CURRICULUM
FOR
MASTER OF SCIENCE
(M.Sc.)
IN
MATHEMATICS
(SPECIALIZATION IN COMPUTING)

(From session 2019-20)

DEPARTMENT OF MATHEMATICS AND SCIENTIFIC COMPUTING
MADAN MOHAN MALAVIYA UNIVERSITY OF TECHNOLOGY, GORAKHPUR-273010, UP

About the Department (In brief):

The Department of Mathematics and Scientific Computing attained its present status of an independent department on 22nd June 2019. Prior to this department was constituent part of Applied Science Department, established in 1962. The department is committed to impart the effective teaching and quality research work in different areas of Mathematics and Scientific Computing.

Vision:

To promote the department as a centre of excellence in mathematics and scientific computing for the welfare and development of society and mankind.

Mission:

- To provide the students a strong mathematical foundation to develop their analytical and logical thinking.
- To inculcate in students the ability to apply mathematical and computational skills to formulate and solve the complex engineering problems.
- To emerge as a centre of excellence in teaching and research through innovative teaching and research methodologies.

Programme:

M. Sc. Mathematics (Specialization in Computing)

Programme Educational Objectives (PEOs):

The Programme Educational Objectives (PEOs) for M.Sc. (Mathematics) describe accomplishments that students are expected to attain within five years after completion of the programme

PEO-1: To provide knowledge and insight in mathematics so that students can work as excellent mathematical professional.

PEO-2: To provide students with strong mathematical knowledge and capability in formulating & analysis of real-life problem using modern tools of mathematics.

PEO-3: To prepare and motivate the students to pursue higher studies and conduct fundamental and applied research for the welfare of society and mankind.

PEO-4: To prepare the students to as per the need of software industry through knowledge of mathematics and scientific computational techniques.

PEO-5: Inculcate value system, critical thinking, and mathematical competence so as to meet societal expectations.

Programme Outcomes (POs):

At the end of the programme, the students will be able to:

PO-1. Scientific knowledge: Apply the knowledge of mathematics and scientific computing to solve complex scientific and real-life problem**.**

PO-2. Problem analysis: Identify, formulate, research literature, and analyse complex scientific and real-life problems reaching substantiated conclusions using fundamental and advanced concept of mathematics, and scientific computing sciences.

PO-3. Formulation/development of solutions: Design solutions for complex scientific problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, and cultural, societal, and environmental considerations.

PO-4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO-5. Modern tools usage: Learn, select, and apply appropriate mathematical tools for documentation and to solve mathematical problem with limitations and accuracies such as MAPLE, MATHEMATICA, MATLAB, SPSS, LATEX etc.

PO-6. Mathematics and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO-7. Environment and sustainability: Understand the impact of the professional mathematical solutions in societal and environmental contexts, and demonstrate the knowledge of, and the need for sustainable development.

PO-8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the data analysis and research practices.

PO-9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO-10. Communication: Communicate effectively on their field of expertise on their activities with their peers and with the society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions

PO-11. Project management: Demonstrate knowledge and understanding of the mathematical principles and apply these to one's work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO-12. Life-long learning: Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Programme Specific Outcome (PSOs):

After the successful completion of M.Sc. in Mathematics the students will be able to:

PSO-1: To develop problem-solving skills and apply them independently to problems in pure and applied mathematics.

PSO-2: Understanding of the fundamental axioms in mathematics and capability of developing ideas based on them.

PSO-3: Apply knowledge of a wide range of mathematical techniques and application of mathematical methods/tools in other scientific and engineering domains.

PSO-4: Employ confidently the knowledge of mathematical software and tools for treating the complex mathematical problems and scientific investigations.

PSO-5: Develop abstract mathematical thinking.

PSO-6: Comprehend and write effective reports and design documentation related to mathematical research and literature, make effective presentations.

PSO-7: Incorporate the mathematics skills to clear the competitive examinations like NET, GATE, NBHM, UPSC etc..

CREDIT STRUCTURE
for
M. Sc. Mathematics (Specialization in Computing)
(From Session 2019-2020)

Category Semesters	I	II	III	IV	Total
Programme Core (PC)	18	14	14	8	**54**
Programme Electives (PE)	-	6	3	3	**12**
Dissertation (D)			4	8	**12**
Audit					
Total	**18**	**20**	**21**	**19**	**78**

Junior Year, Semester I

S. N.	Category	Paper Code	Subject Name	L	T	P	Credits
1.	PC	MMS-101	Mathematical Analysis	3	1	0	**4**
2.	PC	MMS-102	Linear Algebra and Matrix Theory	3	1	0	**4**
3.	PC	MMS -103	Advanced Ordinary Differential Equations	3	1	0	**4**
4.	PC	MMS -104	Mathematical Programming	2	1	0	**3**
5.	PC	MMS -105	Data Analytics	2	1	0	**3**
6.	AC		Audit Subject				**-**
			Total	**13**	**5**	**0**	**18**

Junior Year, Semester II

S. N.	Category	Paper Code	Subject Name	L	T	P	Credits
1.	PC	MMS -106	Complex Analysis	3	1	0	**4**
2.	PC	MMS -107	Topology	3	1	0	**4**
3.	PC	MMS -108	Advanced Algebra	3	1	0	**4**
4.	PC	MMS -109	Seminar	0	0	4	**2**
5.	PE-1	MMS -12X	Program Elective-I	2	1	0	**3**
6.	PE-2	MMS -13X	Program Elective-II	2	1	0	**3**
7.	AC		Audit Subject				**-**
			Total	**13**	**5**	**4**	**20**

Senior Year, Semester III

S. N.	Category	Paper Code	Subject Name	L	T	P	Credits
1.	PC	MMS -201	Computational Functional Analysis	3	1	0	**4**
2.	PC	MMS -202	Theory of Computing	3	1	0	**4**
3.	PC	MMS -203	Numerical Methods for Scientific Computations	2	1	2	**4**
4.	PC	MMS -204	Computing Tools	0	0	4	**2**
5.	PE-3	MMS -22X	Program Elective-III	2	1	0	**3**
6.	D	MMS-350	Dissertation Part-I	0	0	8	**4**
			Total	**10**	**4**	**14**	**21**

Senior Year, Semester IV

S. N.	Category	Paper Code	Subject Name	L	T	P	Credits
1.	PC	MMS -205	Number Theory and Cryptography	3	1	0	**4**
2.	PC	MMS -206	Design and Analysis of Algorithms	2	1	2	**4**
3.	PE-4	MMS -23X	Program Elective-IV	2	1	0	**3**
4.	D	MMS-450	Dissertation Part-II	0	0	16	**8**
			Total	**7**	**3**	**18**	**19**

Programme Core: M. Sc. Mathematics (Specialization in Computing)

S. N.	Paper Code	Subject Name	L	T	P	Credits
1.	MMS-101	Mathematical Analysis	3	1	0	**4**
2.	MMS-102	Linear Algebra and Matrix Theory	3	1	0	**4**
3.	MMS-103	Advanced Ordinary Differential Equations	3	1	0	**4**
4.	MMS-104	Mathematical Programming	2	1	0	**3**
5.	MMS-105	Data Analytics	2	1	0	**3**
6.	MMS-106	Complex Analysis	3	1	0	**4**
7.	MMS-107	Topology	3	1	0	**4**
8.	MMS-108	Advanced Algebra	3	1	0	**4**
9.	MMS-109	Seminar	0	0	4	**2**
10.	MMS-201	Computational Functional Analysis	3	1	0	**4**
11.	MMS-202	Theory of Computing	3	1	0	**4**
12.	MMS-203	Numerical Methods for Scientific Computations	2	1	2	**4**
13	MMS-204	Computing Tools	0	0	4	**2**
14.	MMS-205	Number Theory and Cryptography	3	1	0	**4**
15.	MMS-206	Design and Analysis of Algorithms	2	1	2	**4**

Programme Electives-I (PE-I)

S. N.	Paper Code	Subject Name	L	T	P	Credits
1.	MMS-121	Game Theory	2	1	0	**3**
2.	MMS-122	Differential Geometry and Tensor Analysis	2	1	0	**3**
3.	MMS-123	Integral Equations and Partial Differential Equations	2	1	0	**3**
4.	MMS-124	Discrete Mathematical Structure	2	1	0	**3**
5.	MMS-125	Approximation Theory	2	1	0	**3**

Programme Electives-II (PE-II)

S. N.	Paper Code	Subject Name	L	T	P	Credits
1.	MMS-131	Mathematical Methods	2	1	0	**3**
2.	MMS-132	Measure Theory	2	1	0	**3**
3.	MMS-133	Principles of Optimization Theory	2	1	0	**3**
4.	MMS-134	Graph Theory	2	1	0	**3**
5.	MMS-135	Computational Fluid Dynamics	2	1	0	**3**

Programme Electives III (PE-III)

S. N.	Paper Code	Subject Name	L	T	P	Credits
1.	MMS-221	Rings and Module	2	1	0	**3**
2.	MMS-222	Mathematical Modeling and Computer Simulations	2	1	0	**3**
3.	MMS-223	Mathematical Foundation of Artificial Intelligence	2	1	0	**3**
4.	MMS-224	Mathematical Theory of Coding	2	1	0	**3**
5.	MMS-225	Stochastic Processes and its Applications	2	1	0	**3**

Programme Electives IV (PE-IV)

S. N.	Paper Code	Subject Name	L	T	P	Credits
1.	MMS-231	Parallel Computing	2	1	0	**3**
2.	MMS-232	Operations Research	2	1	0	**3**
3.	MMS-233	Fuzzy Theory and its Application	2	1	0	**3**
4.	MMS-234	Theory of Mechanics	2	1	0	**3**
5.	MMS-235	Dynamical Systems	2	1	0	**3**

***Audit course for M. Sc. Mathematics (Specialization in Computing)**

S. N.	Paper Code	Subject Name	L	T	P	Credits
1.	BCS-01	Introduction to Computer Programming	3	1	2	**5**
2.	BCS-12	Principles of Data Structures through C/C++	3	1	2	**5**
3.	MMS-603	Mathematical Foundations of Computer Science	3	1	0	**4**
4.	MBA-109	Research Methodology	3	1	0	**4**

*****The syllabus of audit courses BCS-01, BCS-12, MMS-603 and MBA-109 recommended for the M.Sc. Mathematics with Specialization in Computing during Ist and IInd Semester will be same as recommended by different department and running as the part of different other courses of this university.

MMS-101	**Mathematical Analysis**	**Credit 4 (3-1-0)**

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course

1. Describe the fundamental properties of the real numbers that underpin the formal development of real analysis.
2. Analyse the unform and pointwise convergence of a sequence and series of functions and concept of region of convergence
3. Use theory of Riemann-Stieltjes integral in solving definite integrals arising in different fields of science and engineering
4. Deal with axiomatic structure of metric spaces and generalize the concepts of compactness, connectedness, and completeness in metric spaces.
5. Extend their knowledge of real variable theory for further exploration of the subject for going into research.

UNIT- I

finite, countable and uncountable sets, Real number system as a complete ordered field, Archimedean property, limit point of a set, supremum, infimum, Bolzano Weierstrass theorem, Heine Borel theorem, Continuity, uniform continuity, differentiability, mean value theorems, Monotonic functions, types of discontinuity, functions of bounded variation, inverse and implicit function theorems. **9**

UNIT- II

Sequences and series of functions: Pointwise and uniform convergence of sequences and series of functions, uniform convergence and its consequences, space of continuous functions on a closed interval, equi-continuous families, Arzela-Ascoli theorem, Weierstrass approximation theorem, Power series. **9**

UNIT- III

Riemann-Stieltjes integral: Existence and properties of the integrals, Fundamental theorem of calculus, first and second mean value theorems, Riemann integrals, Definition and properties of Riemann-Stieltjes integral, differentiation of the integral, Fubini's theorem, Improper integrals. **9**

UNIT- IV

Metric Spaces: Review of complete metric spaces, connectedness, compact metric spaces, completeness, compactness and uniform continuity and connected metric spaces. **9**

Books/References

1. R. G. Bartle and D. R. Sherbert, "Introduction to real analysis", 4th edition, Wiley Publishing, 2011.
2. T. M. Apostol, "Mathematical Analysis", 2nd edition, Narosa Publishing, 1985.
3. W. C. Bauldry, "Introduction to real analysis", Wiley Publishing, 2009.
4. W. Rudin, "Principles of Mathematical Analysis", Mc-GrawHill Book Company, 1976.
5. C. D. Aliprantis and W. Burkinshaw, "Principles of Real Analysis", Elsevier, 2011.

MMS-102 **Linear Algebra and Matrix Theory** **Credit 4 (3-1-0)**

Course Outcomes

The students are expected to be able to demonstrate the following knowledge, skills and attitudes after completing this course

1. Matrix theory, determinants, and their application to systems of linear equations.
2. the basic terminology of linear algebra in Euclidean spaces, including linear independence, spanning, basis, rank, nullity, subspace, and linear transformation.
3. the abstract notions of vector space and inner product space.
4. finding eigenvalues and eigenvectors of a matrix or a linear transformation and using them to diagonalize a matrix.
5. projections and orthogonality among Euclidean vectors, including the Gram-Schmidt orthonormalization process and orthogonal matrices.

UNIT- I

Recall of vector space, basis, dimension and related properties, Algebra of Linear transformations, Dimension of space of linear transformations, Change of basis and transition matrices, Linear functional, Dual basis, Computing of a dual basis, Dual vector spaces, Annihilator, Second dual space, Dual transformations. **9**

UNIT- II

Inner-product spaces, Normed space, Cauchy-Schwartz inequality, Projections, Orthogonal Projections, Orthogonal complements, Orthonormality, Matrix Representation of Inner-products, Gram-Schmidt Orthonormalization Process, Bessel's Inequality, Riesz Representation theorem and orthogonal Transformation, Inner product space isomorphism. **9**

UNIT- III

Operators on Inner-product spaces, Adjoint operator, self-adjoint operator, normal operator and their properties, Matrix of adjoint operator, Algebra of Hom(V,V), Minimal Polynomial, Invertible Linear transformation, Characteristic Roots, Characteristic Polynomial and related results. **9**

UNIT- IV

Diagonalization of Matrices, Invariant Subspaces, Cayley-Hamilton Theorem, Canonical form, Jordan Form. Forms on vector spaces, Bilinear Functionals, Symmetric Bilinear Forms, Skew Symmetric Bilinear Forms, Rank of Bilinear Forms, Quadratic Forms, Classification of Real Quadratic forms and related theorems. **9**

Books/References

1. K. Hoffman and Ray Kunje : Linear Algebra, Prentice - Hall of India private Ltd.
2. Vivek Sahai, Vikas Bist : Linear Algebra, Narosa Publishing House.
3. N.S. Gopalkrishanan, University algebra, Wiley Eastern Ltd.
4. S. Lang: Linear Algebra, Springer Undergraduate Texts in Mathematics, 1989.
5. G. Williams, Linear Algebra with Applications, Jones and Burlet Publishers, 2001.

MMS-103 Advanced Ordinary Differential Equation Credit 4 (3-1-0)

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course

1. Obtain solutions of the Homogeneous equation with constant coefficient and Homogeneous equation with variable coefficient
2. Understand differential equations of Strum Liouville type.
3. Understand the concept and applications of eigen value problems
4. Analyse Green's function and its applications to boundary value problems
5. Establish existence and uniqueness for the solution of $y' = f(x, y)$ when f satisfies the Lipschitz condition

UNIT- I

Initial value problem, Boundary value problem, Linear dependence equations with constant as well as variable coefficient, Wronskian, Variation of parameter, Method of undetermined coefficients, Reduction of the order of equation, Method of Laplace's transform. **9**

UNIT- II

Lipchilz's condition and Gron Wall's inequality, Picards theorems, Dependence of solution on initial conditions and on function, Continuation of solutions, Nonlocal existence of solutions Systems as vector equations, Existence and uniqueness of solution for linear systems. **9**

UNIT- III

Strum-Liouvilles system, Green's function and its applications to boundary value problems, Some oscillation theorems such as Strum theorem, Strum comparison theorem and related results. **9**

UNIT- IV

System of first order equation, fundamental matrix, Nonhomogeneous linear system, Linear system's with constant as well as periodic coefficients. **9**

Books/References

1. P. Haitman, Ordinary Differential Equations, Wiley, New York, 1964.
2. E.A. Coddington and H. Davinson, Theory of Ordinary Differential Equations, McGraw Hill, NY, 1955.
3. George F.Simmons, 'Differential Equations with Applications and Historical Notes', Tata McGraw-Hill Publishing Company Ltd. (1972).
4. Boyce.W.E, Diprma.R.C, 'Elementary Differential Equations and Boundary Value Problems', John Wiley and Sons, NY.
5. S. G. Deo, V. Lakshmikantham, V. Raghvendra, Text book of ordinary Differential Equations. Second edition. Tata Mc-Graw Hill.

MMS-104 **Mathematical Programming** **Credit 3 (2-1-0)**

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Apply the notions of linear programming in solving optimizations problems.
2. Understand the theory of Duality for solving LPP & QPP.
3. Acquire knowledge in formulating quadratic and integer programming problem.
4. Use integer and quadratic programming to solve real life problems.
5. Know the use of dynamic programming in various applications.

UNIT- I

Introduction to Linear Programming. Problem formulations. Linear independence and dependence of vectors. Convex sets. Extreme points. Hyperplanes and Halfspaces. Directions of a convex set. Convex cones. Polyhedral sets and cones. Theory of Simplex Method. Simplex Algorithm. Degeneracy. Bounded variable problem. **6**

UNIT- II

Revised Simplex method. Duality theory. Dual-simplex method, Unconstrained and constrained optimization problems. Types of extrema and their necessary and sufficient conditions. Convex functions and their properties. Fritz-John optimality conditions. Karush-Kuhn-Tucker optimality conditions. **6**

UNIT- III

Quadratic Programming: Wolfe's method. Complementary pivot algorithm, Duality in quadratic programming. Integer Linear Programming: Modeling using pure and mixed integer programming. Branch and Bound Technique. Gomory's Cutting Plane Algorithm, 0-1 programming problem, E-Bala’s algorithm. **6**

UNIT- IV

Dynamic Programming: Additive and Multiplicative Separable returns for objective as well as constraints functions. Applications' of Integer and Quadratic Programming. **6**

Books/References

1. M. S. Bazara, H. D. Sherali, C. M. Shetty: Nonlinear Programming-Theory and Algorithms. Wiley, 3rd Edition. 2006.
2. Hamdy A. Taha: Operations Research-An Introduction, ’Prentice Hall, 8th Edition, 2007
3. Ravindran, D. T. Phillips and James J. Solberg: Operations Research- Principles and Practice, John Wiley & Sons, 2005.
4. G. Hadley: Nonlinear and Dynamic Programming, Addison-Wesley, 1964.
5. M. S. Bazara, J. J. Jarvis, H. D. Sherali: Linear Programming and Network Flows, Wiley, 3rd Edition, 2004.

MMS-105 **Data Analytics** **Credit 3 (2-1-0)**

Course Outcomes

The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Define and apply basic concepts and methods of probability theory.
2. To learn various types of probability distribution functions.
3. To study the theory of estimation and with likelihood.
4. To develop the ability to use of Regression analysis in real life problems.
5. To study the hypothesis theory.

UNIT- I

Descriptive Statistics, Probability Distributions: Binomial, Poisson, Negative binomial, Geometric, Hyper-geometric, Normal, Exponential, Gamma, Beta and Weibull. **6**

UNIT- II

Theory of estimation: Basic concepts of estimation, Interval estimation, point estimation, methods of estimation, method of moments, method of maximum likelihood, unbiasedness, minimum variance estimation, interval estimation, Cramer-Rao, inequality. **6**

UNIT- III

Testing of hypothesis: Null and alternative hypothesis, type I and II errors, power function, method of finding tests, likelihood ratio test, UMP Test, Neyman, Pearson lemma, uniformly most powerful tests .ANOVA. **6**

UNIT- IV

Machine Learning: Introduction and Concepts: Differentiating algorithmic and model-based frameworks, Regression: Ordinary Least Squares, Ridge Regression, Lasso Regression, K Nearest Neighbours Regression & Classification. **6**

Books/References

1. Montgomery, Douglas C., and George C. Runger. Applied statistics and probability for engineers. John Wiley & Sons, 2010
2. Hastie, Trevor, et al. The elements of statistical learning. Vol. 2. No. 1. New York: springer, 2009.
3. Hogg, R. V. and Craig, A., "Introduction to Mathematical Statistics", Pearson Education, 6th Ed. 2006
4. Rohatgi, V. K. and Md. Ehsanes Saleh, A. K., "An Introduction to Probability and Statistics", John Wiley and Sons, 2nd edition. 2000
5. Papoulis, A., Pillai, S.U., Probability, "Random Variables and Stochastic Processes", Tata McGraw-Hill, 4th Ed. 2002

MMS-106 **Complex Analysis** **Credit 4 (3-1-0)**

Course Outcomes

The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Prove basic results in complex analysis.
2. Establish the capacity for mathematical reasoning through analysing, proving, and explaining concepts from complex analysis.
3. Solve the problems using complex analysis techniques applied to different situations in engineering and other mathematical contexts.
4. Evaluate complex integrals and apply Cauchy integral theorem and formula.
5. Extend their knowledge to pursue research in this field.

UNIT- I

Extended complex plane and stereographic projection, Complex differentiability, Cauchy-Riemann equations, Analytic functions, Harmonic functions, Harmonic conjugates, Analyticity of functions defined by power series, The exponential function and its properties.	**9**

UNIT- II

Branch of logarithm, Power of a complex number, Pasic properties of contour integration, M-L inequality, fundamental theorem of contour integration, Cauchy's integral theorem, Cauchy-Goursat theorem (statement only), Cauchy's integral formula, Cauchy's integral formula for higher derivatives, Morera's theorem. Maximum modulus theorem, Schwarz lemma, Taylor's theorem, Laurent's theorem.	**9**

UNIT- III

Zeros of an analytic functions, The identity theorem for analytic functions, Liouville's theorem, The fundamental theorem of algebra, Singularities of functions, Removable singularity, Poles and essential singularities, Residues, Cauchy's residue theorem.	**9**

UNIT- IV

Evaluation of definite and Improper integrals using contour integration, Meromorphic functions, argument principle, Rouche's theorem. Conformality, Möbius transformations, The group of Möbius transformations, Cross ratio, Invariance of circles, Symmetry and orientation principles (statement only).	**9**

Books/References

1. J. B. Conway, Functions of One Complex Variable, Narosa Publishing House, New Delhi, 2002.
2. Dennis G. Zill, Complex Analysis,Jones and Bartlett Publishers, 3ed
3. V. Ahlfors, Complex Analysis (Third Edition), McGraw-Hill, 1979.
4. M. Spiegel, J. Schiller, S. Lipschutz, Schaum's Outline of Complex Variables, 2ed (Schaum's Outlines)
5. James W. Brown & R. V. Churchill: Complex variables and applications, Mcgraw-Hill Asia

MMS-107 **Topology** **Credit: 4 (3-1-0)**

Course Outcomes

The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Concepts of topological spaces and the basic definitions of open sets, neighbourhood, interior, exterior, closure and their axioms for defining topological space.
2. Understand the concept of Bases and Subbases, create new topological spaces by using subbase.
3. Understand continuity, compactness, connectedness, homeomorphism, and topological properties.
4. Understand how points of space are separated by open sets, Housdroff spaces and their importance.
5. Understand regular and normal spaces and some important theorems in these spaces.

UNIT- I

Definitions and examples of topological spaces, Topology induced by a metric, closed sets, Closure, Dense subsets, Neighbourhoods, Interior, Exterior and boundary accumulation points and derived sets, Bases and subbases. **9**

UNIT- II

Topology generated by the subbases, subspaces and relative topology.Alternative methods of defining a topology in terms of Kuratowski closure operator and neighbourhood systems. Continuous functions and homeomorphism. First and second countable space. Lindelöf spaces. Separable spaces. **9**

UNIT- III

The separation axioms T0, T1, T2, T3½, T4; their characterizations and basic properties. Urysohn's lemma. Tietz extension theorem. Compactness. Basic properties of compactness. Compactness and finite intersection property. Sequential, countable, and B-W compactness. Local compactness. **9**

UNIT- IV

Connected spaces and their basic properties. Connectedness of the real line. Components. Locally connected spaces. Tychonoff product topology in terms of standard sub-base and its characterizations. Product topology and separation axioms, connected-ness, and compactness, Tychonoff's theorem, countability and product spaces. **9**

Books/References

1. GF Simmons: Introduction to Topology and Modern Analysis, Mc Graw Hill, 1963

2. James R Munkres: Topology, A first course, Prentice Hall, New Delhi, 2000

3. JL Kelly: Topology, Von Nostrand Reinhold Co. New York, 1995.

4. K.D. Joshi : Introduction to General Topology, Wiley Eastern Ltd.

5. J. V. Deshpande: Introduction to Topology, Tata McGraw Hill, 1988.

MMS-108 **Advanced Algebra** **Credit: 4 (3-1-0)**

Course Outcomes

The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. knowledge and understanding of the concept of Conjugacy class, class equation, Cauchy Theorem and Sylow's theorems.
2. knowledge and understanding of symmetric groups, cyclic groups, direct product of groups and their properties
3. knowledge and understanding of the concept solvable and nilpotent groups.
4. knowledge and understanding of a field extension to various mathematical problems including geometric constructions and perfect division of a circle into n parts
5. knowledge and understanding of Galois theory to the question of solvability of the quintic

UNIT- I

Relation of conjugacy, conjugate classes of a group, number of elements in a conjugate class of an element of a finite group, class equation in a finite group and related results, partition of a positive integer, conjugate classes in Sn, Sylow's theorems, external and internal direct products and related results.	**9**

UNIT- II

subnormal series of a group, refinement of a subnormal series, length of a subnormal series, solvable groups and related results, n-th derived subgroup, upper central and lower central series of a group, nilpotent groups, relation between solvable and nilpotent groups, composition series of a group, Zassenhaus theorem, Schreier refinement theorem, Jordan-Holder theorem for finite groups, Insolvability of S_n for n>5.	**9**

UNIT- III

Field extensions: Finite extension, Finitely generated extension, Algebraic extension, algebraic closure, Simple extension, Transcendental Extension, Finite Field, Splitting field, Algebraically closed field.	**9**

UNIT- IV

Normal extension, Separable extension, Primitive Element Theorem, Automorphism of fields, Galois field, Galois extension, Fundamental Theorem of Galois theory, primitive elements, Solution of polynomial equations by radicals.	**9**

Books/References

1. I. N. Herstein, Topic in Algebra, Wiley, New York, 1975.
2. D. S. Dummit and R.M. Foote, Abstract Algebra, John Wiley, N.Y., 2003.
3. V.Sahai&V.Bist: Algebra, Second edition, Narosa.
4. N. Jacobson, Basic Algebra, Vol. I, Hindustan Publishing Co., New Delhi, 1984.
5. P.M. Cohn, **Basic Algebra,** Springer (India) Pvt. Ltd., New Delhi, **2003.**

MMS-121	**Game Theory**	**Credit 3 (2-1-0)**

Course Outcomes

The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Appreciate the concept of game theory and understand the different methods of Strategies.
2. Explain the concepts of repeated games, Bayesian games, Selfish routing and Quantifying inefficiency of equilibria.
3. Understand the concept of evolutionary game theory, price of stability.
4. Explain the concept of N-person game.
5. Apprehend the concept of Nash bargaining Mechanism design.

UNIT- I

Game Theory Introduction: Overview, Examples and applications of Game Theory, Normal forms, Payoffs, Nash Equilibrium, Dominate Strategies, Perfect Information Games, Games in Extensive Form Game Trees, Choice Functions and Strategies, Choice Subtrees, Two-Person Matrix Games, Mixed strategies, Best Response Strategies. **6**

UNIT- II

Equilibrium in Games: Nash equilibrium, The von Neumann Minimax Theorem, Fixed point theorems, Computational aspects of Nash equilibrium.
Solution Methods for Matrix Games: Linear Programming, Simplex Algorithm, DualSimplex Algorithm. **6**

UNIT- III

Two Person Non-Zero-Sum Games: 2x2 Bimatrix Games, Nonlinear Programming Methods for Non-zero Sum Two-Person Games.
N-Person Cooperative Games: Coalitions and Characteristic Functions, Imputations 5 and their Dominance, The Core, Strategic Equivalence. **6**

UNIT- IV

Continuum Strategies: N-Person Non-Zero-Sum Games with continuum of strategies, Duels, Auctions, Nash Model with Security Point, Threats.
Evolutionary Strategies: Evolution, Stable Strategies. **6**

Books/References

1. M.J. Osborne, An Introduction to Game Theory, Oxford University Press, 2004
2. Peter Morris, Introduction to Game Theory, Springer-Verlag, 1994.
3. Gibbons, Robert, Game Theory for applied economists, Princeton University Press.
4. Leyton Brown & Y. Shoham, Essential Game Theory, K., Morgan &Clayful, 2008.
5. Martin, J. Osborne and Ariel Rubinstein, A course in game theory , , MIT Press.

MMS-122 **Differential Geometry and Tensor Analysis** **Credit 3 (2-1-0)**

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course

1. Understand the basic concepts and results related to space curves, tangents, normals and surfaces.
2. Explain the geometry of different types of curves and spaces.
3. Utilize Geodesics, it's all related terms, properties and theorems.
4. Understand the concept of Differential Manifold
5. Understand the concept of Contravariant and covariant vectors and tensors.

UNIT- I

Plane curves, tangent and normal and binormal, Osculating plane, normal plane and rectifying plane, Helices, SerretFrenet apparatus, contact between curve and surfaces, tangent surfaces, Intrinsic equations, fundamental existence theorem for space curves, Local theory of surfaces-Parametric patches on surface curve of a surface, surfaces of revolutions, metric-first fundamental form and arc length. **6**

UNIT- II

Direction coefficients, families of curves, intrinsic properties, geodesics, canonical geodesic equations, normal properties of geodesics, geodesics curvature, geodesics polars, Gauss-Bonnet theorem, Gaussian curvature, normal curvature, Meusneir's theorem, mean curvature, Gaussian curvature, umbilic points, lines of curvature, Rodrigue's formula, Euler's theorem. The fundamental equation of surface theory – The equation of Gauss, the (vi) equation of Weingarten, the Mainardi-Codazzi equation.. **6**

UNIT- III

Differential Manifold-examples, tangent vectors, connexions, covariant differentiation. Elements of general Riemannian geometry-Riemannian metric, the fundamental theorem of local Riemannian Geometry, Differential parameters, curvature tensor, Geodesics, geodesics curvature, geometrical interpretation of the curvature tensor and special Riemannian spaces. **6**

UNIT- IV

Contravariant and covariant vectors and tensors, Mixed tensors, Symmetric and skew-symmetric tensors, Algebra of tensors, Contraction and inner product, Quotient theorem, Reciprocal tensors, Christoffel's symbols, Covariant differentiation, Gradient, divergence and curl in tensor notation. **6**

Books/References

1. K. Yano, The Theory of Lie Derivatives and its Applications, North-Holland Publishing Company, 1957.
2. C. E. Weatherburn, An Introduction to Riemannian Geometry and the Tensor Calculus, Cambridge University Press.
3. T. J. Willmore, An Introduction to Differential Geometry (Dover Books on Mathematics) Kindle Edition.
4. Struik, D.T. Lectures on Classical Differential Geometry, Addison - Wesley, Mass. 1950.
5. R. S. Mishra, A Course in Tensors with Applications to Riemannian Geometry, Pothishala Pvt. Ltd., Allahabad, 1965.

MMS-123 Integral Equations and Partial Differential Equations Credit 3 (2-1-0)

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course

1. Understand the properties of various kinds of integral equations and its solution
2. Develop the skills while solving the various problems by using integral equations in all engineering sciences and etc
3. Analyse the origin of first order partial differential equations and solving them using Charpit's method.
4. Classify second order PDE and solve standard PDE using separation of variable method.
5. Understand the formation and solution of some significant PDEs like wave equation, heat equation and diffusion equation.

UNIT- I

Fredholm equations of second kind with separable kernels, Fredholm alternative theorem, Eigen values and eigen functions, Method of successive approximation for Fredholm and Volterra equations, Resolvent kernel. **6**

UNIT- II

Formation of Partial Differential Equations, First order P.D.E.'s, Classification of first order P.D.E.'s, Complete, general and singular integrals, Lagrange's or quasi-linear equations, Integral surfaces through a given curve, Orthogonal surfaces to a given system of surfaces, Characteristic curves. **6**

UNIT- III

Pfaffian differential equations, Compatible systems, Charpit's method, Jacobi's Method, Linear equations with constant coefficients, Reduction to canonical forms, Classification of second order P.D.E.'s. **6**

UNIT- IV

Method of separation of variables: Laplace, Diffusion and Wave equations in Cartesian, cylindrical and spherical polar coordinates, Boundary value problems for transverse vibrations in a string of finite length and heat diffusion in a finite rod, Classification of linear integral equations, Relation between differential and integral equations. **6**

Books/References

1. John F., Partial Differential Equations, 2nd Edition, Springer-Verlag. 1981.
2. I. N. Sneddon, Elements of Partial Differential Equations, McGraw-Hill, 1957
3. T. Amaranath, An Elementary Course in Partial Differential Equations, Narosa Publishing House, New Delhi, 2005
4. R. P. Kanwal, Linear Integral Equations, Birkhäuser, Inc., Boston, MA, 1997.
5. E. C. Zachmanoglou and D. W. Thoe, Introduction to Partial Differential Equations with Applications, Dover Publication, Inc., New York, 1986.

MMS-124 **Discrete Mathematical Structure** **Credit 3 (2-1-0)**

Course Outcomes

The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Use logical notation to define different function such as set, function and relation.
2. understand how logic relates to computing problems
3. Use of induction hypotheses to prove formula
4. Explain Boolean logic problems as Truth tables, Logic circuits and Boolean algebra
5. Explain the different concepts in automata theory and formal languages.

UNIT- I

Fundamental – Sets and Subsets, operations on sets, sequence, Division in the integer, Matrices, Mathematics Structures. Logic-Proposition and Logical Operation Conditional Statements, Methods of Proof, Mathematical Induction, Mathematics Logic- Statements and Notation, Connectives,Normal Forms, The Theory of Interface for the statement Calculus, Inference Theory of the Predicate Calculus	**6**

UNIT- II

Counting- Permutation, Combination, The pigeonhole Principle, Recurrence Relations. Relational and Digraphs- Product sets and Partitions, Relations and Digraphs, Paths in Relations and Digraphs Properties of Relations, Equivalence Relations, Computer Representation of Relations and Digraph, Manipulation of Relations, Transitive Closure and Warshall's Algorithms. Functions-Definition and Introduction, Function for Computer Science, Permutation Functions, Growth of Functions.	**6**

UNIT- III

Boolean Algebra as Lattices, Various Boolean Identities Join-irreducible elements, Atoms and Minterms, Boolean Forms and their Equivalence,Minterm Boolean Forms, Sum of Products Canonical Forms, Minimization of Boolean Functions, Applications of Boolean Algebra to Switching Theory (using AND, OR and NOT gates), The Karnaugh Map method.	**6**

UNIT- IV

Finite State Machines and Their Transition Table Diagrams, Equivalence of Finite State Machines, Reduced Machines, Homomorphism, Finite Automata, Acceptors, Non-Deterministic Finite Automata and Equivalence of Its Power to that of Deterministic Finite Automata, Moore and Mealy Machines.	**6**

Books/References

1. Bernard Kolma, Discrete Mathematical Structures, Busby & Sharon Ross [PHI].
2. J.P.Tremblay&R.Manohar, Discrete Mathematical Structures with Application to computer science, Tata McGraw –Hill.
3. C. J. Liu, Combinational Mathematics, Tata McGraw –Hill
4. Seymour Lipschutz, Discrete Mathematics, Marc Lipson (TMH).
5. Rajendra Akerkar, Discrete Mathematics, Pearson.

MMS-125 **Approximation Theory** **Credit 3 (2-1-0)**

Course Outcomes

The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. To study that the general functions may be approximated or decomposed into more simple form such as splines or other special functions.
2. univariate approximation, linear and non-liner approximations.
3. To study some important theorems like Jackson's Theorem, Bernstein Theorems, Zygmund theorem.
4. To study the interpolation.
5. To understand and use the theory of convergence for continuous functions as well as error estimates for smooth functions.

UNIT- I

Different types of Approximations, Least squares polynomial approximation Weierstrass Approximation Theorem, Monotone operators, Markoff inequality, Bernstein inequality, Fejers theorem for HF interpolation. **6**

UNIT- II

Erdos- Turan Theorem, Jackson's Theorems (I to V), Dini-Lipschitz theorem, Inverse of Jackson's Theorem, Bernstein Theorems (I,II, III), Zygmund theorem. **6**

UNIT- III

Lobetto and Radau Quadrature, Hermite and HF interpolation, (0,2)-interpolation on the nodes of π (x), existence, uniqueness, explicit representation and convergence. **6**

UNIT- IV

Spline interpolation, existence, uniqueness, explicit representation of cubic spline, certain external properties and uniform approximation. **6**

Books/References

1. T.J. Rivlin, An Introduction to the Approximation of functions, Dover Publications.
2. E.W. Cheney: Introduction to Approximation Theory, McGraw-Hill Book Company.
3. A. Ralston, A First Course in Numerical Analysis, MacGraw –Hill Book Company.
4. Hrushikesh N. Mhaskar and Devidas V. Pai., "Fundamentals of approximation theory", Narosa Publishing House, New Delhi, 2000
5. Singer I.," Best Approximation in Normed Linear Spaces by element of linear subspaces", Springer-Verlag, Berlin ,1970.

MMS-131 **Mathematical Methods** **Credits 3 (2-1-0)**

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Use of Laplace Transform to solve the differential equations.
2. Use of Fourier transforms to solve integral equations and differential equations and Fourier series.
3. Use of Z transforms to solve the difference equations.
4. To study the calculus of variations for one or more several variables.
5. To study the basic properties of Hankel Transform and applications.

UNIT- I

Calculus of Variations: Functionals, Euler's equations for one and several variables, higher order derivatives, isoperimetric problems, Variational problem in parametric form, Variational problems with moving boundaries, Weierstrass –Erdmann conditions, sufficient conditions for weak and strong maxima and minima, applications. **6**

UNIT- II

Laplace Transform: Laplace of some functions, Existence conditions for the Laplace Transform, Shifting theorems, Laplace transform of derivatives and integrals, Inverse Laplace transform and their properties, Convolution theorem, Initial and final value theorem, Laplace transform of periodic functions, error functions, Heaviside unit step function and Dirac delta function, Applications of Laplace transform to solve ODEs, PDEs and integral equations. **6**

UNIT- III

Z-Transform: Z–transform and inverse Z-transform of elementary functions, Shifting theorems, Convolution theorem, Initial and final value theorem, Application of Z-transforms to solve difference equations.

Hankel Transform: Basic properties of Hankel Transform, Hankel Transform of derivatives, Application of Hankel transform to PDE. **6**

UNIT- IV

Fourier series: Trigonometric Fourier series and its convergence. Fourier series of even and odd functions, Gibbs phenomenon, Fourier half-range series, Parseval's identity.

Fourier Transforms: Fourier integrals, Fourier sine and cosine integrals, Complex form of Fourier integral representation, Fourier transform of derivatives and integrals, Fourier sine and cosine transforms and their properties, Convolution theorem, Application of Fourier transforms to Boundary Value Problems. **6**

Books/References

1. McLachlan N. W., Laplace Transforms and Their Applications to Differential Equations, Dover Publication, 2014.
2. Sneddon I. N. Fourier Transforms, Dover Publication, 2010.
3. Debanth L. and Bhatta D., "Integral Transforms and Their Applications", 2nd edition, Taylor and Francis Group, 2007.
4. I. M. Gelfand and S. V. Fomin, "Calculus of variations", Prentice Hall, INC, Englewood Cliffs, New Jersey.
5. Dean G. Duffy, "Advanced Engineering Mathematics", CRC Press, 1998.

MMS-132 **Measure Theory** **Credits 3 (2-1-0)**

Course Outcomes

The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Understand the fundamentals of measure theory and be acquainted with the proofs of the fundamental theorems underlying the theory of integration.
2. Understand measure theory and integration from theoretical point of view and apply its tools in different fields of applications.
3. Extend their knowledge of Lebesgue theory of integration by selecting and applying its tools for further research in this and other related areas
4. Explain the concept of length, area, volume using Lebesgue theory of integration
5. Apply the general principles of measure theory and integration in such concrete subjects as the theory of probability or financial mathematics.

UNIT- I

Set functions, Algebra and σ -algebra of sets, Borel sets, F_σ -sets and G_δ -sets, Intuitive idea of measure, Elementary properties of measure, Measurable sets and their fundamental properties, Algebra of measurable sets, The Lebesgue measure and its properties, Non measurable sets.	**6**

UNIT- II

Measurable functions, Simple functions, Littlewood’s three principles, Convergence of sequence of measurable functions, Egoroff’s theorem.	**6**

UNIT- III

Lebesgue integral of simple and bounded functions, Bounded convergence theorem, Lebesgue integral of nonnegative measurable functions, Fatou's lemma, Monotone convergence theorem, Integral of a Lebesgue measurable functions, Lebesgue convergence theorem, Convergence in measure.	**6**

UNIT- IV

Vitali covering lemma, Differentiation of monotonic functions, Function of bounded variation and its representation as difference of monotonic functions, Differentiation of indefinite integral, Fundamental theorem of calculus, Absolutely continuous functions and their properties.	**6**

Books/References

1. H. L., Royden, Real Analysis, 4 th Edition, Macmillan, 1993.
2. P. R. Halmos, Measure Theory, Van Nostrand, New York 1950.
3. G. De Barra, Measure Theory and Integration, Wiley Eastern.
4. R.R. Goldberg, Methods of Real Analysis, Oxford & IBH Pub. Co. Pvt. Ltd, 1976.
5. P. K. Jain and V. P. Gupta, Lebesgue Measure and Integration, New Age International (P) Limited Published, New Delhi, 1986

MMS-133 **Principles of Optimization Theory** **Credits 3 (2-1-0)**

Course Outcomes

The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Explain the fundamental knowledge of linear programming and dynamic programming problems.
2. Use classical optimization techniques and numerical methods of optimization.
3. Describe the basics of different evolutionary algorithms.
4. Describe the concept of separable and geometric programming.
5. Enumerate fundamentals of Integer programming technique and apply different techniques to solve various optimization problems arising from engineering areas.

UNIT- I

Convex sets and Convex functions, their properties, Multivariable Optimization with no Constraints and Equality Constraints, Kuhn –Tucker Theory, **1-D Unconstrained Minimization Methods:** Fibonnacci Method, Golden Section, Univariate Method, Steepest Descent Method, Newton's Methods. **6**

UNIT- II

Conjugate Gradient (Fletcher–Reeves) Methods, Hookes and Jeeves Method, Powell Method, Quadratic Interpolation method, Cubic Interpolation method, Broyden–Fletcher–Goldfarb–Shanno method, **Penalty function methods:** Exterior penalty function method, Interior penalty function method. **6**

UNIT- III

Separable Programming, **Geometric Programming**: Unconstrained and Constrained Minimization Geometric Programming, Geometric Programming with mixed Inequality Constraints, Generalized method for problems with positive and negative coefficients, Complementary Geometric Programming. **6**

UNIT- IV

Multi-Objective and Concept of Goal Programming, Graphical solution method, **Nature Inspired Algorithms:** Random walks and Levy Flights, Simulated Annealing, Genetic Algorithm, Differential evaluation, Ant and Bee algorithm, swarm optimization, Harmony search, Firefly Algorithm, Bat Algorithm, Cuckoo search. **6**

Books/References

1. Mohan C. and Deep K., "Optimization Techniques", New Age India Pvt. Pvt. 2009
2. Bazaraa, M.S., Sherali, H. D. and Shetty, C. M. "Non linear Programming Theory and Algorithms", 3rd Edition, John Wiley and Sons, 2006.
3. Deb K., "Optimization for Engineering Design: Algorithms and Examples" Prentice Hall of India, 2004.
4. Singiresu S. Rao, "Engineering Optimization", Fourth Edition, John Wiley & Sons, INC, 2009.
5. Hamdy A. Taha, "Operations Research" Eighth Edition, Pearson, 2007.

MMS-134	**Graph Theory**	**Credits 3 (2-1-0)**

Course Outcomes

The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Write precise and accurate mathematical definitions of basics concepts in graph theory.
2. Understand and apply various proof techniques in proving theorems in graph theory.
3. Understand the basic concepts and fundamental results in matching, domination, coloring and planarity.
4. Apply the theoretical knowledge and independent mathematical thinking in creative investigation of questions in graph theory.
5. Obtain a solid overview of the questions addressed by graph theory and will be exposed to emerging areas of research.

UNIT- I

Connectivity :- Cut- vertex, Bridge, Blocks, Vertex-connectivity, Edge-connectivity and some external problems, Mengers theorems, Properties of n-connected graphs with respect to vertices and edges. **6**

UNIT- II

Planarity:- Plane and Planar graphs, Euler Identity, Non planar graphs, Maximal planar graph Outer planar graphs, Maximal outer planar graphs, Characterization of planar graphs , Geometric dual, Crossing number. **6**

UNIT- III

Colorability :-Vertex Coloring, Chromatic index of a graph, Chromatic number of standard graphs, Bichromatic graphs, Colorings in critical graphs, Relation between chromatic number and clique number/independence number/maximum degree, Edge coloring, Edge chromatic number of standard graphs Coloring of a plane map, Four color problem, Five color theorem, Uniquely colorable graph. Chromatic polynomial. **6**

UNIT- IV

Directed Graphs:- Preliminaries of digraph, Oriented graph, indegree and outdegree, Elementary theorems in digraph, Types of digraph, Tournament, Cyclic and transitive tournament, Spanning path in a tournament, Tournament with a Hamiltonian path, strongly connected tournaments. **6**

Books/References

1. J.A.Bondy and V.S.R.Murthy: Graph Theory with Applications, Macmillan, London, (2004).
2. G.Chartrand and Ping Zhang: Introduction to Graph Theory. McGrawHill, International edition (2005).
3. F. Harary Graph Theory, Addition Wesley Reading Mass, 1969.
4. N. Deo: Graph Theory: Prentice Hall of India Pvt. Ltd. New Delhi – 1990
5. Norman Biggs: Algebraic Graph Theory, Cambridge University Press (2ndEd.)1996.

MMS-135 **Computational Fluid Dynamics** **Credits 3 (2-1-0)**

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. To study the basic properties of fluids and classification of the basic equations of fluid dynamics.
2. The development of various fluid flow governing equations from the conservation laws of motion and Fluid mechanics.
3. The rigorous and comprehensive treatment of numerical methods in fluid flow and heat transfer problems in engineering applications.
4. The student will demonstrate the ability to analyze a flow field to determine various quantities of interest, such as flow rates, heat fluxes, pressure drops, losses, etc.
5. The student will demonstrate an ability to describe various flow features in terms of Helmholtz's vorticity equation, Navier-Stokes equations, dissipation of energy etc.

UNIT- I

Introduction to fluid, Lagrangian and Eulerian descriptions, Continuity of mass flow, circulation, rotational and irrotational flows, boundary surface, streamlines, path lines, streak lines, vorticity. **6**

UNIT- II

General equations of motion: Bernoulli's theorem, compressible and incompressible flows, Kelvin's theorem, constancy of circulation, Stream function, Complex-potential, source, sink and doublets, circle theorem, method of images, Theorem of Blasius, Strokes stream function. **6**

UNIT- III

Helmholtz's vorticity equation, vortex filaments, vortex pair, Navier-Stokes equations, dissipation of energy, diffusion of vorticity, Steady flow between two infinite parallel plates through a circular pipe (Hagen-Poiseuille flow), Flow between two coaxial cylinders. **6**

UNIT- IV

Dimensional analysis, large Reynold's numbers; Laminar boundary layer equations, Similar solutions; Flow past a flat plate, Momentum integral equations, Solution by KarmanPohlhausen methods, impulsive flow, Reyleigh problem, dynamical similarity, Thermal boundary layer equation for incompressible flow. **6**

Books/References

1. Batechelor, G.K., "An Introduction to Fluid Dynamics", Cambridge Press, 2002.
2. Schliting, H., Gersten K., "Boundary Layer Theory", Springer, 8th edition, 2004.
3. Rosenhead, L., "Laminar Boundary Layers", Dover Publications, 1963.
4. Drazin, P.G., Reid W. H., "Hydrodynamic Stability", Cambridge Press 2004.
5. Raisinghania, M. D.," Fluid Dynamics", S. Chand, sixth edition, 2005.

MMS-201 **Computational Functional Analysis** **Credit 4 (3-1-0)**

Course Outcomes

The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Explain the fundamental concepts of functional analysis and their role in modern mathematics.
2. Demonstrate the concepts of functional analysis, for example continuous and bounded linear operators, normed spaces, Hilbert spaces and to study the behaviour of different mathematical expressions arising in science and engineering.
3. Understand and apply fundamental theorems from the theory of normed and Banach spaces including the Hahn-Banach theorem, the open mapping theorem, the closed graph theorem, and uniform boundedness theorem
4. Explain the concept of projection on Hilbert and Banach spaces
5. Corelate Functional Analysis to problems arising in partial differential equations, measure theory and other branches of Mathematics.

UNIT- I

Normed linear spaces, Banach spaces, properties of normed spaces, finite dimensional normed spaces and subspaces, linear operators, bounded and continuous linear operators, linear functionals, normed spaces of operators. **9**

UNIT- II

Bounded linear transformations $B(X, Y)$ as a normed linear space, Open mapping and closed graph theorems. **9**

UNIT- III

Uniform boundedness principle and its consequences, Hahn-Banach theorem and its application, Compact operators. **9**

UNIT- IV

Inner product spaces, Hilbert spaces, properties of inner product spaces, orthogonal complements, orthonormal sets, Hilbert – adjoint operator, self-adjoint, unitary and normal operators, projections on Hilbert spaces. **9**

Books/References

1. Simmons, G. F., Introduction to Topology and Modern Analysis, 2008.
2. Rudin, W., Functional Analysis, International Series in Pure and Applied Mathematics, McGraw-Hill Inc., 1991.
3. Kreyszig, E., Introductory Functional Analysis with Applications, John Wiley and Sons (Asia) Pvt. Ltd., 2006.
4. Bachman, G. and Narici, L., Functional Analysis, Dover, 2000.
5. K. K. Jha, Functional Analysis and Its Applications, Students' Friend, 1986.

MMS-202 **Theory of Computing** **Credit 4 (3-1-0)**

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Acquire a full understanding and mentality of Automata Theory as the basis of all computer science languages design
2. Explain and manipulate the different concepts in automata theory and formal languages such as formal proofs.
3. Able to demonstrate (non-)deterministic automata, regular expressions, regular languages, context-free grammars, context-free languages, Turing machines.
4. Be able to design FAs, NFAs, Grammars, languages modelling, small compilers basics.
5. Be able to design sample automata.

UNIT- I Introduction to defining language, Kleene closures, Arithmetic expressions, defining grammar, Chomsky hierarchy, Finite Automata (FA), Transition graph, generalized transition graph, Nondeterministic finite Automata (NFA), Deterministic finite Automata (DFA), Construction of DFA from NFA and optimization, FA with output: Moore machine, Mealy machine and Equivalence, Applications and Limitation of Finite Automata.	9
UNIT- II Regular and Non-regular languages: Criterion for Regularity, Minimal Finite Automata, Pumping Lemma for Regular Languages, Decision problems, Regular Languages and Computers. Context free Grammars: Introduction, definition, Regular Grammar, Derivation trees, Ambiguity, Simplified forms and Normal Forms, Applications.	9
UNIT- III Pushdown Automata: Definition, Moves, Instantaneous Descriptions, Language recognised by PDA, Deterministic PDA, Acceptance by final state & empty stack, Equivalence of PDA, pumping lemma for CFL, Interaction and Complements of CFL, Decision algorithms.	9
UNIT- IV Turing machines (TM): Basic model, definition and representation, Language acceptance by TM, TM and Type-0 grammar, Halting problem of TM, Modifications in TM, Universal TM, Properties of recursive and recursively enumerable languages, unsolvable decision problem, undecidability of Post correspondence problem, Church's Thesis, Recursive function theory.	9

Books/References

1. John Martin, Introduction to Languages and the Theory of Computation, 3rd edition, TMH.
2. K.L.P. Mishra & N. Chandrasekharan – Theory of Computer Science, PHI 3.
3. Hopcroft JE, and Ullman JD – Introduction to Automata Theory, Languages & Computation, Narosa.
4. Lewis H.R. and Papadimitrou C. H – Elements of the theory of Computation, PHI.
5. Cohen D. I. A., Introduction to Computer theory, John Wiley & Sons.

MMS-203 **Numerical Methods for Scientific Computations** **Credit 4 (2-1-2)**

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Apply numerical methods to find our solution of algebraic equations using different methods under different conditions, and numerical solution of system of algebraic equations.
2. Apply various interpolation methods and finite difference concepts.
3. Work out numerical differentiation and integration whenever and wherever routine methods are not applicable.
4. Work numerically on the ordinary differential equations using different methods through the theory of finite differences.
5. Work numerically on the partial differential equations using different methods through the theory of finite differences.

UNIT- I Solution of algebraic and transcendental equations, Fixed point iteration method, Newton Raphson method, Solution of linear system of equations: Gauss elimination method – Pivoting, Gauss Jordan method, Iterative methods of Gauss Jacobi and Gauss Seidel, Eigenvalues of a matrix by Power method and Jacobi's, Given's method for symmetric matrices.	6
UNIT- II Difference operators and relation, Interpolation with equal intervals, Newton's forward and backward difference formulae, Interpolation with unequal interval, Lagrange's interpolation, Newton's divided difference interpolation, Cubic Splines, Approximation of derivatives using interpolation polynomials.	6
UNIT- III Numerical integration using Trapezoidal, Simpson's 1/3, 3/8 rule, Two point and three-point Gaussian quadrature formulae. Single step methods: Taylor's series method Euler's method, Modified Euler's method, fourth order Runge Kutta method for solving differential equations. Multi step methods– Milne's and Adams - Bash forth predictor corrector methods for solving differential equations.	6
UNIT- IV Finite difference methods for solving second order two -point linear boundary value problems, Finite difference techniques for the solution of two dimensional Laplace's and Poison's equations on rectangular domain, One dimensional heat flow equation by explicit and implicit (Crank Nicholson)methods, One dimensional wave equation by explicit method	6

Experiments:

1. To implement Regula Falsi method to solve algebraic equations.
2. To implement numerical integration to solve algebraic equations.
3. To implement Gauss-Seidel method for solution of simultaneous equations.
4. To implement Runge-Kutta method of order four to solve differential equations.
5. To implement Euler's method to find solution of differential equations.

6. To write Computer based algorithm and program for solution of Eigen-value problems.
7. To find Derivatives of Eigenvalues and Eigen vectors.

Books/References

1. Grewal B.S., Numerical methods in Engineering and Science, Khanna Publishers Delhi.
2. Jain Iyenger, Numerical methods for Scientific and Engineering Computations, New Age Int.
3. P. Kandasamy, K. Thilagavathy and| K. Gunavathy, Numerical Methods, Schand Publishers.
4. M. D. Raisinghania, Advanced Differential Equations, Schand Publishers.
5. Francis Scheld. “Numerical Analysis” TMH

MMS-204 **Computing Tools** **Credit: 2 (0-0-4)**

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. To learn different platform to make presentations and documents
2. To learn various software like Mathematica, Maple.
3. To learn MATLAB to solve real life problems.
4. To learn mathematical tools to solve real life problems.
5. Group learning and problem solving.

Experiments:

1. Prepare a document using LaTex.
2. Find the solution of differential equations using 4th order Runge-Kutta method through MATLAB.
3. Determination of eigen values and eigenvectors of a square matrix through MATLAB.
4. Classification of groups of small order using GAP.
5. Find the solution of differential equations using 4th order Runge-Kutta method through Scilab
6. Determination of eigen values and eigenvectors of a square matrix through SageMath.
7. Determination of roots of a polynomial through Maple.
8. Apply R for statistical computing of a data.

Books/References

1. Leslie Lamport , LaTeX: A document preparation system, User's guide and reference manual 2nd edition, Addison Wesley.
2. R.P. Singh, "Getting Started with MATLAB" Oxford University Press.
3. SageMath – Open-Source Mathematical Software System". Retrieved 2020-01-01.
4. Maple Product History". Retrieved 2019-08-14.
5. GAP Copyright". 2012-06-14. Retrieved 2015-02-26

MMS-205 **Number Theory and Cryptography** **Credit 4 (3-1-0)**

Course Outcomes

The students are expected to be able to demonstrate the following knowledge, skills and attitudes after completing this course.

1. Demonstrate the various properties of and relating to the integers including the Well-Ordering Principle, primes, unique factorization, the division algorithm, and greatest common divisors.
2. Demonstrate certain number theoretic functions and their properties.
3. Demonstrate the concept of a congruence and use various results related to congruences including the Chinese Remainder Theorem.
4. Able to solve certain types of Diophantine equations.
5. Able to know how number theory is related to and used in cryptography.

UNIT- I

Divisibility, greatest common divisor, Euclidean Algorithm, The Fundamental theorem of arithmetic, congruences, Special divisibility tests, Chinese remainder theorem, residue classes and reduced residue classes, Fermat's little theorem, Wilson's theorem, Euler's theorem. **9**

UNIT- II

Arithmetic functions $\phi(n), d(n), \sigma(n), \mu(n),$ Mobius inversion Formula, the greatest integer function, perfect numbers, Mersenne primes and Fermat numbers. **9**

UNIT- III

Primitive roots and indices, Quadratic residues, Legendre symbol, Gauss's Lemma, Quadratic reciprocity law, Jacobi symbol, Diophantine equations: $ax + by = c, x^2 + y^2 = z^2, x^4 + y^4 = z^2$, sums of two and four squares. **9**

UNIT- IV

Cryptography: some simple cryptosystems, need of the cryptosystems, the idea of public key cryptography, RSA cryptosystem. **9**

Books/References

1. Burton, D.M., Elementary Number Theory, 7th Edition. McGraw-Hill Education, 2010.
2. Hardy, G.H. and Wright, E.M., An introduction to the Theory of Numbers, 4th Edition. Oxford University Press, 1975.
3. Niven, I., Zuckerman, H.S. and Montgomery, H.L., Introduction to Theory of Numbers, 5th Edition. John Wiley & Sons, 1991.
4. Stallings, W., Cryptography and Network Security, 5th Edition. Pearson, 2010.
5. Behrouz A. and Mukhopadhyay D., Cryptography and Network Security", 2nd edition, Tata McGraw Hill, 2013.

MMS-206 **Design and Analysis of Algorithms** **Credit 4 (2-1-2)**

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Able to Argue the correctness of algorithms using inductive proofs and analyse worst-case running times of algorithms using asymptotic analysis.
2. Ability to compare algorithms with respect to time and space complexity
3. Derive and solve recurrences describing the performance of divide-and-conquer algorithms.
4. Describe the greedy paradigm and explain when an algorithmic design situation calls for it. Recite algorithms that employ this paradigm. Synthesize greedy algorithms and analyse them.
5. Describe the dynamic-programming paradigm and explain when an algorithmic design situation calls for it. Recite algorithms that employ this paradigm. Synthesize dynamic programming algorithms and analyse them.

UNIT- I

Introduction: What is an Algorithm? Algorithm Specification, Analysis Framework, Performance Analysis: Space complexity, Time complexity. Asymptotic Notations: Big-Oh notation (O), Omega notation (Ω), Theta notation (Θ), and Little-oh notation (o), Mathematical analysis of Non-Recursive and recursive Algorithms with Examples. Important Problem Types: Sorting, Searching, String processing, Graph Problems, Combinatorial Problems. **6**

UNIT- II

Divide and Conquer: General method, Binary search, Recurrence equation for divide and conquer, Finding the maximum and minimum, Merge sort, Quick sort, Strassen's matrix multiplication, Advantages and Disadvantages of divide and conquer, Decrease and Conquer Approach: Topological Sort. **6**

UNIT- III

Greedy Method: General method, Coin Change Problem, Knapsack Problem, Job sequencing with deadlines. Minimum cost spanning trees: Prim's Algorithm, Kruskal's Algorithm, Single source shortest paths: Dijkstra's Algorithm, Optimal Tree problem: Huffman Trees and Codes **6**

UNIT- IV

Dynamic Programming: General method with Examples, Multistage Graphs. Transitive Closure: Warshall's Algorithm, All Pairs Shortest Paths: Floyd's Algorithm, Optimal Binary Search Trees, Knapsack problem, Bellman-Ford Algorithm, Travelling Sales Person problem, Longest Common Subsequence, Polynomials and FFT: Representation of polynomials, The DFT and FFT, Efficient FFT implementation. **6**

Experiments:

1. Implementation and Time analysis of sorting algorithms. Bubble sort, Merge sort and Quicksort
2. Implementation and Time analysis of factorial program using iterative and recursive method
3. Implementation of a knapsack problem using dynamic programming.
4. Implementation of chain matrix multiplication using dynamic programming.

5. Implementation of a knapsack problem using greedy algorithm
6. Implementation of Graph and Searching (DFS and BFS).
7. Implement prim's algorithm
8. Implement kruskal's algorithm.

Books/References

1. Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein, Introduction to Algorithms, PHI.
2. Anany Levitin, Introduction to Design and Analysis of Algorithms, Pearson.
3. Dave and Dave, Design and Analysis of Algorithms, Pearson.
4. Paul Bratley, Fundamental of Algorithms by Gills Brassard, PHI.
5. RCT Lee, SS Tseng, RC Chang and YT Tsai, Introduction to the Design and Analysis of Algorithms, McGraw Hill.

MMS-221 **Rings and Modules** **Credit 3 (2-1-0)**

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills and attitudes after completing this course.

1. The importance of a ring as a fundamental object in algebra.
2. The concept of a module as a generalisation of a vector space and an Abelian group.
3. Constructions such as direct sum, product, and tensor product.
4. Able to demonstrate Simple modules, Schur's lemma, Semisimple modules, Artinian modules, their endomorphisms, Radical, simple and semisimple Artinian rings. Examples.
5. Able to demonstrate Noetherian modules, the Artin-Wedderburn theorem, the concept of central simple algebras, the theorems of Wedderburn and Frobenius.

UNIT- I

Review of Rings, integral domains and Division rings and fields with examples. Sub-rings and ideals. Prime and maximal ideals of a ring, Principal ideal domains, Divisor chain condition, Unique factorization domains, Examples and counterexamples, Chinese remainder theorem for rings and PID's, Polynomial rings over domains, Eisenstein's irreducibility criterion, Unique factorization in polynomial rings over UFD's. **6**

UNIT- II

Modules- Definition and examples, simple modules, sub modules, Module Homomorphisms, Isomorphisms theorems, Quotient modules, Direct sum of modules. **6**

UNIT- III

Exact sequences, Short exact sequence, split exact sequences. Torsion free and torsion modules Free modules- Definition and examples, modules over division rings are free modules. **6**

UNIT- IV

Free modules over PID's, Invariant factor theorem for sub modules, Finitely generated modules over PID, Chain of invariant ideals, Fundamental structure theorem for finitely generated module over a PID, Projective and injective modules, Divisible group. Noetherian modules and rings, Equivalent characterizations, Sub modules and factors of Noetherian modules. **6**

Books/References

1. T. W. Hungerford, Algebra, Springer (India) Pvt. Ltd., New Delhi, 2004.
2. P. Ribenboim, Rings and Modules, Wiley Interscience, N.Y., 1969.
3. J. Lambek, Lectures on Rings and Modules, Blaisedell, Waltham, 1966.
4. Ramji Lal, Algebra, Vols. I & II, Shail Publications, Allahabad, 2002.
5. M. Artin, "Algerba", Prentice Hall, 1991.

MMS-222 **Mathematical Modeling and Computer Simulations** **Credit 3 (2-1-0)**

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills and attitudes after completing this course.

1. To learn history and development of mathematical modelling.
2. To learn basic parameters to develop a mathematical model of real word situations.
3. To learn special types of Mathematical models like Prey-Predator model, Lotka Volterra equations.
4. To learn how to analyse the mathematical models.
5. To learn basic and advanced concept of simulation.

UNIT- I	
Mathematical model, History of Mathematical Modeling, latest development in Mathematical Modeling, Principle of modelling, Characteristics, Merits and Demerits of Mathematical Model, Difference equations: Steady state solution and linear stability analysis.	6
UNIT- II	
Linear Models, Growth models, Decay models, Holling type growth, constant harvesting, logistic and gomperzian growth, Newton's Law of Cooling, Drug Delivery Problem, Economic growth model, Lake pollution model, Alcohol in the bloodstream model, Numerical solution of the models and its graphical representation.	6
UNIT- III	
Carbon Dating, Drug Distribution in the Body, Mathematical Model of Influenza Infection (within host), Epidemic Models (SI, SIR, SIRS, SIC), Spreading of rumour model, Prey-Predator model, Lotka Volterra equations, competition model, Steady State solutions, Linearization, Local Stability Analysis, one and two species models with diffusion.	6
UNIT- IV	
Introduction to simulation, General concept in discrete event simulation, Random number generation, Nature of Simulation, Simulation models, Monte-Carlo simulation, Event type simulation, Demand pattern Simulation, Simulation in inspection work, Simulation of queuing models.	6

Books/References

1. Albright, B., Mathematical Modeling with Excel, Jones and Bartlett Publishers. 2010
2. Marotto, F. R., Introduction to Mathematical Modeling using Discrete Dynamical Systems, Thomson Brooks/Cole. 2006.
3. Kapur, J. N., Mathematical Modeling, New Age International 2005
4. Edsberg, L., Introduction to Computation and Modeling for Differential Equations, John Wiley and Sons. 2008.
5. A.M. Law and W.D. Kelton, Simulation Modeling and Analysis, T.M.H. Edition.

MMS-223 **Mathematical Foundation of Artificial Intelligence** **Credit: 3 (2-1-0)**

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills and attitudes after completing this course.

1. The basic terminology of linear algebra in Euclidean spaces, including linear independence, spanning, basis, rank, nullity, subspace, linear transformation, Eigen values and diagonalization.
2. Able to apply graphs as unifying theme for various combinatorial problems
3. Able to perform test of Hypothesis as well as calculate confidence interval for a population parameter for single sample and two sample cases and non-parametric test such as the Chi-Square test for Independence as well as Goodness of Fit
4. Compute and interpret the results of Bivariate and Multivariate Regression and Correlation Analysis, for forecasting and perform ANOVA and F-test
5. Able to solve optimization problems using classical optimization techniques.

UNIT- I

Vector spaces and Linear transformation: Vector spaces, subspaces, Linear dependence, Basis and Dimension, Linear transformations, Kernel & images, matrix representation of linear transformation, change of basis, Eigen values and Eigen vectors of linear operators, diagonalization. **6**

UNIT- II

Connectivity, Cut- vertex, Bridge, Blocks, Vertex-connectivity, Edge-connectivity and some external problems, Planarity:- Plane and Planar graphs, Euler Identity, Non planar graphs, Colorability :-Vertex Coloring, Chromatic index of a graph, Chromatic number of standard graphs, Bichromatic graphs. **6**

UNIT- III

Statistical Hypothesis: Concept of Statistical Hypothesis, hypothesis, Procedure of testing the hypothesis, Types of Error, Level of Significance, Degree of freedom. Chi-Square Test, Properties, and Constants of Chi-Square Distribution. Student's t-Distribution, Properties & Applications of t-Distribution. Analysis of Variance, F-Test, Properties & Applications of F-Test. **6**

UNIT- IV

Classical Optimization Techniques: Introduction, Review of single and multi-variable optimization methods with and without constraints, Non-linear one-dimensional minimization problems, Examples. **6**

Books/References

1. K. Hoffman, R Kunze, Linear Algebra, Prentice Hall of India, 1971.
2. V. Rohatgi., An Introduction to probability and Mathematical Statistics, Wiley Eastern Ltd. New Delhi.
3. K. Swaroop, P. K. Gupta, Man Mohan, Operation Research, Sultan chand Publishers.
4. J.K. Sharma, Operation Research, Laxmi Publications.
5. S.S.Rao, Engineering Optimization, New Age International.

MMS-224 Mathematical Theory of Coding Credit 3 (2-1-0)

The students are expected to be able to demonstrate the following knowledge, skills and attitudes after completing this course.

1. Knowledge of properties of and algorithms for coding and decoding of linear block codes, cyclic codes, and convolution codes.
2. Knowledge of linear recurrent sequences and feedback shift register.
3. Knowledge of arithmetic in finite fields, linear algebra over finite fields, and rings of power series.
4. able to apply various algorithms and techniques for coding and decoding.
5. Able to create computer programs using the concepts, data structures, and algorithms.

UNIT- I

Introduction to Coding Theory: Code words, distance and weight function, Nearest-neighbour decoding principle, Error detection and correction, Matrix encoding techniques, Matrix codes, Group codes, decoding by coset leaders, Generator and parity check matrices, Syndrome decoding procedure, Dual codes. **6**

UNIT- II

Linear Codes: Linear codes, Matrix description of linear codes, Equivalence of linear codes, Minimum distance of linear codes, Dual code of a linear code, Weight distribution of the dual code of a binary linear code, Hamming codes. **6**

UNIT- III

BCH Codes: Polynomial codes, Finite fields, Minimal and primitive polynomials, Bose-Chaudhuri Hocquenghem codes. **6**

UNIT- IV

Cyclic Codes: Cyclic codes, Algebraic description of cyclic codes, Check polynomial, BCH and Hamming codes as cyclic codes, Maximum distance separable codes, Necessary and sufficient conditions for MDS codes, Weight distribution of MDS codes, An existence problem, Reed-Solomon. **6**

Books/References

1. Vermani L. R., Elements of Algebraic Coding Theory, Chapman and Hall, 1996.
2. Vera P., Introduction to the Theory of Error Correcting Codes, John Wiley and Sons, 1998.
3. Steven R., Coding and Information Theory, Springer Verlag, 1992. 4. Garrett Paul, The Mathematics of Coding Theory, Pearson Education, 2004.
4. Huffman W. C. and Pless V., Fundamentals of Error-Correcting Codes, Cambridge University Press, Cambridge, Reprint, 2010.
5. Van Lint. J. H., Introduction to Coding theory, Graduate Texts in Mathematics, 86, Springer

MMS-225 Stochastic Processes and its Applications Credit 3 (2-1-0)

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Understand the axiomatic formulation of modern Probability Theory.
2. Characterize probability models and function of random variables based on single & multiples random variables.
3. Evaluate and apply moments & characteristic functions and understand the concept of inequalities and probabilistic limits.
4. Understand the concept of random processes and determine covariance and spectral density of stationary random processes.
5. Demonstrate the specific applications to Poisson and Gaussian processes.

UNIT- I Motivation for Stochastic processes, Stochastic Processes, Classification of Stochastic Processes and its examples, Bernoulli Process, Poisson Process, Random Walk, Time Series and related definitions, inter arrival and waiting time distributions, conditional distributions of the arrival times.	6
UNIT- II Non-homogeneous Poisson process, compound Poisson random variables and Poisson processes, conditional Poisson processes. **Markov Chains:** Introduction and examples, Chapman - Kolmogorov equations and classification of states, limit theorems, transitions among classes, the Gambler's ruin problem, mean time in transient states, branching processes, applications of Markov chain.	6
UNIT- III **Continuous-Time Markov Chains:** Introduction, continuous time Markov chains, birth and death processes, The Kolmogorov differential equations, limiting probabilities, time reversibility, applications of reversed chain to queueing theory.	6
UNIT- IV **Martingales:** Introduction, stopping times, Azuma's inequality for martingales, submartingales, supermartingles, martingale convergence theorem.	6

Books/References

1. Ross, S. M., Stochastic Processes. Wiley India Pvt. Ltd., 2nd Ed. 2008.
2. Brzezniak, Z. and Zastawniak, T., Basic Stochastic Processes: A Course through Exercises", Springer 1992.
3. Medhi, J., Stochastic Processes, New Age Science 2009.
4. Resnick, S.I., Adventures in Stochastic Processes, Birkhauser 1999 5. Hoel, P.G. and Stone, C.J., Introduction to Stochastic Processes, Waveland Press 1986.
5. A.M. Law and W.D. Kelton, Simulation Modeling and Analysis, T.M.H. Edition.

MMS-231 **Parallel Computing** **Credit 3 (2-1-0)**

Course Outcomes

The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. To develop an understanding of various basic concepts associated with parallel computing environments.
2. To understand the effects that issues of synchronization, latency and bandwidth have on the efficiency and effectiveness of parallel computing applications.
3. To gain experience in a number of different parallel computing paradigms including memory passing, memory sharing, data-parallel and other approaches.
4. To earn experience in designing parallel computing solutions to programming problems.
5. To understand the concept DPP using parallel computing.

UNIT- I

Introduction: What is parallel computing, Scope of parallel computing, Parallel Programming Platforms: implicit parallelism, Dichotomy of parallel computing platforms, Physical organization for parallel platforms, communication cost in parallel machines, routing mechanism for interconnection networks.	6

UNIT- II

Basic Communication Operation: One-to-all broadcast; All-to-all broadcast; Reduction and prefix sums; One-to-all personalized communication; All-to-all personalized communication	6

UNIT- III

Performance of Parallel Systems: Performance matrices for Parallel systems, Run time, Speed up, Efficiency and Cost; Parallel sorting: Sorting networks; Bubble sort and its variants; Quick sort and other sorting algorithms	6

UNIT- IV

Dynamic Programming: Overview of dynamic programming, Serial monadic DP Formulations: The shortest path Problem, the 0/1 Knapsack Problem, Serial Polyadic DP Formulation : all pair shortest paths algorithms.	6

Books/References

1. Vipin Kumar, Ananth Grama, Anshul Gupta and George Karypis; Introduction to Parallel Computing, The Benjamin/Cumming Publishing Company, Inc., Massachusetts
2. M J Quinn; Parallel Computing: Theory and Practice, McGraw-Hill, New York.
3. JL Hennessy and DA Patterson, Computer Architecture: A Quantitative Approach, 4th Ed., Morgan Kaufmann/Els India, 2006.
4. Peter S Pacheco, An Introduction to Parallel Programming, Morgan Kaufmann, 2011.
5. DE Culler, A Gupta and JP Singh, Parallel Computer Architecture: A Hardware/Software Approach Morgan-Kaufmann, 1998.

MMS-232 **Operations Research** **Credit 3 (2-1-0)**

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills, and attitudes after completing this course.

1. Analyze real life system with limited constraints and depict it in a model form.
2. Convert the problem into a mathematical model.
3. Understand variety of problems such as inventory model, CPM, PERTetc.
4. Understand different queuing situations and find the optimal solutions using models for different situations.
5. Understand game theory problem and their solution.

UNIT- I

Queuing systems and their characteristics, Pure-birth and Pure-death models, Empirical queuing models – M/M/1 and M/M/C models and their steady state performance analysis. 6

UNIT- II

Inventory models, Inventory costs. Models with deterministic demand – model (a) demand rate uniform and production rate infinite, model (b) demand rate non-uniform and production rate infinite, model (c) demand rate uniform and production rate finite, Inventory models with partial backlogging and lost sales. Discrete demand Model, Multi-item Inventory models with constraints. 6

UNIT- III

PERT and CPM with known and probabilistic activity times, constructing project networks: Gantt chart, Activity on arrow/Activity on node, Various types of floats and their significance, Updating PERT charts, Project crashing, Linear programming formulation of Project crashing, Resource constrained project scheduling: Resource levelling & Resource smoothing. 6

UNIT- IV

Games Theory: Competitive games, rectangular game, saddle point, minimax (maximin) method of optimal strategies, value of the game, Solution of games with saddle points, dominance principle, Rectangular games without saddle point mixed strategy for 2 x 2 games, LPP formulation and solution of game. 6

Books/References

1. Hillier, F. S., & Lieberman, G. J. (2010). Introduction to operations research- concepts and cases (9th ed.). New Delhi: Tata McGraw Hill (Indian print).
2. Taha, H. A. (2007). Operations research-an introduction (8th ed.). New Delhi: Pearson Pren tice Hall (Indian print).
3. Ravindran, A., Phillips, D. T., and Solberg, J. J. (2005). Operations research- principles and practice (2nd ed.). New Delhi: Wiley India (P.) Ltd. (Indian print).
4. Kanti Swaroop, P K Gupta and Manmohan, Operations Research, Sultan Chand & Sons
5. Gross, D., Shortle, J. F., Thompson, J. M., & Harris, C. M. (2008). Fundamentals of queueing theory (4th ed.). Wiley

MMS-233 **Fuzzy Theory and its Application** **Credit 3 (2-1-0)**

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills and attitudes after completing this course.

1. Analyse a fuzzy based system.
2. Being able to develop mathematical concepts, especially in the form of fuzzy.
3. Able to formulate a common problem in the form of fuzzy mathematics models and get a settlement.
4. Able to apply the frame of mathematics and computational principles to solve the problems of the development of intelligent systems.
5. Able to identify problems and develop mathematical models and analyze the relevant fuzzy behavior.

UNIT- I

Fuzzy Sets and Uncertainty: Characteristics function, fuzzy sets and membership functions, chance verses fuzziness, convex fuzzy sets, properties of fuzzy sets, fuzzy set operations. 6

Fuzzy Relations: Cardinality, fuzzy cartesian product and composition, fuzzy tolerance and equivalence relations, forms of composition operation.

UNIT- II

Fuzzification and Defuzzification: Various forms of membership functions, fuzzification, defuzzification to crisp sets and scalars.

Fuzzy Logic and Fuzzy Systems: Classic and fuzzy logic, approximate reasoning, Natural language, linguistic hedges, fuzzy rule-based systems, graphical technique of inference. 6

UNIT- III

Development of membership functions: Membership value assignments: intuition, inference, rank ordering, neural networks, genetic algorithms, inductive reasoning. 6

Fuzzy Arithmetic and Extension Principle: Functions of fuzzy sets, extension principle, fuzzy mapping, interval analysis, vertex method and DSW algorithm.

UNIT- IV

Fuzzy Optimization: One dimensional fuzzy optimization, fuzzy concept variables and casual relations, fuzzy cognitive maps, agent-based models.

Fuzzy Control Systems: Fuzzy control system design problem, fuzzy engineering process control, fuzzy statistical process control, industrial applications. 6

Books/References

1. Ross, T. J., Fuzzy Logic with Engineering Applications, Wiley India Pvt. Ltd., 3rd Ed. 2011.
2. Zimmerman, H. J., Fuzzy Set theory and its application, Springer India Pvt. Ltd., 4th Ed. 2006 .
3. Klir, G. and Yuan, B., Fuzzy Set and Fuzzy Logic: Theory and Applications, Prentice Hall of India Pvt. Ltd. 2002.
4. Klir, G. and Folger, T., Fuzzy Sets, Uncertainty and Information, Prentice Hall of India Pvt. Ltd. 2002.
5. Didier J. Dubois, Fuzzy sets and Systems: Theory and Applications.

MMS-234	**Theory of Mechanics**	**Credit 3 (2-1-0)**

Course Outcomes The students are expected to be able to demonstrate the following knowledge, skills and attitudes after completing this course.

1. To determine the static and dynamic forces for dynamical and statical systems.
2. To determine the angular momentum, Euler dynamic and geometrical equations to rigid body
3. To study the various properties of moving particles in the space.
4. To understand the principles of vibrations
5. To study to various principles related to moving particles like Lagrangian approach, Conservation of energy etc.

UNIT- I

Rotation of a vector in two and three-dimensional fixed frame of references, Kinetic energy and angular momentum of rigid body rotating about its fixed point, Euler dynamic and geometrical equations of motion, Generalized coordinates, momentum and force components, Lagrange equations of motion under finite forces, cyclic coordinates and conservation of energy. **6**

UNIT- II

Lagrangian approach to some known problems-motions of simple, double, spherical and cycloidal pendulums, motion of a particle in polar system, motion of a particle in a rotating plane, motion of a particle inside a paraboloid, motion of an insect crawling on a rod rotating about its one end, motion of masses hung by light strings passing over pulleys, motion of a sphere on the top of a fixed sphere and Euler dynamic equations. **6**

UNIT- III

Lagrange equations for constrained motion under finite forces, Lagrange equations of motion under impulses, motion of parallelogram about its centre and some of its particular cases, Small oscillations for longitudinal and transverse vibrations, Equations of motion in Hamiltonian approach and its applications on known problems as given above, Conservation of energy, Legendre dual transformations. **6**

UNIT- IV

Hamilton principle and principle of least action, Hamilton-Jacobi equation of motion, Hamilton-Jacobi theorem and its verification on the motions of a projectile under gravity in two dimensions and motion of a particle describing a central orbit, Phase space, canonical transformations, conditions of canonicality, cyclic relations, generating functions, invariance of elementary phase space, canonical transformations form a group and Liouville theorem, Poisson brackets, Poisson first and second theorems, Poisson, Jacobi identity and invariance of Poisson bracket. **6**

Books/References

1. Ramsay A. S., Dynamic –Part II.
2. Rana N. C. and Joag P. S., Classical Mechanics, Tata McGraw-Hill, 1991.
3. Goldstein H., Classical Mechanics, Narosa Publishing House, New Delhi, 1990.
4. Kumar N., Generalized Motion of Rigid Body, Narosa Publishing House, New Delhi, 2004
5. Hand L.N. and Finch J. D., Analytical Mechanics, Cambridge University Press, 1998.

MMS-235 **Dynamical System** **Credit 3 (2-1-0)**

Course Outcomes

The students are expected to be able to demonstrate the following knowledge, skills and attitudes after completing this course.

1. To study the Continuous Systems through system of equations.
2. To study to the principle of bifurcations.
3. To study the discrete and chaos theory.
4. To study the stability theory.
5. To study how to analyse a real world situations in to mathematical phenomenon.

UNIT- I

Linear Dynamical Continuous Systems: First order equations, existence and uniqueness theorem, growth equation, logistic growth, constant harvesting, system of equations, critical points, stability Theory, phase space, n-dimensional linear systems, stability, Routh criterion, Nyquist criterion and center spaces. 6

UNIT- II

Nonlinear autonomous Systems: Stability through Linearization, Liapunov and global stability, Liapunov method, periodic solutions, Bendixson's criterion, Poincare Bendixson theorem, limit cycle, attractors, index theory, Hartman Grobman theorem. 6

UNIT- III

Local Bifurcation: non-hyperbolic critical points, center manifolds, normal forms, Nullclines, Gradient and Hamiltonian systems, Fixed points, saddle node, pitchfork, trans-critical bifurcation, Hopf bifurcation, co-dimension. 6

UNIT- IV

Discrete systems: Logistic maps, equilibrium points and their local stability, cycles, period doubling, chaos, tent map, horse shoe map.

Deterministic chaos: Duffing's oscillator, Lorenz System, Liapunov exponents, routes to chaos, necessary conditions for chaos. 6

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Books/References

1. Hirsch, M.W., Smale, S., Devaney, R.L. "Differential equations, Dynamical Systems and an Introduction to Chaos", Academic Press 2008.
2. Strogatz, S. H., "Nonlinear Dynamics and Chaos", Westview Press 2008.
3. Lakshmanan, M, Rajseeker, S., "Nonlinear Dynamics", Springer 2003.
4. Perko,L., "Differential Equations and Dynamical Systems", Springer 1996.
5. Hubbard J. H., West, B. H., "Differential equations: A Dynamical Systems Approach", Springer-Verlag 1995.