DEPARTMENT OF MATHEMATICS

M.Sc Mathematics Programme

Regulations, Syllabus and Curriculum

Under Choice Based Credit System (CBCS)

Effective from the academic year **2023-24**

Rajiv Gandhi National Institute of Youth Development

(Institution of National Importance by the Act of Parliment No. 35/2012)
Ministry of Youth Affairs and Sports, Government of India, Sriperumbudur, Tamil Nadu.

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Dr. Parthasakha Das, HoD(i/c)
RGNIYD

Department of Mathematics
Rajiv Gandhi National Institute of Youth Development
M.Sc Mathematics - Syllabus and Curriculum
(For the students admitted during the academic year 2023 - 24 onwards)

Vission

Department of Mathematics aspires to be recognized as an internationally reputed centre for pure and applied mathematics research by creatively using mathematics for the betterment of the society.

Mission

Mission of the department is

- To mentor students by providing them an environment that is supportive in fostering intellectual skills.
- To produce graduates with right attitude who are ready to face the societal and professional challenges.
- To train the graduates with skillsets required for interdisciplinary research.
- To utilize the diverse mathematical and statistical skills for providing consultancy services that solves the societal and industrial problems.

Programme Description

The Mathematics course in RGNIYD is a two years master's course. This is a rigorous course with equal emphasis on theory and application. The course has interdisciplinary topics enabling research in multiple disciplines a possibility. The electives offered give exposure in domains as varied as graph theory,dynamical systems, evolutionary game theory, mathematical modeling, and bio-mathematics.

The course has dedicated labs to give hands on experience in python programming. This makes the learning of statistics, Machine learning and deep learning interesting towards various jobs.

Programme Objectives:

- To impart fundamental knowledge, technical & thinking skills in the areasof mathematical science and applications for gaining superiority.
- Enable the students to get placed in leading organizations across theglobe.
- Enable the students to pursue research in advanced Mathematics or allied subjects like Data Analytics, Machine Learning, and Deep learning.
- To encourage interdisciplinary research through application of Mathematics in science, biological systems, engineering, economics and social science.

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Programme Outcomes:

- Inculcate critical thinking to conduct scientific investigation objectively without being biased with preconceived notions.
- Apply knowledge of Mathematics in all fields of learning, including research and its extensions.
- Equip the student with skills to analyze problems, formulate a hypothesis, evaluate and validate results, and draw reasonable conclusions.
- Prepare students for pursuing research or careers in industry in mathematical sciences and allied fields.
- Imbibe practical scientific and technical communication in both oral and writing.
- Continue to acquire relevant knowledge and skills pertinent to professional activities and exhibit the highest standards of ethical issues in mathematical sciences.
- Create awareness to become an enlightened citizen committed to delivering one's responsibilities within the scope of bestowed rights and privileges.
- Inculcate mathematical reasoning and logic and also develop problems solving capability.
- Work effectively as an individual and as a member or leader in multi-linguistic and multi-disciplinary teams.
- Effectively communicate about their field of expertise in their activities, with their peers and society, such as comprehending and writing useful reports, designing documentation, and making effective presentations.

Programme Specific Outcomes:

- Provide advanced knowledge on pure and applied mathematics topics, empowering the students to pursue higher degrees at reputed academic institutions.
- Prepare and enlighten students for research studies in mathematics and related fields.
- Nurture problem-solving skills, thinking, and creativity through assignments, project works, etc.
- Administer students in preparing (personal guidance, books) for competitive exams, e.g., NET, SET/SLET, GATE, etc.
- Provide knowledge of a wide range of mathematical techniques and application of mathematical methods.
- Provide job-oriented courses to the students.

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CREDIT STRUCTURE

Category-wise Credit distribution

Programme Credit Structure	Credits
Mathematics Core	42
Mathematics Electives	12
Allied Core	12
Soft Core/Open Elective	02
Master Thesis	12
Total Credit	80

L=Lecture, T = Tutorial, P = Practical, PD = Project Discussion, C=Credit

Course Code	Course Title	Category	Mark	L	T	P/PD	C
SEMESTER-I							
MSMA101	Abstract Algebra	Core	100	3	1	0	4
MSMA102	Real Analysis	Core	100	3	1	0	4
MSMA103	Ordinary and Partial Differential Equations	Core	100	3	1	0	4
MSMA104	Probability & Statistics	Core	100	3	1	0	4
MSCS **102**	Python Programming	Allied	100	2	0	0	2
MS**MA105**	Statistical Lab by R/Python	Practicum	100	0	0	4	2
		Total	600	12	4	4	20

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SEMESTER-II							
MSMA201	Topology	Core	100	3	1	0	4
MSMA202	Linear Algebra	Core	100	3	1	0	4
MSMA203	Complex Analysis	Core	100	3	1	0	4
CSAI 2001	Machine Learning	Allied	100	3	0	0	3
CSAI 2003	Machine Learning Lab	Allied Practicum	100	0	0	4	2
MSMAEXX	Elective I	Elective	100	2	1	0	3
		Total	600	14	4	4	20
SEMESTER-III							
MSMA301	Functional Analysis	Core	100	3	1	0	4
MSMA302	Numerical Methods	Core	100	3	1	0	4
MSMA303	Operations Research	Core	100	3	1	0	4
CSAI 3001	Neural Networks And Deep Learning	Allied	100	3	0	0	3
CSAI 3003	Neural Networks And Deep Learning Lab	Allied Practicum	100	0	0	4	2
MSMAEXX	Elective II	Elective	100	2	1	0	3
xxxxxxxxx	SoftCore/Open Elective from other Departments		100	2	0	0	2
		Total	700	16	4	4	22
SEMESTER –IV							
MSMAEXX	Elective III	Elective	100	2	1	0	3
MSMAEXX	Elective IV	Elective	100	2	1	0	3
MSMA401	Project, Dissertation		400	0	0	12	12
		Total	600	4	2	12	18

Total Full Marks=2500, Total Credits-80

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LIST OF ELECTIVE COURSES

Course Code	Course Title	L	T	P	C
MSMAE01	Graph Theory	2	1	0	3
MSMAE02	Dynamical Systems	2	1	0	3
MSMAE03	Statistical Data Analytics	2	1	0	3
MSMAE04	Mathematical Modelling	2	1	0	3
MSMAE05	Bio-Mathematics	2	1	0	3
MSMAE06	Evolutionary Game Theory	2	1	0	3
MSMAE07	Nonlinear Differential Equations	2	1	0	3
MSMAE08	Classical Mechanics & Calculus of Variations	2	1	0	3
MSMAE09	Transform Techniques & Integral Equations	2	1	0	3
MSMAE10	Computational Fluid Dynamics	2	1	0	3
MSMAE11	Financial Mathematics	2	1	0	3
MSMAE12	Sports Analytics	2	1	0	3
MSMAE13	Numerical Linear Algebra	2	1	0	3
MSMAE14	Industrial Statistics	2	1	0	3
MSMAE15	Nonlinear Programming	2	1	0	3
MSMAE16	Advanced Complex Analysis	2	1	0	3
MSMAE17	Fixed point Theory	2	1	0	3
MSMAE18	Fluid Dynamics	2	1	0	3
MSMAE19	Operator Theory	2	1	0	3

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MSMAE20	Measure and Integration	2	1	0	3
MSMAE21	Machine Learning in Finance	2	1	0	3
MSMAE22	Mathematical Image Analysis	2	1	0	3
MSMAE23	Bio-Statistics	2	1	0	3
MSMAE24	Commutative Algebra	2	1	0	3
MSMAE25	Algebraic Topology	2	1	0	3

N:B: Students undergo the elective courses in each semester, offered by Department.

ELECTIVES OFFERED TO ALLIED DEPARTMENTS

Course Code	Course Title	L	T	P	C
MSMA104	Probability & Statistics (Semester-I)	3	1	0	4
MSMA302	Operations Research (Semester-III)	3	1	0	4

OPEN ELECTIVE OFFERED TO OTHER DEPARTMENTS

Course Code	Course Title	L	T	P	C
MSMAOE001	Mathematics for Machine Learning (Semester-II)	2	1	0	3

SOFTCORE/OPEN ELECTIVE

Course Code	Course Title	L	T	P	C
xxxxxxx	Soft Core (English for Communication / Ethics & IPR / Leadership Communication / Understanding human behavior/	2	0	0	2

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JOB ORIENTED ALLIED COURSES

Course Code	Course Title	L	T	P	C
MSMA105	Statistical Lab by R/Python	0	0	4	2
CSAI 2001	Machine Learning	3	0	0	3
CSAI 2003	Machine Learning Lab	0	0	4	2
CSAI 3001	Neural Networks And Deep Learning	3	0	0	3
CSAI 3003	Neural Networks And Deep Learning Lab	0	0	4	2

JOB ORIENTED ELECTIVE COURSES

Course Code	Course Title	L	T	P	C
MSMAE03	Statistical Data Analytics	2	1	0	3
MSMAE04	Mathematical Modelling	2	1	0	3
MSMAE05	Bio-Mathematics	2	1	0	3
MSMAE06	Evolutionary Game Theory	2	1	0	3
MSMAE10	Computational Fluid Dynamics	2	1	0	3
MSMAE11	Financial Mathematics	2	1	0	3
MSMAE12	Sports Analytics	2	1	0	3
MSMAE14	Industrial Statistics	2	1	0	3
MSMAE15	Nonlinear Programming	2	1	0	3
MSMAE21	Machine Learning in Finance	2	1	0	3
MSMAE22	Mathematical Image Analysis	2	1	0	3
MSMAE23	Bio-Statistics	2	1	0	3

ONLINE COURSES

Course Code	Course Title
MSMAE24 & MSMAE25	SWAYAM, MOOC, NPTEL etc.

SWAYAM, MOOC, NPTEL - online course shall be of duration at least 12 weeks with at 3 credits. The course shall be mandatory and shall be completed during the fourth semester for intern student (i.e., before the end of the fourth semester).

VALUE ADDED COURSES

Course Code	Course Title
MA22V001	Introduction to LaTeX and Scientific Writing
MA22V002	MATLAB for Scientific Computing

Pattern for question Papers: 100 Marks

Internal Assessment: 25 Marks

- Internal test=10 Marks (Number of internal:02; which is mandatory by diving into two parts from five units)
- Presentation=10 Marks
- Assignment=05 Marks

External Assessment: 75 Marks

Number pattern: (5 Questions x 6 Marks=35, 5 Questions x15 Marks=45,)

Group-A

1. Attempt all 5 questions. Every question must have one alternative question.

2. It is mandatory to take unit wise question; alternative question must be taken from same unit.

3. Weightage of each question might be divided (2+4) or, (3+3) depending upon level of question

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Group-B

1. Attempt any 3 questions out of 5 questions. (To increase the possibility to attempt more question).
2. It is mandatory to take unit wise question.
3. Weightage of each question might be divided (10+5) or, (8+7), or (9+6) depending upon level of question.

General Guideline:

- It is mandatory to incorporate more mathematical problems rather than theoretical proofs like(Except)

80% Math & 20% Theory

Or,

60% Math & 40% Theory

Or,

70% Math & 30% Theory,

Note: Each question must be taken from suggested text books and references books.

Assessment of M.Sc thesis/Project, viva-voce, presentation, effective from academic session 2023-25

Credit Score: **12,** Assessment: **400 Marks**

Distribution of Evaluation:

External Expert: 200 Marks (Project Dissertation: 100 Marks , Viva-Voce : 50 Marks, Seminar Presentation: 50 marks).

Internal Expert*: 200 Marks (Project Dissertation: 200 Marks Viva-Voce : 50 Marks, Seminar Presentation: 50 marks).

N:B: **Average number will be considered all internal faculties during viva-voce examination.**

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Guidelines for Project Work (On Campus)

Students have to undergo through a Project Work under the guidance of the Faculty(s) of the Department and on the basis of subject interest of the students with project proposal in advanced field of study in different areas of Mathematics. Supervisor allocation would be done during end of third Semester-III based on average number of top three course score from previous each semester(top three score from semester-I+ top three score from semester-II) along with research proposal and a list of preferences of supervisors.

Process of Assigning Supervisors:

- Students are to submit a detailed project proposal outlining the problem, objectives, methodology, timeline, and potential outcomes. The proposal will be reviewed and approved by the faculty advisor.

- Each student will present their project or thesis findings to a panel of faculty members, peers, and potentially external experts during viva-voce The presentation will be followed by a defense where the student will respond to questions from the panel.

- Students present their work to a panel of faculty members, peers, and possibly external experts. They defend their choices, methodology, findings, and insights during a Q&A session. The panel evaluates the project or thesis based on these metrics and their overall alignment with program objectives.

Examination Related Course Criteria

i. Project Work will be made by the students under the guidance of the faculty(s) of the Department and students might collaborate with external experts with approval of supervisors.

ii. Dissertation of the Project Work will be prepared by individual student and the same be submitted to the HOD/ COE after countersigned by the concerned faculty(s) and prior to commencement of Viva-Voce.

iii. Project Work related Record be maintained by the Department.

iv. The project work will be performed on some advanced topics or review work of research papers.

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Evaluation parameters of Dissertation:

- Research Question: Clarity and relevance of the chosen research question.
- Literature Review: Depth and thoroughness of the literature review.
- Research Design and Methodology: Appropriateness and rigor of the research design andmethodology.
- Data Collection and Analysis (if applicable): Quality of data collection methods and depth of analysis.
- Contribution to the Field: Novelty, significance, and potential impact of research findings.
- Insights and Interpretation: Depth and clarity of interpreting research outcomes.
- Writing Quality: Clarity, organization, grammar, and adherence to academic writing standards.

Guidelines for Internship/ Project Work (Off Campus)

If the candidates undergo a **four to six** months dedicated internship/project during their fourth semester course of study in any of the Industries / MNCs / Organizations through approval of Head of Department, then they must take two additional courses of at least 12 weeks with **credit 3 each** from SWAYAM / MOOC / NPTEL etc., instead of their regular course offered by RGNIYD during the fourth semester. Courses from Online Platform (**SWAYAM, MOOC, NPTEL**) are suggested by the Department. Moreover, they have to appear for project- viva voce with dissertation during the same with campus students. A copy of certificates of online courses has to be submitted to COE for issuing mark sheet during end of course.

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MSMA101	Abstract Algebra	L	T	P	C
		3	1	0	4

Pre-requisite: Basic Knowledge in preliminaries of Group Theory & Ring

Course Objectives:

CO1: Learn the elementary concepts involved in homomorphism andisomorphism.
CO2: Develop the ability to form and evaluate group theory and its actions.
CO3: Understand the fundamental concepts of abstract algebra which include Sylowtheorems and relative this concept to the direct products and abelian groups.
CO4: Explain the notion and use the notion of ring theory.
CO5: Demonstrate the relationship between ring, field and module theory.

Unit-I	Groups	12 hrs

Normal subgroups and Quotient groups., Homomorphism of groups and Isomorphism Theorems.

Unit-II	Sylow theorems	12 hrs

Conjugacy classes, Cayley's Theorem. Generalized Cayley's Theorem, Cauchy's Theorem & p-group, Sylow Theorems and their applications. Classifications of small order groups up to isomorphisms.

Unit-III	Solvable groups and Finitely generated abelian groups	12 hrs

Solvable groups, Jordan-Hölder Theorem and its applications. Finite Abelian Group , Finitely Generated Abelian Group, Fundamental theorem of finitely generated abelian group.

Unit-IV	Subrings, Ideals and homeomorphisms	12 hrs

Ideals and quotient rings, homomorphisms, isomorphism theorems, field of quotients, Polynomial rings. Euclidean domains, Prime and irreducible elements . Divisibility Theory.

Unit-V	Euclidean domains & Unique Factorization Domain	12 hrs

Principal Ideal Domain, Unique Factorization Domain, Irreducibility of Polynomial, Eisenstein irreducibility criterion. Field extensions, algebraic field extensions and finite fields.

Text Book:

1. **D.S.Malik, J.M.Mordeson, M.K.Sen; Fundamentals of Abstract Algebra, McGraw-Hill**
2. Abstract Algebra,by David S. Dummit and Richard M. Foote, Third Edition, Wiley (2018).

Reference Books:

1. I.N. Herstein, Topics in Algebra, 2nd Edition, John-Wiley & Sons, 1975. College, 1997
2. Contemporary Abstract Algebra; Joseph A Gallian, Brooks/Cole Cengage Learning, 2013

Course Outcomes:

EO1: Demonstrate ability to think group actions critically by Cayley's theorem.

EO2: Use the logical connectives on abstract algebra to decide whether an argumentis a tautology or contradiction.

EO3: Effectively write abstract mathematical proofs in a clear and logical manner.

EO4: Apply the Sylow theorems to describe the structure of certain finite groups

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MSMA102	Real Analysis	L	T	P	C
		3	1	0	4

Pre-requisite: Calculus

Course Objectives:

CO1: The main objective of this course is to introduce students to the theory andmethods of Real Analysis
CO2: Students should be able to implement the theorems taught in the course to workassociated problems, including proving results of suitable accessibility
CO3: This course will focus on the proofs of basic theorems of analysis
CO4: The way to establish the proofs, many new concepts will be introduced
CO5: Understanding the basic concepts and their properties are important for the development of the present and further courses

Unit-I	Riemann Integrability	12 hrs

Upper and lower Riemann integrals. Riemann integral. A 2^{nd}definition of Riemann integrability. Summation of series Theorem. Necessary and sufficient condition for integrability. Integrability of the sum, difference, product,quotient, modulus and square of integrable functions, . Fundamental theorem of integral calculus. Generalized mean value theorem. Abel's lemma. Second mean value theorem(Weierstrass form). Some useful problems.

Unit-II	Riemann Stieltjes Integral	12 hrs

Partition of a set. Lower and upper Rieman–Stieltjes sums. The lower and upper Riemann–Stieltjes integrals. The Riemann–Stieltjes integral as a limit of sum. Some useful inequalities related to R-S integrals. Reduction of Riemann–Stielijes integral into Riemann integral. Some useful theorems. Some useful problems.

Unit-III	Uniform Convergence Of Sequences And Series Of Functions	12 hrs

Cauchy's general principle of uniform convergence. A test for uniform convergence of sequence of functions. Integrability of uniform limit of a uniformly convergent sequence of integrable functions Test for the uniform convergence of a series. Cauchy's general principle of convergence. Weierstrass' M-Test for uniform convergence. Abel's test and Dirichlet's test. The Weierstrass approximation theorem..

Unit-IV	Metric Spaces	12 hrs

Continuous functions on metric spaces . Homeomorphism. Sequence in a metric space. Cauchy sequence. Complete metric space . Properties of complete metric spaces . Cantor's intersection theorem. Contraction mapping principle . Banach's fixed point theorem. Some useful problems.

Unit-V	Compactness And Connectedness	12 hrs

Compact metric space. Balzano-Weierstrass property (BWP). Sequentially compact metric space. Countably compact metric space. Locally compact metric space. Connected metric spaces. Separated sets. Connected and disconnected sets. Components of a metric spaces . Connectedness of product of connected metric spaces. Some useful problems.

Text Book:

1. **Real Analysis - M.D. Raisinghania (S. Chand Publication)**
2. **Real Analysis, H L Royden, P M Fitzapatrick, pearson, fourth edition,**
3. Principle of Mathematical Analysis -S.L.Gupta,N.R.Gupta(Pearson Publication). S.L.Gupta, N.R. Gupta (Pearson Publication)
4. A. Kumar, S.Kumaresan, A Basic Course in Real Analysis, CRC Press, 2014

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Reference Books:

5. W. Rudin, Principles of Mathematical Analysis,Wiley International Edition,1985
6. T. Apostol, Mathematical Analysis, 2nd Edition, Narosa Publishing House, 1985
7. R.G. Bartle and D.R. Sherbert, Introduction to Real Analysis, 3rd Edition, WileyInternational Student edition, 2001.

Course Outcomes:

EO1: Determine the Riemann integrability and the Riemann- Stieltjes integrability of a bounded function and proved a selection of theorems concerning integration.

EO2: Recognize the difference between point wise and uniform convergence of a sequence of functions.

EO3: Determine the continuity, differentiability, and integrability of functions definedon subsets of the real line.

EO4: Able to learn advanced the metric spaces with relatedproblems.

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MSMA103	Ordinary and Partial Differential Equations	L	T	P	C
		3	1	0	4

Pre-requisite: Basic Knowledge in Algebraic & DifferentialEquations

Course Objectives:

CO1: To understand appropriate numerical methods to solve algebraic and transcendental equations

CO2: To perform an error analysis for various numerical methods and derive appropriate numerical methods to solve definite integrals.

CO3: To develop appropriate numerical methods to solve a system of linear equations.

CO4: To learn special kinds of differential equations such as elliptic, Parabolic andhyperbolic differential equations.

Unit-I	Ordinary Differential Equations	12 hrs

Linear Equation with constant coefficient- Homogeneous linear equation or Cauchy-Euler Equation. Method of variation of Parameters, Linear equation of higher orders and its application.

Unit-II	Successive approximation and Series solution	12 hrs

Picard's iterative method. Uniqueness and existence theorem. Total differential equation. Series solution. Lipschitz condition. Strum Liouville problem (Eigen function and eigen values)

Unit-III	Homogeneous and Non-Homogeneous Partial Differential equation	12 hrs

Homogeneous linear partial differential equation with constant coefficients: Working rule for finding C.F. of linear PDE with constant coefficient, Alternative working rule for finding C.F.

Non-Homogeneous linear partial differential equation with constant coefficients: reducible and irreducible linear partial differential equation with constant coefficients, General method of finding P.I. for reducible non-homogeneous linear PDE with constant coefficient.

Unit-IV	PDE with constant and variable coefficient	12 hrs

Partial Differential equation reducible to equation with constant coefficient: Method of reducible Euler Cauchy and its working rule. PDE of order two with variable coefficient: Type I, Type II, Type III, Type IV.

Unit-V	Canonical Form of PDE	12 hrs

Reduction to canonical or normal form, Riemann method: Laplace Transformation. Reduction to canonical form. Solution of linear hyperbolic equation. Monge's method.

Heat and Wave equation in one space variable;

Wave equation: Cauchy problem and D'Alembert Formula, Heat equation: Cauchy pro

Text Books:

1. Ordinary and Partial Differential Equations : M.D. Raisinghania, S Chand Publisher
2. Elements of Partial Differential Equations" by I. N. Sneddon, McGraw-Hill BookCompany, Singapore, 1957.

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3. G.F. Simmons & S.G. Krantz, Differential Equations: Theory, Technique, andPractice, TataMc-Graw Hill, 2012.
4. "An Introduction to Ordinary Differential Equations" by E.A. Coddington, Prentice Hall of India Ltd., New Delhi, 2009
5. S.L. Ross, Differential Equation, Fourth Edition, JohnWiley & Sons, 1984

Reference Books:

1. R.P. Agarwal and D. O'Regan, Ordinary and Partial Differential Equations, Springer-Verlag
2. "Differential Equations, Graduate Studies in Mathematics" by L.C. Evans PartialVol. 19, American Mathematical Society, 1998
3. L. Perko, Differential Equations and Dynamical Systems, Third Edition, Springer,2006.
4. M. Rama Mohana Rao, Ordinary Differential Equations - Theory and Applications, Affiliated East West Press, New Delhi, 1981.

Expected outcomes:

EO1: Solve algebraic and transcendental equations using appropriate numerical meth- ods and approximate a function using appropriate numerical methods.

EO2: Derive numerical methods for various mathematical operations and tasks such as interpolation, differentiation, integration and the solution of linear and non-linear equations.

EO3: Analyze and evaluate the accuracy of common numerical methods.

EO4: Demonstrate understanding of the numerical methods in real life problems.

EO5: To evaluate the numerical methods using software

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MSMA104	Probability & Statistics	L	T	P	C
		3	1	0	4

Pre-requisite: Basic knowledge in definitions and preliminaries of Mathematical Statistics

Course Objectives:

CO1: To provide a thorough treatment of probability ideas and techniques necessary for a firm understanding of the subject.
CO2: Understanding of the ideas in their proofs, and ability to make direct application of those results to related problems.
CO3: As evidence of that understanding, students should be able to demonstrate mastery of all relevant vocabulary, familiarity with common examples and counter examples, knowledge of the content of the major theorems

Unit-I	Random variables	12 hrs

Random variables - Conditional probability- Probability density function - Distribution function- Marginal and conditional distributions. Two Dimensional Random Variables: Joint distributions – Marginal and conditional distributions – Transformations of random variables of thecontinuous type.

Unit-II	Regression and Correlation	12 hrs

Mathematical expectation I & II: Expectations of functions of random variables. Moment generating function. Regression curve & lines – Correlation.

Unit-III	Some special distributions	12 hrs

Some special distributions: The Normal distribution - The Gamma and Chi-Square Distributions and related problem. Chebyshev's inequality and related problem. Central-limit theorem (statement only).

Unit-IV	Sampling theory	12 hrs

Sampling theory- Introduction to statistical inference: Point Estimation –Unbiased estimator- Maximum Likelihood estimate- Confidence intervals for means & variances of Normal population - Curve fitting by principle of least squares: Straight-line & Parabola – Regression lines- Goodness fit.

Unit-V	Testing Of Hypothesis	12 hrs

Testing Of Hypothesis: Type I and Type II errors- Small and large samples – Tests based on Normal, t and Chi square distributions for testing of mean, variance

Text Book:

1. **Fundamental of Mathematical Statistics, Gupta & Kapoor. Sultan Chand & Sons 2002**
2. Mathematical Probability, Banerjee, De and Sen. U. N Dhur & Sons Private LTD
3. Mathematical Statistics, De and Sen. U. N Dhur & Sons Private LTD

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Reference Books:

1. S. Ross, A first Course in Probability, 6th Edition, Pearson Education, 2006
2. Oliver C Ibe, Fundamental of applied probability & Random Process.
3. "Probability theory and Mathematical statistics" by Marek Fisz, John Wiley andSons, Third Edition, New York, 1963.

Course Outcomes:

EO1: The ability to use and simulate random variables, distribution functions, probability mass functions, and probability density functions.

EO2: Through calculus and functional transformations, to answer quantitative questions about the outcomes of probabilistic systems.

EO3: The ability to use and simulate multivariate distributions, independence, conditioning, and functions of random variables.

EO4: The ability to compute expectations, moments, and correlation functions, to describe relationships between different experimental conditions.

EO5: The ability to use probabilistic reasoning and the foundations of probability theory to describe probabilistic engineering experiments in terms of sample spaces, event algebras, classical probability, and Kolmogorov's axioms.

EO6: Do statistical data analysis like test of hypothesis.

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MSMA105	Statistical Lab by R/Python	L	T	P	C
		0	0	4	2

Pre-requisite: Python

Course Objectives:

CO1:To teach the theoretical foundations of various learning algorithms.
CO2: To train the students better understand the context of supervised and unsupervised · learning through real-life examples.
CO3: To understand the need for Reinforcement learning in real – time problems.
CO4· Apply all learning algorithms over appropriate real-time dataset.
CO5 Evaluate the algorithms based on corresponding metrics identified.

List of Indicative Experiments

1	Test and Debug simple Python programs
2	Different data types in python (variables constants and strings)
3	Programs on different operators
4	Control statements and Loops
5	Control statements and Loops
6	Data structures in python (List, Tuple, Dictionary and Set)
7	Objects and Classes manipulation using python
8	Open, Read and write data from/to files in Python
9	Different plots using Matplotlib
10	Visualization of data using seaborn
11	Mean, Median, Standard Deviation, **Standard Error**
12	Hypothesis Testing
13	Linear Regression

Text Book(s)

1	José Unpingco , Python for Probability, Statistics, and Machine Learning, Springer , 2nd ed. 2019
2	Gareth James · Daniela Witten · Trevor Hastie · Robert Tibshirani · Jonathan Taylor; An Introduction to Statistical Learning with Applications in Python. Springer 2023

Course Outcomes:

EO1: · Students will learn the statistical inference by python
EO2: Students will be able to study statistical data analysis.

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MSCS107	Python Programming	L	T	P	C
		2	0	0	2

Pre-requisite: NIL

Course Objectives:

CO1: Understand the fundamental concepts of python and its main components.

CO2: Develop (Read and Write) python programs using variables, assignments, and conditionalstatements using functions.

CO3: Illustrate and implement different data structures.

CO4: Demonstrate Object-oriented concepts and file handling.

CO5: Analyze and plot data using python visualization libraries

Unit-I	Introduction to Python	6 hrs

Introduction to Python : Introduction to a programming language – History of Python- Python environment setup – Python 2 vs. Python 3 - Comments and documentation in Python- Keywords and Identifiers - Programming Errors - Writing and Running python programs.

Unit-II	Variables and Conditionals in Python	6 hrs

Variables and Conditionals in Python**:** Variables – Constants- Strings - Assignment statements – Expressions-Operators – TypeConversions-Control Flow statements and Loops- Functions.

Unit-III	Data Structures in Python	6 hrs

Data Structures in Python: Basics- List Indexing and Slicing-Appending-Sorting and Ranging-Tuples-Creation- Deletion-Converting tuple to list- Assignment- Dictionaries-Adding-Modifying and Retrieving Values-Traversing all keys in the dictionary-Operations and methods-Sets-Manipulating and accessing sets.

Unit-IV	Exception handling and File I/O	6 hrs

Exception handling and File I/O: Exception handling - Catching and Handling Exceptions -Object Orientated Concepts (Basics) – Creating python class and Objects - Object properties and methods- Inheritance- Operator overloading- Polymorphism- File handling - Opening, Reading, Writing and Deleting files

Unit-V	Graph Plotting	6 hrs

Graph Plotting: Introduction to plotting python libraries -Plots and Graphs- Applied Visualizations – Seaborn –Matplotlib

Text Book:

1. Python: The Complete Reference , 2018
2. Python in easy steps, McGraw Hill, 2nd Reprint , 2014

Reference Books:

1. Python 3 Documentation, https://docs.python.org/
2. https://www.coursera.org/learn/python

Course Outcomes:

EO1: Explain the basic programming knowledge in Python.
EO2: Implement machine learning algorithms on your data sets using Python

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MSMA201	Topology	L	T	P	C
		3	1	0	4

Pre-requisite: Basic Knowledge in Real Analysis

Course Objectives:

CO1: To introduce the fundamental concepts of topology
CO2: To study the properties of Topological spaces.
CO3: To enrich much knowledge in Metric Topology, connected, compact and normalspaces.

Unit-I	Introduction to Topology	12 hrs

Topological spaces: definitions and examples, Basis and sub basis, order topology, continuous functions, product topology, subspace topology, closed sets, closures, limit points, cluster (accumulation) points, interior and boundary of a set, metric topology, quotient topology.

Unit-II	Connectedness	12 hrs

Connectedness, components, Locally connectedness, path-connectedness and locally path-connectedness.

Unit-III	Countability Axioms, Separation Axioms and Metrizations	12 hrs

Countabilityaxioms,T1-spaces, Hausdorff spaces, regular spaces, completely regular spaces, Normal spaces, one-point compactification, Urysohn's lemma and Tietze extension theorem. Embedding theorem, Urysohn Metrization Theorem.

Unit-IV	Compactness and Campactifications	12 hrs

Compactness, tube lemma, Tychonoff's theorem, compact subspaces of real line, characterization of compact metric spaces, locally compactness, Stone Cech Compactification.

Unit-V	NET and Filters	12 hrs

Motivation, Definitions and examples. Inadequacy of Sequences and overcome by NET and Filters, Switch over between NET and Filter and their properties. Tychonoff

Text Book:

1. **"Topology" by James R. Munkres, 2nd Edition, Pearson Education, Delhi, 2006.**
2. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill,1963
3. J. Dugundji, Topology, Allyn and Bacon Inc. 1966.

Reference Books:

1. K.D. Joshi, Introduction to General Topology, New Age International, New Delhi,2000.
2. General Topology J. L. Kelley, Van Nostrand Reinhold Co., New York, 1995

Course Outcomes:

EO1: Acquire knowledge about several constructions of topological spaces.
EO2: Understand various properties of topological spaces.
EO3: Recognize the properties of continuous functions on topological spaces.
EO4: Understand connected, compact and normal topological spaces and their properties.
EO5: Understand normal topological spaces and their properties.

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MSMA202	Linear Algebra	L	T	P	C
		3	1	0	4

Pre-requisite: Basic Knowledge in preliminaries of Abstract algebra

Course Objectives:

CO1: To provide a solid foundation in the mathematics of linear algebra.
CO2: To develop problem solving skills.
CO3: To prepare the students for advanced level of Mathematics.
CO4: To discuss some of the applications of linear algebra.

Unit-I	Vector Spaces and Modules	12 hrs

Vector spaces and modules, difference between vector spaces and modules, submodules, quotient modules, homomorphisms, isomorphism theorems, free modules, torsion modules and finitely generated modules over PID.

Unit-II	Linear Transformations and Linear functional	12 hrs

Linear transformation, Rank – Nullity theorem, Linear functional, dual space, dual basis, double dual, transpose of linear transformation.

Unit-III	Elementary Canonical forms	12 hrs

Elementary Canonical Forms: Introduction, characteristic values, annihilating polynomials, invariant subspaces, diagonalization, triangulation, simultaneous diagonalization, Jordan canonical form and rational canonical form.

Unit-IV	Inner-product Spaces	12 hrs

Inner-products, projection, orthogonal projection, adjoint of linear transformation, unitary operators, self adjoint and normal operators.

Unit-V	Quadratic and Bilinear forms	12 hrs

Quadratic forms, Bilinear forms, Symmetric bilinear forms – skew-symmetric bilinear forms, classification of quadratic forms.

Text Book:

1. K. Hoffman and R. Kunze, Linear Algebra, 2nd edition, Prentice Hall of India,2003.
2. Schaum's Outline of Linear Algebra, Sixth Edi. Marc Lipson and Seymour Lipschutz, 2009
3. G. Strang, Linear Algebra and its applications, 8th Indian reprint Indian edition,Cengage Learning, 2011.
4. Linear Algebra - Vivek Sahai, Vikas Bist (Narosa Publication)

Reference Books:

1. S. Axler, Linear Algebra Done Right, Second edition, Springer, 1997.
2. S. Kumaresan, Linear Algebra - A Geometric Approach, 12th reprint, PrenticeHall of India, 2011.
3. S.H. Friedberg and A.J. Insel, L.E. Spence, Linear Algebra, 4th edition, Prentice-Hall of India, 2003.

Course Outcomes:

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EO1: Solving systems of linear equations; Qualitative analysis of systems of linear equations;

EO2: Develop understanding of vector Spaces, linear independence, determinants, canonical forms,

EO3: Familiarize analysis of Transformations and use of Eigen values and decomposition techniques.

EO4: Get an insight into the enormous applicability of linear algebra

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MSMA203	Complex Analysis	L	T	P	C
		3	1	0	4

Pre-requisite: Basic knowledge in definitions and preliminariesof Complex Numbers

Course Objectives:

CO1: The course presents an introduction to analytic functions, conformal mappings, Mobius transformations and power series.

CO2: Various Cauchy's theorems are discussed and used in evaluation of integral. It deals with locations of zeros of analytic functions and maximum principles

Unit-I	Lines and planes in complex plane	12 hrs

Lines and planes in complex plane, extended complex plane, spherical representation, power series, analytic functions as mappings, branch of logarithm.

Unit-II	Conformal mappings	12 hrs

Conformal mappings, Mobius transformations Evaluation of conformational mapping of various functions like z, $\log z$, $z + 1/z$, $\sin z$, $\cos z$, etc.,

Unit-III	Power series	12 hrs

Power series representation of analytic functions, zeros of analytic functions, index of a closed curve, Cauchy's theorem and integral formula on open subsetsof C.

Unit-IV	Contour integration	12 hrs

Homotopy, homotopic version of Cauchy's theorem, simple connectedness, counting of zeros, open mapping theorem, Goursat's theorem, Classification of singularities, Laurent series.

Unit-V	Residues	12 hrs

Residue, Contour integration, argument principle, Rouche's theorem, Maximum principle, Schwarz lemma.

Text Book:

1. **Complex Variables - H.S. Kasana (PHI Publication)**
2. Ahlfors Lars. Complex Analysis. McGraw Hill Co., New York. 1988.
3. Conway John. Functions of One Complex Variables. 2nd ed, Narosa, New Delhi. 2002.
4. S. Ponnusamy, Foundations of Complex Analysis, 2nd edition, Narosa Publishing House, 2005
5. Complex Variables and Applications, J. W. Brown and R. V. Churchill McGraw Hill 2008

Reference Books:

1. Complex Analysis - R.V. Churchill (Tata McGraw - Hill Publication)
2. Complex Analysis, T. W. Gamelin, Springer 2001.
3. Complex Variables & Applications by R.V. Churchill & J. W. Brown, Mc.GrawHill, 1990.

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Course Outcomes:

EO1: Explain analytic functions as mappings and discuss properties of conformalmappings, and Mobius transformations.
EO2: Obtain series representation of analytic functions.
EO3: Evaluate various integrals by using Cauchy's residue theorem.
EO4: Classify singularities and derive Laurent series expansion

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CSAI2001	Machine Learning	L	T	P	C
		3	0	0	3

Pre-requisite: NIL

Course Objectives:

CO1: To introduce the basic concepts and techniques of Machine Learning
CO2: To enable design and implementation of machine learning solutions to classification, regression, and clustering problems

CO3: Apply supervised learning algorithms and unsupervised learning algorithms on real data

CO4: To study the concepts of deep learning

CO5: Explore data repositories and apply Machine Learning Algorithms on case studies.

Unit-I	Introduction To Machine Learning	8 hrs

Overview of machine learning: Definition, history, and applications. Types of machine learning: Supervised, unsupervised, reinforcement learning. Machine learning process: Data collection, preprocessing, model training, evaluation, deployment. Terminology and concepts: Features, labels, instances. Ethical considerations in machine learning. Data Preprocessing and Exploration Data cleaning and preprocessing techniques. Handling missing data and outliers. Feature selection and feature engineering. Exploratory Data Analysis (EDA).

Unit-II	Supervised Learning	13 hrs

Linear Regression: single & multiple variables, Gradient descent, Bias variance trade-off, Overfitting & Under fitting, Regularization & Generalization. Classification: Logistic regression - Decision Trees, Naive Bayes, Support Vector Machines - linear and non-linear kernel functions. Model evaluation metrics-Accuracy, precision, recall, F1-score, ROC, AUC

Unit-III	Unsupervised Learning	7 hrs

Clustering basics - Partitioned, Hierarchical and Density based - K-Means clustering – K-Mode clustering – Expectation maximization, Dimensionality reduction- t-SNE. Anomaly detection techniques

Unit-IV	Ensemble Learning & Etical Consideration	12 hrs

Random forests, Bagging and Boosting (Random forests, Adaboost, XG boost inclusive) – Metrics & Error Correction. Optimization of hyper parameters. Ethical considerations: Bias, fairness, transparency, and accountability.

Unit-V	Reinforcement Learning (Rl)	12 hrs

Basics of reinforcement learning: Agents, environments, rewards. Markov Decision Processes (MDPs). Q-learning and Deep Q Networks (DQNs). Policy gradients and actor-critic methods

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Text Book:

1. Ethem Alpaydin, Introduction to Machine Learning, MIT Press, Prentice Hall of India, Third Edition 2014.
2. Reinforcement Learning: An Introduction (Adaptive Computation and Machine Learning series) 2nd edition, Richard S. Sutton and Andrew G. Barto, A Bradford Book; 2018, ISBN 978-0262039246.
3. Machine Learning -The Art and Science of Algorithms that Make Sense of Data, Peter Flach Foundations of Machine Learning, Mehryar Mohri, Afshin Rostamizadeh, and Ameet Talwalkar
4. An Introduction to Statistical Learning with Applications in R, Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani

Reference Books:

1. Mehryar Mohri, Afshin Rostamizadeh, Ameet Talwalkar Foundations of Machine Learning, MIT Press, 2012.
2. Tom Mitchell, Machine Learning, McGraw Hill, 3rd Edition,1997.

Course Outcomes:

EO1: Explain Machine Learning algorithms and their limitations.

EO2: Apply common Machine Learning algorithms in practice and implement them.

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CSAI2003	Machine Learning Lab	L	T	P	C
		0	0	4	2

Pre-requisite: Python

Course Objectives:

CO1:To teach the theoretical foundations of various learning algorithms.

CO2: To train the students better understand the context of supervised and unsupervised · learning through real-life examples.

CO3: To understand the need for Reinforcement learning in real – time problems.

CO4· Apply all learning algorithms over appropriate real-time dataset.

CO5 Evaluate the algorithms based on corresponding metrics identified.

List of Indicative Experiments	
1	Linear & Multiple Linear Regression
2	Naïve Bayes classifier
3	Decision trees – ID3 & CART
4	Logistic regression
5	Support Vector Machines – Linear & Non-linear
6	Single & Multi-layer Perceptron
7	K-NN, K-Means & K-mode clustering
8	Random – forest
9	Adaboost, XGboost
10	Principal component analysis
11	Self – Organizing maps
12	Q-Learning

Text Book(s)	
1	Ethem Alpaydin,"Introduction to Machine Learning", MIT Press, Prentice Hall of India, Third Edition 2014.
2	Reinforcement Learning: An Introduction (Adaptive Computation and Machine Learning series) 2nd edition, Richard S. Sutton and Andrew G. Barto, A Bradford Book; 2018, ISBN 978-0262039246

Reference Books	
1	Mehryar Mohri, Afshin Rostamizadeh, Ameet Talwalkar "Foundations of Machine Learning", MIT Press, 2012
2	Tom Mitchell, "Machine Learning", McGraw Hill, 3rd Edition, 1997.
3	Charu C. Aggarwal, "Data Classification Algorithms and Applications", CRC Press, 2014.

Course Outcomes:

EO1: · Understand, visualize, analyze and preprocess the data from a real-time source. ·

EO2: Apply appropriate algorithm to the data.

E03: Analyze the results of algorithm and convert to appropriate information required for the real – time application.

EO4: Evaluate the performance of various algorithms that could be applied to the data and to suggest most relevant algorithm according to the environment

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MSMA301	Functional Analysis	L	T	P	C
		3	1	0	4

Pre-requisite: Basic knowledge in Real Analysis andLinear Algebra

Course Objectives:

CO1: To impart analytic knowledge on infinite-dimensional vector spaces, of which the most important cases are Banach spaces and Hilbert spaces.

CO2: This course provides an introduction to the basic concepts which are crucial in the modern study of partial differential equations, Fourier analysis, quantum mechanics, applied probability and many other fields.

Unit-I	Matric Spaces	12 hrs

Fundamental of Matric Spaces; Convergence, Cauchy Sequence, Completeness Proofs. Completion of Metric Spaces.

Unit-II	Normed Spaces- Banach Spaces	12 hrs

Properties of Normed Spaces, Subspaces, Compactness and Finite Dimension. Theorem of Finite dimension. Theorem of Continuity and boundedness. Linear Functionals, Linear Operators and Functionals on Finite Dimensional Spaces, Dual Space. Theorem (Completeness).

Unit-III	Inner Product Speces- Hilbert Spaces	12 hrs

Properties of Inner Product Spaces, Orthogonal Complements and Direct Sums. Orthonormal Sets and Sequences, Representation of Functionals on Hilbert Spaces, Hilbert-Adjoint Operator Self-Adjoint, Unitary and Normal Operators

Unit-IV	Fundamental theorems	12 hrs

Zorn's Lemma, Hahn-Banach Theorem, Riesz's Theorem, Strong and Weak Convergence. Banach Fixed Point Theorem . Open Mapping Theorem.

Unit-V	Spectral Theory	12 hrs

Spectral Theory in Finite Dimensional Normed Spaces. Spectral Properties of Bounded Linear Operator. Spectral Properties of Bounded Self-Adjoint Linear Operators. Spectral Properties of Bounded Self-Adjoint Linear Operators

Text Book:

1. **E. Kreyszig, Introduction to Functional Analysis with Applications, Wiley, 1989.**
2. **B.V. Limaye, Functional Analysis, Second Edition, New Age International, 1996.**
3. Functional Analysis: Theory and applications, R.E. Edwards, Dover Publications 1995

Reference Books:

4. J. B. Conway, A Course in functional Analysis, 2nd ed., Springer, 1985.
5. G. F. Simmons, Introduction to Topology and Modern Analysis, Krieger Publishing Co., 1983.
6. E. Taylor and D. C. Lay, introduction to Functional Analysis, 2nd ed., Wiley, NewYork, 1980.

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Course Outcomes:

EO1: Appreciate how ideas from different areas of mathematics combine to producenew tools that are more powerful than would otherwise be possible.

EO1: Understand how functional analysis underpins modern analysis.

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MSMA302	Numerical Methods	L	T	P	C
		3	1	0	4

Pre-requisite: Basic Knowledge in Algebraic & DifferentialEquations

Course Objectives:

CO1: To understand appropriate numerical methods to solve algebraic and transcendental equations

CO2: To perform an error analysis for various numerical methods and derive appropriate numerical methods to solve definite integrals.

CO3: To develop appropriate numerical methods to solve a system of linear equations.

CO4: To learn special kinds of differential equations such as elliptic, Parabolic andhyperbolic differential equations.

Unit-I	Interpolation & Solution of Equations	12 hrs

Errors and their Computations. Error Formula, Bisection Method, Method of False Position, Iteration Method. Newton-Raphson Method. Secant Method. Error in Polynomial Interpolation. Finite Difference: Forward, Backward & Central Difference. Newtons Formulae for Interpolation. Gauss Central Difference Interpolation. Interpolation with unevenly spaced points: Lagrange's interpolation. Error in Lagrange's interpolation formula. Hermite's interpolation formula.

Unit-II	Numerical Differentiation and Integration	12 hrs

Numerical Differentiation: Error in Numerical Differentiation. Cubic Splines Method. Numerical Integration: Trapezoidal Rule. Simpson's 1/3 rule. Simpson's 3/8 rule. Newton cotes Integration formula. Euler-Maclaurin Formula. Gauss Integration. Generalized Quadrature.

Unit-III	Numerical Linear Algebra	12 hrs

Triangular Matrices. LU Decomposition of Matrix. Solution of Linear Systems(Direct Methods): Gauss Elimination, Gauss Jordon Method. LU Decomposition Method. Decomposition from Gauss Elimination. Solution of Linear Systems(Iterative Methods). Matrix Eigenvalue method: Eigenvalues of a Symmetric Tridiagonal Matrix.

Unit-IV	Numerical Solution of ODE	12 hrs

Solution By Taylor's series. Picard Method of successive Approximations. Euler's Method. Runge-Kutta Method. Predictor-Corrector Method. Cubic Spline Method. Boundary Value Problems: Finite difference Method, Cubic Spline Method.

Unit-V	Numerical Solution of PDE	12 hrs

Laplace's Equation. Finite difference Approximations to Derivatives. Solution of Laplace's equation: Jacobi's method, Gauss-seidel Method. Heat equation (1D): Finite difference Approximations. Application of Cubic Spline. Wave equation.

Text Books:

1. **S. S. Sastry, Introductory Methods of Numerical Analysis, PHI. 2009.**
2. R.L. Burden, J.D. Faires, Numerical Analysis, 9th Edition, Cengage Learning,2011.
3. Numerical Mathematical Analysis Jsames B. Scarbarough, Oxford University Press 1930
4. Numerical Analysis - R.K. Jain, S.R.K. Iyengar (New Age Publication)

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Reference Books:

1. K.E. Atkinson, An Introduction to Numerical Analysis, Wiley, 1989
2. G.M. Phillips and P.J. Taylor, Theory and Applications of Numerical Analysis,2nd Edition, Elsevier, New Delhi, 2006.

Expected outcomes:

EO1: Solve algebraic and transcendental equations using appropriate numerical meth- ods and approximate a function using appropriate numerical methods.

EO2: Derive numerical methods for various mathematical operations and tasks such as interpolation, differentiation, integration and the solution of linear and non-linear equations.

EO3: Analyze and evaluate the accuracy of common numerical methods.

EO4: Demonstrate understanding of the numerical methods in real life problems.

EO5: To evaluate the numerical methods using software

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MSMA303	Operations Research	L	T	P	C
		3	1	0	4

Pre-requisite: NIL

Course Objectives:

CO1: Formulate various real-life problems as Operations Research models and to studymethodologies to solve the problems.

CO2: Introduce Linear Programming, Transportation and Assignment problems andto discuss methods to find optimum solutions.

CO3: Learn network flow problems and their solution techniques.

CO4: Explore dynamic programming problem and its applications.

CO5: study the algorithms to solve nonlinear programming.

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Unit-I	Linear Programming Problems	12 hrs

Introduction, Models in Operations Research, Linear Programming Problems, Simplex Method, Big-M Method, Two-Phase Method - Special Cases: Degeneracy and Cycling, Unbounded Solutions, Alternative Optima, Dual Linear Programs, Duality Theorems, Dual Simplex Method, Revised Simplex Method.

Unit-II	Transportation Problems	12 hrs

Transportation Problems: Finding an Initial Basic Feasible Solution, Optimality Condition, MODI method, Degeneracy, Assignment Problems: Stepping Stone Method, Hungarian Method.

Unit-III	Network Analysis	12 hrs

Network Analysis, Shortest Route Problems, Minimum Spanning Tree Problems, Maximal Flow Problems, Critical Path Method (CPM), Program Evaluation and Review Techniques (PERT).

Unit-IV	Dynamic Programming	12 hrs

Dynamic Programming: Principle of Optimality, Forward and Backward recursions, Deterministic Dynamic Programming, Probabilistic Dynamic Programming, Applications.

Unit-V	Nonlinear Programming	12 hrs

Nonlinear Programming: Formulation and Types – Unconstrained Optimization – Constrained Optimization - Method of Lagrange multipliers – Karush-Kuhn-Tucker conditions.

Text Book:

1. **Operations Research, Prem Kumar Gupta & D. S. Hira 7th ed., S Chand publication 2014.**
2. Kanti Swarup, P.K. Gupta and Man Mohan, Operations Research, Sultan Chand,2014.
3. Hamdy A. Taha, Operations Research-An Introduction, Prentice Hall of India, 2000.

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Reference Books:

1. Frederick S. Hillier and Gerald J. Lieberman, Introduction to Operations Research, McGraw Hill, 2010.
2. Ravindran, Don T. Phillips and James J. Solberg, Operations Research-Principles and Practice, John Wiley, 2014.

Course Outcomes:

EO1: Solve Linear Programming Problem (LPP) using Simplex, Big-M and Two phasemethods.

EO2: Find an optimum solution for transportation and assignment problems and toanalyze LPP using duality results.

EO3: Solve LPP using Revised Simplex method and to apply duality methods in the study of sensitivity analysis in LPP and parametric programming.

EO4: Determine the shortest path, critical path and maximal flow in a network.

EO5: Use the method of Lagrange multipliers and Karush-Kuhn-Tucker conditions to find an optimum solution of a nonlinear programming problem.

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CSAI3001	Neural Networks And Deep Learning	L	T	P	C
		3	0	0	3

Pre-requisite: NIL

Course Objectives:

CO1: To provide the mathematical and computational demands of building neural networks

CO2: To study the concepts of deep learning

CO3: Learn deep learning supporting environments

CO4: To introduce dimensionality reduction techniques

CO5: To apply deep learning techniques for real time applications

Unit-I	Introduction Of Artificial Neural Networks (ANN)	9 hrs

Introduction of Artificial Neural Networks (ANN) - Functions in ANN – Activation function, Loss function - L1, L2 - Function approximation, classification / clustering problems – Applications.

Unit-II	Foundations Of Deep Networks	9 hrs

Neural networks: Biological neuron - Perceptron - Multilayered Feedforward Networks - Backpropagation learning, Activation functions: Linear - sigmoid - rectified linear and softmax, Loss functions, regularization, Deep networks: Unsupervised Pretrained Networks - Deep Belief Networks - Generative Adversarial Networks

Unit-III	Convolutional Neural Networks (CNNs)	9 hrs

Convolutional Operation, Motivation, Pooling layers, Fully connected layers, A complete CNN architecture: AlexNet - VGG - Inception - ResNet, Training a Convnet: weights initialization - batch normalization - hyperparameter optimization.

Unit-IV	Sequence Modeling Using Recurrent Nets	9 hrs

Recurrent Neural Networks (RNN), Bidirectional RNNs, Encoder-Decoder sequence-to-sequence architectures, Deep RNNs, Recursive NN, Challenge of long term dependencies, Long Short-term Memory (LSTM) and other Gated RN

Unit-V	Generative Adversarial Networks And Transformer	9 hrs

Generative Adversarial Networks (GANs) -GAN Architecture, Training GANs, GAN Variants, valuation and Metrics, Applications of GANs. Transformer Networks - Introduction to Transformers, Self-Attention Mechanism, Positional Encoding, Transformer Architecture, Training Transformers

Text Book:

1. Ian Goodfellow, Yoshua Bengio and Aaron Courville, " Deep Learning", MIT Press, 2017.
2. Josh Patterson, Adam Gibson "Deep Learning: A Practitioner's Approach", O'Reilly Media,2017
1. Tom Mitchell, Machine Learning, McGraw Hill, 3rd Edition, 1997. 4. Charu C. Aggarwal, Data Classification Algorithms and Applications, CRC Press, 2014.

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MSMA3003	Neural Networks And Deep Learning Lab	L	T	P	C
		0	0	4	2

Pre-requisite: Machine learning and Python

Course Objectives:

CO1: Introduce major deep neural network frameworks and issues in basic neural networks

CO2: To solve real world applications using Deep learning

List of Indicative Experiments	
1	Demonstration and implementation of Shallow architecture, using Python, Tensorflow and Keras · Google Colaboratory - Cloning GitHub repository, Upload Data, Importing Kaggle's dataset, Basic File operations · Implementing Perceptron, · Digit Classification : Neural network to classify MNIST dataset
2	Hyper parameter tuning and regularization practice - · Multilayer Perceptron (BPN) · Mini-batch gradient descent,
3	Convolution Neural Network application using Tensorflow and Keras, · Classification of MNIST Dataset using CNN · Face recognition using CNN
4	Object detection using Transfer Learning of CNN architectures
5	Image denoising (Fashion dataset) using Auto Encoders Handling Color Image in Neural Network aka Stacked Auto Encoders (Denoising)
6	Text processing, Language Modeling using RNN
7	Transfer Learning models for classification problems
8	Sentiment Analysis using LSTM
9	Image generation using GAN

Text Book(s)	
1	Deep Learning, Ian Goodfellow Yoshua Bengio Aaron Courville, MIT Press, 2017
2	Neural Networks and Deep Learning, Michael Nielsen,, Determination Press

Reference Books	
1	Deep Learning Step by Step with Python, N D Lewis, 2016
2	Deep Learning: A Practitioner's Approach, Josh Patterson, Adam Gibson, O'Reilly Media, 2017
3	Applied Deep Learning. A Case-based Approach to Understanding Deep Neural Networks, Umberto Michelucci, Apress, 2018
4	Deep Learning with TensorFlow: Explore neural networks with Python, Giancarlo Zaccone, Md. RezaulKarim, Ahmed Menshawy, Packt Publisher, 2017

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Course Outcomes:

EO1: Understand the methods and terminologies involved in deep neural network, differentiate the learning methods used in Deep-nets.

EO2: Identify and apply suitable deep learning approaches for given application.

EO3: Design and develop custom Deep-nets for human intuitive applications

EO4: Design of test procedures to assess the efficiency of the developed model. To understand the need for Reinforcement learning in real – time problems

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MSMAE01	Graph Theory	L	T	P	C
		2	1	0	3

Pre-requisite: NIL

Course Objectives:

CO1: Understand various kind of Graphs and its properties
CO2: Learn the properties of trees, planar Graphs and non-planar graphs
CO3: Understand application of Graphs in various fields

Unit-I	Graphs and Trees	9 hrs

Definition of graph, Basic terminology, Directed graphs and weighted graphs, Types of graphs, Graph isomorphism, Sum and product of graphs, Components, Connected and disconnected graphs, Euler path, Euler circuit and Euler theorem, Hamiltonian path and circuit. Definition, Properties of trees, Distance, radius, diameter and center of graphs andtrees, Binary tree, Binary tree traversal.

Unit-II	Planar graphs and Cut-set and cut-vertices	9 hrs

Definition, Planar and non-planar graphs, Kuratowaski's two graphs, Homeomorphic graphs, Geometric and combinatorial duals, Applications of planar graphs.

Definition of cut-set and cut-vertices, Rank and nullity, Fundamental circuits and fundamental cut-sets, Connectivity and separability, Cut-edge and bridge, Network flow problem

Unit-III	Group Actions Colouring and Matching	9 hrs

Definition, Chromatic number and Chromatic polynomial, Bipartite graph, Chromatic partitioning, Matching and its application, Covering, Five-colour and Four-colour theorems, Applications.

Unit-IV	Graph Algorithms	9 hrs

Matrix representation of graphs, Shortest path algorithms: Dijkstra and Floyd's algorithms, Spanning tree and minimum spanning tree, Prim's and Kruskal'salgorithms
to find spanning tree

Unit-V	Intersection graphs	9 hrs

Intersection graphs: Interval graph, Circular-arc graphs, Permutation graphs, Trapezoid graphs, Chordal graphs. Applications of graphs: Operations Research, Biological Sciences.

Text Book:

1. Introduction to Graph Theory, B. West Douglas, Prentice Hall of India, 2001
2. Graph Theory With Applications to Engineering & Computer Science Narsingh Deo Prentice Hall of India, 1979
3. A Text Book of Graph Theory, R. Balakrishnn, K. Ranganathan, University Text,2000

Reference Books:

1. Model Graph Theory, Bela Bollobas,Springer, 1998
2. Algorithmic Graph Theory & Par fact Graphs Advanced Linear Algebra, M.C. Golumbic Elsevier, 1980

Course Outcomes:

EO1: learnt various kind of Graphs and its properties
EO2: Understand the properties of trees, planar Graphs and non-planar graphs
EO3: Able to understand application of Graphs in various fields

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MSMAE02	Dynamical Systems	L	T	P	C
		2	1	0	3

Pre-requisite: Basic knowledge in Linear algebra

Course Objectives:

CO1: To provide basic knowledge of the dynamical systems.

CO1: Application of dynamical systems to biological, physical and engineering problems.

Unit-I	Dynamical Systems In Continuous	9 hrs

Dynamical Systems , Flows, Evolution, Fixed Points of a System, Linear Stability Analysis, Analysis of One-Dimensional Flows.

Unit-II	Linear Systems & Phase Plane Analysis	9 hrs

Eigenvalue-Eigenvector Method, General Matrix method, Solution Procedure of Linear Systems. Phase Plane Analysis, Local Stability of Two-Dimensional Linear System, Linearization and Its Limitations.

Unit-III	Stability Theory	9 hrs

Stability Theory: Stability of Linear Systems, Methods for Stability Analysis, Stability of Linearized Systems, Basin of Attraction and Basin Boundary

Unit-IV	Dynamical systems in Discrete	9 hrs

Difference equations, existence and uniqueness of solutions, qualitative behavior of solutions to linear difference equations. Steady states and their stability, the logistic difference equation, systems of nonlinear difference equations, stability criteria for second order equations, stability criteria for higher order system

Unit-V	Limit Cycles & Bifurcation	9 hrs

Limit Cycles, Poincaré-Bendixson Theorem, Different Bifurcations in One and two Dimensional Systems.

Text Book:

1. An Introduction to Dynamical Systems and Chaos, G.C. Layek, Springer, 2015.
2. Lakshmanan, M, Rajseeker, S., Nonlinear Dynamics, Springer.
3. Differential Equations and Dynamical Systems by Lawrence Perko, Springer.

Reference Books:

1. Nonlinear dynamics and chaos with applications to physics, biology, chemistry,and engineering by Strogatz, S.H., 2018. CRC Press.

Course Outcomes:

EO1: Understand of the dynamical systems.

CO1: Able to know application of dynamical systems to biological, physical and engineering problems.

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MSMAE03	Statistical Data Analytics	L	T	P	C
		2	1	0	3

Pre-requisite: Basic knowledge in statistics and probability

Course Objectives:

CO1: This course will enable learners to outline the insight of data, explain basic idea of summarizing data.

CO1: Provide a formulation of data acquisition, pre-processing, visualization, and aid in data transformation to useful results without loss of generality.

Unit-I	Introduction to Statistics	9 hrs

Arithmetic mean; Geometric mean; Median; Mode; Fractacls; Kurtosis; Applications of mean, median, mode, fractals, and kurtosis; Population; Sample and techniques of sampling; data visualization.

Unit-II	Data Models with Statistics	9 hrs

What is a data model; Data vs. Information; Distributions in data models; Random numbers and test of randomness; Assumptions in data models; predictive data models; single variable linear regression; Line fit to data; Interpolation and Extrapolation; Confidence and errors; Bayesian estimators.

Unit-III	Prediction Models for Multiple Variables	9 hrs

Introduction; Single variable vs. Multiple variable; Assumptions in model construction; How to fit the data to model; Anamoly Detection; Probabilistic predictive models; ARIMA and SARIMA models; Error measurement and reduction techniques.

Unit-IV	Test of Hypothesis	9 hrs

What is Hypothesis; Framing of Hypothesis; ANOVA – one tail/two tail‟ Chi- square test; Wilcoxon sign test; Box plot – quartiles; Likelihood ratio and large sample test; variance stabilization; Time series analysis - Trends/secular and Seasonal/cyclic; Autocorrelation Functions; Correlogram and Periodogram.

Unit-V	Business Application	9 hrs

Business Application Resampling techniques – Cross validation; Bootstrap, and Jacknife; Data Quality and Dashboards; Metrics in Corporate – Data preparation; Return on Investment – Financial Modeling; Time value of Money; EM method; Fisher‟s scoring method; Iteratively Reweighted Least Square Estimator; Statistical Learning.

Text Book:

1. Friedman J, Hastie T, Tibshirani R. (2009). The Elements of Statistical Learning. New York: Springer series in statistics

2. Rencher, A.C. and Christensen, W.F. (2012). Methods of Multivariate Analysis. 3rd Edition.

Reference Books:

1. P. K. Janert, O‟Reilly, Data Analysis with Open Source Tool, 2010.
2. Andrew Gelman & Jennifer Hill, Data Analysis with Regression & MultilevelHierarchical Models byCambridge University Press, 2006.
3. Kendall & Stuart, Advanced Theory of Statistics by, Vol I & II, 2016

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Course Outcomes:

EO1: Understand data models with statistics.

EO2: Understand Resampling techniques.

EO3: Able to apply testing of hypothesis

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MSMAE04	Mathematical Modelling	L	T	P	C
		2	1	0	3

Pre-requisite: Knowledge of differential and Linear Algebra

Course Objectives:

CO1: The objective of the course is to motivate and equip the students with the basicsin topological as well as metric fixed point theory.

CO2: It also intends to expose the students to some of the interesting applications in fixed point theory and make them understand how this important tool is used in the study of nonlinear phenomena.

Unit-I	Basics of Mathematical Modeling	9 hrs

Basics of Mathematical Modeling: Elementary mathematical models; Role of Mathematics in problem solving; Concept of mathematical modeling; System approach; formulation, analysis of models; Sensitivity analysis, Dimensional analysis.

Unit-II	Mathematical Modelling through ordinary differential equations	9 hrs

Mathematical Modeling through ordinary differential equations: Linear growth and decay model, Nonlinear growth and decay models (Logistic law of population growth).

Unit-III	Mathematical Modelling through system of ordinary differential equations of first order	9 hrs

Mathematical Modeling through system of ordinary differential equations of first order: Prey-Predator models, Compartmental models in Epidemiology, linear stability.

Unit-IV	Mathematical Modelling using delay differential equations	9hrs

Mathematical Modeling using delay differential equations: Delay models, linear stability Analysis.

Unit-V	Mathematical modelling through stochastic Differential Equations	9 hrs

Mathematical modeling through stochastic Differential Equations: Brownian motion and its properties, Ito formula, Ito integrals and its properties.

Text Book:

1. Mathematical Biology, J.D. Murray Springer, 2008
2. Stochastic differential equations, An introduction with applications, B. K. Oksendal, Springer, 2014

Reference Books:

1. Mathematical methods in biology, J.D. Logan and W.R., Wolesensky Wiley. 2009
2. Elements of Mathematical Ecology, Mark Kot, Cambridge University Press, 2012

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Course Outcomes:

EO1: To understand and apply the rules to build mathematical models;

EO2: To understand to analyze the models using mathematical techniques;

EO3: To provide them with basic applications stochastic analysis.

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MSMAE05	Bio-Mathematics	L	T	P	C
		2	1	0	3

Pre-requisite: Basic knowledge in linear algebraand differential equation

Course Objectives:

CO1: To provide basic knowledge of the biological Phenomenal under mathematical frame work.

CO2: To understand the qualitative behavior biological system to under mathematical and dynamical systems.

Unit-I	Deterministic and stochastic models	9 hrs

Deterministic and stochastic models, Characteristics, Classifications, tools, techniques, modeling approaches, Modeling diagram, Compartmental models, Dynamical systems and its mathematical models.

Unit-II	Models from systems of natural sciences	9 hrs

Models from systems of natural sciences: single and interacting populations, prey-predator, competition, Epidemic models Stability analysis. Nicholson-Bailey model, modification of Nicholson-Bailey model (density dependence in the host population), model for plant-herbivore (prey-predator) interaction and its stability analysis.

Unit-III	Mathematical ecology	9 hrs

Mathematical ecology: Single species models, Exponential, logistic, Gompertz growth, Harvest model, Discrete-time and Delay model, Interacting population model, prey-predator, competition & mutualism models.

Unit-IV	Mathematical epidemiology	9 hrs

Mathematical epidemiology: Introducing the SIR and SIS models. The SIR Model with demography. Techniques for analysis of 2 2 ODE systems. Modeling vector-borne, water-borne diseases. Delay equations. Techniques for computation of R_0.

Unit-V	Analytical study of mathematical model	9 hrs

Analytical study of mathematical model: equilibrium, stability, limit cycle, local bifurcation.

Text Book:

1. Mathematical Biology,2002, J.D. Murray, Springer Publication.
2. Brauer F., Castillo-Chavez C.: Mathematical models in population biology and epidemiology, Springer, New York, 2000

Reference Books:

1. Elements of Mathematical Ecology, 2001, Mark Kot, University press, Cam-bridge.
2. Mathematical Models in Biology, 2005, L. E. Keshet, SIAM Publication.

Course Outcomes:

EO1: Understand the biological Phenomenal under mathematical frame work.

EO2: Understand the qualitative behavior biological system to under mathematical and dynamical systems.

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MSMAE06	Evolutionary Game Theory	L	T	P	C
		2	1	0	3

Pre-requisite: Basic Knowledge in Game Theory

Course Objectives:

CO1: Provide knowledge in game theory to understand behavioral strategies towards decision making.

CO2: Apply to biological, economics and social sciences.

Unit-I	Strategy and the evolutionary stable strategy (ESS)	9 hrs

The definition of ESS, basic assumptions, and definitions The problems of optimization for frequency dependent selection. The definition of strategy and the evolutionary stable strategy (ESS). Introduction of the classical Hawk-Dove game. Pure and mixed strategies, polymorph populations.

Unit-II	Games with and without ESS	9 hrs

Games with more ESSs, games without ESS. The Hawk-Dove-Retaliator model. Which ESS will become realized. The Rock-Scissors-Paper game, where ESS might be absent. Finding of ESS in a general symmetric matrix game.

Unit-III	The dynamical view	9 hrs

The dynamical view: replicator dynamics The continuous and discrete replicator dynamics for pure strategies. Fixed points and their stability. Some simple mathematical examples. Replicator dynamics in the case of mixed strategies. Mathematical connections between the fixed points of replicator dynamics and the ESS.

Unit-IV	The Hawk-Dove and the Rock-Scissors-Paper games	9 hrs

Biological examples for the Hawk-Dove and the Rock-Scissors-Paper games. The behavior of Uta stansburiana males and the Rock-Scissors-Paper game. The reproductive strategies of Uta-stansburiana females and the Hawk-Dove game.

Unit-V	The Hawk-Dove game in finite populations	9 hrs

Frequency dependent selection in finite populations. The definition of ESS in finite populations. The Hawk-Dove game in finite populations. Mixed strategies and the polymorph population in finite populations

Text Book:

1. Jorgen Weibull (1995): Evolutionary Game Theory. MIT Press.
2. Josef Hofbauer and Karl Sigmund (1998): Evolutionary Games and Population Dynamics. Cambridge University Press.

Reference Books:

1. Ross Cressman (2003): Evolutionary Dynamics and Extensive Form Games. MIT Press.
2. G-Diaz, I. G-Jurado, M. G.F-Janeiro An Introductory Course on Mathematical Game Theory, Graduate Studies in Mathematics 115, American Mathematical Society.

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Course Outcomes:

EO1: Learn game theory to understand behavioral strategies towards decision making.

EO2: Able to apply to biological, economics and social sciences.

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MSMAE07	Nonlinear Differential Equations	L	T	P	C
		2	1	0	3

Pre-requisite: Basic knowledge in differential equations

Course Objectives:

CO1: Introduce oscillations or wild chaotic fluctuations produced by a nonlinear sys-tem.

CO2: Discuss solution behavior of nonlinear differential equations without findingthe solutions explicitly.

CO3: Develop clear thinking and analyzing capacity for advanced research.

Unit-I	Population models	9 hrs

The general phase plane - Some population models - Linear approximation at equilibrium points - Linear systems in matrix form.

Unit-II	Harmonic balance	9 hrs

An energy balance method for limit cycles - Amplitude and frequency estimates - Slowly varying amplitudes; Nearly periodic solutions - Periodic solutions:Harmonic balance - Equivalent linear equation by harmonic balance - Accuracy of a period estimate.

Unit-III	Forced oscillation and the Perturbation method	9 hrs

Outline of the direct method - Forced oscillations far from resonance Forced oscillations near resonance with weak excitation - Amplitude equation for un-damped pendulum - Amplitude perturbation for the pendulum equation - Lindstedt's method - Forced oscillation of a self - excited equation - The Perturbation method andFourier series.

Unit-IV	The general linear system	9 hrs

Structure of solutions of the general linear system - Constant coefficient system - Periodic coefficients - Floquet theory - Wronskian.

Unit-V	Stability of linear systems	9 hrs

Poincare stability - Solutions, paths and norms - Liapunov stability - Stability of linear systems - Comparison theorem for the zero solutions of nearly - linear systems.

Text Book:

1. Differential Equations by G.F. Simmons, Tata McGraw-Hill, New Delhi, 1979
2. Nonlinear Ordinary Differential Equations by D.W. Jordan and P. Smith, Clarendon Press, Oxford, 1977.

Reference Books:

1. Ordinary Differential Equations and Stability Theory by D.A. Sanchez, Dover,New York, 1968.
2. Notes on Nonlinear Systems by J.K. Aggarwal, Van Nostrand, 1972.

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Course Outcomes:

EO1: Understand the dynamics of basic population models.

EO2: Find approximate solutions of nonlinear equations using averaging and perturbation methods.

EO3: Master the concepts of stability in different perspectives.

EO4: Have an idea on qualitative properties of solutions of linear and nonlinear systems.

EO5: Improve their problem solving capabilities.

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MSMAE08	Classical Mechanics and Calculus of Variation	L	T	P	C
		2	1	0	3

Pre-requisite: NIL

Course Objectives:

CO1: Give the fundamental concept of Lagrangian and Hamiltonian concept to study the motion of rigid body, dynamics of system of particles;

CO2: Provide the theory of optimizing a functional & apply the formula that determines stationary paths of a functional to deduce the differential equations for stationary paths in various cases.

Unit-I	Moving coordinates systems	9 hrs

Moving coordinates systems, Gallilean transformation, inertial and noninertial frames of reference. Constrained motions in Cartesian coordinates, Principle of virtual work, D'Alembert's principle. Degrees of freedom, generalized coordinates. Lagrange's formulation in generalized coordinates, generalized forces, cyclic coordinates

Unit-II	Canonically conjugate coordinates	9 hrs

Canonically conjugate coordinates and momenta, Legendre transformation, Hamiltonian. Principle of least action, Hamilton's principle, Hamilton's equations of motion, Two body central force problem, Symmetry properties and conservation laws, Noether's theorem.

Unit-III	Canonical Transformation	9 hrs

Canonical Transformation, Generating function, Poisson bracket, Identities on Poisson brackets, Hamilton-Jacobi theory, Solution of the Hamilton –Jacobi equation

Unit-IV	Calculus of Variations	9 hrs

Basic concepts of the calculus of variations such as functionals, extremum, variations, function spaces, the brachistochrone problem. Necessary condition for an extremum, Euler's equation with the cases of one variable and several variables, Variational derivative. Invariance of Euler's equations..

Unit-V	Variational problems	9 hrs

Variational problem in parametric form. Functionals dependent on one or two functions, Derivation of basic formula, Variational problems with moving boundaries.

Text Book:

1. Classical Mechanics H. Goldstein, Narosa Publication, 1998
2. Differential equations and the calculus of variations, L. Elsgolts, MIR Publication, Moscow, 1977
3. Introduction to Quantum Mechanics David Griffiths Pearson 2015
4. Calculus of Variations - A. S. GUPTA (Narosa Publication)
5. Classical Mechanics - J. C. Upadhyaya (Himalaya Publication)

Reference Books:

1. Mechanics L. Landau, E. Lifshitz Pergamon Press, 1969
2. Calculus of Variations with applications A. S. Gupta Prentice-Hall of India Pvt.Ltd. 2004
3. Quantum Mechanics F. Schwable Springer, 2007.

Course Outcomes:

EO1: Understand Variational problems with moving boundaries

EO2: Understand Moving coordinates systems

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MSMAE09	Transform techniques & Integral Equations	L	T	P	C
		2	1	0	3

Pre-requisite: NIL

Course Objectives:

CO1: Understand various types of Integral Transformations and Integral Equations and related application in applied mathematics and theoreticalphysics

CO2: Learn different methods to solve Integral Equations solve various physical problems by integral transforms and integralequation methods

CO3: Learn to apply various transformations to solve ODE and PDE.

Unit-I	Linear integral equations	9 hrs

Fourier Integral Representation, Fourier IntegralTheorem, Different forms of Fourier Integrals, Fourier Transform and Inverse of Fourier Transform, Fourier Sine and Cosine transforms and their inverse Transforms, Complex Fourier Transform and its inversion formula, Properties of Fourier Transform, Fourier Transforms for functions of many variables, Perseval's Relations.

Unit-II	Laplace Transforms	9 hrs

Definition of Laplace Transform, Existence Theorem, Properties of Laplace Transform, Laplace Transform of Derivatives, Laplace Transform of Integrals, Special techniques for finding Laplace Transform, Inverse of Laplace Transform, Properties of Inverse Laplace Transforms, Partial Fraction method for finding the Inverse of Laplace Transform,

Unit-III	Linear integral equations	9 hrs

Introduction to Linear integral equations, Formation of Integral equations and classification Volterra integral equations, Fredholm integral equations, conversion of initial and boundary value problems to an integral equation

Unit-IV	Various types of kernels	9 hrs

Symmetric kernel, Separable kernel, Iterated kernel, resolvent kernel, Solution of Volterra integral equation using: Resolvent kernel, Successive approximation, Neumann series method. Cauchy kernel, Abel Equation

Unit-V	Fredholm integral equations	9 hrs

Fredholm integral equations, Fredholm equations of the second kind, the method of Fredholm determinants, iterated kernels, integral equations with degenerate kernels, Eigen values and Eigen functions of a Fredholm alternative, construction of Green s function for BVP, singular integral equations

Text Book:

1. **Linear Integral Equations, Theory and Technique**, R. P. Kanwal Academic Press 1971
2. Linear Integral Equations, S.G. Mikhlin Routledge 1961
3. The Uses of Integral Transforms, I.N. Sneddon, McGraw-Hill. 1972
4. Linear Integral Equations - M D Raisinghania (S.Chand Publication)

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Reference Books:

1. Linear Integral Equations, W. V. Lovitte, Dover Publications, 2005
2.Integral Transforms for Engineers Andrews, Shivamoggi, PHI 2003
3.Integral Transforms C. J. Tranter Methuen & Co,1962

Course Outcomes:

EO1: find Laplace transform of functions and discuss various properties of Laplacetransforms.

EO2: express periodic functions in terms of sinusoidal functions.

EO3: find Fourier transform of functions and discuss various properties of Fouriertransforms.

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MSMAE10	Computational Fluid Dynamics	L	T	P	C
		2	1	0	3

Pre-requisite: Basics of continuum mechanics and knowledge of computer algorithms such as Newton Raphson Method, shooting method, finite difference methods etc.

Course Objectives:

CO1: Understanding of basic principles of numerical computing and procedures for solution of partial differential equations for real life systems such as flow through channels, porous media, and lubrication and so on.

CO2: learn the motion of fluid flows and associated flow interactions and mathematics associated with various types of geometrical properties.

CO3: Applying numerical procedures to time dependent flows and to learn associated nature of solutions.

CO4: To solve complex boundaries with suitable modification of numerical schemes.

CO5: To know the efficiency of the numerical schemes.

Unit-I		9 hrs

Introduction to Numerical Methods: Finite Approximations, Discretization Approaches: Finite Difference Method, Finite Volume Method, Finite Element Method. Solution of Linear Systems, Solution of IVP &BVP, Shooting Method, Tridiagonal Systems, LU decomposition, Multigrid Methods, Coupled Equations and their solutions.

Unit-II		9 hrs

Basic Concepts of Fluid Flow: conservation principles, Mass Conservation, Momentum Conservation, Dimensional Forms of Equations, Mathematical Classification of Flows: Hyperbolic, Parabolic, Elliptic and Mixed Type.

Unit-III		9 hrs

Methods for Unsteady Problems: Two level Methods, P-C and Multipoint Methods, Application to the Transport Equation.

Unit-IV		9 hrs

Finite Volume Methods: Approximation of Surface and Volume Integrals, Boundary Conditions, Upwind Interpolation, QUICK Scheme.

Unit-V		9 hrs

Stability, Convergences of Numerical Schemes: Complex Geometries, Efficient, Accuracy and convergency, Stability criterion of Numerical Schemes.

Text Books:

1. J.H. Ferziger and M. Peric: Computational Methods for Fluid Dynamics, Springer (South Asian 2003 Reprint).

Reference Books:

1. P. Niyogi, S.K. Chakrabarty, M.K. Laha: Introduction to Computational Fluid Dynamics, Pearson Education Asia, 2005.

2. John D. Anderson Jr.: Computational Fluid Dynamics, CRC Press, 2019 (Reprint).

Expected outcomes:

EO1: A student would be able to simulate real life systems in CFD such as food processing, oil recovery, heat engines, and structural mechanics and so on.

EO2: The student would be able to do mathematical formulation and their relevance to convergence, stability of numerical scheme thereby improving the space and time complexity.

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MSMAE11	Financial Mathematics	L	T	P	C
		2	1	0	3

Pre-requisite: Basic knowledge of probability and statistics

Course Objectives:

CO1: To introduce the applications of mathematics and statistics in finance.

CO2: Understand money investment strategy and portfolio management

CO3: Understand bond valuation and stock price, and other mathematical models.

Unit-I	Introduction: A Simple Market Model	8 hrs

Introduction- a simple market model : basic notions and assumptions, no– arbitrage principle.

Unit-II	Risk-free assets	10 hrs

time value of money, future and present values of a single amount, future and present values of an annuity, Intra-year compounding and discounting, continuous compounding.

Unit-III	Portfolio management:	9 hrs

. risk of a portfolio with two securities and several securities, capital asset pricing model, minimum variance portfolio, some results on minimum variance portfolio.

Unit-IV	Valuation of bonds and stocks:	9 hrs

bond valuation, bond yields, equity valuation by dividend discount model and the P/E ratio approach. Risky assets: risk of a single asset, dynamics of stock prices, binomialtree model, other models, geometrical interpretations of these models, martingale property.

Unit-V	Options Option valuation:	9 hrs

Call and put option, put-call parity, European options, American options, bounds on options, variables determining option prices, time value of options.Binomial model (European option, American option), Black-Scholes model (Analysis, Black-Scholes equation, Boundary and final conditions, Black-Scholes formulae etc)

Text Books:

1. **Capinski M. and Zastawniak T., "Mathematics for Finance- An introduction to Financial Engineering" , Springer 2003.**
2. **Chandra P., "Financial Management – Theory and Practice", Tata McGraw Hill 2004.**
3. Wilmott P.,Howison S. and Dewynne J., "The Mathematics of Financial Derivatives- A Student Introduction", Cambridge University Press

Reference Books:

1. Teall J. L. and Hasan I., "Quantitative Methods for Finance and Investments", Blackwell Publishing2002
2. 3 Hull J.C., "Options, Futures and other Derivatives", Pearson education 2005

Course Outcomes:

EO1: able to understand the applications of mathematics and statistics in finance

EO2: learnt money investment strategy and portfolio management

EO3: Understand the mathematical models in Finance

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MSMAE12	Sports Analytics	L	T	P	C
		2	1	0	3

Pre-requisite: NIL

Course Objectives:

CO1: At present it is a very important area in Data Analytics. This course will provide exposure to theory as well as applications related to Sports Analytics

CO2:. Introduce data games, analytics in sport marketing

CO3: Understand media and technology, and various Managements.

Unit-I		9 hrs

Analytics and its importance in the sport industry What is data? Types of data Some key statistical concepts Data analysis Case study: managing a youth soccer organization's dataHow to get the best system Compatibility Processing data Cost Speed of delivery System operation.

Unit-II		9 hrs

The Data Game, Strategic Talent Management Analytics, Analytics in Sport Marketing, Choosing performance metrics for players and teams.

Unit-III		9 hrs

Big data in sports, Predicting outcomes of games, tournaments, and seasons, Machine learning in sports, Evaluating performance through profit and loss

Unit-IV		9 hrs

Analytics in Digital Marketing, Sport Finance by the Numbers, Sport Law by the Numbers, Sports Telecom, Media and Technology.

Unit-V		9 hrs

Manufacturing/Production Analytics, Event Management by the Numbers, Facility Management Analytics

Text Book:

1. Thomas W. Miller, Sports Analytics and Data Science: Winning the Game with Methods and Models, O'Reilly Publication, 2015.
2. **G. Fried and C. Mumcu, Sport Analytics, Routledge, Taylor & Francis Group, 2016**.

Reference Books:

3. F. Green, Winning With Data: CRM and Analytics for the Business of Sports, Routledge, Taylor & Francis Group, 2018.
4. Jim Albert, Mark E. Glickman, Tim B. Swartz and Ruud H. Koning, Handbook of Statistical Methods and Analyses in Sports, CRC Press, 2016.

Course Outcomes:

EO1: This unit will help students to understand Talent Management Analytics, Analytics in Sport Marketing, Choosing performance metrics for players and teams.

EO2: This unit will help students to get the concept Big data in sports, Predicting outcomes of games, tournaments, and seasons, Machine learning in sports, Evaluating performance through profit and loss.

EO3: This unit will help students to get the concept of Sport Finance by the Numbers, Sport Law by the Numbers, Sports Telecom, Media and Technology

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MSMAE13	Numerical Linear Algebra	L	T	P	C
		2	1	0	3

Pre-requisite: Basic knowledge in linear algebra

Course Objectives:

CO1: Understanding the concept of factorization of matrix into two products of two matrices.

CO2: Student will able to understand the SVD and its application in real life problem.

CO3: Solving eigenvalue and eigenvector problem using numerical linear algebraic technique.

CO4: Student will learn algorithm for the computation of singular value computation

CO5: Students will able to solve the large linear system of equations using Krylov subspace methods

Unit-I		9 hrs

LU factorization, Pivoting, Cholesky decomposition, Iterative refinement, QR factorization, Gram-Schmidt orthogonalization.

Unit-II		9 hrs

Projections, Householder reflectors, Givens rotation, Singular Value Decomposition, Rank and matrix approximations, image compression using SVD, Least squares and least norm solution of linear systems

Unit-III		9 hrs

Pseudoinverse, normal equations, Eigenvalue problems, Gershgorin theorem, Similarity transform, Eigenvalue & eigenvector computations and sensitivity, Power method, Schur decomposition, Jordan canonical form, QR iteration with & without shifts.

Unit-IV		9 hrs

Hessenberg transformation, Rayleigh quotient, Symmetric eigenvalue problem, Jacobi method, Divide and Conquer, Computing the Singular Value Decomposition, Golub-Kahan-Reinsch algorithm, Chan SVD algorithm, Generalized SVD, Generalized and Quadratic eigenvalue problems

Unit-V		9 hrs

Generalized Schur decomposition (QZ decomposition), Iterative methods for large linear systems: Jacobi, Gauss-Seidel and SOR, convergence of iterative algorithms. Krylov subspace methods: Lanczos, Arnoldi, MINRES, GMRES, Conjugate Gradient and QMR, Pre-conditioners, Approximating eigenvalues and eigenvectors

Text Books:

1. B.N. Dutta, Numerical Linear Algebra and Applications, SIAM, 2010

Reference Books:

1. R. Bellman, Introduction to Matrix Analysis, SIAM, 1997
2. R.S. Varga, Matrix Iterative Analysis, Springer, 2000

Expected outcomes:

EO1: Students will get an exposure to Matrix Iterative Methods for Analysis Real Life System.

EO2: Student understand the SVD and its application in real life problem

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MSMAE15	Industrial Statistics	L	T	P	C
		2	1	0	3

Pre-requisite: Probability and Statistics

Course Objectives:

CO1: Understand the philosophy and basic concepts of quality improvement and international standards on quality management and quality assurance.

CO2: Students will be able to use the methods of statistical process control and able to design, use, and interpret control charts for variables and attributes.

CO3: Perform analysis of process capability and measurement system capability.

CO4: Learn the DMAIC process (define, measure, analyze, improve, and control)

CO5: Students will learn to design, use and interpret exponentially weighted moving average and moving average control charts.

Unit-I		9 hrs

Quality and quality assurance, Methods of quality assurance, Introduction to TQM and ISO 9000 standards.

Unit-II		9 hrs

Introduction to statistical quality control, chance and assignable causes of variation, Choice of Control Charts, Rational Subgroups, Control Charts for Variables: and R Chart, and S Chart, Control Chart for Attributes: Control Chart for Fraction Defectives, Control Chart for Defects, Choice between Variable and Attribute Control Charts.

Unit-III		9 hrs

Shewhart Control Chart, Modified Control Charts, Process Capability Analysisusing Histogram, Probability Plot. Acceptance Sampling Plan, Single-sampling for Attributes, OC curve, Double, multiple and sequential sampling plans.

Unit-IV		9 hrs

Students will learn to design, use and interpret exponentially weighted moving average and moving average control charts. Dodge-Romig sampling plan, Acceptance sampling by variables, Designing a sampling plan with a specified OC curve, sequential sampling by variables, continuous sampling plans

Unit-V		9 hrs

Process capability studies, Statistical aspect of six sigma philosophy, Control charts with memory: CUSUM charts, EWMA-mean charts, OC and ARL for control charts; The Taguchi Method: The Taguchi philosophy of quality, Loss functions, SN ratios, Performance measures.

Text Books:

1. D.C. Montgomery (2012). Introduction to Statistical Quality Control, 7th Ed., Wiley.
2. J.T. Rabbit and PA Bergle, The ISO 9000 book, 2nd Ed., Quality resources, Chapter-I

Reference Books:

1. 1. H.J. Mittag and H. Rinne (1993) Statistical Methods for Quality Assurance, Chapman & Hall, Chapters 1, 3 and 4.
2. E.G. Schilling, (1982) Acceptance Sampling in Quality Control, Marcel Dekker.
3. A.J. Duncan (1986) Quality Control and Industrial Statistics, 5th Ed., Irwin.

4. E.L. Grant and R.S. Leaven Worth (1980) Statistical Quality Control, McGraw-Hill

Expected outcomes:

EO1: Understand the philosophy and basic concepts of quality improvement and describe the DMAIC process (define measure, analyze, improve, and control).

EO2: Students will be able to use the methods of statistical process control and able to design, use, and interpret control charts for variables and attributes.

EO3: Perform analysis of process capability and measurement system capability. 4. Design, use and interpret exponentially weighted moving average and moving average control charts.

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RGNIYD

MSMAE16	Nonlinear Programming	L	T	P	C
		2	1	0	3

Pre-requisite: Basic idea of Optimization problems

Course Objectives:

CO1: t provides the basic idea of convexity and its generalizations. Also, build the basic concept related to the convex function

CO2: to learn different types of constraints qualifications

CO3 to obtain the necessary optimality conditions for constrained and unconstrained optimization problem under suitable conditions.

CO4: able to optimize the optimization problem with the help of Lagrangian duality and saddle-point criteria

Unit-I		9 hrs

Convex Analysis: Affine Sets, Convex Sets and Cones, Algebra of Convex Sets, Convex Functions and Its Properties, Differentiable and Subgradients of Convex Functions, Generalizations of Convex Functions

Unit-II		9 hrs

Constraint Qualifications: The Cone and Tangents, Linearly Constraint Qualification, Linear Independent Constraint Qualification, Mangasarian-Fromovitz Constraint Qualification, Slater's Constraint Qualification, Abadie's Constraint Qualification

Unit-III		9 hrs

The Fritz-John and Karush-Kuhn-Tucker Optimality Conditions: Unconstrained Problems, Problems with Equality and Inequality Constraints,

Unit-IV		9 hrs

Second-Order Necessary and Sufficient Optimality Conditions for Constrained Problems, Lagrangian Duality and Saddle Point Optimality Conditions: The Lagrangian Dual Problem,

Unit-V		9 hrs

Duality Theorems and Saddle Point Optimality Conditions, Properties of the Dual Function, Formulating and Solving the dual problem, Getting the Primal Solution, Linear and Quadratic Programs

Text Books:

1. M.S. Bazaraa, H.G. Sherali, C.M. Shetty, Nonlinear Programming Theory and Algorithms, John Wiley and Sons, 2013.
2. R.T. Rockafellar, Convex Analysis, Princeton University Press, 2015

Reference Books:

1. G. Giorgi, A. Guerraggio, J. Thierfelder, Mathematics of Optimization: Smooth and Nonsmooth Case, Elesvier, 2004.
2. A. Bagirob, N. Karmitsa, M.M. Mäkelä, Introduction to Nonsmooth Optimization: Theroy, Practice and Software, Springer, 2014

Expected outcomes:

EO1: able to identify the appropriate methods to solve the different kinds of Optimization Problems

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MSMAE17	Advanced Complex Analysis	L	T	P	C
		2	1	0	3

Pre-requisite: Basic knowledge in complex analysis

Course Objectives:

CO1: Understand the concepts of complex integration, series expansion of a meromorphic function, infinite product expansion of an entire functions

CO2: Find the complex integrals and infinite sums and series using the Cauchy's residue theorem.

CO3: Evaluate Definite Integrals

Unit-I	Review of complex analysis	8 hrs

Quick review of complex derivative, partial derivative, c-r equations, power series. branch of log and some other functions, cauchy's theorem for rectangle, rectangle theorem with exceptional points, exact differentiable form, cauchy's theorem for disc, winding number, cauchy's theorem for disc with exceptional points, cauchy's integral formula, higher order derivatives.

Unit-II	Residues	9 hrs

Residues - cauchy's residue theorem - residue at infinity - the three types of isolated singular points - residues at poles - examples - zeros of analytic functions - zeros and poles - behavior of functions near isolated singular points.

Unit-III	Evaluation of Definite Integrals	9 hrs

Estimation of sums - Definite Integrals Involving Sines and Cosines - Evaluation of Improper Integrals - Jordan's Lemma .

Unit-IV	Integration along contours	9 hrs

Integration along Indented contours - Other types of contours- Integration through a branch cut.

Unit-V	Laplace transform	8 hrs

Laplace transform –Properties- complex inversion formula

Text Book:

1. L.V. Ahlfors, Complex Analysis, 3rd edition, McGraw-Hill Inc., 1979.
2. Complex Variables - H.S. Kasana (PHI Publication)
3. J. Bak and D.J. Newmann, Complex analysis, 2nd edition, Springer Indian Edition (SIE), 2009.
4. H.A. Priestley, Complex analysis, 2nd edition,Oxford University Press, Indian Edition, 2006.
5. S. Ponnusamy and H. Silverman, Complex variables with applications, Birkhauser, Boston, 2006.

Reference Books:

1. T.W. Gamelin, Complex analysis, Springer, 2004.
2. J.B. Conway, Functions of one complex variable, 2nd edition, SISE, Narosa, 1996

Course Outcomes:

EO1: Learnt the concepts of complex integration, series expansion of a meromorphic function, infinite product expansion of an entire functions

EO2: Understand the application of evaluating residues.

EO3: Understand the application of Laplace transforms

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MSMAE18	Fixed point Theory	L	T	P	C
		2	1	0	3

Pre-requisite: Topology and Functional analysis

Course Objectives:

CO1: The objective of the course is to motivate and equip the students with the basicsin topological as well as metric fixed point theory

CO2: It also intends to expose the students to some of the interesting applications in fixed point theory and make them understand how this important tool is used in the study of nonlinear phenomena

Unit-I		9 hrs

The Background of Metrical Fixed Point Theory, Fixed Point Formulationof Typical Functional Equations, Fixed Point Iteration Procedures, The Principle of Contraction mapping in complete metric spaces.

Unit-II		9 hrs

Some generalizations of Contraction mapping, A converse of Contraction Principle, some applications of Contraction Principle.

Unit-III		9 hrs

Convexity, Smoothness, and Duality Mappings, Geometric Coefficients of Banach Spaces, Existence Theorems in Metric Spaces, Existence Theorems in Banach Spaces, Approximation of Fixed Points, Strong Convergence Theorems

Unit-IV		9 hrs

Compactness in metric spaces. Measure of noncompactness, Measure of noncompactness in Banach spaces, Classes of special operators on Banach spaces

Unit-V		9 hrs

The Fixed point property, Brower's Fixed point theorem, equivalent formulations, some examples and applications, The computation of fixed points, Schauder's fixed point theorem and its generalizations, Applications of Fixed Point Theorems.

Text Books:

1. 1. V. Berinde, Iterative approximation of fixed points, Springer-Verlag, Berlin, Heidelberg, 2007.
2. R. P. Agarwal, Maria Meehan and D.O' Regan, Fixed point theory and applica-tions, Cambridge University Press, 2001.

Reference Books:

3. E.Zeidler, Nonlinear Functional Analysis and its Applications I: Fixed Point The-orems, Springer-Verlag, New York, 1986.
4. V. I. Istratescu, Fixed Point Theory - An Introduction, D. Reidel Publishing Com-pany, Dordrecht, Holland, 1981.
5. W. A. Kirk and B. Sims, Handbook of Metric Fixed Point Theory, Kluwer AcademicPublishers, 2001.

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MSMAE19	Fluid Dynamics	L	T	P	C
		2	1	0	3

Pre-requisite: NIL

Course Objectives:

CO1: Understand the basic properties and principles of viscous and non-viscous fluids
CO2: Derive and deduce the consequences of the governing equations of fluids
CO2: Solve kinematics problems such as finding particle paths and streamlines

Unit-I	Kinematics of fluids in motion	9 hrs

Real and ideal fluids. Coefficient of viscosity. Steady and unsteady flows. Isotropy. Orthogonal curvilinear coordinates. Velocity of a fluid particle. Material local and convective derivative. Acceleration. Stress. Rate of strain. Vorticity and vortex line. Stress analysis. Relation between stress and rate of strain,

Unit-II	Equation of continuity	9 hrs

Streamline. Path lines. Streak lines. Velocity potential. Eulerian and Lagrangian forms of Equation of continuity. Boundary conditions and boundary surfaces

Unit-III	Equations of motion of a fluid	9 hrs

Pressure at a point in a fluid. Euler's equations of Motion. Momentum equations in cylindrical and spherical polar coordinates. Conservative field of force. Flows involving axial symmetry. Equations of motion under impulsive forces. Potential theorems

Unit-IV	In viscid flows	9 hrs

Energy equation. Cauchy's Integrals. Helmholtz equations. Bernoulli's equation and applications. Lagrange's hydro-dynamical equations.

Unit-V	Boundary layer theory	9 hrs

Bernoulli's theorem and applications. Torricelli's theorem. Trajectory of a free jet. Pitot tube. Venturi meter**.** Boundary layer theory.

Text Book:

1. G.K. Batchelor, An Introduction to Fluid Dynamics, Cambridge University Press, 1993.
2. M.D. Raisinghania, Fluid Dynamics, S Chand, New Delhi, 2000.

Reference Books:

1. F. Chorlton, Text book of Fluid Mechanics, CBS Publishers, New 58 Delhi, 1985.
2. F. White, Viscous Fluid Flow, McGraw -Hill, 1991

Course Outcomes:

EO1: learnt the basic properties and principles of viscous and non-viscous fluids
EO2: Understand the conservation equations.

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MSMAE20	Measure and Integration	L	T	P	C
		2	1	0	3

Pre-requisite: Basic knowledge in Analysis

Course Objectives:

CO1: Gain understanding of the abstract measure theory, definition and main properties of the integral.

CO2: Construct Lebesgue's measure on the real line and in n-dimensional Euclidean Space.

CO3: Explain the basic advanced directions of the theory.

Unit-I		9 hrs

Measure on the Real line - Lebesgue Outer measure - Measurable sets - Regularity - Abstract Measure Spaces - Measures and Outer Measures - Extension of a Measure.

Unit-II		9 hrs

Measure on the Real Line - Measurable functions - Borel and Lebesgue Measurability.

Unit-III		9 hrs

Integration of Functions of a Real Variable - Integration of Non-negative Functions - The General Integral - Integration of series - Riemann and Lebesgue integrals.

Unit-IV		9 hrs

Signed Measures and their Derivatives - Signed Measures and the Hahn Decomposition - The Jordan Decomposition - the Radon-Nikodym Theorem

Unit-V		9 hrs

Measure and Integration in a Product Space - Measurability in a Product Space - The Product Measure and Fubini's Theorem.

Text Books:

1. 1. Measure Theory and Integration by G. De Barra, Wiley Eastern, New Delhi, 1981
2. Lebesgue Measure and Integration by P.K. Jain and V.P. Gupta, , New Age Int. (P) Ltd., New Delhi, 2000.

Reference Books:

6. Real Analysis by H.L. Royden, McMillian Publ. Co, New York, 1993.
7. Real and Complex Analysis by Walter Rudin, Tata McGraw Hill Publ. Co. Ltd.,New Delhi, 1966.

Expected outcomes:

EO1: Demonstrate understanding of the basic concepts underlying the definition of the general Lebesgue integral.

EO2: Prove basic results of measure theory and integration theory.

EO3: Demonstrate understanding of the statement and proof of the fundamental integral convergence theorems, and their applications.

EO4: Demonstrate understanding of the statements of the main results on integration on product spaces and an ability to apply these in examples.

EO5: Apply the theory of the course to solve a variety of problems at an appropriate level of difficulty.

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MSMAE21	Operator Theory	L	T	P	C
		2	1	0	3

Pre-requisite: Functional Analysis

Course Objectives:

CO1: to introduce fundamental topics in operator theory

CO2: to study compact operators, spectral theory of Banach space operators and Hilbert space operators.

Unit-I — **9 hrs**

Banach algebras, Gelfand theory, C*- algebras the GNS construction, spectral theorem for normal operators, Fredholm operators and its properties, semi-Fredhlom operators, product of operators.

Unit-II — **9 hrs**

Hilbert Space Operators, Parts of Spectrum, Orthogonal Projections, In-variant Subspaces, Reducing Subspaces, Shifts, Decompositions of Operators. Com- pact linear operators, Spectral properties of compact bounded linear operators, spectral theorem and functional calculus for compact normal operators.

Unit-III — **9 hrs**

Spectral projections, spectral decomposition theorem, spectral theorem for a bounded normal operator, Measures of operators.

Unit-IV — **9 hrs**

Perturbation classes, strictly singular operators, Spectral theory of integral operators: Hilbert Schmidt theorem, Mercer,s theorem, Trace formula for integral operators, integral operators as inverse of differential operators. Sturm-Liouville systems.

Unit-V — **9 hrs**

Unbounded operators: Basic theory of unbounded self adjoint operators, unbounded Fredhlom operators and its properties, essential spectrum, unbounded semi-Fredhlom operators, Spectral theorem for an unbounded self adjoint operators.

Text Book:

1. 1 J. B. Conway, A course in Functional Analysis, Springer-Verlag, 2th Edn., 1990.
2. Rudin W., Functional Analysis, Tata Mcgraw-Hill, 1974.
3. M. Schechter, Principles of Functional Analysis, AMS,2th Edn., 2002

Reference Books:

1. I. Gohberg & S. Goldberg, Basic operator Theory, Birkhauser,1981.
2. M. Ahues, A. Largillier B.V. Limaye, Spectral Computations for Bounded Opera-tors, Chapman & Hall/CRC, 2001.
3. B.V. Limaye, Functional Analysis, New Age Publishers, 2th Edn., 2006.

Course Outcomes:

EO1: Understand various operators on Hilbert spaces such as self-adjoint, normal, unitary, isometry, partial isometry, projections, and positive operators.

EO2: apply the acquired knowledge to use these concepts to analyze the qualitative behavior of the partial differential equations.

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MSMAE21	Machine Learning to Finance	L	T	P	C
		2	1	0	3

Pre-requisite:

Course Objectives:

CO1:, To study Machine learning in financial markets

CO2:. To gather knowledge of implication of ML in Finance.

CO3:

Unit-I	Introduction to Financial Markets and Algorithmic Trading	9 hrs

FX Market; Exchange Rate; Exchange Rate Movement; Bids and Offers; The Interbank Market; The Retail Market Understanding Leverage and Margin; The Contract for Difference Trading; The Share Market; RaisingCapital Stocks Index

Unit-II	Forecasting Using ARIM	9 hrs

Test for White Noise; Test for Stationary; Autocorrelation Function Partial Autocorrelation Function; The ARIMA Model; ARIMA Hyperparameter Optimization; Develop the ARIMA Model Forecast Using the ARIMA Model;

Unit-III	Forecasting Using SARIMA,	9 hrs

The SARIMA Model SARIMA Hyperparameter Optimization; Develop a SARIMA Model; Forecast Using the ARIMA Model

Unit-IV	Univariate Time Series Using Recurrent Neural Nets	9 hrs

Optimize an Artificial Neural Network; The Sequential Data Problem TheRNN Model; The Recurrent Neural Network Problem The LSTM Model ; Develop an LSTM Model Using Keras; Forecasting Using the LTSM

Unit-V	Stock Clustering	9 hrs

Investment Portfolio Diversification ; Stock Market Volatility; K-Means Clustering K-Means in Practice

Text Book:

1. Implementing Machine Learning for Finance, A Systematic Approach to Predictive Risk and Performance Analysis for Investment Portfolios, Tshepo Chris Nokeri, 2021. Apress
2. Machine Learning for Finance, Jannes Klaas 2019 Packt Publishing

Reference Books:

1.

Course Outcomes:

EO1 Demonstrate understanding of the statements of the financial results

EO2: Apply the acquired knowledge to use these concepts to analyze the qualitative behavior financial Markets

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MSMAE22	Mathematical Image Analysis	L	T	P	C
		2	1	0	3

Pre-requisite:

Course Objectives:

CO1:, To introduce mathematical concepts in image processing

CO2: To impart knowledge to the students how digital image is a mathematical finite values or pixels and how extract.

Unit-I	Introduction of Mathematical image	9 hrs

What Are Images? The Basic Tasks of Imaging ;Mathematical Preliminaries; Basic Tools: Continuous and Discrete Images; Interpolation- Sampling-Error Measures- Histograms- Linear Filters- Definition and Properties- Applications-Discretization of Convolutions.

Unit-II	Morphological Filters	9 hrs

Fundamental Operations: Dilation and Erosion-Concatenated Operations-Applications-Discretization of Morphological Operators.

Unit-III	Partial Differential Equations in Image Processing	9 hrs

: Axiomatic Derivation of Partial Differential Equations-Scale Space Axioms-Examples of Scale Spaces-Existence of an Infinitesimal Generator-Viscosity Solutions

Unit-IV	Variational Methods	9 hrs

Foundations of the Calculus of Variations and Convex Analysis-The Direct Method- Convex Analysis-Subdifferential Calculus-Fenchel Duality

Unit-V	Numerical Methods	9 hrs

Solving a Partial Differential Equation - Primal-Dual Methods-Application of the Primal-Dual Methods

Text Book:

1. Mathematical Image Processing Kristian Bredies Dirk Lorenz Birkhäuser, 2018, Springer
2. Image Processing and Analysis, Variational, PDE, Wavelet, and Stochastic Methods By Tony F. Chan, Jianhong Shen · 2005

Reference Books:

Course Outcomes:

EO1: Students will understand image filtering, discretization of Convolutions

EO2: Students will learn how partial differential equation plays important role in image analysis.

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MSMAE24	Commutative Algebra	L	T	P	C
		2	1	0	3

Pre-requisite: Algebra

Course Objectives:

CO1: provides the basic idea of algebra

CO2: to learn Finitely generated modules

CO3: Understand Notherian rings. Artinian rings.

Unit-I		9 hrs

Rings, ring homomorphism, ideals, quotients, zero divisors, nilpotents, and units. Prime and maximal ideals, nilradical and Jacobsons radical

Unit-II		9 hrs

Operations on ideals, extension and contraction, Modules and module homomorphisms, Submodules and quotient modules, Operations on submodules, Direct sum and product

Unit-III		9 hrs

Finitely generated modules, Exact sequences, Tensor product of modules. Restriction and extension of scalars, Exactness properties of the tensor product.

Unit-IV		9 hrs

Localization Integral dependence, Going-up and Going-down theorems, Chain conditions, Noetherian rings

Unit-V		

Primary decomposition in Notherian rings. Artinian rings

Text Books:

1. M. F. Atiyah & I. G. Macdonald, Introduction to Commutative Rings, Addison Wesley
2. Zarinski and P. Samuel, Commutative Algebra with a view towards Algebraic

Reference Books:

1. Irving Kapalansky– Commutative Rings
2. N. S. Gopalakrishnan – Commutative Algebra, Oxonian Press

Expected outcomes:

EO1: Able to understand basic theory of commutative algebra

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MSMAE25	Algebraic Topology	L	T	P	C
		2	1	0	3

Pre-requisite: Basic topology

Course Objectives:

CO1: : Provides the basic idea of algebraic Topology

Unit-I		9 hrs

Homotopy of paths, fundamental group of a topological space, fundamental group functor, homotopy of maps of topological spaces; homotopy equivalence; contractible and simply connected spaces; Calculation of fundamental groups of n (n > 1) using Van Kampen's theorem (special case); fundamental group of a topological group; Brouwer's fixed point theorem; fundamental theorem of algebra; vector fields, Frobenius theorem on eigenvalues of 3 x 3 matrices

Unit-II		9 hrs

Covering spaces, unique lifting theorem, path-lifting theorem, covering homotopy theorem, fundamental group of 1, 1 x 1 etc., degree of maps of 1

Unit-III		9 hrs

Applications; criterion of lifting of maps in terms of fundamental groups; universal coverings and its existence; special cases of manifolds and topological groups.

Unit-IV		9 hrs

Category and Functors, Singular homology, relative homology, Eilenberg-Steenrod axioms (without proof), Reduced homology, relation between Π1 and H1;.

Unit-V		9 hrs

Calculations of homology of n; Brouwer's fixed point theorem and its applications to spheres and vector fields; Meyer-Vietoris sequence and its application.

Text Books:

1 Munkres, J. R. (2000) Topology: A First Course, Prentice-Hall of India Ltd., New Delhi.

2. Greenberg, M. J. and Harper, J. R. (1997) Algebraic Topology: A First Course (2nd edition), Addison-Wesley Publishing Co.

3. Hatcher, A. (2002) Algebraic Topology, Cambridge University Press.

Reference Books:

1. Armstrong , M. A. (2000) Basic Topology, UTM Spinger
2. Spanier, E. H. (2000) Algebraic Topology (2nd edition), Springer-Verlag, New York.
3. Rotman, J. J. (2004) An Introduction to Algebraic Topology, Text in Mathematics, No. 119, Springer, New York.

Expected outcomes:

EO1: Able to understand basic theory of Algebraic Topology

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MSMAE23	Bio-Statistics	L	T	P	C
		2	1	0	3

Pre-requisite:

Course Objectives:

CO1:, During the process of life sciences, medicinal and clinical experiments, precious data are being generated, which need careful and valid statistical analysis for drawing the meaningful conclusions.

Unit-I		9 hrs

Statistical Methods in Clinical Trials: Introduction and its phases I, II, III and IV, statistical designs-fixed sample trials design and Sequential design, Randomization, Blinding.

Unit-II		9 hrs

Biological Assays, Feller's theorem. Dose-response relationships-qualitative and quantitative response.

Unit-III		9 hrs

Data editing and transformations, Transformation in general: logarithmic, square root and power transformations; transformations for proportions: angular, probit and logit transformations. Outlying observations: box plot, M- estimators. Test for normality - p-p plot and q-q plot and Kolmogorov-Smirnov test

Unit-IV		9 hrs

Categorical Data Analysis: Categorical response data, logistic regression-odds ratio, Wald's statistic, logistic regression and its diagnostics memory databases

Unit-V		9 hrs

Repeated Measures ANOVA: One Way and Two Classified Data, Epidemiological study designs and its analysis

Text Book:

1. Fundamentals of Biostatistics, ANE Books, India by Rastogi, V.B

Reference Books:

1. Biostatistical Analysis, Pearson by Jerrold H. Zar
2. Biostatistics: A Foundation for Analysis in the Health Sciences, 10th Edition by Daniel W. W and CrossL. C
3. Biostatistics and Epidemiology – A Primer for Health and Biomedical professionals, 3rd Ed, Springer by Sylvia Wasserthial and Smoller

Course Outcomes:

EO1 Gives the idea about fundamentals and different approaches of survey sampling

EO2: Gives the idea about advanced sampling schemes and important estimators.

EO3: Provides the concept of successive sampling and introduces some natural estimators.

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Course Code	Course Title	L	T	P	C
MSMAOE001	Mathematics for Machine Learning	3	0	0	3

Pre-requisite :NIL

Course Objectives:

- To study the basics of linear space and linear transformation.
- To learn various methods in matrix theory and decomposition methods.
- To apply the concepts of differentiation and integration for solving maxima and minima problems.
- To represent networks using graph models.
- To apply and evaluate the optimization problems.

Expected Course Outcome:

- CO1: Identify the standard distributions and apply them in solving problems.
- CO2: Acquire knowledge of linear spaces and solve problems.
- CO3. Apply various methods in matrix theory to solve decomposition problems.
- CO4: Understand the concepts of differential and integral calculus and solve problems.
- CO5: Acquire knowledge of graphs and cut-sets and apply in network flow problems.

Unit:1	VECTOR SPACES	6 hours

Vector spaces –Subspaces –Linear combinations and system of Linear equations –Linear Independence and Linear dependence – Basis and Dimensions.

Unit:2	LINEAR TRANSFORMATION AND MATRIX DECOMPOSITION	9 hours

Linear transformations –Null spaces Range –Matrix representation of linear transformation – Eigenvalues –Eigenvectors –Diagonalization - Inner and outer products – Inner product space – orthogonality and orthonormality - Singular value decomposition -LU decomposition, Principal Component Analysis (PCA), Singular Value Decomposition (SVD).

Unit:3	DIFFERENTIAL AND INTEGRAL CALCULUS	9 hours

Functions of a single variable, limit, continuity, differentiability - Mean value theorems, indeterminate forms, L'Hospital's rule - Maxima and minima - Taylor's series, infinite series summation/integration concepts - Fundamental and mean value-theorems of integral calculus, Evaluation of definite and improper integrals - Beta and gamma functions.

Unit:4	GRAPHS THEORY	9 hours

Graphs: Directed and Undirected – Subgraphs – Matrix Representation of graphs– Cut-Sets and Cut vertices: Properties of a Cut-Set – Fundamental Circuits and Cut-Sets – Connectivity and Separability – Case Studies: Applications of Bayesian networks.

Unit:5	COMPLEX ANALYSIS & PARTIAL DIFFERENTIAL EQUATIONS (PDES)	12 hours

Analytic functions and Cauchy's theorem-Residue theorem and contour integration, Classification of PDEs (elliptic, parabolic, hyperbolic).Boundary value problems and initial value problems-Numerical methods for solving PDEs.

1. 1.Friedberg A.H, Insel A.J. and Spence L, Linear Algebra, Prentice Hall of India, New Delhi,2004.
2. Strang G, Linear Algebra and its applications, Thomson (Brooks/Cole), New Delhi, 2005. O'Neil, P.V., Advanced Engineering Mathematics, Thomson Asia Pvt. Ltd., Singapore, 2003.
3. NarsinghDeo, Graph Theory with Applications to Engineering & Computer Science, Dover Publications, Inc. Mineola, New York, 2016.
4. Elias M. Stein and Rami Shakarchi, Complex Analysis, Princeton University Press, 2010. Stanley J. Farlow, "Partial Differential Equations for Scientists and Engineers", Dover Publications, India, 2003.

Reference Books

1. B. S. Grewal, Higher Engineering Mathematics, Krishna Publications, 2017.
2.Linear Programming and Network Flows. by Mokhtar S. Bazaraa, Wiley; 4th edition (15January 2010).
Johnson, R.A. and Gupta, C.B., Miller and Freund's Probability and Statistics for Engineers,Pearson Education, Asia, 8th Edition, 2011.

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MSMAXXX	Introduction to LATEX	L	T	P	C
		2	0	1	2

Pre-requisite: NIL

Course Objectives:

CO1: To provide basic knowledge of LATEX.

CO2: To use of LATEX

Unit-I	Basics of a LATEX	12 hrs

Text formatting, TEX and its offspring, What's different in LATEX 2ϵ, Distinguishing LATEX 2ϵ , Basics of a LATEX file.

Unit-II	Commands and environments	12 hrs

Commands and environments, Command names and arguments, Envi- ronments, Declarations, Lengths, Special Characters, Fragile Commands, Exercises

Unit-III	Document layout and organization	12 hrs

Document layout and organization, Document class, Page style, Parts of the document, Table of contents, Fine - tuning text, Word division. Displayed text, Changing font, Centering and indenting, Lists, Generalized lists, Theorem-like decla-rations, Tabulator stops, Boxes.

Unit-IV	Settings and Drawings	12 hrs

Tables, Printing literal text, Footnotes and marginal notes. Drawing pictures with LATEX.

Unit-V	Mathematical symbols and formulas	12 hrs

Mathematical formulas, Mathematical environments, Main elements of math mode, Mathematical symbols, Additional elements, Fine-tuning mathematics.

Text Book:

1.A Guide to LATEX by H. Kopka and P.W. Daly, Third Edition, Addison - Wesley,London, 1999.

Reference Books:

1.A Guide to LATEX and Electronic Publishing Fourth edition Helmut Kopka Patrick W. Daly
2. http://tobi.oetiker.ch/lshort/lshort.pdf
3. http://www.ctan.org/

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MSMAXXX	MATLAB	L	T	P	C
		2	0	1	2

Pre-requisite: NIL

Course Objectives:

CO1: To provide basic knowledge MATLAB.

CO2: To use of MATLAB

Unit-I	Basics of a MATLAB	12 hrs

Starting with Matlab, Creating arrays, Mathematical operations witharrays.

Unit-II	Files and function files	12 hrs

Script files, Functions and function files

Unit-III	Plots	12 hrs

Two-dimensional plots, Three-dimensional plots

Unit-IV	Programming in MATLAB	12 hrs

Programming in MATLAB

Unit-V	Applications	12 hrs

Polynomials, Curve fitting and interpolation, Applications in numericalanalysis.

Text Book:

1. MATLAB An Introduction with Application by A. Gilat, John Wiley & Sons, Sin-gapore, 2004.
2. Getting Started with MATLAB - A Quick Introduction for Scientists and Engi-neers by R. Pratap, Oxford University Press, New Delhi, 2006.
3. Introduction to Matlab 7 for Engineers by W.J. Palm, McGraw-Hill Education,New York, 2005.
4. Introduction to MATLAB 7 by D. M. Etter, D. C. Kuncicky and H.Moore, PrenticeHall, New Jersy, 2004.

Course Outcomes:

EO1: Able to write programes in MATLAB.

EO2: Able to know application of MATLAB

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RGNIYD

REGULATIONS AND SYLLABUS
OF
Ph.D COURSE WORK

Course Objectives :

CO1: To teach students to identify a research problem or research question;
CO2: To familiarize students with the methodology of working with primary sources and performing patent searches;
CO3: To familiarize students with the main body of the research's work;
CO4: To teach students to present and discuss their own work;
CO5: To teach students to read and comment on the work of other students;
CO6: To familiarize students with the basic principles and requirements for submitting a dissertation for defense.

Learning Outcomes :

By the end of the course, students will know:
EO1: Writing a thesis and an article outline;
EO2: References and research ethics;
EO3: Prepare a presentation of science project.

By the end of the course, students will be able to:
EO4: Define a research problem or research question;
EO5: Build a scientific argument;
EO6: Present and discuss own work;
EO4: Read and comment upon another students' work.

By the end of the course, students will possess:
EO7: Independent work, critical/analytical thinking;
EO8: Use scientific methods to analyze technical dimensions of knowledge and technology

Course Code	Course Title	L	T	P	C	Marks
Semester-I						
PHDMA001	Research Methodology	2	0	0	2	100
PHDMA002	Research and Publication Ethics (CPE-RPE)	2	0	0	2	100
Semester-II						
PHDMA003	Research Paper as decided by DRC	3	0	0	3	100
PHDMA004	Research Seminar	o	0	4	2	100
PHDMA005	Research Paper as decided by DRC	3	0	0	3	100
Total Credits		10	0	4	12	500

Minimum Credits from Courses: 12 Max Credits from Elective Courses: 16

- **If PG course is opted, then course code will be that of PG Course.**
- **If new subject is opted, the code can be given by the RAC.**

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Dr. Parthasakha Das, HoD(i/c)
RGNIYD

PHDMA103	Research Methodology	L	T	P	C
		0	0	2	2

Pre-requisite: NIL

Course Objectives:

CO1: This paper highlights the various postulates of research problems, research design, writing a thesis and modern statistical methods.

CO2: This helps to carry out research problem individually in perfect scientific methods.

Unit-I	Meaning of Research - Function of Research	12 hrs

Meaning of Research - Function of Research – Characteristics of Research –Steps involved in Research – Research in Pure and Applied Sciences - Inter Disciplinary Research. Factors which hinder Research – Significance of Research - Research and scientific methods – Research Process– Criteria of good Research – Problems encountered by Researchers – Literature review.

Unit-II	Identification of Research Problem	12 hrs

Selecting the Research problem – Necessity of defining the problem – Goals and Criteria for identifying problems for research. Perception of Research problem – Techniques involved in defining the problem – Source of problems – Personal consideration

Unit-III	Research design	12 hrs

Formulation of Research design – Need for Research design – Features of a good design – Important concepts related to Research design. Different research designs – Basic principles of experimental designs – Computer and internet in designs.

Unit-IV	Interpretation and Report Writing	12 hrs

Meaning and Technique of interpretation – Precautions in interpretation – Significance of report writing – Different steps in writing a report – Layout of a Research report. Types of report – Mechanics of writing a research report – Precautions for writing a research report – Conclusion.

Unit-V	Statistical Techniques and Tools	12 hrs

Introduction of statistics – Functions – Limitations – Measures of central tendency - Arithmetic mean – Median – Mode – Standard deviation – Co-efficient of variation (Discrete serious and continuous serious) – Correlation - Regression –Multiple Regression. Sampling distribution – Standard error – Concept of point and interval estimation – Level of significance – Degree of freedom – Analysis of variance – One way and two way classified data – 'F'-test

Text Book and Reference Books:

1. A Hand Book of Methodology of Research, Rajammall, P. Devadoss and K. Kulandaivel, RMM Vidyalaya press, 1976.
2. Research Methodology Methods & Techniques, C.R. Kothari – New Age international Publishers, Reprint 2008.
3. Thesis and Assignment Writing, J. Anderson, Wiley Eastern Ltd., 1997.
4. Research Methodology, Mukul Gupta, Deepa Gupta – PHI Learning Private Ltd., New Delhi, 2011.
5. Fundamentals of Mathematical statistics, S.C. Gupta and V.K. Kapoor, Sultan Chand &Sons,

Course Outcomes:

EO1: Able to carry out research problem individually in perfect scientific methods.

EO2: Understand research design, writing a thesis

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PHDMA103	Research Seminar	L	T	P	C
Pre-requisite : NIL		0	0	2	2

Week	Research Seminar
1-2	Survey of the subject area of research. Search and selection of a personal area of interest. Review of sources in the subject area of research.
3-4	Presentation of the results of the analytical review in the selected area of interest. Collective discussion of the research topic.
5-6	Development of a research plan. Discussion of the main idea for the practical implementation of the research results. Collective brainstorming to shape the proposed scientific novelty of the research.
7-8	Preparation of an article based on the results of the work. Project presentation for collective discussion.
9-10	Development of the required models and the formation of a list of basic metrics for modeling technical solutions on the research topic.
11-12	Presentation of the second section of the dissertation. Preparation of an article based on the results of model development.
13-14	Development of a plan for experimental testing of the solutions obtained.
15-16	Comparative analysis of the expected and obtained results of the dissertation work. Proof of the alleged scientific novelty of the research. Presentation of the third section of the dissertation.
17-18	Complex presentation of tentative dissertation work.

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Member of Board of Studies

Department of Mathematics

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