riesz's Lemma, and its application in Banach spaces. Series and its convergence in normed linear spaces, equivalence of two norms in a linear space, some properties of a finite dimensional normed linear space. [15 H]

Fundamental theorems on normed linear spaces: Hahn-Banach theorems and its consequences, dual and 2nd dual of a normed linear space, separability and reflexivity of normed linear space,Open mapping theorem, closed graph theorem and uniform boundedness principle, some applications of these theorems.
[10 H]

Inner product spaces: Hilbert space, orthonormality, orthogonal complement, orthonormal basis, Bessel's inequality, Parseval's equation, Gram-Schmidt orthonomalisation process, Riesz representation theorem, reflexivity of Hilbert space, separable and non-separable Hilbert space.
[15 H]

References:

1. Simmons, G.F., Introduction to Topology and Modern analysis, McGraw-Hill, 1963.
2. Kreyszig, E., Introductory Functional Analysis with Applications, John Wiley and Sons (Asia) Pvt. Ltd., 2006.
3. Aliprantis, C.D., Burkinshaw, O., Principles of Real Analysis, 3rd Edition, Harcourt Asia Pvt Ltd.
4. Goffman, C., Pedrick, G., First Course in Functional Analysis, PHI, New Delhi, 1987.
5. Bachman, G., Narici, L., Functional Analysis, Academic Press, 1966.
6. Taylor, A.E. Introduction to Functional Analysis, John Wiley and Sons, New York, 1958.
7. Conway, J.B., A course in Functional Analysis, Springer Verlag, New York, 1990.

CORE COURSE-3

Course Code: MSCMATHC103

Course Name: Algebra

Course Structure

Course Type: **Core (Theoretical)**	Course Details: **CC-3**			L-T-P: 4-**0-0**	
Credit: **4**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To give students a foundation for all future mathematics courses.
- To explain the fundamentals of algebraic problem-solving methods.
- To explore the Algebraic structures, Groups, Rings, Ideals, Fields, Homomorphisms etc.
- To make students aware of the applicability of abstract mathematics and linear algebra in real world problems.

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

- Utilize the class equation and Sylow theorems to solve different related problems.
- Identify and analyze different types of algebraic structures such as Solvable groups, Simple groups, Alternate groups to understand and use the fundamental results in Algebra.
- Know in detail about polynomial rings, fundamental properties of finite field extensions and classification of Finite Fields.
- Acquaint with the basic concepts of Galois Theory such as the concepts of normal extensions, fixed field, the fundamental theorem of Galois theory etc.
- Realize the importance of adjoint of a linear transformation, its canonical form and its applications.

Course content

Groups: Normal subgroups, quotient groups, homomorphisms, Cayley's theorem, extended Cayley's theorem, Burnside theorem, conjugacy classes, class equation. Direct product of groups, Cauchy's theorem on finite groups, *p*-group, Centre of *p*-groups. Sylow's theorems, some applications of Sylow's theorems, Simple groups, non-simplicity of groups of orderp^n (n >1), pq, p^2q, p^2q^2(p, q are primes), normal and subnormal series, composition series, Jordan–Holder theorem, solvable groups and nilpotent groups, Finite groups, structure theorem for finite Abelian groups

[12H]

Rings: Ideals and Homomorphism, Isomorphism theorems, Quotient Rings, Prime and maximal Ideals, Relation between Prime and Maximal Ideals, maximal ideals in some familiar rings of functions, Quotient field of an integral domain, Euclidean domain, Principle Ideal domain, Unique factorization Domain, Gauss Theory, Polynomial ringsand factorization of polynomials over a commutative ring with identity, the division algorithm, Eisenstein's irreducibility criterion, Noetherian and Artinian rings, Hilbert Basis Theorem.

[12H]

Fields: Field Extensions-Algebraic and Transcendental Extensions, Finite Extension, Algebraic Closure of a field, Algebraically Closed Field, Splitting Field of a polynomial, Normal Extension, Separable Extension, Finite Fields and their properties, Galois Group of automorphisms and Galois Theory.

[16 H]

Linear algebra: Canonical Forms: Similarity of linear transformations, Diagonalization, Invariant Subspaces, Reduction to Triangular Forms. Nilpotent Transformations, Index of Nilpotency, Invariants of a nilpotent transformation, Jordan Blocks and Jordan Forms, Rational Canonical Form, Generalized Jordan Form over an arbitrary field,Sylvester's law of inertia, simultaneous reduction of two quadratic forms, applications to Geometry & Mechanics.

[10 H]

References:

1. D. S. Malik, J. M. Mordeson, M. K. Sen, Fundamentals of abstract algebra, The McGraw-Hill Companies, Inc.
2. J. A. Gallian, Contemporary abstract algebra, Cengage learning India pvt. Ltd.
3. J. B. Fraleigh, A first course in abstract algebra, , Pearson education.
4. M. Artin, Algebra, Pearson education.
5. T. W. Hungerford , Algebra, Springer-Verlag.
6. D. S. Dummit, R. M. Foote, Abstract algebra, Wiley.
7. I. N. Herstein, Topics in algebra, Wiley.
8. N. Jacobson, Basic Algebra I & II(2nd edition), Dover Publications, Inc.
9. Gilbert Strang, Linear Algebra and its Applications (2nd edition), (2014),Elsevier.
10. Kenneth Hoffman & Ray Kunze, Linear Algebra (2nd edition), (2015), Prentice-Hall.

CORE COURSE-4

Course Code: MSCMATHC104

Course Name: Numerical Analysis

Course Structure

Course Type: **Core (Theoretical)**	Course Details: **CC-4**			L-T-P: 4-**0-0**	
Credit: **4**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To enhance the problem solving skills using numerical methods.
- To handle large system of equations, non-linearity and and that are often impossible to solve analytically
- To solve ordinary and partial differential equations by numerical methods

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

- Understand interpolation formula and analyze error terms
- Apply techniques to find the roots of algebraic equations and system of equations.
- Solve initial and boundary value problems
- Solve partial differential equations by using finite difference method

Course content

Polynomial approximation: Polynomial interpolation, Hermite's interpolation, Piecewise polynomial approximation, Cubic spline interpolation. [4H]

Numerical integration: Richardson extrapolation and Romberg's integration method, Gaussian quadrature, Gauss-Legendre and Gauss-Chebyshev integration rule, Quadrature formula for singular integrals. [6H]

Roots of polynomial equation: Graffae's root squaring method and Bairstow's method, Solution of a system of non-linear equations by fixed point method and Newton Raphson method. [6H]

Solution of ordinary differential equation: Fourth order R-K method for the solution of second order ordinary differential equations and simultaneous first order ordinary differential equations. Adam-Bashforth-Moulton and Milne's predictor corrector method to solve first order initial value problems. [8H]

Solution of second order boundary value problems by finite difference method and Shooting method. [4H]

Solution of a system of linear equations: LU decomposition method, Solution of tri-diagonal system of equations, Ill-conditioned linear systems, Relaxation method. [6H]

Eigenvalue problems of a matrix: Determination of eigenvalues by- Power method, Jacobi's method for Eigenvalues of symmetric matrices, Eigenvalues of symmetric tri-diagonal matrix, Bounds of Eigenvalues, Gershgorin's circle theorem. [6H]

Solution of partial differential equations: Finite difference approximations to partial derivatives, Schmidt explicit and Crank-Nicolson implicit method for solving heat equation, Finite difference method for solution of Hyperbolic and Elliptic equations. Convergence and stability analysis. [8H]

References:

1. K. E. Atkinson, An Introduction to Numerical Analysis, John Wiley & Sons, Singapore.
2. A. Gupta and S.C. Basu, Introduction to Numerical Analysis, Academic Publishers.
3. M. K. Jain, S. R. K. Iyenger & P. K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International (P) Ltd., New Delhi.
4. A. Ralston, A First Course in Numerical Analysis, McGraw Hill, New York.
5. E.A. Volkov, Numerical Methods, Mir Publishers, Moscow
6. J.H. Mathews, Numerical Methods for Mathematics, Science, and Engineering, Prentice-Hall, Inc., N.J., U.S.A.

CORE COURSE-5

Course Structure

Course Code: MSCMATHC105

Course Name: Computational Techniques Using MATLAB

Course Type: **Core (Practical)**	Course Details: **CC-5**		L-T-P: **0-0-4**
		CA Marks	ESE Marks

Credit: **2**	Full Marks: **50**	Practical	Theoretical	Practical	Theoretical
		30	**…**	**20**	**…**

Course Objectives:

- To understand the basic structure of MATLAB programming language
- To learn the use of arrays, functions and matrix manipulation
- To acquire skills of plotting graphs using MATLAB
- To acquire problem solving skills of various mathematical problems

Course Learning Outcomes: After completion of this course, students will have

- Knowledge of numeric computation, advanced graphics and visualization using MATLAB
- Ability of graph plotting, advanced graphics and visualization using MATLAB
- Ability of solving problems such as algebraic, differential using MATLAB
- Skill in solving several real-life and mathematical problems

Course content

Introduction: Basics of MATLAB, MATLAB windows, MATLAB workspace, Data types, MATALB variables, Assignment statements, Arrays, Matrices, String, Cell arrays and structures, General commands, Managing workspace, Mathematical operators, Writing mathematical expressions in MATLAB. [4H]

Working with Arrays: Creating an Array, Mathematical operations on arrays, Addition, Subtraction, Element-by-element multiplication, Element-by-element division, Element-by-element left division, Element-by-element power. Relational and Logical operators on arrays, Multidimensional arrays, Cell arrays, Characters and text in array. [4H]

Working with Matrices: Generating matrix, Matrix manipulation, Deleting rows and columns, Creating special matrices, Symmetric matrix, The transpose, determinant and inverse of a Matrix, Mathematical operations on Matrices, Matrix analysis using function. Working with anonymous functions, Symbolic computation. [6H]

Graph Plotting: Plotting process, Creating a graph, Graph components, Figure tools, Arranging graphs within a figure, Choosing a type of graph to plot, Basic 2-D Plots, Labels, title, legend, and other text objects, Axis control, Zoom in and zoom out, Modifying plots with the plot editor, Using subplot for multiple graphs, 3-D Plots, View, Rotate view, Mesh and surface plots, Saving and printing graphs, Saving graphs to reusable files, Annotating graphs for presentation, Exporting the graph. [8H]

Using Basic Plotting Functions: Creating a plot, Specifying line styles and colors, Plotting lines and markers, Graphing imaginary and complex data, Adding plots to an existing graph, Figure windows, Displaying multiple plots in one figure, Controlling the axes. [4H]

Programming: Conditional control statements–if, if-else, switch-case-otherwise, Loop control statements–for loop, while loop, Nested loop control, continue statement, break statement, Error control– try, catch, Program termination–return. Simple examples. [6H]

Scripts and Functions: Script files, Function files, Types of functions, Global variables, Passing string arguments to functions, The *eval* function, Function handles, Factorization. [4H]

Linear Algebra: Solving a system of linear equations, Gaussian elimination, Inverses and determinants, Finding eigenvalues and eigenvectors, Factorizations, Powers and exponentials. [4H]

Polynomials: Polynomial functions in the MATLAB environment, Representing Polynomials, Evaluating Polynomials, Roots of equations, Addition multiplication and division of polynomials, Derivatives of polynomials, Examples of MATLAB applications. [4H]

Curve Fitting and Interpolation: Polynomial curve fitting, Least-square approximations, Interpolation, Piecewise linear interpolation, Characteristic Polynomials. [4H]

References:

1. Etter, Delores M., Introduction to MATLAB for Engineers and Scientists, Prentice-Hall.
2. R. Pratap, Getting Started with MATLAB: A Quick Introduction for Scientists & Engineers, Oxford University Press.
3. A. Gilat, MATLAB: an Introduction with Applications, New York: Wiley.
4. Fausett, Laurene, Applied Numerical Analysis Using MATLAB, Prentice-Hall.
5. J. P. William, Introduction to MATLAB for Engineers, New York: McGraw-Hill.
6. C. Lopez, MATLAB programming for numerical analysis, Apress; 2014.

SEMESTER-II

CORE COURSE-6

Course Code: MSCMATHC201

Course Name: Complex Analysis

Course Structure

Course Type: **Core (Theoretical)**	Course Details: **CC-4**		L-T-P: 4-**0-0**	
Credit: **4**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To study the topology of the complex plane.
- To get knowledge of complex integrations, maximum modulus principle and basic idea of analytic continuation.
- To understand spaces of continuous functions, analytic functions and meromorphic functions.
- To get clear concepts on harmonic functions.

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

- visualize the complex plane and the extended complex plane
- integrate complex valued functions along a curve and find the Laurent series of certain functions.
- apply Schwarz's lemma in the geometry of unit disc.
- Solve Dirichlet's problem and apply Green's function to different branches of applied mathematics.

Course content

Algebra of complex numbers, complex plane, extended complex plane and its spherical, topology of the complex plane. [6H]

Functions of one complex variable, analytic functions and harmonic functions, Möbius transformations, conformal mapping, power series, Cauchy-Riemann equations, analytic branches of a multiple-valued function. [8H]

Integration along a contour, fundamental theorem of calculus, homotopy, Goursat's theorem, Cauchy's theorem, Cauchy's integral formula, Liouville's theorem,Cauchy's inequalities and other consequences, winding number, open mapping theorem. [8H]

Singularities of a holomorphic function, residues, Laurent series, Cauchy's residue theorem, Cassoratti-Weierstrass theorem, argument principle, Rouche's theorem and its applications.

[8H]

Maximum modulus theorem, Schwarz's lemma, automorphisms of unit disc, Schwarz reflection principle, Open mapping theorem, Analytic continuation along path. [6H]

Space of continuous functions, space of analytic functions, space of meromorphic functions. [6H]

Basic properties of harmonic functions, harmonic functions on a disc, subharmonic and superharmonic functions, Dirichlet's problem, Green's functions. [8H]

References:

1. J. B. Conway, Functions of one complex variable, 2nd Ed., Springer international student edition.
2. James Ward Brown and Ruel V. Churchill, Complex Variables and Applications, 8th Ed., McGraw – Hill International Edition, 2009.
3. Joseph Bak and Donald J. Newman, Complex Analysis, 2nd Ed., Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., NewYork, 1997.
4. S. Ponnusamy, Foundations of complex Analysis, Alpha Science International, 2005.
5. E.M.Stein and R. Shakrachi, Complex Analysis, Princeton University Press, 2010.
6. P.K. Nayak, M.R. Seikh, A Textbook of Complex Analysis, Narosa Publishing House.

CORE COURSE-7

Course Code: MSCMATHC202

Course Name: Topology

Course Structure

Course Type: **Core (Theoretical)**	Course Details: **CC-7**			L-T-P: 4-**0-0**	
Credit: **4**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To introduce basic concepts of point set topology, derived concepts, basis and sub-basis for a topology and order topology.
- To explain the idea of continuity, topological equivalence and define homeomorphisms.
- To study the notions of connectedness, path connectedness, local connectedness, local path connectedness, convergence, compactness of spaces.
- To familiarize with the concept of countability and separation axioms etc.

Course Outcomes: After successful completion of the course the student would be able to

- Demonstrate knowledge and understanding of concepts such as open and closed sets, interior, closure and boundary.
- Check whether a collection of subsets is a basis for a given topological spaces or not, and determine the topology generated by a given basis.
- Understand separation axioms and find their differences.

- Determine the connectedness, path connectedness, compactness etc. of the product of an arbitrary family of spaces.
- Create new topological spaces by using subspace, product and quotient topologies.

Course content

Topological spaces: Definition and examples of topological spaces, Open sets, Neighbourhoods, Neighbourhood systems, Neighbourhood operator, Generation of a topology using neighbourhoodoperators, Bases, Subbases, Limit points, Derived sets, Closure of a set,Closed sets, Kuratowski closure operator, Interior of a set, Continuous functions, Open maps, Closed maps, Homeomorphism and topological invariants, Product topological spaces, quotient topological space**.**

[15H]

Separation axioms: T_0spaces,T_1 spaces,T_2spaces, Regularspaces,T_3spaces, Normal spaces,T_4 spaces, Uryshon's lemma(Statement only), Completely regular spaces and $T_{3.5}$spaces, their properties, characterizations and relationships. Tietze's extension theorem (Statement only).

[10H]

Countability axioms: First and second countable spaces, Separable spaces, Lindelof space, Examples and relation, Properties on continuity and subspaces of the above spaces. [5H]

Compactness: Compact spaces, compact subspaces, characterizations in terms of finite intersection property, Alexander subbase theorem, compactness and separation axioms, compactness and continuous functions, sequentially, Fréchet and countably compact spaces, subspaces and their mutual relationship, locally compact spaces. [12H]

Connectedness: Connected spaces and their characterizations, Connected subspaces, Connectedness of the real line, Components, Totally disconnected spaces, Locally connected spaces, Path connectedness, Path components, Locally path connected spaces**.** [8H]

References:

1. Munkers, J.R., Topology, Pearson.
2. Simmons, G.F., Introduction to Topology and Modern analysis, McGraw-Hill, 1963.
3. Kelley, J.L., General topology, Van Nostrand Reinhold Co., New York, 1995.
4. Joshi, K.D., Introduction to General Topology, New age International Publishers, 1983.
5. Hocking, J., Young, G., Topology, Addison-Wesley Reading, 1961.
6. Steen, L., Seebach, J., Counter Examples in Topology, Holt, reinhart and Winston, New York.

CORE COURSE-8

Course Code: MSCMATHC203

Course Structure

Course Name: Classical Mechanics and Variational Calculus

Course Type: **Core (Theoretical)**	Course Details: **CC-8**			L-T-P: 4-**0-0**	
Credit: **4**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To know the concept of generalized co-ordinates
- To have the knowledge of Lagrange's equation of motion, Hamilton's principle, Canonical transformations, Hamilton's equations of motion, Euler's dynamical equations, etc.
- To understand the concept of Calculus of Variations and its applications.

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

- Acquire a deep knowledge of different types of principles of motion.
- Apply the equations of motion to solve analytically the problems of motion
- Apply the Hamilton's principle for deriving the equations of motion of a system
- Understand basic theories of calculus of variations

Course content

Constrained motion: Generalised co-ordinates, Constraints, Types of Constraints, unilateral, bilateral, holonomic, schleronomic, rheonomic. Forces of constraints, Classification of a Dynamical system, Virtual Work, Generalised Principle of D'Alembert, Generalised forces and generalized momentum, Expression for kinetic energy, Lagrange's equation of motion of first kind. [6H]

Lagrangian mechanics: Lagrange's equations of motion for holonomic and non-holonomic systems, Velocity dependent potential, Dissipative forces, Rayleigh's dissipation function. [4H]

Hamiltonian mechanics: Cyclic co-ordinates, Routh's process for the ignoration of co-ordinates and applications, Legendre dual transformation, Hamilton's canonical equations of motion. [4H]

Variational principles: Action Integral, Hamilton's principle for conservative, non-holonomic system, Hamilton's principle for non-conservative, non-holonomic system, derivation of Hamilton's principle from Lagrange's equations, derivation of Lagrange's equations from Hamilton's principle, Principle of least action, Principle of energy. [6H]

Canonical transformations: Generating functions and canonical transformations, Properties of canonical transformations, Condition of canonicality, Infinitesimal canonical transformations. [4H]

Brackets: Poisson bracket, Lagrange bracket and their properties, Invariance of Poisson and Lagrange brackets under canonical transformations, Hamilton-Jacobi's equation, Hamilton's equations of motion in terms of Poisson bracket. [6H]

Motion of a Rigid Body. Euler's Theorem. Motion about a Fixed Point in it. Euler's Dynamical Equations. Motion of a symmetric top in absence of torque. Eulerian angles. Components of angular velocity in terms of Euler angles, Motion of a Symmetrical top under gravity. Stability of top motion.

[6H]

Variational Calculus: Concept of variation, Linear functional, Euler-Lagrange equation- Some special cases, Shortest distance, minimum surface of revolution, Brachistochrone problem, geodesic, Euler-Ostrogradsky equation, Parametric representation of variational problem, Isoperimetric problem, Variational problems with moving boundaries, Sufficient conditions for extrema, Jacobi's condition, Legendre condition. Direct method to solve variational problem, Rayleigh-Ritz method to find approximate solution.

[12H]

References:

1. H. Goldstein, Classical Mechanics. Narosa Publ., New Delhi.
2. N. C.Rana and P. S. Joag, Classical Mechanics, Tata McGraw Hill, New Delhi.
3. F. Chorlton, Text Book of Dynamics, CBS Publishers.
4. J. L. Synge and B.A. Griffith, Principles of Mechanics, McGraw-Hill, N.Y.
5. A. S. Gupta, Calculus of Variations with Applications, Prentice Hall, India
6. I. M. Gelfand and S.V. Fomin, Calculus of Variations, Prentice Hall Inc.
7. G. M. Ewing, Calculus of variations with Applications, Dover Publications
8. L. D. Elsgolc, Calculus of Variations, Dover Publications, New York.
9. R. Weinstock, Calculus of Variations, Dover Publications.

CORE COURSE-9

Course Code: MSCMATHC204

Course Structure

Course Name: Computer Aided Numerical Practical

Course Type: **Core (Practical)**	Course Details: **CC-9**			L-T-P: **0-0-4**	
Credit: **2**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	……	**20**	……

Course Objectives:

- To acquire knowledge of computer programming language
- To solve different numerical problems using computer programming language
- To develop problem solving skills

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

- Solve different numerical problems which cannot be solved analytically
- Apply programming skills in interdisciplinary areas
- Acquire a practical knowledge which helps to solve the problems in higher studies.

Course content

Programming Problems:

i. Cubic spline interpolation
ii. Roots of polynomial equations
iii. Integration by Romberg's method
iv. Solution of system of linear equations by LU decomposition method
v. Initial value problem for first ODE by Milne's method and Adams-Bashforth method
vi. Initial value problem for second order ODE by 4^{th} order Runge-Kutta method
vii. B.V.P for second order ODE by finite difference method and Shooting method
viii. Dominant Eigen-Pair of a real matrix by power method (largest and least)
ix. Solution of one dimensional Wave equation by finite difference method
x. Parabolic equation (in two variables) by two layer explicit method

References:

1. M. K. Jain, S. R. K. Iyenger & P. K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International (P) Ltd., New Delhi.
2. S. A. Teukolsky, W. T. Vetterling, B. P. Flannery, Numerical Recipes in C: The Art of Scientific Computing, Cambridge University Press.
3. Xavier, C., C Language and Numerical Methods, New Age International Pvt. Ltd.
4. Balagurusamy, E., Programming in C, TMH.
5. W. Y. Yang, W. Cao, T-S Chun and J. Morris, Applied numerical methods using MATLAB. WileyInterscience, John Wiley & Sons.
6. Lopez C. MATLAB programming for numerical analysis. Apress.

MINOR ELECTIVE-1

Course Code: MSCMATHMIE201

Course Structure

Course Name: Introduction to Operations Research

Course Type: **MIE (Theoretical)**	Course Details: **MIEC-1**		L-T-P: **4-0-0**	
Credit: **4**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To impart knowledge and understanding of fundamentals in operations research
- To understand linear programming models and simplex method
- To learn techniques to solve transportation and assignment problems
- To provide the students with a rigorous framework to analyze project scheduling and job sequencing problems in real-life

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

- Identify the goals and objectives of operations research
- Learn techniques to solve transportation and assignment problems
- Apply linear programming techniques to real life situations
- Analyze project scheduling and job sequencing problems in real-life

Course content

Operations Research: Introduction, Definition and Scope of Operations Research, Application of Operations research in different areas. [4H]

Linear programming and game theory: Examples from industrial cases, formulation & definitions, Simplex methods, bounded variables algorithm, Duality, Formulation of the dual problem, primal-dual relationships. Matrix games, Simple results. [12H]

Transportation problem: mathematical formulation, north-west-corner method, least cost method and Vogel's approximation method for determination of starting basic solution, algorithm for solving transportation problem. Assignment problem: mathematical formulation, Hungarian method for solving assignment problem, Travelling Salesman Problem. [15H]

Network Analysis: Introduction to network analysis, Shortest path problem, Construction of minimal spanning tree, Flows in networks, Maximal flow problems. Definition of a project, Job and events, Construction of arrow diagrams, Determination of critical paths and calculation of floats. Resource allocation and least cost planning, Use of network flows for least cost planning. Project Scheduling by PERT/CPM, Basic difference between PERT and CPM, Steps of PERT/CPM Techniques, PERT/CPM Network components and precedence relationships, Critical path analysis. [15H]

Sequencing Models: The mathematical aspects of Job sequencing and processing problems, Processing n jobs through Two-machines, processing n jobs through m machines. [6H]

References:

1. Ravindran, A. , Don T. Phillips, James J. Solberg, *Operations Research: Principles and Practice*, Wiley.
2. Hadley, G. Linear Programming, Narosa Publishing House, New Delhi.
3. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, Linear Programming and Network Flows, 2nd Ed., John Wiley and Sons, India.
4. Hillier, F.S., *Introduction to operations research*. Tata McGraw-Hill Education
5. Taha, H.A., Operations Research-An Introduction, Pearson.
6. Sharma, J.K., Opeartions Research, Mcmillan, India.

MINOR ELECTIVE COURSE- 1

Course Structure

Course Code: MSCMATHMIE202

Course Name: Mathematical Logic and Set theory

Course Type: **MIE (Theoretical)**	Course Details: MIEC-1			L-T-P: 4-**0-0**	
Credit: 4	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To give an introduction to basic concepts and techniques of mathematical logic.
- To provide reasoning skills of Mathematical Logic and its applications to Computer Science.
- To acquaint with the knowledge of basic set theory, the concept of poset and lattices

Course Learning Outcomes: This course will enable the students to

- Understand the syntax of first-order logic and semantics of first-order languages
- Understand about truth table, different propositions, predicates and quantifiers, basic Theorems like the Compactness Theorem, Meta Theorem and Post Tautology Theorem.
- Grasp the concept basic set theory, partially ordered set and lattices.
- model and solve simple logical problems exploiting the techniques presented in the course.
- Apply logic techniques to the resolution of specific Computer Science's problems.

Course content

Mathematical Logic: First-order languages, Terms of language, Formulas of language, first order theory. [3H]

Structures of first order languages, Truth in a structure, Model of a theory, Embeddings and isomorphism. [5H]

Introduction, propositions, truth table, negation, conjunction and disjunction. Implications, biconditional propositions, converse, contra positive and inverse propositions and precedence of logical operators. Propositional equivalence: Logical equivalences. Predicates and quantifiers: Introduction, Quantifiers, Binding variables and Negations. [10H]

Proof in first-order logic, Meta theorems in first order logic, some meta theorem in arithmetic, Consistency and completeness. [4H]

Completeness theorem, Interpretation in a theory, Extension by definitions, Compactness theorem and applications, complete theories, Applications in algebra. [8H]

Set Theory:

Set: Definition, example, subsets, union, intersection, universal set, complementof a set, difference, symmetric difference, Venn diagrams, De Morgan's Laws, cardinality, Cartesian product of sets, relation, mappings. [8H]

Partially Ordered Sets: Definitions, examples and basic properties of partially ordered sets (poset), Order isomorphism, Hasse diagrams, Dual of a poset, Duality principle, Maximal and minimal elements, Least upper bound and greatest upper bound, Building new poset, Maps between posets. [6H]

Lattices: Lattices as posets, Lattices as algebraic structures, sublattices, Products and homomorphisms; Definitions, examples and properties of modular and distributive lattices; Complemented, relatively complemented and sectionally complemented lattices. [6H]

References:

1. Richard E. Hodel , An Introduction to Mathematical Logic, Dover Publications, 2013.

2. Yu I. Manin, A Course in Mathematical Logic for Mathematicians, Springer, 2nd Edition, 2010.

3. Elliot Mendelson , Introduction to Mathematical Logic, Chapman & Hall/CRC, 6th Edition, 2015.

4. Shashi Mohan Srivastava, A Course in Mathematical Logic, Springer, 2nd Edition, Springer, 2013.

5. R.P. Grimaldi, Discrete Mathematics and Combinatorial Mathematics, Pearson Education, 1998

6. Robert R. Stoll, Set Theory and Logic, Dover Publications, Inc, New York, 1963.

SEMESTER-III

CORE COURSE-10

Course Code: MSCMATHC301

Course Name: Multivariate Calculus

Course Structure

Course Type: **Core (Theoretical)**	Course Details: **CC-10**		L-T-P: 4-**0-0**	
Credit: **4**	Full Marks: **50**	CA Marks	ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To understand the concept of multivariate functions
- To study the continuity, differentiability and integrabilty of multivariate functions
- To acquire knowledge about manifolds
- To study Stokes' theorem, Green's theorem and divergence theorem on manifolds.

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

- Understand the differentiation and integration of multivariate functions
- Realize the structure of manifolds
- Apply multivariable calculus in various optimization problems
- Learn the applications of multivariable calculus in different fields like Physics, Economics, Medical Sciences, Animation & Computer Graphics, etc

Course content

Points in R^n, Topology of R^n, norm and inner product on R^n, subsetsof R^n, limit and continuity of functions $f: \mathrm{R}^n \rightarrow \mathrm{R}^m$. [6H]

Differentiability of function $f: \mathrm{R}^n \rightarrow \mathrm{R}^m$, chain rule, mean value theorem, partial derivatives, inverse function theorem (local and global), implicit function theorem. [10H]

Integrability of function $f: \mathrm{R}^n \rightarrow \mathrm{R}^m$, Fubini's theorem, partitions of unity, change of variables. [10H]

Multilinear function, tensor product, vector field, differential form, Poincare lemma, singular n-cube, curve, Stokes' theorem. [10H]

k-dimensional manifold in R^n, fields and forms on manifolds, Stokes' theorem, Green's theorem and divergence theorem on manifolds. [10H]

References:

1. M. Spivak, Calculus on Manifolds, Addision-wiseley publishing company
2. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
3. M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.

4. E. Marsden, A.J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer (SIE), Indian reprint, 2005.
5. James Stewart, Multivariable Calculus, Concepts and Contexts, 2nd Ed., Brooks Cole, Thomson Learning,USA, 2001
6. Tom M. Apostol, Mathematical Analysis, Narosa Publishing House, 2nd Ed.,2002

CORE COURSE-11

Course Code: MSCMATHC302

Course Structure

Course Name: Ordinary Differential Equations and Special Functions

Course Type: **Core (Theoretical)**	Course Details: **CC-11**		L-T-P: 4-**0-0**	
Credit: **4**	Full Marks: **50**	CA Marks		ESE Marks
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To provide knowledge of ordinary differential equations required for practicing scientific problems
- To identify ordinary and singular points of ordinary differential equations
- To acquire knowledge about greens functions and applications to boundary value problem
- To find series solutions of Hermite equation, Legendre equation and Bessel's equation

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

- Understand the properties of eigenvalues and eigenfunctions that will be useful in studying Mathematical physics
- Apply ideas of phase plane analysis and stability in dynamical systems or mathematical biology
- Utilize the concept of special functions in continuum mechanics or theoretical physics
- Solve and analyse differential equations arising in different real-life problems

Course content

Ordinary Differential Equations:

System of linear differential equations: Solution of homogeneous and non-homogeneous linear system of equations, Wronskian of vector functions, Fundamental matrix and its properties, Fundamental set of solutions. [4H]

Non-linear differential equations: Autonomous system, Phase plane analysis, Qualitative solutions, Critical Points, Types of critical points, Stability of the critical points, Linearization, Liapunov stability, Limit cycles. [8H]

Boundary value problems: Construction of two-point boundary value problems, Sturm-Liouville problems, Eigenfunctions expansion, Orthogonality of eigenfunctions, Completeness of the eigenfunctions, Green's functions, Construction of Green's functions for both homogeneous and nonhomogeneous boundary conditions. [12H]

Special Functions:

Series Solution: Ordinary point and singularity of a second order linear differential equation in the complex plane, Fuch's theorem, Solution about an ordinary point, Solution of Hermite equation as an example, Regular singularity, Frobenius method- solution about a regular singularity. [6H]

Hypergeometric equation: Series solution near zero, one and infinity, Hypergeometric functions, Integral formula for the hypergeometric function, Differentiation of hypergeometric function. The confluent hypergeometric function, Integral representation of confluent hypergeometric function. [6H]

Legendre equation: Series solution of Legendre equation, Legendre polynomial, Generating function, Rodrigue's formula, Schlaefli's integral, Recurrence relations, Its orthogonality, Expansion of a function in a series of Legendre Polynomials. Legendere functions of first kind and second kind, Laplace integral. [8H]

Bessel's equation: Series solution of Bessel's equation, Bessel's function, Generating function, Integral representation of Bessel's function, Recurrence relations, Asymptotic expansion of Bessel functions. [6H]

References:

1. E.A. Codington, and N. Levinson, Theory of Ordinary Differential Equation, McGraw-Hill.
2. G.F. Simmons, Differential Equations, Tata McGraw Hill
3. S.L. Ross, Ordinary Differential Equations, John Wiley & Sons
4. R. P. Agarwal and D. O'Regan, Introduction to ordinary differential equations, Springer
5. D. W. Jordan and P. Smith, Nonlinear Ordinary Differential Equations: Problems and Solutions, Oxford University Press.
6. E.D. Rainville, , Special Functions, Macmillan.
7. N.N. Lebedev, Special Functions and Their Applications.
8. P. Hartman, Ordinary Differential Equation, John Wiley and Sons.
9. A. Chakraborty, Elements of ordinary differential equations and special functions, New Age India International.

CORE COURSE-12

Course Structure

Course Code: MSCMATHC303

Course Name: Integral Equations and Integral Transforms

Course Type: **Core (Theoretical)**	Course Details: **CC-12**			L-T-P: 4-**0-0**	
Credit: **4**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To identify and classify linear integral equations
- To learn several solution methodologies for solving linear integral equations
- To recognize when, why, and how integral transforms are used
- To apply integral transforms to ordinary and partial differential equations

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

- Identify and classify linear integral equations
- Solve many practical problems utilizing the concept of integral equations
- Understand the theory and properties of Fourier transform, Laplace Transform and Z-Transform and their applications to relevant problems
- Apply integral transform techniques to different scientific problems

Course content

Integral Equations:

Preliminary concepts of integral equations, Linear integral equations, Classification of linear integral equations, Volterra integral equations, Fredholm integral equations, Singular integral equations, Integro-differential equations, Solution of an integral equation, Relation between integral equations and initial boundary value problems. [4H]

Existence and uniqueness of continuous solutions of Fredholm and Volterra's integral equations of second kind, Solution by the method of successive approximations, The method of successive substitutions, Resolvent kernel method, Iterated kernel method, Volterra integral equations of the first kind. [8H]

Integral equations with degenerate kernels, Fredholm theorem, Fredholm's determinant, Fredholm alternatives, Homogeneous Fredholm integral equations, Eigenvalue and eigenfunction of integral equation and their simple properties, Fredholm integral equations of the first kind, The Method of Regularization. [8H]

Integral equations with symmetrical kernels, Properties of symmetric kernels, Hilbert-Schmidt theory of symmetrical kernels, Schmidt's solution of Fredholm's integral equations. Integro-differential equations, The variational iteration method. [6H]

Integral Transforms:

Fourier Transforms: Fourier integral theorem, Definition and properties of Fourier Transforms, Fourier Transforms of Derivatives, Fourier Transforms of some useful functions, Fourier sine and cosine transforms, Inversion formula of Fourier Transforms, Convolution Theorem, Parseval's relation, Application of Fourier transforms to solving ordinary and partial differential equation. [10H]

Laplace Transforms: Definition and properties of Laplace transforms, Sufficient conditions for the existence of Laplace Transform, Laplace Transform of some elementary functions, Laplace Transforms of the derivatives, Initial and final value theorems, Convolution theorems, Inverse of Laplace Transform, Bromwich integral theorem, Application to Ordinary differential equations, Partial differential equations and linear integral equations. [12H]

Z-Transform: Definition and properties. Properties of Z-transform, Z-transform of some standard functions. Theorems on Z-transform, Differentiation, Convolution theorem, Inverse Z-transforms. Applications. [6H]

References:

1. Chakraborti, A., Applied Integral Equation, Vijay Nicole Imprints Pvt Ltd.
2. Abdul-Majid Wazwaz, A First Course in Integral Equations, World Scientific.
3. W. V. Lovitte, Linear Integral Equations, Dover Publications.
4. Rahman, M. Integral Equations and their Applications, WIT Press, Boston.
5. Kanwal, R.P., Linear Integral Equations: Theory and Technique, Academic Press, New York.
6. Seikh, M.R. & Nayak, P.K., Integral Equations and Calculus of Variations, Narosa Pub House.
7. Debnath, L. & Bhatta, D., Integral Transforms and Their Applications, Chapman and Hall/CRC.
8. Sneddon, I.N., Use of Integral Transforms, McGraw-Hill Pub.
9. Erwin Kreyszig, Advanced Engineering Mathematics, Wiley.
10. Andrews, L.C., Shivamoggi, B., Integral Transforms for Engineers, PHI.

MAJOR ELECTIVE 1 & MAJOR ELECTIVE 2

Course Code: MSCMATHMJE301

Course Name: Advanced Complex Analysis I

Course Structure

Course Type: **MJE (Theoretical)**	Course Details: **MJE-1 & MJE-2**		L-T-P: **4-1-0**	
Credit: **5**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To study the zeros of analytic functions and the related theorems
- To understand the behavior of critical points
- To realize the topology of Riemann surfaces and hyperbolic geometry

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

- Identify the zeros and critical points of different analytic functions
- Construct Riemann surfaces
- Extend the domain of analytic functions
- Apply Hurwitz's theorem, Rouche's theorem, Open Mapping theorem, Inverse and Implicit Function theorems, Riemann mapping theorem.

Course content

Fundamental Theorems Connected with Zeros of Analytic Functions, The Argument (Counting) Principle, Rouche's Theorem and The Fundamental Theorem of Algebra, Morera's Theorem and Normal Limits of Analytic Functions, Hurwitz's Theorem and Normal Limits of Univalent Functions; [6H]

Open Mapping Theorem, Inverse Function Theorem, Univalent Analytic Functions have never-zero Derivatives and are Analytic Isomorphisms, Implicit Function Theorem [8H]

Riemann Surfaces for Multi-Valued Functions, Doing Complex Analysis on a Real Surface: The Idea of a Riemann Surface, Constructing the Riemann Surface for the Complex Logarithm and m-th root function, The Riemann Surface for the functional inverse of ananalytic mapping at acritical point, The Algebraic nature of the functional inverses of ananalytic mapping at a critical point; [10H]

Analytic Continuation, The Idea of Direct Analytic Continuation or an Analytic Extension, General or Indirect Analytic Continuation and the Lipschitz Nature of the Radius of Convergence, Analytic Continuation Along Paths, Monodromy Theorem, Harmonic Functions, Maximum Principles, Schwarz's Lemma and Uniqueness of Riemann Mappings. [10H]

Pick's Lemma and Hyperbolic Geometry on the Unit Disc, Differential or Infinitesimal Schwarz's Lemma, Pick's Lemma, Hyperbolic Arc lengths, Metric and Geodesics on the Unit Disc, Hyperbolic Geodesics for the Hyperbolic Metric on the Unit Disc, Schwarz-Pick Lemma for the Hyperbolic Metric on the Unit Disc; [8H]

Arzela-Ascoli Theorem: Under Uniform Boundedness, Equicontinuity and Uniform Sequential Compactness are Equivalent, Montel Theorem, Existence of a Riemann Mapping, The Candidate for a Riemann Mapping, Proof of The Riemann Mapping Theorem. [8H]

References:

1. S. Ponnusamy and H. Silverman, Complex Variables with Applications, 2006, Birkhaeuser, Boston.
2. T. Gamelin Complex Analysis (UTM) by, Springer, 2003.
3. J. B. Conway, Functions of one complex variable, 2nd Ed., Springer international student edition.
4. James Ward Brown and Ruel V. Churchill, Complex Variables and Applications, 8th Ed., McGraw – Hill International Edition, 2009.
5. Joseph Bak and Donald J. Newman, Complex Analysis, 2nd Ed., Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., NewYork, 1997.
7. E.M.Stein and R. Shakrachi, Complex Analysis, Princeton University Press, 2010.

MAJOR ELECTIVE 1 & MAJOR ELECTIVE 2

Course Code: MSCMATHMJE302

Course Structure

Course Name: Advanced Functional Analysis I

Course Type: **MJE (Theoretical)**	Course Details: **MJE-1 & MJE-2**			L-T-P: 4-**1-0**	
Credit: **5**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives: The course fulfills the objectives

- To study certain topological-algebraical structures and the methods by which the knowledge of these methods can be applied to analytic problems.
- To show students the use of abstract algebraic/topological structures in studying spaces of functions.

- To familiarize with the concept of topological vector space
- To discuss about locally convex topological vector space which can be generated from a family of semi-norms and also from a locally convex space one can construct a separating family of seminorms.
- To taught convexity structure in Topological vector space, Banach space, Hilbert space.

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

- understand basic properties of topological vector spacesand know relevant examples.
- Realize that existence of convex local base at zero vector is strong enough for metrizablity of a topological vector space.
- explain the fundamental concepts of functional analysis and their role in modern mathematics and applied contexts
- Demonstrate accurate and efficient use of functional analysis techniques
- Apply problem-solving method using functional analysis techniques applied to diverse situations in physics, engineering and other mathematical contexts

Course content

Topological vector spaces: Definition and different examples of Topological vector space, Local base and its properties, Separation properties, Symmetric sets, Balanced sets, absorbing sets, convex sets, Bounded sets in topological vector space. [5H]

Linear operators over topological vector space: Definition and properties, Locally compact topological vector spaces and its dimension, Metrization of topological vector space, Boundedness and continuity of linear operator. [8H]

Local convexity and seminorms: Locally convex topological vector spaces, Semi-norms, Minkowski functional, Generating family of semi norms in locally convex topological vector spaces,Criterion for normability,Quotient spaces [12H]

Fundamental theorems on topological vector space: Equicontinuity, The Banach- Steinhaus theorem and its consequences, the open mapping theorem, the closed graph theorem, The Hahn-Banach Theorem and its consequences. [12H]

Weak topologies: The weak and weak* topology of a topological vector space, convergence, closure, Compact convex sets, The Banach-Alaoglu theorem and its applications in separable and locally convex topological vector space. [8H]

Barreled spaces and Bornological spaces: Definition and several examples, Criterion for locally convex topological vector spaces to be (i) Barreled and (ii) Bornological. [5H]

References:

1. Rudin, W., Functional Analysis, TMG Publishing Co.Ltd., New Delhi, 1973
2. Kelly J. L.& Namioka I., Linear Topological spaces, Springer-Verlag, New York, Heidelberg, Berlin.
3. Schaffer, A.A.,Topological Vector Spaces, Springer, 2nd Edn., 1991
4. Bachman, G., Narici, L., Functional Analysis, Academic Press, 1966
5. Diestel, Application of Geometry of Banach Spaces
6. Narici & Beckerstein, Topological Vector spaces, Marcel Dekker Inc, New York and Basel, 1985
7. Simmons, G. F.,Introduction to topology and Modern Analysis, Mc Graw Hill, New York, 1963

Course Code: MSCMATHMJE303

Course Structure

Course Name: Advanced Topology I

Course Type: **MJE (Theoretical)**	Course Details: **MJE-1 & MJE-2**		L-T-P: **4-1-0**	
Credit: **5**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To study basic notions in nets, filters and ultra filters.
- To acquaint with the construction of product of a family of topological spaces and study the productive properties of compactness and connectedness.
- To understand the notion of compactification, metrization etc.
- To use Embedding lemma in compactification.

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

- Describe basic properties of Nets and filters.
- Explain product spaces and the productive properties of compactness and connectedness, Urysohn's Metrization theorems.
- Establish the relationship between Nets associated with filters and filter associated with nets.
- Construct different types of compactifications.

Course content

Nets and Filters: Directed sets, Nets and its convergence, Cluster point of a net, Subnets, Characterization of topological properties in terms of convergence of nets, Filter, Filter associated with nets and nets associated with filters, Baseand subbase of a filter, Filters in Topology, Ultra filter and its properties, Ultra filter and compactness. [20H]

Product space: Product of an arbitrary family of topological spaces, Productive properties of compactness and connectedness, separation and countability axioms, Embedding Lemma and Tychonoff embedding theorem. [12H]

Compactification: One-point compactification, Stone-Cech compactification, Hausdorff compactification. [6H]

Seperation and Metrization: Urysohn's lemma and Tietze Extension Theorem, Pseudometric spaces, Equicontinuity, Urysohn's embedding theorem, Urysohn's Metrization theorem, Paracompactness. [12 H]

References:

1. Munkers, J.R., Topology, Pearson
2. Dugundji, J., Topology, Allyn and Bacon, 1966.

3. Simmons, G.F., Introduction to Topology and Modern analysis, McGraw-Hill, 1963.
4. Kelley, J.L., General topology, Van Nostrand Reinhold Co., New York, 1995.
5. Hocking, J., Young, G., Topology, Addison-Wesley Reading, 1961.
6. Steen, L., Seebach, J., Counter Examples in Topology, Holt, reinhart and Winston, New York.

MAJOR ELECTIVE 1 & MAJOR ELECTIVE 2

Course Code: MSCMATHMJE304

Course Structure

Course Name: Operator Theory I

Course Type: **MJE (Theoretical)**	Course Details: **MJE-1 & MJE-2**		L-T-P: 4-**1-0**	
Credit: 5	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To familiarize with the concept of operators, adjoint operators on normed linear spaces, Resolvent Set and different types of Spectrums.
- To discuss different theorems to find out the spectrum of a bounded linear operator and its adjoint.
- To study the behavior of compact linear operator.
- To give an idea of Banach algebra and its properties.

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

- Define different special types of spectrums and state their relations.
- Determine the spectral radius of different types of operators.
- Test the behavior of an operator.
- Apply different standard theorems involving bounded linear operators.

Course content

Bounded and Continuous Linear Operators: Definition, Examples, Basic properties of linear operators, Inverse operator, Product of inverse operators, Definition, Example of Bounded linear operator, Norm of an operator, norm space of operators, boundedness and dimension, boundedness and continuity, bounded linear extension, unbounded operator, weak, strong and uniform convergence of operators.

[15H]

Adjoint Operator: Adjoint operators over normed linear spaces, their algebraic properties, compact operators on normal linear spaces, sequence of compact operators and its convergence, compact extensions, weakly compact-operators, Operator equation involving compact operators, Fredhölm alternative.

[15H]

Spectral Theory: Resolvent Set, Spectrum, Point spectrum, Continuous spectrum, Residual spectrum, Approximate point spectrum, Spectral radius, Spectral properties of a bounded linear operator, Spectral mapping theorem for polynomials. Numerical range, Numerical radius, Relation between the numerical radius and norm of a bounded linear operator. [15H]

Banach Algebra: Definition of normed and Banach algebra and examples, Singular and non-singular elements, The spectrum of an element, The spectral radius. [5H]

References:

1. Kreyszig, E., Introductory Functional Analysis with Appliactions, John Wiley and Sons.
2. Bachman, G., and Narici, L., Functional Analysis, Dover Publications.
3. Taylor, A.E. Introduction to Functional Analysis, John Wiley and Sons, New York, 1958.
4. Dunford, N., and Schwarts, J.T., Linear Operators-3, John Willey and Sons.
5. Halmos, P.R., Introduction to Hilbert Space and the theory of Spectral Multiplicity, Chelsea Publishing Co., N.Y.

MAJOR ELECTIVE 1 & MAJOR ELECTIVE 2

Course Structure

Course Code: MSCMATHMJE305

Course Name: Advanced Optimization Techniques I

Course Type: **MJE (Theoretical)**	Course Details: **MJE-1 & MJE-2**		L-T-P: **4-1-0**	
Credit: **5**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To understand the theory of revised simplex method and sensitivity analysis
- To understand the theory of convex and concave functions
- To learn classical optimization techniques for uncontrained optimization problems
- To understand the concept of gradient method for constrained optimization problems
- To know the basics of different evolutionary algorithms

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

- Solve linear programming problem by revised simplex method
- Conduct sensitivity analysis of linear programming problems
- Use classical optimization techniques for nonlinear programming problems
- Apply different evolutionary algorithms for solving large scale real-world problems

Course content

Revised simplex method: Standard forms of revised simplex method, Computational procedure, Comparison of simplex method and revised simplex method. [6H]

Sensitivity Analysis: Change in profit (or cost) contribution co-efficient, Change in availability of resources, Change in input output co-efficient, Addition and deletion of variables, Addition of constraints. Bounded variable technique, The computational procedure. [10H]

Convex and concave functions: Basic properties of convex and concave functions, Geometrical Interpretation, Some fundamental theorems of convex/concave functions, Differentiable convex and concave functions. twice differentiable convex and concave functions, theorems in cases of strict convexity and concavity of functions. [10H]

Unconstrained Optimization: Optimization of Functions of a Single Variable, Optimization of Functions of Several Variables, Search Methods-Fibonacci search, Golden section search, interpolation methods-quadratic & cubic interpolation methods, Gradient Methods-Method of steepest descent, Damped Newtown's Method, Davidson-Fletcher-Powell Method, Line search derivatives, Projection Methods. [15H]

Constrained Optimization: Multi-variable non-linear optimization with equality constraints, Lagrange's multiplier method, Interpretation of Lagrange multiplier, Multivariable optimization with inequality constraints: Kuhn-Tucker Conditions. [10H]

Computational optimization: Differences and similarities between conventional and evolutionary algorithms, Fundamentals of Genetic Algorithm & Particle Swarm optimization. [6H]

References:

1. S. S. Rao. Engineering optimization: theory and practice. John Wiley & Sons, 2009.
2. Belegundu, Ashok D., and Tirupathi R. Chandrupatla. Optimization concepts and applications in engineering. Cambridge University Press, 2011.
3. Mokhtar S. Bazaraa, Hanif D. Sherali, and C. M. Shetty, Nonlinear Programming: Theory and Algorithms, Second Edition, John Wiley & Sons, New York 1993.
4. Ruhul Amin Sarker and Charles S. Newton, Optimization Modelling: A practical Approach, CRC Press, 2008.
5. C. Mohan & K. Deep, Optimization Techniques, New Age Science, 2009.
6. Achille Messac, Optimization in Practice with MATLAB, Cambridge University Press, 2015.
7. Michel Gendreau, Jean -Yves Potvin, Handbook of Metaheuristics, Springer, 2019.
8. Convex Optimization By S. Boyd Pub: Cambridge University Press
9. D.E.Goldberg, Genetic algorithms in Search, Optimization, and Machine learning, Addison-Wesley Publishers.
10. Andrea E. Olsson, Particle Swarm Optimization: Theory, Techniques and Applications, Nova Science Publishers, 2011.

MAJOR ELECTIVE 1 & MAJOR ELECTIVE 2

Course Code: MSCMATHMJE306

Course Structure

Course Name: Biomathematics I

Course Type: **MJE (Theoretical)**	Course Details: **MJE-1 & MJE-2**		L-T-P: **4-1-0**		
Credit: **4**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- Demonstrate an understanding of the foundations of biomathematics
- To gain experience with the scientific practice of mathematical modeling
- To understand real-world applications of scientific modeling

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

- Understand the modelling of exponentially-growing or -declining population.
- Use the model to recommend appropriate action for population management.
- Acquire basic knowledge of mathematical theory of Epidemic

Course content

Mathematical Model of Population Biology or Ecology

Mathematical models: Deterministic and Stochastic. Single species non-age structured population models. The logistic models with the effect of time-delay. Stability of equilibrium position for the logistic model with general delay function. Stability of logistic model for discrete time lag. Linear birth-death-immigration-emigration processes. [15H]

Population growth- An age structured model.

Interaction between two species: Host-Parasite type of interaction, Competitive type of interaction. Trajectories of interaction of H-P and competitive types between two species. Effect of migration on H-P interaction. Some consequences of Lotka-Volterra equation. Generalized L-V equation. Pure birth process. Pure death process. Birth and Death process. [15H]

Mathematical Theory of Epidemics

Introduction, Some basic definitions. Simple epidemic, General epidemic. Karmack-McKendrik threshold theorem. Recurring epidemic.

Control of epidemic. Stochastic epidemic model without removal.

Epidemic model with multiple infections. Stochastic epidemic model with removal. Stochastic epidemic model with removal, immigration and emigration. Special discussion on the stochastic epidemic model with carriers. [15H]

References:

1. J. D. Murray, Mathematical Biology, Springer and Verlag.
2. J. N. Kapur, Mathematical Models in Biology and Medicine, East West Press Pvt. Ltd
3. D. A. MacDonald, Blood Flow in Arteries,Williams and Wilkins Company, Baltimore.
4. Y.C. Fung, Biomechanics of Soft Biological Tissues, Springer Verlag.
5. R. Habermann, , Mathematical Models, Prentice Hall.
6. R. W., Poole, An Introduction to Quantitative Ecology, McGraw- Hill.
7. E. C. Pielou, An Introduction to Mathematical Ecology, Wiley, New York.
8. R. Rosen, Foundation of Mathematical Biology (Vol I & II), Academic Press

Course Code: MSCMATHMJE307

Course Name: Fluid Mechanics I

Course Structure

Course Type: **MJE (Theoretical)**	Course Details: **MJE-1 & MJE-2**			L-T-P: 4-**1-0**	
Credit: 5	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To describe the motion of fluids.
- To identify derivation of basic equations of fluid mechanics and apply
- To know about Irrotational motion in two and three dimensions
- To apply the equation of the conservation of energy.

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

- Will be able to identify Lagrange's and Euler's methods in fluid motion
- Identify Velocity field and kinetic energy of a vortex system
- Identify how to derive basic equations and know the related assumptions.

Course content

Lagrange's and Euler's methods in fluid motion. Equation of motion and equation of continuity, Boundary conditions and boundary surface, Stream lines and path of particles. Irrotational and rotational flows, velocity potential. Bernoulli's equation. Impulsive action. Equation of motion and equation of continuity in orthogonal curvilinear coordinate. Euler's momentum theorem and D' Alemberts Paradox. [10H]

Theory of irrotational motion. Flow and circulation. Permanence irrotational motion. Connectivity of regions of space. Cyclic constant and acyclic and cyclic motion. Kinetic energy. Kelvin's minimum energy theorem. Uniqueness theorem. [8H]

Irrotational motion in two and three dimensions. [4H]

Function. Complex potential, sources, sinks, doublets and their images. Circle theorem. Theorem of Blasius. Motion of circular and elliptic cylinders. Circulation about circular and elliptic cylinder. Steady streaming with circulation. Rotation of elliptic cylinder. [8H]

Theorem of Kutta and Juokowski. Conformal transformation. Juokowski transformation. The Schwarz Christoffel theorem. [6H]

Motion of a sphere. Stoke's stream function. Source, sinks, doublets and their images with regard to a plane and sphere. [6H]

Vortex motion. Vortex line and filament. Equation of surface formed by streamlines and vortex lines in case of steady motion. Strength of a filament. Velocity field and kinetic energy of a vortex system. Uniqueness theorem. Rectilinear vortices. Vortex pair. Vortex doublet. Image of a vortex with regard to a plane and a circular cylinder. Angle infinite row of vortices. Karman's vortex street. [8H]

Waves: Surface waves. Paths of particles. Energy of waves. Group velocity. Energy of a long wave. [6H]

References:

1. Ramsay, A.S., Hydrodynamics (Bell).
2. Lamb, H., Hydrodynamics (Cambridge)
3. Landau, L.D., Lifchiz, E.M., Fluid Mechanics (Pergamon), 1959
4. Milne-Thomson, I.M., Theoretical Hydrodynamics
5. Chorlton, F., Textbook of Fluid Dynamics.

MAJOR ELECTIVE 1 & MAJOR ELECTIVE 2

Course Code: MSCMATHMJE308

Course Name: Operations Research I

Course Structure

Course Type: **MJE (Theoretical)**	Course Details: **MJE-1 & MJE-2**		L-T-P: 4-**1-0**	
Credit: 5	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To idenfy and solve integer programming problems
- To know about the mathematical aspects of Job sequencing and processing problems
- To solve nonlinear programming problems
- Identify the goals and objectives of inventory management
- To provide the students with a comprehensive study of various application areas of inventory models through case studies and relevant examples.

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

- Identify job sequencing problems and able to solve
- Formulate real-world problems as nonlinear programming model
- Understand the various selective inventory control techniques and its applications.

Course content

Integer Programming: Standard form of Integer Programming, The concept of cutting plane for linear integer programs, Gomory's cutting plane method, Gomory's All-Integer Programming Method, Branch-and-Bound Algorithm for general integer programs. [10H]

Optimal Control: Performance indices, Methods of calculus of variations, simple optimal problems of mechanics. [6H]

Non-linear Programming: Formulation of Non-linear programming problem, Unconstrained optimization, Optimization with equality constraints, Kuhn-Tucker conditions for constrained optimization. [10H]

Quadratic Programming: Wolfe's modified simplex method, Beale's method. Convex Programming. [6H]

Inventory Control: Historical background and Introduction of this topic, Nature of inventory problems, Features of inventory system, Definition of inventory problem. Important parameters associated with inventory problems, Variables in inventory problems, Inventory model building, Deterministic inventory models with-No shortage, Shortage, Multi-item inventory models with constraints probabilistic Models-single period probabilistic models-without setup cost, with setup cost. Probabilistic Inventory Management-Single period inventory models, newspaper boy problems with or without salvage value, Periodic and Continuous review models, Inventory management of items with deterioration, Inventory management of items with inflation. [20H]

References:

1 Hadley, G., Nonlinear and Dynamic Programming, Pearson.
2. Rao, S.S., Optimization Theory and Application, Wiley Eastern.
3. Taha, H.A., Operations Research-An Introduction, Pearson.
4. Dano, S., Nonlinear and Dynamic Programming.
5. Edward A. Silver, David F. Pyke, Douglas J. Thomas, Inventory and Production Management in Supply Chains, Fourth Edition, CRC Press, 2016.
6. Edwin K.P. Chong and Stanislaw H. Zak, An Introduction to Optimization, Second Edition 2001, John Wiley & Sons, INC.
7. Singiresu S. Rao, Engineering Optimization: Theory and Practice , Wiley, 2009.
8. Mangasarian O.L., Non-linear Programming, McGraw Hill, New York.
9. Mokhtar S. Bazara and C.M. Shetty, Non-linear Programming-Theory and Algorithms, Weiley, New York.
10. Mordecai Auriel, Non-linear Programming – Analysis and Methods, Prentice Hall Inc. Englewood Cliffs, New Jersey.

MINOR ELECTIVE COURSE- 2

Course Code: MSCMATHMIE301

Course Structure

Course Name: Graph Theory

Course Type: MIE	Course Details:MIEC-2		L-T-P: 4-**0-0**		
Credit: 4	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To familiarize with the concept of different types of graphs and its components.
- To discuss the difference between walk and path, cycles and circuits, Adjacency matrix and Incidence matrix etc.

- To understand the fundamental concepts in graph theory and construct examples and to distinguish examples from non-example.
- To analyze new networks using the main concepts of graph theory.
- To apply graph theory based tools in solving practical problems

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

- Describe different graphs and its components.
- Understand the Eulerian circuits, Eulerian graphs, Hamiltonian cycles, representation of a graph by matrix.
- Integrate core theoretical knowledge of graph theory to solve problems.
- Apply theories and concepts to test and validate intuition and independent mathematical thinking in problem solving.

Course content

Basic concepts: Graphs: Undirected graphs, directed graphs, basic properties of graphs, walks, paths, trails, cycles, Circuits, connected graphs, components of a graph, complete graph, complement of a graph, bipartite graphs, characterization a bipartite graph, Adjacency matrices, Incidence matrices, Isomorphism. [10H]

Graphs with special properties: Königsberg bridge problem, Eulerian Trails, Eulerian Circuits, Eulerian Graphs, characterization, Hamiltonian (Spanning) cycles, Hamiltonian graphs: Necessary conditions, sufficient conditions, Hamiltonian closure, Travelling salesman problem. [10 H]

Trees: Basic properties, Distance, radius and centre, Diameter, Rooted trees, Binary trees, Minimal spanning tree, Shortest path problem, Kruskal's algorithm, Prim's algorithm, Dijkstra's algorithm, Chinese Postman Problem. [8H]

Planar graphs: Planar graphs and non-planar graphs, face-size equation, Euler's formula for a planar graph. The graphs K_5 and $K_{3,3}$, Kuratowski's theorem (statement only). [5H]

Coloring of Graphs: Vertex coloring, proper coloring, k-colorable graphs, chromatic number, upper bounds, Cartesian product of graphs, Structure of k-chromatic graphs, Mycielski's Construction, Color-critical graphs, Chromatic Polynomial, Clique number, Independent (Stable) set of vertices, Independence number, Clique covering, Clique covering number, Edge-coloring, Edge-chromatic number. [12H]

References:

1. J. Clark and D. A. Holton: A First Look at Graph Theory, Allied Publishers Ltd., 1995.
2. D. S. Malik, M. K. Sen and S. Ghosh: Introduction to Graph Theory, Cengage Learning Asia, 2014.
3. Narsing Deo :Graph Theory with Applications to Engineering and computer science, PHI, 1997.
4. J. A. Bondy and U.S.R. Murty: Graph Theory with Applications, Macmillan, 1976.
5.D. B. West, Introduction to Graph Theory, Pearson.
6. D.N.Ghosh, Discrete Mathematics, Academic Publishers .
7. D.K.Ghosh, Introduction to Graph Theory, New Central Book Agency(P) Ltd.

SEMESTER-IV

CORE COURSE-13

Course Structure

Course Code: MSCMATHC401

Course Name: Partial Differential Equations and Generalized Functions

<table>
<tr><td colspan="2">Course Type: Core (Theoretical)</td><td colspan="3">Course Details: CC-13</td><td colspan="2">L-T-P: 4-0-0</td></tr>
<tr><td rowspan="3">Credit: 4</td><td rowspan="3">Full Marks: 50</td><td colspan="2">CA Marks</td><td colspan="2">ESE Marks</td></tr>
<tr><td>Practical</td><td>Theoretical</td><td>Practical</td><td>Theoretical</td></tr>
<tr><td>……</td><td>15</td><td>……</td><td>35</td></tr>
</table>

Course Objectives:

- To understand the analytic methods for solving hyperbolic, elliptic and parabolic type partial differential equations
- To analyze and interpret the solutions of PDEs
- To acquire knowledge about the basic definitions and properties of generalized functions

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

- Solve analytically hyperbolic, elliptic and parabolic type partial differential equations
- Test the stability analysis of the solutions of PDEs
- Learn the basic concepts of generalized functions
- Formulate and solve problems from allied branches of science and engineering

Course content

Pre-requisite: Origins of Partial Differential Equations (PDEs). Linear and non-linear PDE. Charpit's method, Jacobi's method, Integral surfaces, Method of characteristics, Cauchy problem, Monge cone, Characteristic strip. Origin of second Second order PDEs, Classification, Well-posedness. [6H]

Hyperbolic Equations: The equation of vibration of a string. Formulation of mixed initial and boundary value problem. Existence, Uniqueness and continuous dependence of the solution to the solution to the initial conditions. D'Alembert's formula for the vibration of an infinite string. The domain of dependence, the domain of influence. Use of the method of separation of variables for the solution of the problem of vibration of a string. Investigation of the conditions under which the infinite series solution convergence and represents the solution. Riemann method of solution, problems, Transvers vibration of membranes. Rectangular and circular membranes, problems. [15H]

Elliptic Equations: Occurrence of Laplace's equation. Fundamental solutions of Laplace's equation in two and three independent variables. Laplace equation in polar, Spherical polar and in Cylindrical polar co-ordinates, Minimum-maximum theorem and its consequences. Boundary value problems, Dirichlet's and Neumann's interior and exterior problems. Uniqueness and continuous dependence of the solution on the boundary conditions. Use of the separation of variables method for the solution of Laplace's equations in two or three dimension. Interior and exterior Dirichlet's problem for a circle and a semi circle, steady state heat flow equation problems, Higher dimensional problems, Dirichlet's problem for a cube, Cylinder and sphere, Green's function for the Laplace equation in two and three dimension. [15H]

Parabolic Equations: Conduction of heat in a bounded strip, First boundary value problem, Maximum-Minimum theorem and its consequences, uniqueness, continuous dependence of the solution and existence of the solution. Poisson formula. Solution of the inhomogeneous heat equation. Conduction of heat in an infinite strip (Cauchy problem), Problems. [10H]

Generalized Functions: The Dirac Delta function and Delta sequences. Test functions. Linear functionals. Regular and singular distributions. Sokhotski-Plemelj equation. Operations on distributions. Properties of the generalized of the generalized derivatives. Some transformation properties of the delta function. Convergence of distributions. [10H]

References:

1. I.N. Sneddon, Elements of Partial Differential Equations, Dover Publications.
2. Y. Pinchover and J. Rubinstein, An Introduction to Partial Differential Equations, Cambridge University Press.
3. L.C. Evans, Partial Differential Equations, American Mathematical Society.
4. F. John, Partial Differential Equations, Springer-Verlag, New York.
5. P. Prasad, R. Ravindran, Partial Differential Equations, New Age International (p) Ltd.
6. R. F. Hoskins, Generalized functions, Horwood, Chichester and New York.
7. I. M. Gelfand and G.E. Shilov, Generalized functions, Academic Press, New York.
8. J. J. Duistermaat and J. A. C. Kolk, Distributions Theory and Applications, Birkhäuser Basel.
9. R. P. Kanwal, Generalized Functions: Theory and Technique, Birkhauser, New York.
10. D. S. Jones, Generalized Functions, Cambridge University Press.

CORE COURSE- 14

Course Code: MSCMATHC402

Course Structure

Course Name: Measure and Integration

<table>
<tr><td colspan="2">Course Type: Core (Theoretical)</td><td colspan="3">Course Details: CC-14</td><td colspan="2">L-T-P: 4-0-0</td></tr>
<tr><td rowspan="3">Credit: 4</td><td rowspan="3">Full Marks: 50</td><td colspan="2">CA Marks</td><td colspan="3">ESE Marks</td></tr>
<tr><td>Practical</td><td>Theoretical</td><td colspan="2">Practical</td><td>Theoretical</td></tr>
<tr><td>……</td><td>15</td><td colspan="2">……</td><td>35</td></tr>
</table>

Course Objectives:

- To study basic notions in abstract integration theory, integration theory on n-dimensional space.
- To acquaintwith the construction of product measures and use Fubini's theorem.
- To use Lebesgue monotone and dominated convergence theorems and Fatous' Lemma
- To understand the notion of absolute continuity and singularities of measures and apply Lebesgue decomposition and the Radon-Nikodym theorem

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

- Describe basic properties of sigma-algebras and the Lebesgue integral.
- Explain the construction of the Lebesgue measure on Euclidean space
- Describe the relationship between continuous functions and general integrable functions
- Determine questions related to different kinds of convergence, convergence in measure and convergence almost everywhere
- Understand the main ideas of the proofs for the Fubini-and Radon-Nikodym theorem.
- Apply the fundamental concepts of measure theory for further study in a range of other fields, e.g. Stochastic calculus, Quantum Theory and Harmonic analysis.

Course content

Lebesgue integral: Lebesgue integral of bounded functions over a set of finite measure and its properties, Comparison of Riemann integral and Lebesgue integral, Passing to the limit under the sign of integration, Bounded convergence theorem, Labesgue integral of a nonnegative measurable functions, Fatou's lemma, Dominated convergence theorem. Characterization of absolutely continuous functions in the context of Lebesgue integration. [15H]

General measure space: Measure and measurable sets, Signed Measures: The Hahn and Jordan Decompositions, The Caratheodory Measure Induced by an Outer Measure, The Construction of Outer Measures, The Caratheodory-Hahn Theorem: The Extension of a Premeasure to a Measure. [10H]

Integration on general measure space: Measurable functions, integration of nonnegative measurable functions, The monotone convergence theorem, integration of general measurable functions, The Dominated Convergence Theorem, The Vitali-convergence theorem, absolute continuity of measure, Radon-Nikodym theorem and its consequences, The Lebesgue Decomposition Theorem, Integration on product measure, Fubini's theorem. [15H]

Convergence in general measure space: Almost everywhere convergence and convergence in measure, Lebesgue's theorem, Egoroff's theorem, Approximation of Lebesgue measurable functions by continuous functions, Lusin's theorem and Frechet's theorem. [10H]

References:

1. Measure Theory, P. R. Halmos (Springer-Verlag, 1974).
2. Measure Theory and Integration, G. D. Barra (New Age International (P) Ltd, 2013).
3. Real Analysis, H.L.Royden, P.M. Fitzpatrick,4th edition (PHI, 2010).
4. Theory of Functions of a Real Variable, Vol. I & II. I. P. Natanson (Fedrick Unger Publi. Co., 1961).
5. Real and Complex Analysis, W. Rudin (Tata Mc Graw Hill, 1993).
6. Measure, Integration and Function Spaces, Charles Swartz, (World Scientific, 1994).
7. An Introduction to Measure and Integration, I. K. Rana (Narosa Publishing House, 1997).

CORE COURSE-15

Course Code: MSCMATHC403

Course Structure

Course Name: Geometry of Curves and Surfaces

Course Type: **Core (Theoretical)**	Course Details: **CC-15**			L-T-P: 4-**0-0**	
Credit: **4**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To understand the concepts of curves and surfaces
- To study isometries and conformality of surfaces.
- To realize normal, geodesic, Gaussian, mean and principal curvatures of different surfaces and study their inter relations.
- To study the idea of spherical and hyperbolic geometry.

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

- give an idea of curves and surfaces.
- identify smooth surfaces, orientable surfaces.
- find length and curvature of curves on different surfaces.
- apply the above concepts in different fields of Mathematics.

Course content

Curves, level curves and parametrized curves, arc length, reparametrization, closed curves. [2H]

Curvature, plane curves, space curves. [2H]

Simple closed curves, isoperimetric inequalities. [2H]

Surfaces, smooth surfaces, smooth maps tangents and derivatives, normals and orientability. [4H]

Level surfaces, quadric surfaces, ruled surfaces, compact surfaces. [4H]

First fundamental form, length of curves on surfaces, isometries of surfaces, conformal mapping on surfaces, equiareal maps. [4H]

Second fundamental form, Gauss and Weingartenmaps, normal and geodesic curvature. [4H]

Third fundamental form, Gaussian and mean curvature, principal curvatures of a surface, Meusnier's theorem, surfaces of constant Gaussian curvature, flat surfaces, surfaces of constant mean curvature, Gaussian curvature of compact surfaces. [8H]

Geodesics, Geodesic equations, Geodesics on surfaces of revolution, geodesics as shortest paths, geodesic coordinates. [6H]

Gauss and Codazzi–Mainardi equations, Gauss' Theorem Egregium, [4H]

Introduction to Spherical geometry, idea of hyperbolic geometry, upper half-plane model, Poincar´e disc model, Beltrami–Klein model. [6H]

References:

1. Pressely, Andrew, Elementary differential Geometry, Springer.
2. Carmo, M. P. do: Differential geometry of curves and surfaces, Prentice-Hall Inc.
3. Singer, I. M. and Thorpe, J. A., Lecture notes on elementary topology and geometry, Springer.
4. Spivak, M., A comprehensive introduction to differential geometry, Vol. I, Publish or Perish Inc., Houston.
5. Eisenhert, L.P., An introduction to Differential Geometry, Princeton University Press.
6. Willmore, T.J., An Introduction to Differential Geometry, Oxford University Press.

CORE COURSE-16

Course Code: MSCMATHC404

Course Name: Project Work

Course Structure

Course Type: **Core (Practical)**	Course Details: **CC-16**			L-T-P: **2-0-4**	
Credit: **4**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		30	……	20	……

Course Objectives:

- To give an idea about research work
- To familiarize with literature review, reference and bibliography, APA style, data analysis, etc.
- To develop skills of computer software and languages
- To develop communication and presentation skills such as Power point and Latex presentation

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

- Acquire knowledge about literature review, data collection, data analysis, references, etc
- Discuss the possible research problems and its solving methods
- Write a report to a particular topic
- Deliver a presentation seminar using ICT

The project work will be performed on some advanced topics or review work of research papers. The marks distribution of project work is as follows: 30 marks allotted for written submission, 10 marks allotted for seminar presentation and 10 marks allotted for viva-voce examination. The evaluation of project work of each student will be done by the concerned internal teacher/supervisor and one external examiner.

Course Code: MSCMATHMJE401

Course Name: Advanced Complex Analysis II

Course Structure

Course Type: **MJE (Theoretical)**	Course Details: **MJE 3 & MJE 4**			L-T-P: **4-1-0**	
Credit: **5**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To study the sequential compactness and normal convergences in families of analytic and meromorphic functions
- To understand the Great and Little Picard theorems
- To study Montel's theorem, Marty's theorem, Royden's theorem, Schottky's theorem.

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

- Find the spherical metric on the Riemann sphere
- Construct the Laurent series at infinity
- Understand the Cauchy's residue theorem for domains containing infinity
- Apply sequential compactness and normal convergence criterion to the families of analytic and meromorphic functions.

Course content

Theorems of Picard, Casorati-Weierstrass and Riemann on removable singularities, neighborhoods of infinity, limits at infinity and infinite limits. [6H]

Infinity as a point of analyticity, Laurent expansion at infinity and Riemann's removable singularities theorem for the point at infinity, the generalized Liouville theorem: Little brother of Little Picard and analogue of Casorati-Weierstrass; failure of Cauchy's theorem at infinity, Morera's theorem at infinity, infinity as a pole and behaviour at infinity of rational and meromorphic functions. [8H]

Residue at infinity and residue theorem for the extended complex plane, the behavior of transcendental and meromorphic functions at infinity. [8H]

Normal convergence in the inversion-invariant spherical metric on the extended plane, Hurwitz theorems on normal limits in the spherical metric, the inversion-invariant spherical derivative for meromorphic functions, from compactness to boundedness via equicontinuity. [12H]

The Montel theorem - The holomorphic avatar of the Arzela-Ascoli theorem, The Marty theorem - The Meromorphic avatar of the Montel and Arzela-Ascoli theorems, The Hurwitz, Montel and Marty theorems at infinity. [8H]

Local analysis of normality by the zooming Process and Zalcman's lemma, Montel's normality criterion and theorems of Picard, Royden and Schottky. [8H]

References:

1. S. Ponnusamy and H. Silverman, Complex Variables with Applications, 2006, Birkhaeuser, Boston.
2. T. Gamelin Complex Analysis (UTM) by, Springer, 2003.
3. J. B. Conway, Functions of one complex variable, 2^{nd} Ed., Springer international student edition.
4. James Ward Brown and Ruel V. Churchill, Complex Variables and Applications, 8th Ed., McGraw – Hill International Edition, 2009.
5. Joseph Bak and Donald J. Newman, Complex Analysis, 2nd Ed., Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., NewYork, 1997.
6. E.M.Stein and R. Shakrachi, Complex Analysis, Princeton University Press, 2010.

MAJOR ELECTIVE 3 & MAJOR ELECTIVE 4

Course Structure

Course Code: MSCMATHMJE402

Course Name: Advanced Functional Analysis II

Course Type: **MJE (Theoretical)**	Course Details: MJE 3& 4			L-T-P: 4-**1-0**	
Credit: 5	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To show students the use of abstract algebraic/topological structures in studying spaces of functions.
- To familiarize convexity structure in Topological vector space, Banach space, Hilbert space.
- To learn the behavior of special types of abstract spaces such as C (X,R) and C (X,C) where X is a compact Hausdorff space.
- To state and prove the Stone- Weierstrass theorem in the above spaces and its utility.
- To give students a working knowledge of the basic properties of commutative Banach Algebra and some important theorems such as the spectral mapping theorem, Gelfand Mazur Theorem, Gelfand Representation theorem, Gelfand Neumark Theorem etc.

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

- explain the fundamental concepts of functional analysis and their role in modern mathematics and applied contexts.
- understand the basics of Commutative Banach algebra andrecognize the importance of fundamental theorems on Gelfand algebra such as Gelfand Mazur theorem, Gelfand Representation theorem, Gelfand Neumark Theorem etc.
- Demonstrate accurate and efficient use of functional analysis techniques.
- Apply Stone- Weierstrass theorems in other related courses.

Course content

Strictly convex and Uniformly convex space: Definition and several examples of strictly convex and uniformly convex Banach space. Clarkson's renorming lemma, Uniform Convexity of a Hilbert Space. Milman-Pettit theorem, Clarkson's inequalities, Reflexivity of a uniformly convex Banach space, Uniqueness of extension of functional on normed linear space. [8H]

Approximation theory: Weierstrass approximation theorem in C [a,b], Stone- Weierstrass theorem in C (X,R) and C (X,C) where X is a compact Hausdorff space, Representation theorem for bounded linear functional on C[a,b], lp ($1\leq p<\infty$) and Lp [a,b], ($1\leq p<\infty$).Approximation Theory in Normed Linear space, Best approximation, Uniqueness Criterion. [12 H]

Convexity in topological vector space: Convex Hull and representation Theorem, Extreme points, Hyperplanes, Separation of convex sets by Hyperplanes, Krein-Milman Theorem on extreme points. [6H]

Banach Algebra: Analytic vector valued functions, normed and Banach algebra, Identity element, Gelfand Mazur Theorem, Analytic property of resolvent Operator, Compactness of Spectrum, the resolvent operator, Spectral radius and Spectral mapping Theorem for polynomials, Topological divisors of zero. [12 H]

The Gelfandtheory: Ideals, Maximal Ideals,Quotient space, Maximal ideal space, Gelfand topology, Gelfand mapping, Gelfand Theory on representation of Banach Algebra, involutions in Banach algebra, The Gelfand Neumark Theorem. [15H]

References:

1. Rudin, W., Functional Analysis, TMG Publishing Co.Ltd., New Delhi, 1973
2. Simmons, G. F.,Introduction to topology and Modern Analysis, Mc Graw Hill, New York, 1963
3. Bachman, G., Narici, L., Functional Analysis, Academic Press, 1966
4. Kelly J. L.& Namioka I., Linear Topological spaces, Springer-Verlag, New York, Heidelberg, Berlin.
5. Schaffer, A.A.,Topological Vector Spaces, Springer, 2nd Edn., 1991
6. Diestel, Application of Geometry of Banach Spaces
7. Narici & Beckerstein, Topological Vector spaces, Marcel Dekker Inc, New York and Basel, 1985.

MAJOR ELECTIVE 3 & MAJOR ELECTIVE 4

Course Code: MSCMATHMJE403

Course Structure

Course Name: Advanced Topology II

Course Type: **MJE (Theoretical)**	Course Details: **MJE-1 & MJE-2**		L-T-P: 4-**1-0**		
Credit: 5	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To study basic notions of uniform spaces and neighbourhood system of identity..
- To acquaint with the construction of quotient groups.
- To understand the notion of neighbourhood systems of identity.
- To use equicontinuity and Urysohn's lemma in Metrization theorems.
- To familiar with the notion of proximity space

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

- Describe basic properties of Uniform spaces, neighbourhood systems of identity..
- Explain uniformity structure and associated family of pseudometrices.
- Establish the relationship between Neighbourhood system of any point with identity.
- Construct different types of groups using quotient group.

Course content

Metrizability Topological imbedding, Imbedding theorem of a regular space with countable base, Nagata-Smirnov Metrization theorem. [8H]

Uniform spaces: Uniformity and its uniform topology, neighbourhoods, bases and subbases, uniform continuity, product uniformities, uniform isomorphism, relativization and products. Characterization of metrizability, uniformity of pseudometric spaces, uniformity generated by a family of pseudometrics, Uniformizability and complete regularity, the gauge of uniformity, Completeness, Cauchy net, Cauchy filter, complete spaces, extension of mappings, completion-existence and uniqueness, Compactness and uniformity, diagonal uniformities, uniformity via uniform covers. [20H]

Proximity Spaces: Topology induced by a proximity, subspaces and products of proximity spaces, elementary proximity, p-continuity and p-isomorphism, Compactification of proximity spaces-clusters and ultrafilters, Smirnov's theorem. [10H]

Topological Group: Definition, Example, Homeomorphism of translation mapping, Neighbourhood systems of identity, separation axioms, uniform structures, subgroups, quotient groups, continuous and open homomorphism, Isomorphism. [12H]

References:

1. Munkers, J.R., Topology, Pearson
2. Dugundji, J., Topology, Allyn and Bacon, 1966.
3. Joshi, K.D., Introduction to General Topology, New age International Publishers, 1983.

4. Simmons, G.F., Introduction to Topology and Modern analysis, McGraw-Hill, 1963.
5. Kelley, J.L., General topology, Van Nostrand Reinhold Co., New York, 1995.
6. Hocking, J., Young, G., Topology, Addison-Wesley Reading, 1961.
7. Steen, L., Seebach, J., Counter Examples in Topology, Holt, reinhart and Winston, New York.
8. Hossain, T, Introduction to topological groups, Dover Publications, Inc. Mineola, New York.

Course Code: MSCMATHMJE404

Course Name: Operator Theory II

Course Structure

Course Type: **MJE (Theoretical)**	Course Details: **MJE-3 & MJE-4**		L-T-P: 4-**1-0**	
Credit: 5	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To familiarize with the concept of Hilbert adjoint operators, self adjoint operators, Normal operators, unbounded linear operators etc.
- To discuss the properties of various operators such as positive operators, projection operators etc.
- To study the behavior of spectrum theory in self adjoint linear operators.
- To state different theorems related to the above concepts and to use the same in real life problems, higher mathematics.

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

- Define different special types of operators such as Positive operators, Square root of a positive operator, Projection operators etc.
- Determine spectral family of different types of operators.
- Test the behavior of unbounded linear operators.
- Use unitary and self adjoint operators, Multiplication operators, differentiation operators in the application of Quantum Mechaniques.

Course content

Hilbert adjoint operators: Sesquilinear functionals, Riesz representation theorem, Hilbert adjoint operators, its existence and their algebraic properties, Self-adjoint operators, Unitary operators, Normal operators, their relation and basic properties. [10H]

Positive operators: Definition, examples, their-sum, product, monotone sequence of positive operators, square-root of positive operator. [8H]

Projection operators: Definition, positivity and norm, product of projections, sum of projections, partial order, difference of projections, monotone sequence of projection operators. [8H]

Spectral properties of bounded self adjoint operators: Eigenvalues, eigenvectors of self-adjoint operators in Hilbert space, resolvant sets, real property of spectrum of self-adjoint operators, range of spectrum of a self adjoint operator. [8H]

Spectral family: Spectral family of a bounded self adjoint linear operator and its properties, Spectral representation of bounded self adjoint linear operators (Spectral theorem for a bounded self adjoint linear operator), Spectral representation of polynomial of a bounded self adjoint linear operator, Extension of spectral theorem to continuous functions. [10H]

Unbounded linear operators in Hilbert space: Hellinger-Toeplitz theorem, Symmetric and self adjoint operators, Closed linear operators, Spectrum of an unbounded self adjoint operator linear operator. [6H]

References:

1. Kreyszig, E., Introductory Functional Analysis with Appliactions, John Wiley and Sons.
2. Bachman, G., and Narici, L., Functional Analysis, Dover Publications.
3. Dunford, N., and Schwarts, J.T., Linear Operators-3, John Willey and Sons.
4. Halmos, P.R., Introduction to Hilbert Space and the theory of Spectral Multiplicity.

MAJOR ELECTIVE 3 & MAJOR ELECTIVE 4

Course Code: MSCMATHMJE405

Course Structure

Course Name: Advanced Optimization Techniques II

Course Type: **MJE (Theoretical)**	Course Details: **MJE-3 & MJE-4**			L-T-P: **4-1-0**	
Credit: **5**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To understand the theory of geometric and stochastic programming problems
- To learn the solution algorithm of bimatrix games
- To understand the basic concept multi-objective Optimization
- To learn the different techniques of Multi attribute decision making

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

- understand the theory of geometric and stochastic programming problems
- learn the solution algorithm of bimatrix games
- utilize several techniques to solving multi-attribute decision making problems
- apply different optimization techniques to solve various real-life problems

Course content

Geometric Programming: Introduction to Geometric Programming, Unconstrained and constrained geometric programming. [8H]

Stochastic Programming: Chance constrained programming technique, Stochastic linear programming, Stochastic non-linear programming, Two stage programming technique. [10H]

Games Theory: Concept of matrix and bi-matrix games, Nash equilibrium, Solution of bi-matrix games through Quadratic Programming (Relation with Nonlinear Programming). Concepts of strategic game, performances of game player, leadership theory in game problem. Solution approach of game problems under fuzzy systems. [10H]

Multi-objective Optimization: Concept of multi-objective optimization problems (MOOPs) and issues of solving them. Multi Objective Decision Making, Multi-Objective Evolutionary Algorithm (MOEA). [10H]

Multi attribute decision making: Constructing the Decision Model, Normalization Method, Weight Assignment Methods, Preference Modeling, Elementary Methods, MAVT Method, SAW and WP Methods, Basics and Principles of AHP Method, Calculating Total Weights, Measuring Inconsistency Introduction to "Expert Choice", Distance Based Methods-TOPSIS and VIKOR, Outranking Methods-PROMETHEE and ELECTRE, Group Decision Making. [15H]

References:

1. Taha, Hamdy A. Operations research: An introduction. Pearson Education India, 2004.
2. Belegundu, Ashok D., and Tirupathi R. Chandrupatla. Optimization concepts and applications in engineering. Cambridge University Press, 2011.
3. Ruhul Amin Sarker and Charles S. Newton, Optimization Modelling: A practical Approach, CRC Press, 2008.
4. Michel Gendreau, Jean -Yves Potvin, Handbook of Metaheuristics, Springer, 2019.
5. Kalyanmoy Deb, Multi-Objective Optimization using Evolutionary Algorithms, Wiley.
6. Tzeng, G-H. & Huang, J-J. Multiple Attribute Decision Making: Methods and Applications, Chapman and Hall/CRC, 2011
7. Figueira, J. Greco, S. & Ehrgott, M. Multiple Criteria Decision Analysis: State of the Art Surveys, Springer, 2007
8. Achille Messac, Optimization in Practice with MATLAB, Cambridge University Press, 2015

MAJOR ELECTIVE 3 & MAJOR ELECTIVE 4

Course Code: MSCMATHMJE406

Course Structure

Course Name: Biomathematics II

Course Type: **MJE (Theoretical)**	Course Details: **MJE-3 & MJE-4**		L-T-P: **4-1-0**	
Credit: **4**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To impart knowledge about basic equation for an n-compartment system
- To know the importance of studies on the mechanics of blood vessels

- To have knowledge of constituents of bloods and Mechanical properties of blood.
- To study Constitutive equations for blood vessels and equations of motion for the vascular wall

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

- Identify basic equation for an n-compartment system
- Understand the importance of studies on the mechanics of blood vessels
- Understand the geometrical shape of head and Hypotheses on brain damage

Course content

Blood flow models: Constituents of bloods, Structure and functions of the constituents of blood. Mechanical properties of blood. Equations of motion applicable to blood flow. Non-Newtonian fluids- Power law, Bingham Plastic, Herschel-Bulkley and Casson fluids. Steady non- Newtonian fluid flow in a right circular tube. Fahraeus-Lindqvist effect. Pulsatile flow in both rigid and elastic tubes. Blood flow through arteries with mild stenosis. [20H]

Mathematical models in Pharmacokinetics: Compartmental Analysis Technique. Two-compartment model- Clinical Bromsulphalein Test. Basic equation for an n-compartment system. Distribution of drugs in n-compartment model for (i) given initial dose, (ii) repeated medication (iii) constant rate of infusion and (iv) truncated infusion. Compartment model for diabetes mellitus. Stochastic compartment models. Drug action. [15H]

Models for Population Genetics: Introduction, basic model for inheritance of genetic characteristic, Hardy-Wienberg law, models for genetic improvement, selection and mutation- steady state solution and stability theory. [10H]

Models for other fluids:Peristaltic motion in a channel and in a tube. Two dimensional flow in renal tubule. Lubrication of human joints. [8H]

References:

1. J. D. Murray, Mathematical Biology, Springer and Verlag.
2. J. N. Kapur, Mathematical Models in Biology and Medicine, East West Press Pvt. Ltd
3. D. A. MacDonald, Blood Flow in Arteries,Williams and Wilkins Company, Baltimore.
4. Y.C. Fung, Biomechanics of Soft Biological Tissues, Springer Verlag.
5. R. Habermann, , Mathematical Models, Prentice Hall.
6. R. W., Poole, An Introduction to Quantitative Ecology, McGraw- Hill.
7. E. C. Pielou, An Introduction to Mathematical Ecology, Wiley, New York.
8. R. Rosen, Foundation of Mathematical Biology (Vol I & II), Academic Press

Course Code: MSCMATHMJE407

Course Name: Fluid Mechanics II

Course Structure

Course Type: **MJE (Theoretical)**		Course Details: **MJE-3 & MJE-4**		L-T-P: 4-**1-0**	
Credit: 5	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To study basic thermodynamics of compressible fluids
- To analyse characteristics and their use for solution of plane irrotational problem
- To impart knowledge of steady linearised subsonic and supersonic flows
- To know the motion due to a two dimensional source and vortex.

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

- Identify basic thermodynamics of compressible fluids
- Solve plane irrotational problem
- Solve Chaplygin's equation and subsonic gas jet problem

Course content

Basic Thermodynamics of compressible fluids: Field equation of fluid motion, crocco-vazsonyl equation. Propagation of small disturbances in a gas. Dynamics similarity of two flows. Plane rotational and irrotational motion with supersonic velocity. Steady flow through a De Level nozzle. Normal and oblique shock wave shock polar diagram. [15H]

Characteristics and their use for solution of plane irrotational problem. Prandtl-Mayer flow past a convex corner. [8H]

Steady linearised subsonic and supersonic flows. Prandtl-Glauert transformation. Flow along a wavy boundary. Flow past a slight corner. Jangen-rayleigh method of approximation. Ackeret's formula. [10H]

Lagendre and molenbroek transformations Chaplygin's equation for stream function. Solution of Chaplygin's equation. Subsonic gas jet problem, Limiting line. Motion due to a two dimensional source and vortex. Karman-Tsien approximation. Transonic vflow. Euler's_tricomi equation and its fundamental solution. Hypersonic flow. [15H]

References:

1. Thompson, P. A.,Compressible fluid dynamics.
2. Shaproo, A. H., Compressible fluid flow.
3. Lipman, B., Aspects of subsonic and transonic flows.
4. Niyogi, P., Inviscid gas dynamics, Mcmillan, 1975 (India)
5. Oswatitsch, K., Gas dynamics.

MAJOR ELECTIVE 3 & MAJOR ELECTIVE 4

Course Code: MSCMATHMJE408

Course Name: Operations Research II

Course Structure

Course Type: **MJE (Theoretical)**	Course Details: **MJE-3 & MJE-4**			L-T-P: 4-**1-0**	
Credit: **5**	Full Marks: **50**	CA Marks		ESE Marks	
		Practical	Theoretical	Practical	Theoretical
		……	**15**	……	**35**

Course Objectives:

- To develop operational research models of the real system.
- To understand the mathematical tools that are needed to solve optimization problems.
- To formulate and solve problems as networks
- To analyse and solve replacement and maintenance models
- To provide necessary mathematical support to tackle real-life problems of queue theory.

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

- Able to acquire skills in handling replacement and maintenance models
- Able to apply basic techniques to analyze in networking
- Understand and characterize the phenomena of dynamic programming problems
- Expose the basic characteristic features of a queuing system and acquire skills in analyzing real world queuing models.
- Deep understanding of the theoretical background of queueing systems.

Course content

Goal Programming: Introduction, Difference between LP and GP approach, graphical solution method of Goal programming, Modified simplex method of Goal programming. [10H]

Dynamic Programming: Characteristic of dynamic programming problems, Bellman's principle of optimality (Mathematical formulation), Single additive constraint, multiplicative separable return, Single additive constraint, additively separable return, Single multiplicative constraint, additively separable return, Shortest route problems. Multistage decision process- Forward and Backwar recursive approach, Dynamic Programming approach for solving linear and non-linear programming problems, Applications.
[15H]

Replacement and Maintenance Models: Introduction, Failure Mechanism of items, Replacement of items deteriorates with time, Replacement policy for equipments when value of money changes with constant rate during the period, Replacement of items that fail completely— individual replacement policy and group replacement policy, other replacement problems — staffing problem, equipment renewal problem.
[12H]

Queuing Theory: Introduction, Features of Queuing systems, Queue disciplines, The Poisson process (Pure birth process), Arrival distribution theorem, Properties of Poisson process, Distribution of inter arrival times (exponential process), Markovian property of inter arrival times, Pure death process (Distribution of departures), Derivation of service time distribution, Analogy of exponential service times with Poisson arrivals, Kendals notations, Solution of Queuing models: {(M/M/1):($\infty|FCFS)$}, {(M/M/1):($n|FCFS)$}, {(M/M/s):($\infty|FCFS)$},{(M/M/s):($n|FCFS)$}. Non-Poisson queuing models-M/ E_k /1, M/G/1

[15H]

References:

1. Hadley, G., Nonlinear and Dynamic Programming, Pearson.
2. Rao, S.S., Optimization Theory and Application, Wiley Eastern.
3. Joshi, M.C., and Moudgalya, K.M., Optimization theory and Practice, Narosa Pub.
4. John F Shortle, James M Thompson, Donald Gross, Carl M Harris, *Fundamentals of Queueing Theory*, Fifth Edition, Wiley.
5. T. L. Saaty, *Elements of Queueing Theory, with Applications*, Dover Publications Inc.
6. Bector, C.R., Chandra, S., and Dutta, J., Principles of Optimization Therory, Narosa Pub.
7. Frederick S. Hillier, Gerald J. Lieberman, *Introduction to Operations Research*, McGraw Hill Education.

***