MANIPAL
UNIVERSITY JAIPUR
University under Section 2(f) of the UGC Act

PROGRAMME PROJECT REPORT (PPR)

For

Master of Science (Mathematics)
(ONLINE DEGREE PROGRAMME)

CENTRE FOR DISTANCE AND ONLINE EDUCATION (CDOE)
MANIPAL UNIVERSITY JAIPUR
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Manipal University Jaipur CDOE

MANIPAL UNIVERSITY CIQA JAIPUR

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PROGRAMME PROJECT REPORT

Introduction

At every stage of life, transformation, competition, and improvement are essential to thrive. In today's ever-evolving environment, simply knowing concepts is not enough. It is crucial to constantly enhance and update one's understanding of various aspects of mathematics. The Manipal University Jaipur Online M.Sc Mathematics Programme empowers students with advanced knowledge and skills to address real-world challenges effectively. It emphasizes applying innovative practices to solve current mathematical and computational problems. The Programme fosters analytical thinking to tackle contemporary issues alongside a robust theoretical foundation.

This program offers a collaborative and engaging learning environment, supported by dedicated faculty to help students realize their full potential. It equips students to work smarter, make informed decisions in critical situations, and play a pivotal role in advancing mathematical and interdisciplinary applications. Graduates of the M.Sc Mathematics Programme not only work efficiently but also contribute to shaping the academic, scientific, and industrial landscapes, creating opportunities for innovation and growth.

The Online Master of Science in Mathematics (M.Sc Mathematics) Programme is a two-year curriculum. It incorporates diverse specializations aimed at developing individuals with expertise in their chosen areas of focus while ensuring they are well-grounded in core mathematical concepts and theories. Additionally, the Programme emphasizes the development of soft skills, such as critical thinking and problem-solving, which are vital in both academic and professional settings. Designed to build confidence, enhance knowledge, and act as a springboard for success, the M.Sc Mathematics Programme is an ideal choice for those seeking to excel in the dynamic world of mathematics.

1. Programme's Mission and Objectives

To offer a high-quality Master's degree in Science – Mathematics (M.Sc Mathematics) through Online mode to students and working professionals, helping them develop Analytical, Managerial, and Leadership skills to enhance their career prospects. The program enables students to advance in their career paths and/or embark on entrepreneurial ventures in mathematics-driven domains.

The objectives of the program include:

- Introduce students to fundamental and advanced concepts of mathematics

- Equip students with analytical and logical reasoning skills
- Enhance students' computational skills for applying mathematics to real-world problems
- Inculcate entrepreneurial and managerial skills along with leadership abilities
- Develop an understanding of emerging trends and applications of mathematics in modern fields such as Data Science, Computational Science and Econometrics.

2. Relevance of Programme with Manipal University Jaipur Mission and Goals

In alignment with the mission and goals of Manipal University Jaipur, the Online M.Sc Mathematics Programme is designed to enable students and working professionals to gain expertise in various domains of mathematics, specialize in a field of their choice, acquire advanced skills in analytical thinking, computational techniques, problem-solving, and quantitative decision-making, and prepare them for leadership roles in emerging fields and interdisciplinary applications of mathematics.

Vision

Global Leadership in Higher Education and Human Development

Mission

- Be the most preferred University for innovative and interdisciplinary learning
- Foster Academic research and professional excellence in all domains
- Transform young minds into competent professionals with good human values.

3. Nature of Prospective Target Group of Learners

M.Sc in Mathematics is an essential avenue for individuals to enhance their knowledge, excel in demanding positions, expand their employment opportunities, and engage in research-focused pursuits. This online program caters to traditional students, working individuals, and anyone looking to acquire advanced mathematical expertise and qualifications. Recognizing the time and financial challenges many faces in pursuing a full-time, on-campus degree, the online format provides a flexible, accessible, and cost-effective way to obtain vital skills and understanding in mathematics. By allowing learners to study anytime, anywhere, and at their own pace, this program promotes inclusivity while also supporting the Government of India's goal of reaching a 50% Gross Enrolment Ratio (GER) by 2035. It delivers high-quality education to empower those who might otherwise miss opportunities for full-time academic engagement, helping them fulfil their professional and educational goals.

4. Appropriateness of programme to be conducted in Online mode to acquire specific skills and competence

The courses in the programme are delivered through Self-Learning e-Module which is a modular unit of e-learning material which is inter-alia self-explanatory, self-contained, self-directed at the learner, and amenable to self-evaluation, and enables the learner to acquire the prescribed level of learning in a course of study and includes contents in the form of a combination of the following e-Learning content, and made available through four-quadrant approach namely,
(a) e-Tutorial - faculty led Audio - Video Lectures, (b) e-Content (combination of PDF/ epub) Text Materials, (c) Discussion forum for raising of doubts and clarifying the same on real time basis by the Course Coordinators/Course Mentors assigned to students (d) Self-Assessment Quiz, Test and Assignments to reinforce learning. Reference books are also mentioned in the syllabus. Latest Edition of Reference books may be referred to.

A robust Learning Management System that keeps track of delivery of e-Learning Programmes, learner's engagement, assessment, results and reporting in one centralized location, is in place. All of the above can be done/delivered by online and other platforms without much loss of fidelity. Hence the M.SC Mathematics programme is suited for Online mode of learning.

5. Instructional Design

5.1. Curriculum design

The curriculum is designed by experts in Mathematics, incorporating contemporary topics while fostering analytical skills and awareness of mathematical applications in real-world and interdisciplinary contexts. The curriculum and syllabus are approved by the Board of Studies, the Centre for Internal Quality Assurance (CIQA), and the University Academic Council which consists of experts from Academia and Industry.

5.2. Programme structure and detailed syllabus

5.2.1. Programme Structure

1st Semester		
Course Code	**Title**	**Credits**
DMM1101	Advanced Linear Algebra	4
DMM1102	Mathematical Analysis	4
DMM1103	Advanced Differential Equations	3
DMM1104	Advanced Complex Analysis	4
DMM1105	Topology-I	3
DMM1106	Dynamics of a Rigid Body	3
Total Credits		21
2nd Semester		
DMM1201	Partial Differential Equation	4
DMM1202	Optimization Theory and Techniques	4
DMM1203	Functional Analysis	4
DMM1204	Measure Theory & Integration	4
DMM1205	Research Methodology & Technical Writing	4
DMM1206	Seminar	2
Total Credits		22
3rd Semester		
DMM2101	Fluid Dynamics	4
DMM2102	Special Functions	4
DMM2103	Integral Equations and Calculus of Variations	4
DMM2104	Theory of Field Extensions	4
DMMEX1	Elective-I	3
DMMEX2	Elective-II	3
	Total Credits	22
Elective I, II - subject in electives' basket under Sem 03 (3 credit each)		
Mathematics Elective		
DMMEM1	Fuzzy Sets & Their Applications	3
DMMEM2	Mechanics of Solids	3
Data Science Elective		
DMMED1	Fundamentals of Data Science	3
DMMED2	Machine Learning	3
Computational Science Elective		
DMMEC1	Theory of Computation	3
DMMEC2	Simulation and Modelling	3
Econometrics Elective		
DMMEE1	Mathematics for Economists	3
DMMEE2	Econometrics Applications	3
4th Semester		

DMM2201	Project	10
DMMEX3	Elective-III	3
DMMEX4	Elective-IV	3
Total Credit		16
Elective III, IV - subject in electives' basket under Sem 04 (3 credit each)		
Mathematics Elective		
DMMEM3	Mathematical Statistics	3
DMMEM4	Linear Models	3
Data Science Elective		
DMMED3	Data Visualization	3
DMMED4	Business Analytics	3
Computational Science Elective		
DMMEC3	Quantum Computing	3
DMMEC4	Natural Language Processing (Deep Learning)	3
Econometrics Elective		
DMMEE3	Econometric Methods	3
DMMEE4	Bayesian Econometrics	3

5.2.2. Detailed syllabus

SEMESTER – I

Course Code- DMM1101	**Advanced Linear Algebra**

Learning objectives:

- To acquaint the students with the working of linear algebra concepts in real life.
- To develop skills in linear transformations and related techniques.
- To master decomposition and diagonalization for solving complex systems.
- To explore inner-product spaces and quadratic forms for practical problem-solving.

Unit I: Linear Transformations: Recall of vector space, basis, dimension and related properties.

Unit II: Algebra of linear transformations, vector space of linear transformations L(U,V), dimension of space of linear transformations

Unit III: Change of basis and transition matrices, linear functional, dual basis, computing of a dual basis, dual vector spaces, annihilator, second dual space, dual transformations

Unit IV: Inner-Product Spaces: Normed space, Cauchy-Schwartz inequality, pythagorean theorem, projections, orthogonal projections, orthogonal complements, orthonormality, matrix representation of inner-products

Unit V: Gram-Schmidt orthonormalization process, Bessel's inequality, Riesz representation theorem and orthogonal transformation

Unit VI: Inner product space isomorphism, operators on inner-product spaces, isometry on inner-product spaces and related theorems, adjoint operator, selfadjoint operator, normal operator and their properties, matrix of adjoint operator

Unit VII: Algebra of Hom (V,V), minimal polynomial, invertible linear transformation, characteristic roots, characteristic polynomial and related results

Unit VIII: Diagonalization: Diagonalization of matrices, invariant subspaces

Unit IX: Cayley-Hamilton theorem, canonical form, Jordan Form

Unit X: Forms on vector spaces, bilinear functionals, symmetric bilinear forms,skew symmetric bilinear forms, rank of bilinear forms, quadratic forms, and classification of real quadratic forms.

Textbook:

R. B. Dash and D. K. Dalai, Fundamentals of Linear Algebra, Himalaya Publishing house, 2008.

Reference Book:

1. K. B. Datta, Matrix and Linear Algebra, Prentice Hall of India Pvt. Ltd, New Delhi, 2007.
2. P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, First course in Linear Algebra, New Age International Ltd, 2012
3. K. Hoffman and R. Kunze, Linear Algebra, 2nd edition, Prentice Hall, Englewood Cliffs, New Jersey, 2014.
4. S. Kumaresan, Linear Algebra-A geometric approach, Prentice Hall of India,
5. 2000.
6. R. B. Dash and D. K. Dalai, Fundamentals of Linear Algebra, Himalaya Publishing house, 2008.
7. S. Lang, Linear Algebra, 3rd edition, Springer-Verlag, New York 2005.

Course Code- DMM1102	Mathematical Analysis

Learning objectives:

- Understand the Riemann-Stieltjes Integral and its properties in integration and differentiation.
- Learn the fundamental theorem of calculus and integration of vector-valued functions and rectifiable curves.
- Analyse convergence of sequences and series of functions using uniform convergence, Cauchy criterion, and convergence tests.

Unit I - Riemann-Stieltjes Integral: Introduction, existence and properties, integration and differentiation

Unit II- Fundamental theorem of calculus, integration of vector-valued functions, rectifiable curves

Unit III- Sequence and Series of Functions: Pointwise and uniform convergence, Cauchy criterion for uniform convergence

Unit IV- Weirstrass M test, Abel and Dirichlet tests for uniform convergence, uniform convergence and continuity, uniform convergence and differentiation

Unit V- Weierstrass approximation theorem, power series, uniform convergence and uniqueness theorem, Abel theorem, Tauber theorem

Unit VI- Young and Schwarz theorems, Taylor theorem, higher order differentials, **Unit VII-** Patinkin's money demand functions, equilibrium concept in classical model.

Unit VIII- Explicit and implicit functions, implicit function theorem, inverse function theorem

Unit IX- change of variables, extreme values of explicit functions, stationary values of implicit functions

Unit X- Lagrange multipliers method, Jacobian and its properties

Textbook:

W. Rudin, Principles of Mathematical Analysis, 3rd edition, McGraw-Hill, Kogakusha, 2017.

Reference Book:

1. W. Rudin, Principles of Mathematical Analysis, 3rd edition, McGraw-Hill, Kogakusha, 2017.
2. H.L. Royden, Real Analysis, Macmillan Pub. Co., Inc. 4th edition, New York, 2009.
3. S.C. Malik and Savita Arora, Mathematical Analysis, New Age International Limited, New Delhi, 2012.
4. T. M. Apostol, Mathematical Analysis, Addison-Wesley Publishing Company, 2008.
5. G. De Barra, Measure Theory and Integration, Wiley Eastern Limited, 2003.
6. R. G. Bartle, The Elements of Real Analysis, Wiley International Edition, 2011.

Course Code- DMM1103	Advanced Differential Equations

Learning objectives:

- Construct approximate solutions using ε-approximation and Cauchy-Euler methods
- Apply key theorems for existence, uniqueness, and continuity of differential equation solutions
- Analyze solution dependence on initial conditions and solve linear systems using matrices and Wronskian theory

- Study Sturm theory and self-adjoint equations for second-order differential systems

Unit I- Preliminaries: ε-approximate solution, Cauchy-Euler construction of an ε-approximate solution of an initial value problem, Equicontinuous family of functions

Unit II- Basic Theorems: Ascoli-Arzela lemma, Cauchy-Peano existence theorem, Lipschitz condition, Picards-Lindelof existence and uniqueness theorem for dy/dt=f(t,y), Solution of initial-value problems by picards method

Unit III- Dependence of Solutions on Initial Conditions: Linear systems, Matrix method for homogeneous first order system of linear differential equations

Unit IV- Fundamental Set of Solutions: Fundamental matrix of solutions, Wronskian of solutions, basic theory of the homogeneous linear system, Abel-Liouville formula, nonhomogeneous linear system

Unit V- Strum theory, self-adjoint equations of the second order, Abel formula, Strum separation theorem, Strum fundamental comparison theorem, nonlinear differential systems, phase plane, path, critical points

Unit VI- Poincore- Bendixson Theory: Autonomous systems, isolated critical points, path approaching a critical point

Unit VII- Path entering a critical point, types of critical points, enter, saddle points, spiral points, node points, stability of critical points, asymptotically stable points, unstable points, critical points

Unit VIII- Paths of linear systems, almost linear systems, nonlinear conservative dynamical system

Unit IX- Dependence on a parameter, Liapunov direct method, limit cycles, periodic solutions, Bendixson nonexistence criterion

Unit X- Poincore- Bendixson theorem, index of a critical point, Strum-Liouville problems, orthogonality of characteristic functions.

Textbook:

W.E. Boyce and R.C. Diprima, Elementary Differential Equations and Boundary Value Problems, John Wiley and Sons, Inc., New York, 4th edition, 2012

Reference Book:

1. E.A. Coddington and N. Levinson, Theory of Ordinary Differential Equations, Tata McGraw Hill, 2000.
2. S.L. Ross, Differential Equations, John Wiley and Sons Inc., New York, 2004.
3. W.E. Boyce and R.C. Diprima, Elementary Differential Equations and Boundary Value Problems, John Wiley and Sons, Inc., New York, 4th edition, 2012.
4. G.F. Simmon, Differential Equations, Tata McGraw Hill, New Delhi, 2016.

Course Code- DMM1104	ADVANCED COMPLEX ANALYSIS

Learning objectives:

- Understand integral functions and factorization through Weierstrass' theorem, Gamma and Zeta functions, and related concepts
- Explore analytic continuation techniques including power series, Schwarz reflection, and the monodromy theorem
- Analyze harmonic functions using Poisson kernel, Dirichlet problems, and green functions
- Study entire and univalent functions with growth, zeros, factorization, and key theorems like Picard, Bloch, and Bieberbach

Unit I- Integral Functions: Factorization of an integral function, Weierstrass primary factors, Weierstrass' factorization theorem

Unit II- Gamma function and its properties, Stirling formula integral version of gamma function, Riemann Zeta function, Riemann functional equation, Mittag-Leffler theorem, Runge theorem

Unit III- Analytic Continuation: Natural boundary, uniqueness of direct analytic continuation, uniqueness of analytic continuation along a curve, power series method of analytic continuation

Unit IV-Schwarz reflection principle, germ of an analytic function, monodromy theorem and its consequences, Harmonic functions on a disk, Poisson kernel, Dirichlet problem for a unit disc

Unit V- Harnack inequality, Harnack theorem, Dirichlet region, Green function,

Unit VI- Canonical product, Jensen formula, Poisson-Jensen formula

Unit VII- Hadamard three circles theorem; Entire Function: Growth and order of an entire function, an estimate of number of zeros, exponent of convergence

Unit VIII- Borel theorem, Hadamard factorization theorem, range of an analytic function

Unit IX- Bloch theorem, Schottky theorem, Little Picard theorem

Unit X - Montel Caratheodory theorem, Great Picard theorem, univalent functions, Bieberbach conjecture and the "1/4 theorem"

Textbook:

J.B. Conway, Functions of one Complex variable, Springer-Verlag, Narosa Publishing House, 2002.

Reference Book:

1. S. Ponnusamy, Foundations of Complex Analysis, Narosa Publishing House, 2011.

2. J.B. Conway, Functions of one Complex variable, Springer-Verlag, Narosa Publishing House, 2002.

3. H.S. Kasana, Complex Variable Theory and Applications, PHI Learning Private Ltd, 2011.

4. M. J. Ablowitz and A.S. Fokas, Complex Variables: Introduction and Applications, Cambridge University Press, South Asian Edition, 2003.

5. R. V. Churchill and James Ward Brown, Complex Variables and Applications, McGraw-Hill Publishing Company, 2013.

6. L.V. Ahlfors, Complex Analysis, Mc-Graw Hill, 1979.

Course Code- DMM1105	**Topology-I**

Learning objectives:

- Understand the fundamental concepts of topology, including open and closed sets, neighborhoods, bases, subbases, and closure operators.
- Explore connectedness and compactness, their characterizations, properties, and implications in topological spaces.
- Analyze continuity and homeomorphisms in topological spaces and their impact on compact and connected subsets.
- Learn separation axioms (T_0, T_1, T_2) and countability properties, including their characterizations and applications.

Unit I- Basic Concepts: Definition and examples of topological spaces, comparison of topologies on a set, intersection and union of topologies on a set, neighborhoods

Unit II- Interior point and interior of a set, closed set as a complement of an open set , adherent point and limit point of a set, closure of a set, derived set, properties of closure operator

Unit III- Boundary of a set, dense subsets, interior, exterior and boundary operators

Unit IV- Alternative methods of defining a topology in terms of neighborhood system and Kuratowski closure operator, relative (induced) topology, base and subbase for a topology

Unit V- Base for Neighborhood system, continuous functions, open and closed functions, homeomorphism. connectedness and its characterization

Unit VI- Connected Spaces: connected subsets and their properties, continuity and connectedness, components, locally connected spaces

Unit VII- Compact Spaces: Compact spaces and subsets, compactness in terms of finite intersection property, continuity and compact sets, basic properties of compactness **Unit VIII-** closeness of compact subset and a continuous map from a compact space into a Hausdorff and its consequence, sequentially and countably compact sets, Local compactness and one-point compatification **Unit IX-** Seperations Axioms: First countable, second countable and separable spaces, Hereditary and topological property **Unit X-** Countability of a collection of disjoint opensets in separable and second countable spaces, Lindelof theorem, T0, T1, T2 (Hausdorff) separation axioms, their characterization and basic properties.

Textbook:

W.J. Pervin, Foundations of General Topology, Academic Press Inc. New York, 2014.

Reference Book:

1. C.W. Patty, Foundation of Topology, Jones & Bertlett, 2009.

2. Fred H. Croom, Principles of Topology, Cengage Learning, 2009.

3. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 1983.

4. J. R. Munkres, Toplogy, Pearson Education Asia, 2002.

5. K. Chandrasekhara Rao, Topology, Narosa Publishing House Delhi, 2009.

6. K.D. Joshi, Introduction to General Topology, Wiley Eastern Ltd, 2006.

7. W.J. Pervin, Foundations of General Topology, Academic Press Inc. New York, 2014.

Course Code- DMM1106	**DYNAMICS OF A RIGID BODY**

Learning objectives:

- Understand properties, metrics, and bounded linear transformations in normed and Banach spaces
- Apply Hahn-Banach and Riesz theorems to continuous linear functionals and conjugate spaces
- To study compact operators and their connection to continuous operators
- Explore key theorems like Open Mapping, weak and strong convergence, and solvability in Banach spaces

Unit I- Normed Linear Spaces: Metric on normed linear spaces, completion of a normed space

Unit II- Banach Spaces: Introduction, subspace of a banach space, Holder and Minkowski inequality, completeness of quotient spaces of normed linear spaces, completeness of lp, Lp, Rn, Cn and C[a,b], incomplete normed spaces, finite dimensional normed linear spaces and subspaces

Unit III- bounded linear transformation, equivalent formulation of continuity, spaces of bounded linear transformations, continuous linear functional, conjugate spaces

Unit IV - Hahn-Banach extension theorem (real and complex form), Riesz representation theorem for bounded linear functionals on Lp and C[a,b], second conjugate spaces, reflexive space

Unit V- Uniform boundedness principle and its consequences, open mapping theorem and its application, projections

Unit VI- Closed graph theorem equivalent norms, weak and strong convergence, their equivalence in finite dimensional spaces, weak sequential compactness, solvability of linear equations in banach space

Unit VII- Compact Operator Theory: Compact operator and its relationship with continuous operator

Unit VIII- Compactness of linear transformation on a finite dimensional space, properties of compact operators, compactness of the limit of the sequence of compact operators.

Textbook:

G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 2003.

Reference Book:

1. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 2003.

2. E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley, 2007.

3. A. H. Siddiqi, Khalil Ahmad and P. Manchanda, Introduction to Functional Analysis with Applications, Anamaya Publishers, New Delhi, 2006

4. K.C. Rao, Functional Analysis, Narosa Publishing House, 2nd edition, 2006

SEMESTER – II

Course Code- DMM1201	PARTIAL DIFFERENTIAL EQUATION

Learning objectives:

- Understand and apply methods such as Cauchy's and Charpit's methods to solve first-order linear and non-linear PDEs.
- Analyze and solve higher-order PDEs, including Laplace's and wave equations, with elementary solutions and boundary value problems.
- Apply the separation of variables technique to solve PDEs like the diffusion and wave equations.

Unit I- Partial Differential Equations (PDE): Definition of PDE, origin of first-order PDE, determination of integral surfaces of linear first order partial differential equations passing through a given curve, surfaces orthogonal to given system of surfaces
Unit II- Non-linear PDE of first order, Cauchy's method of characteristic
Unit III- Compatible system of first order PDE, Charpit's method of solution
Unit IV- Origin of second order PDE, linear second order PDE with constant coefficients
Unit V- linear second order PDE with variable coefficients, characteristic curves of the second order PDE
Unit VI- Monge's method of solution of non-linear PDE of second order, separation of variables in a PDE
Unit VII- Higher Order Partial Differential Equations: Laplace's equation, elementary solutions of Laplace's equations
Unit VIII- Families of equipotential surfaces, wave equation, the occurrence of wave equations
Unit IX- Elementary solutions of one-dimensional wave equation
Unit X- Diffusion equation, resolution of boundary value problems for diffusion equation, elementary solutions of diffusion equation, separation of variables

Textbook:

I.N. Sneddon, Elements of Partial Differential Equation, 3rd edition, Dove Publication, 2006.

Reference Book:

1. I.N. Sneddon, Elements of Partial Differential Equation, 3rd edition, Dove Publication, 2006.
2. M.D. Raisinghania, Ordinary and Partial Differential Equations, S. Chand & Sons, 2010.
3. E.T. Copson, Partial Differential Equations, Cambridge University Press, 1995.
4. L.C. Evans, Partial Differential Equations, Vol. 19, AMS, 2010.

5. J.R. Buchanan and Z. Shao, A First Course of Partial Differential Equation, World Scientific Publishing, 2017.

Course Code- DMM1202	OPTIMIZATION THEORY AND TECHNIQUES

Learning objectives:

- Apply methods like Fibonacci, golden section, and steepest descent for optimization problems.
- To solve nonlinear problems using Kuhn-Tucker conditions and optimality criteria.
- To solve quadratic programming using Beale's and Wolfe's methods, analyzing duality.

Unit I- Unconstrained Optimization: Fibonacci golden section and quadratic interpolation methods for one dimensional problem

Unit II- Steepest descent, conjugate gradient and variable metric methods for multidimensional problems

Unit III- Nonlinear Programming: Generalized convexity, quasi and psuedo convex functions and their properties

Unit IV- General nonlinear programming problem, difficulties introduced by nonlinearity, Kuhun-Tucker necessary conditions for optimality, insufficiency of K-T conditions

Unit V- Sufficiency conditions for optimality, solution of simple NLPP using K-T conditions

Unit VI- Quadratic Programming: Beale's method, restricted basis entry method (Wolfe's method), proof of termination for the definite case

Unit VII- Resolution of the semi definite case, duality in quadratic programming

Unit VIII- Convex Programming: Methods of feasible directions, Zoutendijk's method

Unit IX- Rozen's gradient projection method for linear constraints

Unit X- Kelly's cutting plane method to deal with nonlinear constraints

Textbook:

S. Kasana, Introductory Operation Research: Theory and Applications, Springer Verlag, 2005.

Reference Book:

1. S.S. Rao, Optimization Theory and Applications, Wiley Eastern, 2009.
2. G. Hadley, Nonlinear and Dynamic Programming, Addison Wesley, 2018.
3. M. Bazara and Shetty, Nonlinear Programming: Theory and Algorithms, 3rd edition, John Wiley, 2006.
4. H.S. Kasana, Introductory Operation Research: Theory and Applications, Springer Verlag, 2005.
5. R. L. Rardin, Optimization in Operations research, Pearson Education, 2005.

Course Code- DMM1203	FUNCTIONAL ANALYSIS

Learning objectives:

- Understand properties, metrics, and bounded linear transformations in normed and Banach spaces Apply Hahn-Banach and Riesz theorems to continuous linear functionals and conjugate spaces.
- To study compact operators and their connection to continuous operators.
- Explore key theorems like Open Mapping, weak and strong convergence, and solvability in Banach spaces.

Unit I- Normed Linear Spaces: Metric on normed linear spaces, completion of a normed space
Unit II- Banach Spaces: Introduction, subspace of a banach space
Unit III- Holder and Minkowski inequality, completeness of quotient spaces of normed linear spaces, completeness of lp, Lp, Rn, Cn and C[a,b]
Unit IV- Incomplete normed spaces, finite dimensional normed linear spaces and subspaces, bounded linear transformation, equivalent formulation of continuity
Unit V- Spaces of bounded linear transformations, continuous linear functional, conjugate spaces
Unit VI- Hahn-Banach extension theorem (real and complex form), Riesz representation theorem for bounded linear functionals on Lp and C[a,b]
Unit VII- second conjugate spaces, reflexive space, uniform boundedness principle and its consequences
Unit VIII- open mapping theorem and its application, projections, closed graph theorem equivalent norms, weak and strong convergence, their equivalence in finite dimensional spaces, weak sequential compactness, solvability of linear equations in banach spaces
Unit IX- Compact Operator Theory: Compact operator and its relation with continuous operator
Unit X- Compactness of linear transformation on a finite dimensional space, properties of compact operators, compactness of the limit of the sequence of compact operator

Textbook:

G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 2003.

Reference Book:

1. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 2003.
2. E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley, 2007.
3. A. H. Siddiqi, Khalil Ahmad and P. Manchanda, Introduction to Functional Analysis with Applications, Anamaya Publishers, New Delhi, 2006
4. K.C. Rao, Functional Analysis, Narosa Publishing House, 2nd edition, 2006

Course Code-DMM1204	MEASURE THEORY & INTEGRATION

Learning objectives:

- Understand measurable sets, their properties, and equivalent formulations of measurable functions.
- Explore the Lebesgue integral as a generalization of the Riemann integral, including convergence theorems.
- To study differentiation of monotonic functions and the Fundamental Theorem of Calculus for continuous functions.

Unit I- Measurable Sets: Set functions, intuitive idea of measure, elementary properties of measure, measurable sets and their fundamental properties

Unit II- Lebesgue measure of a set of real numbers, algebra of measurable sets, Borel set, equivalent formulation of measurable sets in terms of open, closed

Unit III- non-measurable sets, measurable functions and their equivalent formulations

Unit IV- Properties of measurable functions, approximation of a measurable function by a sequence of simple functions, measurable functions as nearly continuous functions

Unit V- Egoroff theorem, Lusin theorem, convergence in measure and F. Riesz theorem, almost uniform convergence

Unit VI- Measureable Function and Lebesgue Integral: Shortcomings of Riemann integral, Lebesgue integral of a bounded function over a set of finite measure and its properties,

Unit VII- Lebesgue integral as a generalization of Riemann integral, bounded convergence theorem, Lebesgue theorem regarding points of discontinuities of Riemann integrable functions

Unit VIII- Integral of non-negative functions, Fatou lemma, monotone convergence theorem,

general Lebesgue integral, Lebesgue convergence theorem **Unit IX-** Vitali covering lemma, differentiation of monotonic functions, function of bounded variation and its representation as difference of monotonic functions **Unit X-** Differentiation of indefinite integral, Fundamental theorem of calculus, absolutely continuous functions and their properties.

Textbook:

W. Rudin, Principles of Mathematical Analysis, 3rd edition, McGraw-Hill, Kogakusha, 2017.

Reference Book:

1. W. Rudin, Principles of Mathematical Analysis, 3rd edition, McGraw-Hill, Kogakusha, 2017.

2. H.L. Royden, Real Analysis, Macmillan Pub. Co., Inc. 4th edition, New York, 1993.

3. P. K. Jain and V. P. Gupta, Lebesgue Measure and Integration, New Age International (P) Limited Published, New Delhi, 2012.

4. G. De Barra, Measure Theory and Integration, Wiley Eastern Ltd., 2003.

5. R.R. Goldberg, Methods of Real Analysis, Oxford & IBH Pub. Co. Pvt. Ltd, 2012.

6. R. G. Bartle, The Elements of Real Analysis, Wiley International Edition, 2011.

7. R. R. Goldberg, Methods of Real Analysis, John Wiley & Sons, 2012.

Course Code-DMM1205	**Research Methodology & Technical Writing**

Learning objectives:

- To understand research methods, objectives, and scientific language.
- To formulate research questions and hypotheses, addressing measurement issues.
- To apply statistical methods like regression, t-tests, and ANOVA.

Unit I- Foundations of Research: Meaning, objectives, motivation, utility, empiricism, deductive and inductive theory, characteristics of scientific method, understanding the language of research **Unit II-** Research Process: Problem identification & formulation, research question, investigation question, measurement issues, hypothesis, qualities of a good hypothesis, types of hypothesis **Unit III-** Research Design: Concept and importance in research, features of a good research design, exploratory research design, descriptive research designs, experimental research design

Unit IV- Types of Data: Classification of data, uses, advantages, disadvantages, sources

Unit V- Measurement: Concept of measurement, problems in measurement in research, validity and reliability, levels of measurement

Unit VI- Statistical Techniques and Tools: Introduction of statistics, functions, limitations, graphical representation, measures of central tendency, measure of dispersion, skewness, kurtosis, correlation, regression,

Unit VII- Tests of significance based on t, F, Chi-square, Z and ANOVA test

Unit VIII- Paper Writing: Layout of a research paper, Scopus/Web of Science journals, impact factor of journals, when and where to publish,

Unit IX- Ethical issues related to publishing, plagiarism and self-plagiarism

Unit X- Introduction to LATEX and MATLAB.

Textbook:

C.R. Kothari, Research Methodology Methods & Techniques, New Age International Publishers, Reprint 2008.

Reference Book:

1. C.R. Kothari, Research Methodology Methods & Techniques, New Age International Publishers, Reprint 2008.

2. R. Singh, Research Methodology, Saga Publication, 4th edition, 2014.

3. J. Anderson and M. Poole, Thesis and Assignment Writing, Wiley India 4th edition, 2011.

4. Mukul Gupta and Deepa Gupta, Research Methodology, PHI Learning Private Ltd., New Delhi, 2011.

5. S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand & Sons, New Delhi, 1999.

SEMESTER – III

Course Code- DMM2101	FLUID DYNAMICS

Learning objectives:

- Understand Euler's and Lagrange's equations and methods of motion.
- Study stream functions, velocity potentials, and image methods.
- Learn properties of vortices and vortex motion in various fields.
- Analyse Navier-Stokes equations and steady flow in viscous fluids.

Unit I - Kinematics: Euler's equations of motion, Lagrange's equations of motion. **Unit II -** Lagrangian and Eulerian methods, equations of continuity in Lagrangian and Eulerian methods. **Unit III -** Stream line, velocity potential, path line, velocity and circulation, boundary surface, rotational and irrotational motion, equation of energy. **Unit IV -** Motion in Two Dimensions: stream function, complex velocity potential, source, sink and doublet, their image. **Unit V -** Motions in Two Dimensions: images in two dimensions, images of a source with regard to a plane, a circle and a sphere, image of a double. **Unit VI -** Milne-Thomson circle theorem, theorem of Blasius. **Unit VII -** Vortex Motion: Helmholtz properties of vortices, velocity in a vortex field. **Unit VIII -** Vortex motion due to circular vortex, infinite rows of vortices, Ka'rma'n vortex street. **Unit IX -** Viscous Fluid: Navier- Stokes equations; diffusion of vorticity, dissipation of energy. **Unit X -** Viscous Fluid: steady motion of a viscous fluid between two parallel planes, steady flow through cylindrical pipes. model.

Textbook:

- Y. A. Cengel and John M. Cimbara, Fluid Mechanics: Fundamentals and Applications, McGraw Hill Eduction, 4th edition, 2017.

Reference Book:

- Y. A. Cengel and John M. Cimbara, Fluid Mechanics: Fundamentals and Applications, McGraw Hill Eduction, 4th edition, 2017.
- M.D. Raisinghania, Fluid dynamics, S. Chand Publication, 2010.
- J.L. Bansal, Viscous Fluid Dynamics, Oxford Publications, 2003.
- G.K. Batchelor, An Introduction to Fluid Dynamics, Foundation Books, 2005.

Course Code- DMM2102	Special Functions

Learning objectives:

- Understand properties, series solutions, and transformations of the Gauss hypergeometric function.

- Learn Rodrigues' formula, orthogonality, and recurrence relations of Legendre polynomials.
- Study the properties and recurrence relations of Bessel functions.
- Explore definitions, representations, and recurrence relations for generalized hypergeometric and Laguerre polynomials.

Unit I - Gauss Hypergeometric Function: Introduction and its properties, Series solution of Gauss hypergeometric equation.

Unit II - Integral representation, Linear and quadratic transformation formulas.

Unit III - Contiguous function relations, Differentiation formulae, Linear relation between the solutions of Gauss hypergeometric equation.

Unit IV - Kummer's confluent hypergeometric function and its properties, Integral representation, Kummer's first transformation.

Unit V - Legendre Polynomials: Introduction, Rodrigue's formula, orthogonality, recurrence relations. Functions Pn(x) and Qn(x) and their properties.

Unit VI - Bessel Function: Introduction, Jn(x) and its properties, recurrence relation.

Unit VII - Generalized Hypergeometric Function: Definition, Special cases, Series, integral and contour representations.

Unit VIII - Convergence conditions of these representations, Saalssutz.

Unit IX - Whipple theorems, Contiguous function relations, Differentiation and integral formulas.

Unit X - Laguerre polynomial: Introduction, recurrence relations, Propeties.

Textbook:

- N. Saran, S.D Sharma, T. N. Trivedi, Special Functions, Pragati Prakashan, 2019.

Reference Book:

- G.E. Andrews, R. Askey and R. Rose, Special Functions, Cambridge University Press, 2001.
- R.Y. Denis and U.P. Singh, Special Function and Their Applications, Dominant Publishers, 2001.
- N. Saran, S. D. Sharma & T. N. Trivedi, Special Functions: For Mathematical, Physical & Engineering Sciences, Pragati Prakashan, 2008.
- N. Saran, S.D Sharma, T. N. Trivedi, Special Functions, Pragati Prakashan, 2019

Course Code- DMM2103	Integral Equations and Calculus of Variations

Learning objectives:

- To solve Volterra and Fredholm equations using successive approximation and Neumann series.
- To study methods for solving Fredholm equations with separable and degenerate kernels.
- To construct and apply green functions to boundary value problems and integral equations.
- To solve extremum problems using Euler's equation for dependent functions and constraints.

Unit I - Linear Integral Equations: Some basic identities, initial value problems reduced to Volterra integral equations.

Unit II - Volterra integral equations methods of successive substitution and successive approximation to solve Volterra integral equations of second kind iterated kernels.

Unit III - Neumann series for Volterra equations, resolvent kernel as a series, Laplace transform method for a difference kernel solution of a Volterra integral equation of the first kind, boundary value problems reduced to Fredholm integral equations.

Unit IV - Fredholm integral equations methods of successive approximation and successive substitution to solve Fredholm equations of second kind, iterated kernels and Neumann series for Fredholm equations, resolvent kernel as a sum of series.

Unit V - Fredholm resolvent kernel as a ratio of two series, Fredholm equations with separable kernels, approximation of a kernel by a separable kernel, Fredholm Alternative, non homonogenous Fredholm equations with degenerate kernels.

Unit VI - Green function, use of method of variation of parameters to construct the green function for a nonhomogeneous linear second order boundary value problem, basic four properties of the green function, alternate procedure for construction of the green function by using its basic four properties.

Unit VII - Reduction of a boundary value problem to a Fredholm integral equation with kernel as green function, Hilbert-Schmidt theory for symmetric kernels.

Unit VIII - Calculus of Variation: Motivating problems of calculus of variations, shortest distance, minimum surface of resolution.

Unit IX - Brachistochrone problem, isoperimetric problem, Geodesic, fundamental lemma of calculus of variations.

Unit X - Euler equation for one dependent function and its generalization to 'n' dependent functions and to higher order derivatives, conditional extremum under geometric constraints and under integral constraint.

Textbook:

- A.S. Gupta, Calculus of Variations with Applications, PHI Learning, 2015.

Reference Book:

- A.J. Jerri, Introduction to Integral Equations with Applications, Wiley-Interscience Publication, 1999.
- R.P. Kanwal, Linear Integral Equations, Theory and Techniques, Academic Press, New York, 1996.
- P.C. Bhakta, Integral Transforms, Integral Equations and Calculus of Variations, Sarat, 2011.
- A.S. Gupta, Calculus of Variations with Applications, PHI Learning, 2015.
- F.B. Hilderbrand, Methods of Applied Mathematics, Dover Publications, 2005.
- I.M. Gelfand, S.V. Fomin, Calculus of Variations, Dover Publications, 2000.

Course Code- DMM2104	**Theory of Field Extensions**

Learning objectives:

- Understand simple, algebraic, and transcendental extensions, and explore properties
- Learn the structure of Galois groups, automorphisms, and the fundamental theorem of Galois theory.
- Study cyclotomic extensions, their polynomials, and properties of normal extensions.

Unit I - Extension of Fields: Elementary properties, simple extensions, algebraic and transcendental extensions.

Unit II - Factorization of polynomials, splitting fields, algebraically closed fields, separable extensions, perfect fields.

Unit III - Galios Theory: Automorphism of fields, monomorphisms and their linear independence.

Unit IV - Fixed fields, normal extensions, normal closure of an extension.

Unit V - Fundamental theorem of Galois theory.

Unit VI - Norms and traces, normal basis, Galios fields.

Unit VII - Cyclotomic extensions, cyclotomic polynomials, cyclotomic extensions of rational number field.

Unit VIII - Cyclic extension, Wedderburn theorem, ruler and compasses construction, solutions by radicals.

Unit IX - Extension by radicals, generic polynomial.

Unit X - algebraically independent sets, insolvability of the general polynomial of degree $n \geq 5$ by radicals.

Textbook:

I.S. Luther and I.B.S. Passi, Algebra, Vol. IV-Field Theory, Narosa Publishing House, 2012

Reference Book:

- I.S. Luther and I.B.S. Passi, Algebra, Vol. IV-Field Theory, Narosa Publishing House, 2012.
- I. Stewart, Galios Theory, Chapman and Hall/CRC, 2004.
- V. Sahai and V. Bist, Algebra, Narosa Publishing House, 2003.
- P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, Basic Abstract Algebra, 2nd edition, Cambridge University Press, Indian Edition, 2012.
- S. Lang, Algebra, 3rd edition, Addison-Wesley, 2002.
- I. T. Adamson, Introduction to Field Theory, Cambridge University Press, 2007.

MATHEMATICS ELECTIVE SEMESTER - III

Course Code- DMMEM1	Fuzzy Sets & Their Applications

Learning objectives:

- Understand the fundamentals of fuzzy sets, their mathematical representation, and operations.
- Apply fuzzy relations, including equivalence and compatibility, to model complex systems.
- Explore possibility theory and its contrast with probability measures in decision-making.
- Design and implement fuzzy controllers using rule-based systems and function approximation techniques.

Unit I - Fuzzy Sets: Introduction, classical sets vs fuzzy sets, need for fuzzy sets.

Unit II - Definition and mathematical representations, level sets, fuzzy functions, Zadeh's extension principle.

Unit III- Operations on Fuzzy Sets: Operations on [0, 1], fuzzy negation, triangular norms, t-conorms.

Unit IV- Fuzzy implications, aggregation operations, fuzzy functional equations, fuzzy number.

Unit V - Fuzzy Relations: Fuzzy binary and n-ary relations, composition of fuzzy relations, fuzzy equivalence relations, fuzzy compatibility relations, fuzzy relational equations.

Unit VI - Possibility Theory: Fuzzy measures, evidence theory, necessity and belief measures, probability measures vs possibility measures.

Unit VII - Approximate Reasoning: Fuzzy decision making, fuzzy relational inference.

Unit VIII- Positional rule of inference, efficiency of inference, hierarchical.

Unit IX - Fuzzy Controllers: fuzzy if-then rule base, inference engine.

Unit X - Takagi-Sugeno fuzzy systems, function approximation.

Textbook:

- A.K. Bhargava, Fuzzy Set Theory Fuzzy Logic and Their Applications, S. Chand & Co., 2013.

Reference Book:

- A.K. Bhargava, Fuzzy Set Theory Fuzzy Logic and Their Applications, S. Chand & Co., 2013.
- K. Pundir and R. Pundir, Fuzzy Sets and Their Applications, Pragati Prakashan, Meerut, 2008.
- G. J. Klir and B. Yuan, Fuzzy Sets and Fuzzy Logic: Theory and Applications, Prentice Hall of India Pvt. Ltd., New Delhi, 2001.
- H. J. Zimmermann, Fuzzy Set Theory and its Applications, Springer, 2001.

Course Code- DMMEM2	Mechanics of Solids

Learning objectives:

- Apply tensor analysis to analyze stress and strain in solid mechanics.
- Understand the stress tensor, its components, invariants, and principal stresses.
- Analyze deformation and strain tensors, including their geometrical interpretation and compatibility conditions.
- Utilize equations of elasticity, including Hook's law and compatibility conditions, for different material symmetries.

Unit I - Tensor Analysis: Cartesian tensors of different orders, contraction of a tensor.

Unit II - Multiplication and quotient laws for tensors, substitution and alternate tensors, symmetric and skew symmetric tensors, isotropic tensors, eigenvalues and eigenvectors of a second order symmetric tensor.

Unit III - Analysis of Stress: Stress vector, normal stress, shear stress, stress components, Cauchy equations of equilibrium.

Unit IV - Stress tensor of order two, symmetry of stress tensor, stress quadric of Cauchy, principal stresses, stress invariants, maximum normal and shear stresses, mohr diagram.

Unit V - Analysis of Strain: Affine transformations, infinitesimal affine deformation, pure deformation.

Unit VI - Components of strain tensor and their geometrical meanings, strain quadric of Cauchy.

Unit VII - Principal strains, strain invariants, general infinitesimal deformation, saint-venant conditions of compatibility, finite deformations.

Unit VIII - Equations of Elasticity: Generalized Hook's law, Hook's law in an elastic media with one plane of symmetry, orthotropic and transversely isotropic symmetries.

Unit IX - Homogeneous isotropic elastic media, elastic moduli for an isotropic media, equilibrium and dynamical equations for an isotropic elastic media.

Unit X - Beltrami - Michell compatibility conditions.

Textbook:

A.S. Saada., Elasticity-Theory and applications, Pergamon Press, New York, 2009

Reference Book:

- M. Teodar Atanackovic and Ardeshiv Guran, Theory of Elasticity for Scientists and Engineers, Birkhausev, Boston, 2000.
- A. K. Singh, Mechanics of Solid, Prentice Hall India Learning Private Limited, 2007.
- A.S. Saada., Elasticity-Theory and applications, Pergamon Press, New York, 2009.
- D.S. Chandersekhariah and L. Debnath, Continuum Mechanics, Academic Press, 1994.
- A.K. Malik and S.J. Singh, Deformation of Elastic Solids, Prentice Hall, New Jersey, 199

DATA SCIENCE ELECTIVE SEMESTER - III

Course Code- DMMED1	Fundamentals of Data Science

Learning objectives:

- Understand the data science lifecycle, including data collection, cleaning, analysis, and deployment across industries.
- Learn data cleaning techniques, exploratory data analysis, and statistical methods like hypothesis testing and regression.

- Learn key machine learning algorithms for supervised and unsupervised learning with practical implementation.

Unit I - Definition and significance of data science Data science lifecycle: Data Collection, Cleaning, Analysis, Modeling, and Deployment Role of a data scientist, Applications of data science across industries.

Unit II - Data sources: Structured, semi-structured, and unstructured data,Data cleaning: Handling missing values, outliers, and duplicates,Data transformation and normalization.

Unit III - Data cleaning: Handling missing values, outliers, and duplicates,Data transformation and normalization Importance of EDA in data science Descriptive statistics (mean, median, mode, variance).

Unit IV - Visualization techniques: Histograms, Box plots, Scatter plots Identifying patterns and anomalies.

Unit V - Introduction to probability concepts Probability distributions (normal, binomial, Poisson) Hypothesis testing and confidence intervals Statistical significance.

Unit VI - Overview of supervised and unsupervised learning Key machine learning algorithms Training and testing datasets.

Unit VII - Introduction to regression analysis Simple linear regression and multiple regression Evaluation metrics (RMSE, R-Squared).

Unit VIII - Logistic regression Decision trees Support Vector Machines (SVM)Practical implementation with real datasets.

Unit IX - Data privacy and security Ethical considerations in AI and machine learning Regulatory frameworks (e.g., GDPR, HIPAA).

Unit X - Case studies in healthcare, finance, retail, and transportation Real-world applications and industry use cases Future trends in data science.

Textbook:

- Cathy O'Neil, Weapons of Math Destruction

Reference Book:

- Joel Grus, Data Science from Scratch
- Cathy O'Neil, Weapons of Math Destruction
- Wes McKinney, Python for Data Analysis
- Hadley Wickham, R for Data Science

Course Code: DMMED2	Machine Learning

Learning objectives:

- Understand the fundamentals of supervised and unsupervised learning, including linear and logistic regression.
- Explore advanced machine learning techniques such as SVM, decision trees, and nearest neighbours with practical coding examples.
- Learn clustering methods like K-means and hierarchical clustering for data segmentation.

Unit I - Introduction to Machine Learning: What is Supervised Learning? What is Unsupervised Learning?

Unit II - Linear Regression: Concept of Linear Regression, Simple Linear Regression, Demo.
Unit III - Linear Regression: Multiple Linear Regression, Regularization, Demo.

Unit IV - Logistic Regression: Concept of Logistic Regression, Logistic Regression example with Python.

Unit V - SVM: Concept of Support Vector Machine, SVM example with Python.

Unit VI - Decision Trees: Classification using Decision Tree, Code to Demonstrate Decision Tree.

Unit VII - Nearest Neighbours: What is K-NN Classification, KNN Regression, Code to demonstrate K-NN Classification, Code to demonstrate K-NN Regression.

Unit VIII - Naïve Bayes: What is Naïve Bayes Classification, Code to demonstrate Naïve Bayes.

Unit IX - Clustering, Different Clustering Techniques, K-Means Clustering, Hierarchical Clustering.

Unit X - Recommendation System: Different Types of Recommender System, Implementing a Basic Recommender System.

Textbook:

- Machine Learning with R Edition 2, Brett Lantz

Reference Book:

- Machine Learning with R Edition 2, Brett Lantz
- Data Mining and Business Analytics with R
- The Analysis of Time Series – an Introduction by Chris Chatfield, Chapman & Hall/CRC
- Time Series Analysis: Forecast and Control by Box and Jenkins

COMPUTATIONAL SCIENCE ELECTIVE SEMESTER - III

Course Code: DMMEC1	Theory of Computation

Learning objectives:

- Understand the fundamental concepts of sets, functions, relations, and logical proofs in the context of computation.
- Analyze regular languages and finite automata, including minimization, non-deterministic automata, and applications of Kleene's theorem.
- Explore context-free languages, push-down automata, parsing, and equivalence with context-free grammars.

Unit I - Sets, Functions, Logical statements, Proofs, Relations, Languages, The Principle of Mathematical induction, Recursive definitions.

Unit II - Regular expressions, Regular languages, Memory required to recognize a language.

Unit III - Finite automata, Distinguishable strings, Union, intersection and complement of regular languages.

Unit IV - Automata with output-Moore machine, Mealy machine.

Unit V - Non-deterministic finite automata, non-deterministic finite automata with ^ transitions, Kleen's theorem- Part-1.

Unit VI - Minimization of Finite automata, non-regular and regular languages, Pumping Lemma, Decision problems and decision algorithms, regular languages in relation to programming languages.

Unit VII - Context-free languages, Regular Grammars, Derivation tree and ambiguity, An Unambiguous CFG, Simplified and Normal forms, Chomsky normal form, Chomsky Classification of Grammars.

Unit VIII - Push -Down Automata, Deterministic PDA, Types of acceptances and their equivalence, Equivalence of CFG and PDA, parsing, Non-CFL and CFL, Pumping Lemma for CFL, Intersection and Complement of CFL.

Unit IX - Models of computation, Combining TMs, Computing a function with TMs.

Unit X - Variations on Turing Machines, doubly infinite and more than one Tapes, Non-deterministic and Universal TM.

Textbook:

- Introduction to Languages and Theory of Computation: By John C. Martin

Reference Book:

- Introduction to Languages and Theory of Computation: By John C. Martin
- Computation: Finite and Infinite: By Marvin L. Minsky, Prentice-Hall

- Introduction to formal languages: By G. E. Reevsz, Mc-graw hill
- Introduction to Formal Language Theory: By M.H. Harrison

Course Code: DMMEC2	Simulation and Modelling

Learning objectives:

- To Learn types of models and mathematical model formulation.
- To Apply probability, statistics, and Monte Carlo methods in simulation.
- To Model discrete events, system dynamics, and agent interactions.
- To Study optimization, hybrid models, and emerging simulation trends.

Unit I - "Definition and importance of simulation and modeling, Types of models: Deterministic, stochastic, static, dynamic, discrete, and continuous models, Steps in the modeling process.

Unit-II -Mathematical Models: Formulation of mathematical models, Linear and nonlinear models, Analytical vs numerical approaches, Dimensional analysis and scaling

Unit-III Probability and Statistics in Simulation: Random variables and probability distributions, Monte Carlo methods, Random number generation techniques, Statistical measures in simulation: Mean, variance, confidence intervals

Unit-IV Series Discrete Event Simulation (DES): Basics of discrete event systems, Simulation clock and event scheduling, Queuing models: Single-server and multi-server systems

Unit-V System Dynamics Modeling: Fundamentals of system dynamics, Feedback loops, stock and flow diagrams, Differential equations in system dynamics

Unit-VI "Agent-Based Modeling (ABM): Introduction to agent-based models, Agent behaviours and interactions,Emergent phenomena and complexity

"**Unit-VII** Continuous and Hybrid Models: Continuous system modeling using differential equations, Hybrid models combining discrete and continuous dynamics, Stability and sensitivity analysis

Unit-VIII Optimization in Simulation: Optimization techniques in simulation, Linear programming, Nonlinear programming, Genetic algorithms

Unit-IX Advanced Topics in Simulation: Parallel and distributed simulation, Machine learning and artificial intelligence in simulation

Unit-X Data-driven simulation models,Real-time simulation and digital twins, Emerging trends in simulation and modeling

Textbook:

Banks, J., Carson, J. S., Nelson, B. L., & Nicol, D. M. (2005). Discrete-Event System Simulation. Prentice Hall.

Reference Book:

- Law, A. M., & Kelton, W. D. (2000). Simulation Modeling and Analysis. McGraw-Hill.
- Ross, S. M. (2012). Simulation. Academic Press.
- Banks, J., Carson, J. S., Nelson, B. L., & Nicol, D. M. (2005). Discrete-Event System Simulation. Prentice Hall.

ECONOMETRICS ELECTIVE SEMESTER - III

Course Code- DMMEE1	Mathematics for Economists

Learning objectives:

- Understand the concepts of multi-variable functions, derivatives, and optimization techniques in economics.
- Apply unconstrained and constrained optimization methods, including Kuhn-Tucker conditions and the Simplex method.
- Utilize Riemann's integral and differential equations to solve economic problems and calculate present value, mean value, and distributions.
- Analyze economic applications of finite difference equations and understand their role in economic modeling.

Unit I- Multi-variable Functions: Terminology and Basic Mathematical Concepts, Definition of IRn in IRm Functions, Graphic Representation, Types of Functions

Unit II- Multi-variable Real Functions: Function Limits, Continuity Study of Multi-variable Functions, Function Derivatives: Successive and Partial Derivatives Concept of Differential of a Function, Differentiation of Compound Functions: Chain Rule, Homogeneous Functions, Euler’s Theorem

Unit III- Optimization: Definition, Searching and Interpreting Optimum, Weier strass’ Theorem, Local-Global Theorem

Unit IV-Unconstrained and Constrained Equality Optimization, Taylor’s Theorem Applied to Multivariable Functions, Unconstrained Optimization, Constrained Optimization

Unit V- Optimization with Inequality Constraints: Introduction, Necessary First-order Conditions for the Existence of Local Optima: Kuhn-Tucker's Theorem and Its Economic Interpretation, Globality Theorem: Convex Programming

Unit VI- Lineal Programming: Introduction, Properties, Graphic Resolution, Applying Kuhn-Tucker Conditions, Simplex Method, Economic Applications

Unit VII- Integral Calculus: Riemann's Integral: Definition and Application in Economics, Properties, Integrability Conditions, Relation between Integrals and Derivatives, Integration by Parts, Change of Variables Integration Method

Unit VIII- Applications of Rienmann's Integral in Business and Economics, Distribution Function, Present Value of a Cash Flow, Mean Value of a Function in an Enclosure, Pierre-Simon Laplace and His Contribution

Unit IX- Ordinary Differential Equations: Introduction, Definition, Classification, First Order Differential Equations, Exact Differential Equations, Greater Than One Ordinary Differential Equations (with Constant Coefficients)

Unit X - Finite Difference Equations: Introduction, Discrete Variable Functions or Discrete Functions, First-order Linear Finite Difference Equations with Constant Coefficients, Order Linear Finite Difference Equations with Constant Coefficients, Economic Applications

Textbook:

Alpha C. Chiang and Kevin Wainwright, Fundamental Methods of Mathematical Economics, McGraw-Hill Education, 2005.

Reference Book:

- Carl P. Simon and Lawrence E. Blume, Mathematics for Economists, W.W. Norton & Company, 1994.
- Alpha C. Chiang and Kevin Wainwright, Fundamental Methods of Mathematical Economics, McGraw-Hill Education, 2005.
- Angel de la Fuente, Mathematical Methods and Models for Economists, Cambridge University Press, 2000.
- Avinash Dixit, Optimization in Economic Theory, Oxford University Press, 1990.
- Rakesh V. Vohra, Advanced Mathematical Economics, Routledge, 2005.
- Gilbert Strang, Linear Algebra and Its Applications, Brooks/Cole, 2006.

Course Code- DMMEE2	**Econometrics Applications**

Learning objectives:

- Apply OLS method to linear regression models and analyze assumptions.
- Perform hypothesis testing and calculate confidence intervals in regression.
- Conduct residual analysis and address specification issues in models.
- Analyze time series data with autocorrelation and use dummy variables in GLRM.

Unit I- Introduction to Econometrics Applications, Scope and significance of econometrics in real-world applications, Econometric models in practice: deterministic vs. stochastic models

Unit II- Analysis of Income and Allied Size Distributions Pareto distribution, graphical test and fitting, universality of Pareto's Law.

Unit III- Lognormal distribution-properties, graphical test and fitting, law of proportionate effect. Income inequality - notion of economic inequality

Unit IV- Lorenz curve, Lorenz ratio and their properties, other common measures of inequality; poverty - concept and measurement.

Unit V- Demand Analysis and elasticities of demand; Engel curve specification and estimation from budget data, treatment of demographic factors in Engel curve analysis.

Unit VI- Production Analysis: Production function - theoretical properties, elasticity of substitution: problems of estimation of a production function.

Unit VIII- Cobb-Douglas production function - properties, specification, problem of identification and alternative estimation techniques; constant elasticity of substitution (CES) production function - properties

Unit IX- Causal Inference in Econometrics: Endogeneity and instrumental variables (IV), Difference-in-differences (DiD) and propensity score matching, Applications: Program evaluation, policy impact assessment

Unit X – Application of Econometrics to Macro-economic Problems Macro econometric models, Econometric issues in the specification and estimation: illustrative application; uses in forecasting and policy evaluation.

Textbook:

- Greene, William H. - Econometric Analysis

Reference Book:

- Colin Cameron and Pravin K. Trivedi - Micro econometrics: Methods and Applications
- James H. Stock and Mark W. Watson - Introduction to Econometrics
- Greene, William H. - Econometric Analysis

<u>SEMESTER – IV</u>

Course Code: DMM2201	Project

The students carry out a project in any organistaion or carry a Dissertation work under the guidance of faculty member.

MATHEMATICS ELECTIVE SEMESTER - IV

Course Code- DMMEM3	Mathematical Statistics

Learning objectives:

- Understand basic probability, conditional probability, and Bayes' theorem.
- Learn about discrete and continuous random variables, and their associated distributions.
- Apply mathematical expectation, variance, covariance, and moment generating functions.

Unit I - Probability: Basic concepts of probability, conditional probability, Bayes theorem and its applications.

Unit II - Random Variable and Probability Functions: discrete and continuous random variables, probability mass and density functions.

Unit III - Distribution function, concepts of bivariate random variable: joint, marginal and conditional distributions, cumulative generating function.

Unit IV - Mathematical Expectation and its properties, variance, covariance, moment generating function.

Unit V - Probability Distributions: Discrete Distributions- Uniform, Bernoulli, Binomial, Poisson and Geometric distributions with their properties.

Unit VI - Continuous Distributions- Uniform, Normal, Exponential, Beta and Gamma distributions with their properties.

Unit VII - Testing of Hypothesis: Parameter and statistic.

Unit VIII - Sampling distribution and standard error of estimate, null and alternative hypotheses, simple and composite hypotheses, critical regions.

Unit IX - Level of significance, one tailed and two tailed tests, two types of error.

Unit X - Tests of Significance: Large sample tests for single mean, single proportion, difference between two means and two proportions.

Textbook:

R.V. Hogg, and E.A. Tanis, Probability and Statistical Inference, 9th edition, Macmillan Publishing Co. Inc., 2014

Reference Book:

- S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand and Co., 3rd edition, New Delhi, 2008.
- V.K. Rohtagi and A.K.M. E Saleh, An Introduction to Probability & Statistics, John Wiley & Sons, 2011.
- P. L. Meyer, Introductory Probability and Statistical Applications, Addison-Wesley, 2017. 170

- W. Feller, An Introduction to Probability Theory and Its Applications, Vol. 1, 3rd edition, John Wiley, 2005.
- P. Mukhopadhyay, Mathematical Statistics, Books & Allied (P) Ltd., 2009.
- G. Casella, and R.L. Berger, Statistical Inference, 2nd edition. Thomson Duxbury, 2002.
- R.V. Hogg, and E.A. Tanis, Probability and Statistical Inference, 9th edition, Macmillan Publishing Co. Inc., 2014

Course Code- DMMEM4	Linear Models

Learning objectives:

- Understand the principles, assumptions, and applications of linear models in various fields.
- Apply matrix algebra and statistical techniques in simple and multiple linear regression models.
- Perform diagnostics and model adequacy checks, including residual analysis and outlier detection.
- Explore advanced topics such as generalized linear models, ridge regression, and principal component analysis.

Unit I - Definition and scope of linear models, Assumptions of linear models, Examples of linear models in mathematics and applied sciences.

Unit II - Matrix Algebra for Linear Models:Matrices and vectors: basic operationsRank of a matrix, inverse, and generalized inverse, Idempotent and projection matrices, Applications of matrix algebra in linear models.

Unit III - Simple Linear Regression: Model formulation Least Squares Estimation (LSE), Properties of estimators: unbiasedness, efficiency, Analysis of variance (ANOVA) in simple linear regression.

Unit IV - Multiple Linear Regression: General formulation and assumptions, Estimation and interpretation of coefficients, Hypothesis testing: t-tests and F-tests, Model selection techniques.

Unit V - Diagnostics and Model Adequacy: Residual analysis, Detection of outliers and influential observations, Collinearity and its impact, Transformation of variables for improving model fit.

Unit VI - Generalized Linear Models (GLMs): Introduction to GLMs, Link functions and exponential family distributions Logistic regression and Poisson regression Applications of GLMs.

Unit VII - Design of Experiments and Analysis: Principles of experimental design Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design
Analysis of covariance (ANCOVA) Factorial designs.

Unit VIII - Advanced Topics in Linear Models: Multivariate linear models, Ridge regression, Lasso regression, and Elastic Net, Principal Component Analysis (PCA) and its connection to regression.

Unit IX - Computational Aspects: Numerical methods for solving linear models, Use of software tools (e.g., R, Python, or MATLAB), Implementation of linear models and diagnostics in software.

Unit X - Applications of Linear Models: Applications in social sciences, economics, and natural sciences, Case studies and real-world examples.

Textbook:

Draper, N. R., & Smith, H. (1998). Applied Regression Analysis (3rd ed.). Wiley.

Reference Book:

- Draper, N. R., & Smith, H. (1998). Applied Regression Analysis (3rd ed.). Wiley.
- Seber, G. A. F., & Lee, A. J. (2012). Linear Regression Analysis (2nd ed.). Wiley.
- Belsley, D. A., Kuh, E., & Welsch, R. E. (2005). Regression Diagnostics: Identifying Influential Data and Sources of Collinearity. Wiley.
- Johnson, R. A., & Wichern, D. W. (2019). Applied Multivariate Statistical Analysis (6th ed.). Pearson.

DATA SCIENCE ELECTIVE SEMESTER – IV

Course Code- DMMED3	Data Visualization

Learning objectives:

- Learn basic and advanced techniques like bar charts, pie charts, and line charts.
- Create interactive plots and dashboards using R and R-Shiny.
- Develop skills in data connections, views, formatting, and LOD expressions using Tableau.
- Gain proficiency in connecting data and building visualizations using Power BI.

Unit I - Introduction to Data Visualization: Basics of Data Visualization; Data Visualization in Data Analytics Cycle; Techniques of Visualization: Bar Charts and Pie Charts; Techniques of Visualization: Line Charts.

Unit II - Visualizations using R: Plots using R; Creating Advanced Plots Using R.

Unit III - Introduction to R-Shiny: What is Visual Analytics; Visual Analytics Using R.

Unit IV - Dashboard Design using R-Shiny: Creation of R-Shiny Dashboard, Adding features in R-Shiny Dashboard.

Unit V - Creating Advanced Dashboard and Visualization: Creation of advanced Interactive R-Shiny Dashboard, Addition of Advanced Visualizations in R-Shiny Dashboard.

Unit VI - Introduction to Tableau: Introduction to Tableau, getting started with Tableau, Connecting to Data, Data: Joining and Blending I and II, Understanding Tableu.

Unit VII - Editing, Building Views and Formatting: Edit Datasources /Extracts/Replace and Metadata, Building Views and Formatting I and II, Formatting Views.

Unit VIII - Mapping, Sorting and Filters: Mapping I and II, Sorting and Filters I and II.

Unit IX - LOD: Aggregating Dimensionality other than View Level using LOD, Include LOD Expression, Exclude LOD Expression, Nested LOD.

Unit X - Introduction to Power BI-Connecting Data using Power Query: Getting Started with Power BI; Connecting the Database Files; Introduction to Excel Power BI.

Textbook:

Hoelscher, J., & Mortimer, A. (2018). Using Tableau to visualize data and drive decision-making. Journal of Accounting Education, 44, 49-59.

Reference Book:

- Batt, S., Grealis, T., Harmon, O., & Tomolonis, P. (2020). Learning Tableau: A data visualization tool. The Journal of Economic Education, 51(3-4), 317-328.

Course Code- DMMED4	Business Analytics

Learning objectives:

- Understand the role and applications of analytics across various business domains.
- Learn to use Conjoint Analysis, Campaign Analytics, and Multi-dimensional Scaling in business decision-making.
- Develop skills in customer propensity modeling and credit risk modeling.

Unit I - Using Analytics in Business: What is Analytics, Use of Analytics in different Business Domains.

Unit II - Conjoint Analysis: What is Conjoint Analysis, Use of Conjoint Analysis, How is it done.

Unit III - Campaign Analytics: How Campaign Success is Measured, TRP and GRP, Trend and Adstock Effect, Modelling Campaign Effectiveness.

Unit IV - Multi-dimensional Scaling: What is MDS, Performing MDS.

Unit V - Perceptual Maps: What is Perceptual Map, Creating Perceptual Maps.

Unit VI - Credit Risk Modelling: What is Credit Risk, Different Credit Risk Models, Credit Risk Modelling.

Unit VII - Customer Propensity Modelling: What is Propensity Model, Different Types of Propensity Models.

Unit VIII - Advanced Propensity Models: Creating Propensity Models, Using Neural Networks in Propensity Models.

Unit IX - Price Optimization: Price Elasticity of Demand, Modelling Price Demand Curve, Optimizing Price.

Unit X - RPC Concepts and Implementation Approach: Different Approaches of RPA, 5-Step Implementation Approach of RPA.

Textbook:

Marketing Models (Kotler, Lilien, Moorthy)

Reference Book:

- Marketing Models (Kotler, Lilien, Moorthy)
- Measuring Marketing: 101 key metrics every marketer needs (Davis)Marketing Analytics, Wayne L Winston, Wiley.

COMPUTATIONAL SCIENCE ELECTIVE SEMESTER - IV

Course Code: DMMEC3	Quantum Computing

Learning objectives:

- Understand quantum mechanics, qubits, and their role in computation and measurement.
- Explore quantum algorithms like Grover's search algorithm and quantum Fourier transform.
- Analyze quantum problem-solving techniques, including quantum tree search and optimization.
- Study quantum computing models, reversible circuits, and applications in optimization and neural computation.

Unit I - Introduction to quantum physics – -ary Evolution – Quantum Mechanics – Hilbert space – Quantum Time Evolution -Von Neumann.

Unit II - Entropy – Measurement – Schrodinger Equation – Heisenbergs uncertainty principle – Randomness – Computation with Qubits -Matrix Representation of Serial and Parallel Operations.

Unit III - Quantum Boolean Circuits -Periodicity – Quantum Fourier Transform – N-ary Transforms – Search and Quantum Oracle – Grovers Amplification.

Unit IV - Circuit Representation – Speeding up the Traveling Salesman Problem -The Generate-and -Test Method – Quantum Problem – Solving -Heuristic Search – Quantum Tree Search - Tarratacas Quantum Production System.

Unit V - Problem Solving-Rules-Logic-based operators-Frames – Categorial representation.

Unit VI - Binary vector representation-Production System-Deduction systems – Reaction systems – Conflict resolution – Human problem – solving – Information and measurement.

Unit VII - Reversible Computation-Reversible circuits – Toffoligate – Gate based Quantum Computer – standard gates and their operations.

Unit VIII - A General Model of a Quantum Computer – Cognitive architecture – Representation - Quantum Cognition.

Unit IX - Decision making – Unpacking Effects – Quantum Walk on a graph -Quantum annealing.

Unit X - Optimization problems – Quantum Neural Computation – Applications on Quantum annealing Computer – Development libraries – Quantum Computer simulation toolkits.

Textbook:

Jack D. Hidary, Quantum Computing: An Applied Approach, Firstedition, Springer International Publishing, 2019

Reference Book:

- Jack D. Hidary, Quantum Computing: An Applied Approach, Firstedition, Springer International Publishing, 2019
- N. David Mermin, Quantum Computer Science: An Introduction Firstedition, Cambridge University Press, 2007
- I. Chuang and M.Nielsen, Quantum Computation and Quantum Information, Cambridge University Press, 2012
- Michael A. Nielsen & Isaac L. Chuang, Quantum Computation and Quantum Information, 10th Anniversary Edition, Cambridge Press.
- Phillip Kaye, Raymond Laflamme, and Michele Mosca, An Introduction to Quantum Computing, Oxford University Press, 2007.

Course Code: DMMEC4	Natural Language Processing (Deep Learning)

Learning objectives:

- Apply Naïve Bayes, logistic regression, and neural networks for text classification and feature selection.
- Explore sentiment analysis, word sense disambiguation, and sequence labeling techniques.
- Understand unsupervised learning, language modeling, and sequence prediction with RNNs and HMMs.
- Study syntax parsing, part-of-speech tagging, and context-free grammar for NLP tasks.

Unit I - The bag of words, Learning algorithms -Naıve Bayes, Discriminative learning.

Unit II - Loss functions and large-margin classification, Logistic regression, Optimization, Additional topics in classification, Feature selection by regularization.

Unit III - Feed forward neural networks, designing neural networks, Learning neural networks, Convolutional neural networks.

Unit IV - Sentiment and opinion analysis, Word sense disambiguation, Design decisions for text classification, evaluating classifiers, Building datasets.

Unit V - Unsupervised learning, Applications of expectation-maximization, Semi supervised learning, Domain adaptation, other approaches to learning with latent variables.

Unit VI - N-gram language models, Smoothing and discounting, recurrent neural network language models, evaluating language models, Held-out likelihood, Perplexity, Out-of-vocabulary words.

Unit VII - Sequence labeling as classification, Sequence labeling as structure prediction, The Viterbi algorithm, Hidden Markov Models, Discriminative sequence labeling with features, neural sequence labeling, unsupervised sequence labeling.

Unit VIII - Part-of-speech tagging, Morph syntactic Attributes, Named Entity Recognition, Tokenization, Code switching, Dialogue acts.

Unit IX - Regular languages, Context-free languages, mildly context-sensitive languages.

Unit X - Deterministic bottom-up parsing, Ambiguity, Weighted Context-Free Grammars, Learning weighted context-free grammars, Grammar refinement, beyond context-free parsing.

Textbook:

Akmajian, A., R. A. Demers, A. K. Farmer, and R. M. Harnish (2010). Linguistics: An introduction to language and communication (Sixth ed.). Cambridge, MA: MIT press.

Reference Book:

- Akmajian, A., R. A. Demers, A. K. Farmer, and R. M. Harnish (2010). Linguistics: An introduction to language and communication (Sixth ed.). Cambridge, MA: MIT press.

ECONOMETRICS ELECTIVE SEMESTER - IV

Course Code- DMMEE3	Econometric Methods

Learning objectives:

- Apply OLS method to linear regression models and analyze assumptions.
- Perform hypothesis testing and calculate confidence intervals in regression.
- Conduct residual analysis and address specification issues in models.
- Analyze time series data with autocorrelation and use dummy variables in GLRM.

Unit I- The Ordinary Least Squares (OLS) Method, Linear Regression Models, Types of Content, General Line and OLS Estimation

Unit II- OLS Method in Other Scenarios, Abandoning Basic Assumptions, Method Behavior, Effect of Measurement Changes

Unit III- Properties of OLS Estimators: Moments and Properties, Variance Estimation, Matrix Forms

Unit IV-OLS Variance Calculation, Basic Concepts, Hypothesis Testing, Model Coefficients

Unit V- Hypothesis Testing in Linear Regression Models, T-Contrast, F-Contrast, Global Contrasts

Unit VI- Confidence Intervals: Objectives, In a Coefficient, In a Combination of Coefficients, Specification Problems: Use and Concept, Types of Problems, Unobservable Explanatory Variables

Unit VII- Prediction in Linear Regression Models, Prediction, Average Value Intervals, Applications

Unit VIII- Residual Analysis in Linear Prediction, Objectives and General Concepts, Analysis Tools, Waste Analysis

Unit IX- Qualitative Variables in GLRM I, Fundamentals, Models with Various Types of Information, Linear Metrics, Qualitative Variables in GLRM II, Binary Variables, Use of Dummy Variables, Time Series

Unit X - Autocorrelation: Basic Concepts, Consequences, Contrast, Heteroscedasticity, Concept and Contrasts, Consequences, Time Series

Textbook:

Jeffrey M. Wooldridge, Introductory Econometrics: A Modern Approach, Cengage Learning, 2020.

Reference Book:

- Damodar N. Gujarati and Dawn C. Porter, Basic Econometrics, McGraw-Hill Education, 2009.
- Jeffrey M. Wooldridge, Introductory Econometrics: A Modern Approach, Cengage Learning, 2020.
- William H. Greene, Econometric Analysis, Pearson Education, 2018.
- A.H. Studenmund, Using Econometrics: A Practical Guide, Pearson, 2016.
- James H. Stock and Mark W. Watson, Introduction to Econometrics, Pearson, 2019.
- Christopher F. Baum, An Introduction to Modern Econometrics Using Stata, Stata Press, 2006.
- Russell Davidson and James G. MacKinnon, Econometric Theory and Methods, Oxford University Press, 2004.

Course Code- DMMEE4	Bayesian Econometrics

Learning objectives:

- Understand Bayesian inference, including priors, likelihood, and posterior distributions.
- Apply Bayesian decision theory and posterior analysis for decision-making and hypothesis testing.
- Implement Bayesian regression and time series models, using techniques like MCMC.
- Apply Bayesian econometric models to real-world problems in finance, macroeconomics, and big data.

Unit I- Introduction to Bayesian Econometrics: Historical development and foundations of Bayesian inference, Comparison of Bayesian and frequentist approaches, Principles of subjective probability, Bayes' theorem and its applications, Role of prior, likelihood, and posterior distributions

Unit II- Bayesian Decision Theory: Decision-making under uncertainty, Loss functions and risk minimization, Posterior predictive distributions,

Unit III- Prior Distributions: Types of priors: informative, non-informative, and improper priors, Elicitation of priors, Conjugate priors and their role in Bayesian analysis, Hierarchical priors and shrinkage priors

Unit IV-Posterior Analysis: Properties of posterior distributions, Analytical derivation of posteriors for common models, Credible intervals and hypothesis testing

Unit V- Bayesian Computational Techniques: Numerical integration and simulation methods, Markov Chain Monte Carlo (MCMC) methods: Gibbs sampling and Metropolis-Hastings algorithm

Unit VI- Bayesian Regression Models: Bayesian linear regression, Posterior analysis for regression coefficients, Bayesian model selection and comparison, Predictive performance evaluation

Unit VII- Bayesian Time Series Analysis: Introduction to time series models in a Bayesian framework, Bayesian dynamic linear models, Bayesian estimation of ARIMA models, Application to forecasting

Unit VIII- Bayesian Econometric Models: Bayesian estimation of common econometric models: Probit, Logit, and Tobit, Bayesian hierarchical models, Bayesian treatment of endogeneity and instrumental variable models

Unit IX- Applications of Bayesian Econometrics: Applications in finance: portfolio allocation, risk modelling,

Unit X - Applications in macroeconomics: forecasting and policy evaluation, Bayesian approaches to big data econometrics

Textbook:

- Andrew Gelman, John B. Carlin, Hal S. Stern, David B. Dunson, Aki Vehtari, Donald B. Rubin - Bayesian Data Analysis (3rd Edition).

Reference Book:

- Andrew Gelman, John B. Carlin, Hal S. Stern, David B. Dunson, Aki Vehtari, Donald B. Rubin - Bayesian Data Analysis (3rd Edition)
- William H. Greene - Econometric Analysis (6th Edition)
- Robert L. McCulloch, Peter E. Rossi, and John Geweke - Bayesian Statistics and Marketing.

5.3. Duration of the programme

Programme	**Level**	**Duration**	**Maximum duration for completion**	**Credits**
M.Sc (Mathematics)	Master's Degree	2 years	(2+ 2) years (As per UGC Notification on Specification of Degree, 2014)	81 Credits

5.4. Faculty and support staff requirement

Academic Staff	**Number available to meet the required delivery norms**
Programme Coordinator	1 member
Course Coordinator	1 member
Course Mentor	1 member per batch of 250 students

5.5. Instructional delivery mechanisms

The Centre for Distance & Online Education of MUJ comprises of faculty members and staff who are well versed in Distance Education and Online delivery.

An Academic calendar depicting dates for all major events during each semester will be prepared by faculty members and shared with students through LMS, at the beginning of each academic session.

Apart from providing content in the form of Self Learning Material, enough e-learning resources in the form of Audio and Video content will be provided to students. Regular engagement of students will be ensured through the following means:

- Conduct of Webinars/live lectures/online lectures/Virtual Class
- By encouraging them to participate in mandatory Discussion Forums to stimulate their thinking, and to be able to fearlessly express their views in forums. These discussion forums will be moderated by faculty to provide equal opportunity for everyone to participate, as well as to ensure maintenance of decorum of the forum.
- Through periodic formative assessments

Regular evaluation of content learnt will be provided for, through Self-Assessment Questions within the SLM, as well as quizzes on the LMS. The quizzes can be taken any number of times, so that they reach a stage of being able to answer questions without errors, which is a reflection of their understanding of the concept.

Effort will be made to provide case studies to enhance their analytical ability and make right decisions.

Link to National Portals (SWAYAM/NPTEL) will be provided, as also link to University's digital library portal.

All links to additional reading will be provided in the LMS. Interested students can study beyond the confines of the syllabus.

5.6. Identification of media–print, audio or video, online, computer aided

LMS provides for all audio video content (e-learning material, e-pubs, faculty-led video sessions, virtual classrooms and discussion boards), dashboard of their progress in learning, comparison with their peers in terms of learning, regular notifications regarding upcoming Webinars/virtual classes, Assignments, Discussion Forum participations and Examinations. It also provides an opportunity for raising queries if any, and seek answers to the same, by chat bot or course mentors.

5.7. Student Support Services

The Student Support services will be facilitated by the Centre for Distance & Online Education, Manipal University Jaipur, Rajasthan which includes the pre-admission student support services like counselling about the programme including curriculum design, mode of delivery, fee structure and evaluation methods. Post-admission student support services include guiding students towards accessing e-identity card, LMS portal, Academic calendar and academic delivery. Examinations support staff shall answer queries pertaining to conduct of end-semester examinations, evaluation and issue of certificates.

6. Procedure for Admission, Curriculum Transaction and Evaluation

The purpose of Online education by Manipal University, Jaipur is to provide flexible learning opportunities to students to attain qualification, wherever learners are not able to attend the regular classroom teaching. Academic programmes offered for such candidates under Online Learning mode will be conducted by Centre for Distance & Online Education-Manipal University Jaipur with support of the various University schools. The programmes/courses may be termed Online mode for award of Degree. Eligibility criteria, programme/course structure, curriculum, evaluation criteria and duration of programme shall be approved by Board of Studies and Academic Council which are based on UGC guidelines.

Candidates seeking admissions in any programme offered by Centre for Distance & Online Education-Manipal University, Jaipur shall fill up online application form available on CDOE-MUJ website. Before applying, candidates must check eligibility criteria for programme that they are interested in. Details about Eligibility criteria, programme structure, curriculum, duration, and fee structure are available on the website.

6.1. Procedure for Admission

6.1.1 Minimum Eligibility Criteria for admission

- Candidate must have a 10 + 2 + 3 years BSc degree or equivalent qualification as recognized by Association of Indian Universities (AIU) or other competent body in any discipline from a recognized University/Institution with a minimum of 50% (45% for Reserved category) marks in aggregate.

Important Instructions:

- All admissions shall be provisional until and unless candidates meet the eligibility criteria.
- Admission will stand cancelled if a candidate CDOEs not meet eligibility criteria, or there is failure to pay programme/course fees.
- Admission will stand cancelled, if candidate CDOEs not submit proof of eligibility within stipulated time given by Centre for Distance & Online Education-Manipal University, Jaipur.

- Centre for Distance & Online Education-Manipal University, Jaipur has the right to make necessary changes from time to time as deemed fit in Eligibility criteria, programme/course structure, curriculum, duration, fee structure and programme announcement dates. All changes will be notified on website.
- Candidates should carefully read all instructions given in Programme prospectus before start of application form.

6.1.2. Fee Structure and Financial assistance policy

Suggested Fee for M.SC Mathematics programme is INR 80,000/- (Eighty Thousand only).

A scholarship of up to 20% on tuition fees will be provided to Divyang students / Defence background. A scholarship of up to 10% on tuition fees will be provided to students from Public Sector Undertaking / Merit scholarship (80% in graduation and above).

6.2. Curriculum Transactions

6.2.1. Programme Delivery

Manipal University, Jaipur has state-of-the-art mechanism for online mode of Academic delivery to ensure quality education. Faculty members at MUJ offer expert guidance and support for holistic development of the students. Faculty members are not mere facilitators of knowledge but they also mentor students to make learning more engaging and maintain high retention level. The programme will be delivered with an aim to provide expertise and ensure that students excel in their domains. The features of programme delivery are:

- Online Mode of Academic Delivery
- Periodic review of Curriculum and Study material
- Live Interactive lectures from faculty / Course coordinators
- Continuous Academic and Technical support
- Guidance from Course Co-ordinators
- Learning and delivery support from Course Mentors

6.2.2. Norms for Delivery of Courses in Online Mode

S. No.	Credit value of the course	No. of Weeks	No. of Interactive Sessions		Hours of Study Material		Self-Study hours including Assessment etc.	Total Hours of Study (based on 30 hours per credit)
			Synchronous Online Counselling/ Webinars/ Interactive Live Lectures (1 hour per week)	Discussion Forum/ asynchronous Mentoring (2 hours per week)	e-Tutorial in hours	e-Content hours		
1.	2 Credits	6 weeks	6 hours	12 hours	10	10	22	60
2.	3 Credits	9 weeks	9 hours	18 hours	15	15	33	90
3.	4 Credits	12 weeks	12 hours	24 hours	20	20	44	120

6.2.3. Learning Management System to support Online mode of Course delivery

LMS Platform has been built to help learners reach their potential in their chosen programme. It is a secure, reliable learning experience tool that works consistently on Web and Mobile devices. Its simple interface makes it easy for instructors to design courses, create content and grade assignments. It provides a great mobile experience due to the responsive design which is paired with purpose-built native apps. It provides seamless accessibility to ensure all tools are standards-compliant and easy for students to navigate using assistive technologies. It provides 24 X 7 learning experience to facilitate learning as per the pace chosen by learners. Digital portfolio functionality allows students to document and share their learning journey as it happens, on both web and mobile platforms.

6.2.4. Course Design

The Course content is designed as per the SWAYAM guidelines using 4-quadrant approach as detailed below to facilitate seamless delivery and learning experience

(a) Quadrant-I i.e. e-Tutorial, that contains – Faculty led Video and Audio Contents, Simulations, video demonstrations, Virtual Labs

(b) Quadrant-II i.e. e-Content that contains - Portable Document Format or e-Books or Illustration, video demonstrations, documents as required.

(c) Quadrant-III i.e. Discussion forums to raise and clarify doubts on real time basis by the Course Coordinator and his team.

(d) Quadrant-IV i.e. Self-Assessment, that contains MCQs, Problems, Quizzes, Assignments with solutions and Discussion forum topics.

6.2.5. Academic Calendar

Sl No.	Event	Batch	Last Date (Tentative)
1	Commencement of semester	January	1st January
		July	1st July
2	Enrol student to Learning Management system	January	Within 2 working days of fee confirmation
		July	
3	Assignment Submission	January	March end and April end
		July	September end and October end
4	Submission of Synopsis (Applicable during Pre final semester)	January	30th April
		July	30th October
5	Project Report Submission (Applicable during Final semester)	January	30th April
		July	30th October
6	Webinars / Interactive Live Lectures and Discussion Forum for query resolution	January	Mar to May
		July	September to November
7	Admit Card Generation	January	3rd week of May
		July	3rd week of Nov
8	Term End Examination	January	2nd week of June (TEE June)
		July	2nd Week of December (TEE December)
9	Result Declaration of End Term Examination	January	Last week of August
		July	Last week of February

6.3. Evaluation

The students' learning in a course would be evaluated based on Internal assignments, students' response sheets, and semester end examinations. University adopts rigorous process in development of question papers, question banks, assignments and their moderation, conduct of examinations, evaluation of answer scripts by qualified teachers, and result declaration. The Directorate shall frame the question papers so as to ensure that no part of the syllabus is left out of study by a learner.

The evaluation shall include two types of assessments-continuous or formative assessment in the form of assignments, and summative assessment in the form of end semester examination or term end examination which will be held with technology supported remote proctored examination tool.

However, we shall be considering the guidelines issued by the Regulatory bodies from time-to-time about conduct of examinations.

The examinations shall be conducted to assess the knowledge acquired during the study. There shall be two systems of examinations viz., internal and external examinations. In the case of theory courses, the internal evaluation shall be conducted as Continuous Internal Assessment via Student assignments preparation, quizzes. The internal assessment shall comprise of maximum of 30 marks for each course. The end semester examination shall be of three hours duration for each course at the end of each semester.

6.3.1. Question Paper Pattern

Time: 3 Hours
Max. Marks: 70

Part A - (Multiple Choice Questions) - 10 x 2 Marks = 20 Marks

Part B - (Short Answers) - Answer any 4 (out of 6) 4 x 5 Marks = 20 Marks

Part C – (Long Answers) – Any 3 (out of 4) x 10 Marks = 30 Marks

6.3.2. Distribution of Marks in Continuous Internal Assessments

The following procedure shall be followed for awarding internal marks for theory courses. Student must submit two assignments each carrying 30 marks and average of both will be considered as internal assessment marks.

6.3.3. Passing Minimum

The students are considered as passed in a course if they score 40% marks in the Continuous Evaluation (IA) and Term-End Examinations (TEE) individually. If a student fails in any one component (failure to get 40% marks either in IA or TEE), then he/she will be required to re-appear for that component only (IA or TEE as the case may be).

6.3.4. Marks and Grades

Based on the total marks obtained for each course in Internal Assessment and Term End examinations, student will be awarded grade for that course. The following table gives the marks, grade points, letter, grades and classification to indicate the performance of the candidate.

Range of Marks	Grade Points	Letter Grade	Description
≥90 to ≤100	10	A+	Outstanding

≥80 to <90	9	A	Excellent
≥75 to <80	8	B+	Distinction
≥70 to <75	7	B	Very Good
≥60 to <70	6	C+	Good
≥50 to <60	5	C	Average
≥40 to <50	4	D+	Below Average
<40	0	F	Re-appear
ABSENT	0	AAA	ABSENT

For a semester:

Grade Point Average [GPA] = $\sum_i C_i G_i / \sum_i C_i$

Grade Point Average =

$$\frac{\text{Sum of the multiplication of grade points by the credits of the courses}}{\text{Sum of the credits of the courses in a semester}}$$

C_i = Credits earned for the course i in any semester
G_i = Grade Point obtained for course i in any semester.

n refers to the semester in which such courses were credited

For the entire programme:

Cumulative Grade Point Average [CGPA] = $\sum_n \sum_i C_{ni} G_{ni} / \sum_n \sum_i C_{ni}$

$$\text{CGPA} = \frac{\text{Sum of the multiplication of grade points by the credits of the entire programme}}{\text{Sum of the credits of the courses for the entire programme}}$$

7. Requirement of the Laboratory Support and Library Resources

7.1. Laboratory Support

No lab-based courses are offered in this program.

7.2. Library Resources

Centre for Distance & Online Education, Manipal University Jaipur, Rajasthan has excellent Library facility with adequate number of copies of books in relevant titles for M.Sc (Mathematics) programme. The Central Library of Manipal University Jaipur is also having good source of reference books. The books available at both the libraries are only for reference purpose and lending services. In addition, reference books as prescribed will be procured. The

Digital library access will also be made available to students who are enrolled into online mode of education. In addition, the university membership on Swayam/ NPTEL/ Knimbus will also be made available to students. Complete e-Learning resources to course would be made available on Learning Management System for learning along with e-tutorial lectures. Further, expert lectures/workshops/ webinars by industry experts would also be conducted for the students.

8. Cost Estimate of the Programme and the Provisions

The cost estimate of the Programme and provisions for the fund to meet out the expenditure to be incurred in connection with M.Sc (Mathematics) Programme as follows:

Sl. No.	Expenditure Heads	Approx. Amount
1	Programme Development (Single Time Investment)	82,00,000 INR
2	Programme Delivery (Per Year)	9,00,000 INR
3	Programme Maintenance (Per Year)	42,00,000 INR

9. Quality assurance mechanism and expected programme outcomes

The quality of the programme depends on scientific construction of the curriculum, strong-enough syllabus, sincere efforts leading to skilful execution of the course of the study. The ultimate achievement of M.Sc (Mathematics) programme of study may reflect the gaining of knowledge and skill in area of mathematics. Gaining of knowledge and skills in mathematics may help the students to get new job opportunities, upgrading their position not only in employment, but also in the society.

The benchmark qualities of the programme may be reviewed based on the performance of students in their end semester examinations. Also, the feedback from the alumni, students, parents and employers will be received and analysed for further improvement of the quality of the programme.

Manipal University Jaipur has constituted Centre for Internal Quality Assurance (CIQA), which will assist Director, Centre for Distance & Online Education to conduct periodic review and assessments and assist the Directorate to implement necessary quality measures and effectiveness in programme delivery. CIQA is constantly involved in reviewing all materials prepared by CDOE, including syllabus, SLMs and e-learning content. CIQA will be involved in conducting studies to measure effectiveness of methods adopted for learning. As we proceed further, CIQA will involve in benchmarking quality of academic delivery, and perform various analyses, and guide all stakeholders towards upgrading quality constantly.

Centre for Internal Quality Assurance Committee (CIQAC) chaired by the Vice Chancellor consisting of internal and external experts oversees the functioning of Centre for Internal Quality Assurance and approve the reports generated by Centre for Internal Quality Assurance on the effectiveness of quality assurance systems and processes.

In addition to CIQA, as per the guidelines of National Assessment and Accreditation Council (NAAC), Manipal University Jaipur has constituted Internal Quality Assurance Cell (IQAC), in which academicians, industry representatives and other stakeholders are nominated as members. The IQAC is a part of the institution's system and work towards realisation of the goals of quality enhancement and sustenance, as quality enhancement is a continuous process. The prime task of the IQAC is to develop a system for conscious, consistent, and catalytic improvement in the overall performance of institutions. The work of the IQAC is the first step towards internalization and institutionalization of quality enhancement initiatives. IQAC's elementary motive is to promote measures for institutional functioning towards quality enhancement through internalization of quality culture and institutionalization of best practices.

The guidelines on quality monitoring mechanism prescribed by the UGC have been adopted by the Centre for Internal Quality Assurance for conducting institutional quality audits, to promote quality assurance and enhance as well as spread best-in-class practices of quality assurance. University has setup an effective system for collecting feedback from the stakeholders regularly to improve its programmes. The University will conduct self-assessments regularly and use the results to improve its systems, processes etc. and finally quality of programmes.