SHIVAJI UNIVERSITY, KOLHAPUR

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Accredited By NAAC with ‘A’ Grade

CHOICE BASED CREDIT SYSTEM

Syllabus For

M.A. / M.Sc. Mathematics Part -II

Semester III and IV

(Syllabus to be implemented from June, 2020 onwards.)

M.Sc. (Mathematics) Programme structure (CBCS PATTERN) (2020-21)
M.Sc. (Mathematics) Part – I

SEMESTER-I (Duration- Six Month)											
	Sr. No.	Course Code	Teaching Scheme			Examination Scheme					
			Theory and Practical			University Assessment (UA)			Internal Assessment (IA)		
			Lectures (Per week)	Hours (Per week)	Credit	Maximum Marks	Minimum Marks	Exam. Hours	Maximum Marks	Minimum Marks	Exam. Hours
CGPA	1	CC-101	5+1	6	5	90	36	3	30	12	1
	2	CC-102	5+1	6	5	90	36	3	30	12	1
	3	CC-103	5+1	6	5	90	36	3	30	12	1
	4	CC-104	5+1	6	5	90	36	3	30	12	1
	5	CC-105	5+1	6	5	90	36	3	30	12	1
Total (A)			**--**	**--**	**25**	**450**	**--**	**--**	**150**	**--**	**--**
Non-CGPA	1	AEC-106	2	2	2	--	--	--	50	20	2
SEMESTER-II (Duration- Six Month)											
CGPA	1	CC-201	5+1	6	5	90	36	3	30	12	1
	2	CC-202	5+1	6	5	90	36	3	30	12	1
	3	CC-203	5+1	6	5	90	36	3	30	12	1
	4	CC-204	5+1	6	5	90	36	3	30	12	1
	5	CC-205	5+1	6	5	90	36	3	30	12	1
Total (B)			**--**	**--**	**25**	**450**	**--**	**--**	**150**	**--**	**--**
Non-CGPA	1	SEC-206	2	2	2	--	--	--	50	20	2
Total (A+B)					**50**	**900**	**--**	**--**	**300**	**--**	**--**

• Student contact hours per week : **30** Hours (Min.)	• Total Marks for M.Sc.-I : **1200**
• Theory and Practical Lectures : **60** Minutes Each	• Total Credits for M.Sc.-I (Semester I & II) : **50**
• CC-Core Course • CCPR-Core Course Practical • AEC-Mandatory Non-CGPA compulsory Ability Enhancement Course • SEC- Mandatory Non-CGPA compulsory Skill Enhancement Course	• Practical Examination is annual. • Examination for CCPR-105 shall be based on Semester I Practicals. • Examination for CCPR-205 shall be based on Semester II Practicals. • Duration of Practical Examination as per respective BOS guidelines • ***Separate passing is mandatory for Theory, Internal and Practical Examination***

M.Sc. (Mathematics) Programme structure (CBCS PATTERN) (2020-21)
M.Sc. (Mathematics) Part – II

SEMESTER-III (Duration- Six Month)											
	Sr. No.	Course Code	Teaching Scheme			Examination Scheme					
			Theory and Practical			University Assessment (UA)			Internal Assessment (IA)		
			Lectures (Per week)	Hours (Per week)	Credit	Maximum Marks	Minimum Marks	Exam. Hours	Maximum Marks	Minimum Marks	Exam. Hours
CGPA	1	CC-301	5+1	6	5	90	36	3	30	12	1
	2	DSE -302	5+1	6	5	90	36	3	30	12	1
	3	CCS-303	5+1	6	5	90	36	3	30	12	1
	4	CCS -304	5+1	6	5	90	36	3	30	12	1
	5	CCS -305	5+1	6	5	90	36	3	30	12	1
Total (C)			**--**	**--**	**25**	**450**	**--**	**--**	**150**	**--**	
Non-CGPA	1	AEC-306	2	2	2	--	--	--	50	20	2
	2	EC (SWM MOOC)-307	Number of lectures and credit shall be as specified on SWAYAM MOOC								
SEMESTER-IV (Duration- Six Month)											
CGPA	1	CC-401	5+1	6	5	90	36	3	30	12	1
	2	DSE -402	5+1	6	5	90	36	3	30	12	1
	3	CCS-403	5+1	6	5	90	36	3	30	12	1
	4	CCS -404	5+1	6	5	90	36	3	30	12	1
	5	CCS -405	5+1	6	5	90	36	3	30	12	1
Total (D)			**--**	**--**	**25**	**450**	**--**	**--**	**150**	**--**	**--**
Non-CGPA	1	SEC-406	2	2	2	--	--	--	50	20	2
	2	GE-407	2	2	2	--	--	--	50	20	2
Total (C+D)					**50**	**900**	**--**	**--**	**300**	**--**	**--**

• Student contact hours per week : **30** Hours (Min.)	• Total Marks for M.Sc.-II : **1200**
• Theory and Practical Lectures : **60** Minutes Each	• Total Credits for M.Sc.-II (Semester III & IV) : **50**
• CC-Core Course • CCS- Core Course Specialization • CCPR-Core Course Practical • DSE-Discipline Specific Elective • AEC-Mandatory Non-CGPA compulsory Ability Enhancement Course • SEC- Mandatory Non-CGPA compulsory Skill Enhancement Course • EC (SWM MOOC) - Non-CGPA Elective Course • GE-Generic Elective	• Practical Examination is annual. • Examination for CCPR-305 shall be based on Semester III Practicals. • Examination for CCPR-405 shall be based on Semester IV Practicals. • Duration of Practical Examination as per respective BOS guidelines • ***Separate passing is mandatory for Theory, Internal and Practical Examination***

	M.Sc.-I	**M.Sc.-II**	**Total**
Marks	**1200**	**1200**	**2400**
Credits	**50**	**50**	**100**

I. CGPA course:

1. There shall be 12 Core Courses (CC) of 60 credits per programme.
2. There shall be 06 Core Course Specialization (CCS)of 30 credits per programme.
3. There shall be 02 Discipline Specific Elective (DSE) courses of 10 credits per programme
4. Total credits for CGPA courses shall be of 100 credits per programme

II. Mandatory Non-CGPA Courses:

1. There shall be 02 Mandatory Non-CGPA compulsory Ability Enhancement Courses (AEC) of 02 credits each per programme.
2. There shall be o1 Mandatory Non-CGPA compulsory Skill Enhancement Course (SEC) of 02 credits per programme.
3. There shall be one Elective Course (EC) (SWAYAM MOOC). The credits of this course shall be as specified on SWAYAM MOOC.
4. There shall be one Generic Elective (GE) course of 02 credits per programme. Each student has to take generic elective from the department other than parent department.
5. The total credits for Non-CGPA course shall be of 08 credits + 2-4 credits of EC as per availability.
6. The credits assigned to the course and the programme are to be earned by the students and shall not have any relevance with the work load of the teacher.

M.A. / M.Sc. (Mathematics) Part -II (Semester III)

Course code	Title of course
CC-301	Real Analysis
DSE-302	**Any one of the following** 1. Advanced Discrete Mathematics 2. Topological Vector Spaces
CCS-303, CCS-304, CCS-305	**Any Three of the following:** 1. Number Theory 2. Operations Research – I 3. Fuzzy Mathematics –I 4. Fluid Dynamics 5. Fractional Calculus 6. General Relativity – I 7. Lattice Theory – I 8. Approximation Theory 9. Dynamical Systems – I 10. Graph Theory-I 11. Differential Geometry 12. Combinatorics 13. Commutative Algebra - I 14. Space Dynamics- I 15. Theory of Computation 16. Algebraic Topology 17. Probability and Stochastic Processes
AEC-306	Communicative English-II
EC (SWM MOOC)-307	

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CC- 301
Title of Course: Real Analysis
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:
1. generalise the concept of length of interval.
2. analyse the properties of Lebesgue measurable sets.
3. demonstrate the measurable functions and their properties.
4. understand the concept of Lebesgue integration of measurable functions.
5. characterize Riemann and Lebesgue integrability.
6. prove completeness of L^p Spaces.

UNIT I:
σ - algebraand Borel sets of real numbers, Lebesgue outer measure, The sigma algebra of Lebesgue measurable sets, Outer and inner approximation of Lebesgue measurable sets, Countable additivity, Continuity and Borel-Cantelli lemma. **15 Lectures**

UNIT II:
Non measurable Sets, Lebesgue Measurable Functions: Sums, product and composition of measurable functions, Sequential point wise limits and simple approximation, Littlewood's three principles, Egoroff's theorem, and Lusin's theorem. **15 Lectures**

UNIT III:
Lebesgue integration of a bounded measurable function, Lebesgue integration of a non-negative measurable function, Thegeneral Lebesgue integral, Characterization of Riemann and Lebesgueintegrability. **15 Lectures**

UNIT IV:
Differentiability of Monotone Functions, Lebesgue's theorem, Functions of bounded variations, Jordan's theorem (Statement only),Absolutely continuous functions, integrating derivatives: differentiating indefinite integrals, The L^p Spaces: Normed linear spaces, The inequalities of Young, Hölder and Minkowski, The Riesz-Fischer Theorem. **15 Lectures**

Unit- V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Books:
1. H. L. Royden, P.M. Fitzpatrick, Real Analysis, Fourth Edition,PHI Learning Pvt. Ltd.,New Delhi, 2010

Reference Books:
1. G. deBarra, Measure Theory and Integration, New Age International (P) Ltd., 1981.
2. I. K. Rana, An Introduction to Measure and Integration, Narosa Book Company, 1997.
3. S. K. Berberian, Measure and Integration, McMillan, New York, 1965.
4. P. K. Jain, V. P. Gupta, Lebesgue Measure and Integration, Wiley Easter Limited, 1986.
5. P. K. Halmos, Measure Theory, Van Nostrand, 1950.

M. A. / M. Sc. Mathematics (Part II) (Semester IV)

(Choice Based Credit System)

(Introduced from June 2020 onwards)

Course Code: DSE- 302

Title of Course: Advanced Discrete Mathematics

Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:
1. classify the graphs and apply to real world problems.
2. simplify the graphs using matrix.
3. study Binomial theorem and use to solve various combinatorial problems.
4. simplify the Boolean identities and apply to switching circuits.
5. locate and use information on discrete mathematics and its applications.

Unit I **15 Lectures**

Graph: Definition, examples, isomorphism, simple graph, bipartite graph, complete bipartite graph, vertex degrees, regular graph, sub-graphs, complement of a graph, self complementary graph, paths and cycles in a graph, the matrix representation of a graph, fusion, definition and simple properties of a tree.

Unit II **15 Lectures**

Bridges, spanning trees, cut vertices and connectivity, Euler Tours and Hamiltonian cycles, Fleury's Algorithm, Hamiltonian graphs, plane and planar graphs, Euler's formula.

Unit III **15 Lectures**

Principle of inclusion and exclusion, Pigeonhole principle, permutations and combinations, Binomial theorem, discrete numeric functions, manipulation of numeric functions, generating functions, linear recurrence relations with constant coefficients, particular solutions of linear recurrence relations, total solutions, solution by the method of generating function.

Unit IV **15 Lectures**

Posets: Definition, examples, Hasse diagrams of posets, supremum and infimum, isomorphic ordered sets, duality. Lattices: Definition, examples, sublattices. Ideals: Definition, examples, bounded lattices, distributive lattices, modular lattices, complemented lattices, Boolean algebra, basic definitions, basic theorems, Boolean algebras as lattices, CNF, DNF, applications of Boolean algebra to switching circuit.

Unit V **15 Lectures**

Examples, seminars, group discussions on the above four units.

Recommended Books:

1. John Clark and Derek Holton , A first look at Graph Theory, Allied Publishers Ltd.,1991.
2. C. L. Liu, D. P. Mohapatra, Elements of Discrete Mathematics, Tata McGraw Hill Pvt Ltd, 1985.
3. G. Gratzer, General Lattice Theory, Birkhauser,2002.

Reference Books:

1. SeymonLipschutz and Mark Lipson, Discrete Mathematics (second edition) Tata Mc Graw Hill Publishing Company Ltd. New Delhi.
2. Garrett Birkhoff : Lattice Theory, American mathematical society,1940.
3. Richard A. Brualdi: Introductory Combinatorics,Pearson,2004.

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: DSE- 302
Title of Paper: Topological Vector Spaces
Total Credits: 05

Course Outcomes : Upon successful completion of this course, the student will be able to:

1. Apply topological concepts on vector spaces.
2. Construct homeomorphisms on different topological vector spaces.
3. Understand and apply separation properties.
4. formulate compatible metric on topological vector spaces.
5. Study Frechet spaces.

Unit I: Normed spaces, Banach spaces, Vector spaces, topological spaces, topological vector spaces, types of topological vector spaces, invariance, homeomorphism, separation properties of topological vector spaces, Linear mappings on topological vector spaces. **15 Lectures**

Unit II: Finite dimensional topological vector spaces, locally compact topological spaces, locally bounded topological vector spaces, Heine-Borel property, metrizable topological vector spaces, metric compatible with the topology of the vector space, Cauchy sequences in topological vector spaces, F-space, invariant metric on a topological vector space, translation invariant metric on topological vector space, bounded subsets in topological vector spaces, d- bounded subsets in topological vector spaces, balanced neighborhood. **15 Lectures**

Unit III: Bounded linear transformations, seminorm and local convexity, absorbing sets, properties of continuous seminorms, local convexity, separating family of seminorms, quotient spaces, quotient map, quotient topology, seminorm on quotient spaces, The space $H(\Omega)$, $C(\Omega)$, differential operator, properties of differential operator. **15 Lectures**

Unit IV: Baire category, Baire 's theorem, The Banach Steinhaus theorem, equicontinuity, open mappings, The open mappings theorem. Corollaries to open mapping theorem, graph, Hausdorff separation axiom, The closed graph theorem, bilinear mapping. **15 Lectures**

Unit V: Examples, Seminars and group discussion on the above four units. **15 Lectures**

Recommended Books :

1. Walter Rudin, Functional Analysis, Tata McGraw Hill publishing company (1986).

Reference Books:

1. Yau-Chuen Wong, Introductory Theory of Topological Vector Spaces, Marcel Dekker, Inc, New York 1992

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-303, CCS-304, CCS-305
Title of Paper: Number Theory
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student should be able to:

1. learn more advanced properties of primes and pseudo primes.
2. apply Mobius Inversion formula to number theoretic functions.
3. explore basic idea of cryptography.
4. understand concept of primitive roots and index of an integer relative to a given primitive root.
5. derive Quadratic reciprocity law and its apply to solve quadratic congruences.

Unit I: Review of divisibility : The division algorithm, G.C.D., Euclidean algorithm, Diophantine equation ax + by = c. Primes and their distribution : Fundamental theorem of Arithmetic, The Goldbach Conjecture. **15 Lectures**

Unit II: Congruences : Properties of Congruences, Linear congruences, Special divisibility tests. Fermat's theorem : Fermat's factorization method, Little theorem, Wilsons theorem. Number theoretic functions : The functions τ and σ. The Mobius Inversion formula, The greatest integer function.

15 Lectures

Unit III: Euler's Generalization of Fermat's theorem: Euler's phi function, Euler's theorem, properties of phi function, An application to Cryptography. Primitive roots : The order of an integer modulo n.

15 Lectures

Unit IV: Primitive roots for primes, composite numbers having primitive roots, The theory of Indices. The Quadratic reciprocity law : Eulerian criteria, the Legendre symbol and its properties, quadratic reciprocity, quadratic reciprocity with composite moduli . **15 Lectures**

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Book:

1. D.M.Burton : Elementary Number Theory, Seventh Ed.MacGraw Hill Education(India)Edition 2012, Chennai.

Reference Books:

1. S.B.Malik :Baisc Number theory, Vikas publishing House.
2. George E.Andrews : Number Theory, Hindusthan Pub. Corp.(1972).
3. Niven, Zuckerman : An Introduction to Theory of Numbers. John Wiley & Sons.
4. S. G. Telang , Number Theory, Tata Mc.Graw-Hill Publishing Co., New Delhi.
5. M.B. Nathanson, Methods in Number Theory, Springer(2009).

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-303, CCS-304, CCS-305
Title of Course: Operations Research I
Total Credits: 05

Course Outcomes-: Upon successful completion of this course, the student will be able to:-

1. identify Convex set and Convex functions.
2. Construct linear integer programming models and discuss the solution techniques,
3. Formulate the nonlinear programming models,
4. Propose the best strategy using decision making methods,
5. solve multi –level decision problems using dynamic programming method.

Unit I : Convex set and their properties: Lines and hyper planes, convex set, Important Theorems, Polyhedral convex sets, Convex combination of vectors, Convex hull, Convex polyhedron, Convex cone, Simple and convex functions. General formulation of linear programming, Matrix form of linear programming problem, Definitions of standard linear programming problem, Fundamental Theorem of linear programming, Simplex method, Computational procedure of simplex method, Problem of degeneracy and method to resolve degeneracy. **15 Lectures**

Unit II: Revised simplex method in standard form I, Duality in linear programming, duality theorems, Dual simplex method, Integer linear programming, Gomory's cutting plane method, Branch and bound method.
15 Lectures

Unit III: Dynamic programming: Bellman's principle of optimality, Solution of problem with a finite number of stages, Application of dynamic programming in production, Inventory control and linear programming.
15 Lectures

Unit IV : Non – linear programming unconstrained problems of maximum and minimum,
Lagrangian method ,Quadratic programming, Kuhn Tucker necessary and sufficient condition, Wolfe method, Beale's method. **15 Lectures**

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Books :

1. S.D. Sharma : Operations Research , KedarNath Ram Nath and Co.
2. J K Sharma: Operations Research Theory and Applications, Mac Millan Co.

Reference Books :

1. KantiSwarup ,P.K.Gupta and Manmohan : Operations Research , S. Chand & Co.
2. Hamady Taha : Operations Research : Mac Millan Co.
3. S.D. Sharma: Linear Programming ,KedarNath Ram Nath and Co.
4. S.D. Sharma : Nonlinear and Dynamic Programming,KedarNath Ram Nath and Co. Meerut.
5. R.K.Gupta : Operations Research, Krishna PrakashanMandir , Meerut.
6. G.Hadley : Linear Programming , Oxford and IBH Publishing Co.

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-303, CCS-304, CCS-305
Title of Paper: Fuzzy Mathematics-I
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. acquire the knowledge of notion of crisp sets and fuzzy sets,
2. understand the basic concepts of crisp set and fuzzy set,
3. develop the skill of operation on fuzzy sets and fuzzy arithmetic,
4. demonstrate the techniques of fuzzy sets and fuzzy numbers.
5. apply the notion of fuzzy set, fuzzy number in various problems.

Unit I: Fuzzy sets and crisp sets, examples of fuzzy sets, types of fuzzy sets, standard operations, cardinality, degree of subset hood, level cuts and its properties, **r**epresentation of fuzzy sets, decomposition theorems, extension principle, properties of direct and inverse images of fuzzy sets. **15 Lectures**

Unit II: Operations on fuzzy sets, types of operations, fuzzy complement, equilibrium and dual point, Increasing and decreasing generators, fuzzy intersection: t-norms. **15 Lectures**

Unit III: Fuzzy union t-conorms, characterization theorem of t-conorm, combination of operators, aggregation operations, ordered weighted averaging operations. **15 Lectures**

Unit IV: Fuzzy numbers, characterization theorem, linguistic variables, arithmetic operations on intervals, arithmetic operations on fuzzy numbers, lattice of fuzzy numbers, fuzzy equations.

15 Lectures

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Books:

1. George J. Klir, Bo Yuan, Fuzzy sets and Fuzzy Logic. Theory and Applications, PHI, Ltd.2000

Reference Books:-

1. M.Grabish, Sugeno, and Murofushi Fuzzy Measures and Integrals: Theory and Applications,PHI, 1999.

2. H.J.Zimmerermann, Fuzzy Set Theory and its Applications, Kluwer, 1984.

3. M. Hanss, Applied Fuzzy Arithmetic, An Introduction with EngineeringApplications, Springer-Verlag Berlin Heidelberg 2005.

4. M. Ganesh, Introduction to Fuzzy Sets & Fuzzy Logic; PHI Learning Private Limited, New Delhi 2011.

5. Bojadev and M. Bojadev, Fuzzy Logic and Application, World Scientific Publication Pvt.Ltd. 2007.

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-303, CCS-304, CCS-305
Title of Paper: Fluid Dynamics
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:
1) explain physical properties of fluids.
2) represent general motion of fluid element.
3) test possible fluid flows, classify rotational and irrotational fluid flows .
4) transform stress components from one co-ordinate system to another, establish relation between strain and stress tensor..
5) develop constitutive equations for Newtonian fluids, conservation laws and Navier-Stokes equation.
6) determine the complex potential and images of a two dimensional source, sink and doublet.

Unit I: Physical properties of fluids and kinematics of fluids: Concepts of fluids, continuum hypothesis, density, specific weight, specific volume, pressure, viscosity, surface tension, Eulerion &Lagrangian methods of description of fluids, Equivalence in Eulerian and Lagrangian methods, General motion of a fluid element, Integrability and compatibility conditions, general orthogonal curvilinear co-ordinate system, stream lines, path lines, streak lines, stream function, vortex lines, circulation, condition at rigid boundary. **15 Lectures**

Unit II: Stresses in fluids: Strain rate tensor, stress tensor, normal stress, shearing stress, symmetry of stress tensor, Transformation of stress components from one co-ordinate system to another, principle axes and principle values of stress tensor. Newtonian fluids, non Newtonian fluids, purely viscous fluids, Constitutive equations for Newtonian fluids. **15 Lectures**

Unit III: Conservation laws: Equation of conservation of mass, equation of conservation of momentum, Navier-Stokes equation, equation of moment of momentum, Equation of energy, Basic equations in different co-ordinate systems: Cartesian co-ordinate system, Cylindrical co-ordinate system, Spherical co-ordinate system, boundary conditions. **15 Lectures**

Unit IV: Rotational and irrotational flows: Theorems about rotational and irrotational flows: Kelvins minimum energy theorem, Kinetic energy of finite and an infinite fluid, uniqueness of irrotational flows, Bernoullis's equation, Bernoullis equation for irrotational flows, Two dimensional irrotational incompressible flows, Blasius theorem, circle theorem, Sources and sinks, sources, sinks and doublets in two dimensional flows, Methods of images. **15 Lectures**

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Books:
1. R. K. Rathy, An introduction to Fluid Dynamics, Oxford & IBH publishing company.
2. F. Chorlton, Text book of Fluid Dynamics, CHS Publishers, Delhi, 1985.

Reference Books:
1. L. D. Landay and E. M. Lipschitz, Fluid Mechanics, Pergamon Press London 1985.
2. Kundu and Cohen, Fluid Mechanics, Elsevier pub. 2004.
3. L M Milne-Thomson, Theoretical Hydrodynamics, Macmillan Education Ltd, London 1986.

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-303, CCS-304, CCS-305
Title of Course:Fractional Calculus
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. compare Grünwald-Letnikov,Riemann-Liouville,and Caputo fractional derivative.
2. evaluate fractional derivatives and fractional integral of power function and trigonometric functions
3. analyze the behaviour of fractional derivatives near and far from the lower terminal
4. derive important properties such as linearity, compositions, Commutatively and Leibnitz rule for fractional derivatives
5. evaluate transforms of fractional derivatives and integrals.
6. solve fractional differential equations using transform methods.

Unit I: Brief review of Special Functions of the Fractional Calculus: Gamma Function, Mittag-Leffler Function, Wright Function, Fractional Derivative and Integrals: Grünwald-Letnikov (GL) Fractional Derivatives-Unification of integer order derivatives and integrals, GL Derivatives of arbitrary order, GL fractional derivative of $(t-a)^{\beta}$, Composition of GL derivative with integer order derivatives, Composition of two GL derivatives of different orders. **15 Lectures**

Unit II:Riemann-Liouville (RL) fractional derivatives- Unification of integer order derivatives and integrals, Integrals of arbitrary order, RL derivatives of arbitrary order, RL fractional derivative of $(t-a)^{\beta}$, Composition of RL derivative with integer order derivatives and fractional derivatives, Link of RL derivative to Grünwald-Letnikov approach, Caputo's fractional derivative, generalized functions approach, Left and right fractional derivatives.

15 Lectures

Unit III:Properties of fractional derivatives: Linearity, The Leibnitz rule for fractional derivatives, Fractional derivative for composite function Riemann-Liouville fractional differentiation of an integral depending on a parameter, Behaviour near the lower terminal, Behaviour far from the lower terminal, Laplace transform of the Riemann-Liouville fractional derivative, Caputo derivative and Grünwald-Letnikov fractional derivative. Fourier transforms of fractional integrals and derivatives. **15 Lectures**

Unit IV: Mellin transforms of the Riemann-Liouville fractional integrals and fractional derivative, Mellin transforms of Caputo derivative. Methods of solving FDE's: The Laplace transform method: Ordinary fractional differential equations, Partial fractional differential equations, The Mellin transform method, Power series method: One term equation, Equation with non-constant coefficients, Two-term nonlinear equation.
15 Lectures

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Book(s):

1. Igor Podlubny, Fractional Differential Equations. San Diego: Academic Press; 1999.
2. L. Debnath, D. Bhatta, Integral Transforms and Their Applications, CRC Press, 2010.

Reference Books:

1. A. Kilbas, H.M. Srivastava, J.J. Trujillo, Theory and Applications of Fractional Differential Equations, Elsevier, Amsterdam, 2006.
2. Kai Diethelm, The Analysis of Fractional Differential Equations, Springer, 2010.
3. K. S. Miller, B. Ross AnIntroduction to the Fractional Calculus and Differential Equations, Wiley, New York, 1993.
4. S. G. Samko, A. A. Kilbas, O. I. Marichev, Fractional Integrals and Derivatives,Theory and Applications, Gordon and Breach, New York, 1993.

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-303, CCS-304, CCS-305
Title of Course: General Relativity I
Total Credits: 05

Course outcomes-: Upon successful completion of this course, the student will be able to:

1. understand Albert Einstein's special and general theory of relativity.
2. formulate fields of General Relativity.
3. relate the covariant derivative and geodesic curves
4. calculate components of the Riemann curvature tensor form a line element.
5. derive Necessary and Sufficient condition for isometry

Unit I: Review of special theory of relativity and the Newtonian theory of gravitation, Distinction between Newtonian space and relativistic space, The conflict between Newtonian theory of gravitation and special relativity, Non-Euclidean time, General relativity and gravitation. Desirable features of gravitational theory, Principle of equivalence and Principle of covariance. **15 Lectures**

Unit II: Transformation of co-ordinates, Tensor, Algebra of tensor. Symmetric and Skew-symmetric tensor. Contraction of tensors and quotient law. Tensor calculus :Christoffel Symbols, Covariant derivative. Intrinsic derivative. Riemannian Christoffel curvature tensor and it's symmetric properties. Bianchi identities and Einstein tensor. **15 Lectures**

Unit III: Riemannian metric. Generalized Kronecker delta , alternating symbols and Levi-Civitatensor, Dual tensor .parallel transport and Lie derivative. Geodesic : Geodesic as a curve of unchanging direction .Geodesic as a curve of shortest distance .Geodesic through variational principle. The first integral of geodesic and types of geodesic Geodesic Deviation and geodesic deviation equation. **15 Lectures**

Unit IV: Killing vector fields. Isometry. Necessary and Sufficient condition for isometry. Integrability condition. Homogeneity and isometry. Maximally symmetric space – time. Einstein space. **15 Lectures**

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended books :

1. L.N. Katkar : Mathematical Theory of General Relativity. Narosa publishing house, New Delhi, (2014)
2. J.V. Narlikar : Lectures on General Relativity and Cosmology, The Mac Millan com.(1978).

Reference Book :

1. R. Adler, M. Bazinand M. Schiffer : Introduction of General Relativity , McGraw-Hill Book com.(1975).
2. M. Carmeli: Classical Fields: General Relativity and Gauge Theory,Wiley – Interscience publication (1982)
3. J.L. Synge : The General Relativity , North Holland Publishing com. (1976)
4. L.D. Landau and E.M.Lifshitz : The Classical Theory of Field ,Pergamon press. (1980)
5. B.F. Shutz : A First Course in General Relativity , Cambridge University press (1990).
6. H. Stepheni : General Relativity : An Introduction to the Theory of Gravitational Field, Cambridge University press.(1982)

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-303, CCS-304, CCS-305

Title Of Paper: Lattice Theory –I

Total Credits: 05

Course Outcomes: On successful completion of this course student will be able

1. Students should acquire thorough knowledge of fundamental notions from lattice theory and properties of lattices
2. To learn Modular and Distributive lattice
3. To learn about Boolean algebra
4. To know Stone Algebra
5. Students should develop ability to solve individually and creatively advanced problems of lattice theory and also problems connected with its applications to mathematics
6. Describe Lattices and Posets and their use

Unit I :Basic concepts: Posets: Definition and examples. Two definitions of lattices and their equivalence, examples of lattices. Description of Lattices, some algebraic concepts. Homomorphism, Isomorphism and isotone maps. Polynomials, Identities and Inequalities. Free lattices: definition and examples, Special elements. **15 lectures**

Unit II :Special types of Lattices: Distributive lattices – Properties and characterizations. Modular lattices – Properties and characterizations. Congruence relations. Boolean algebras – Properties and characterizations. Topological representation: definition and examples. Pseudo complementation. **15 lectures**

Unit III: Concurrences and Ideals: Ideals and filters in lattices. Lattice of all ideals I(L). Properties and characterizations of I(L).Stone's theorem and its consequences. Distributive, Standard and Neutral Elements. **15 lectures**

Unit IV: Stone Algebra : Pseudo complemented lattices. S(L) and D(L) – special subsets of pseudo complemented lattices. Distributive pseudo complemented lattice. Stone lattices – properties and characterizations. Semi modular Lattices: definition and examples. **15 lectures**

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Books :

1) George Grätzer , General Lattice Theory, Birkhäuser Verlag (Second Edition).
2)G. Birkhoff, Lattice Theory, Amer. Math. Soc. Coll. Publications, Third Edition 1973

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-303, CCS-304, CCS-305
Title of Paper: Approximation Theory
Total Credits: 05

Course outcomes: Having successfully completed this course, the students will be able to--

1. Construct approximate polynomial for periodic function using Bernstein polynomials
2. Interpolate given function using finite interpolation.
3. determine error bounds in polynomial approximations and establish uniqueness of approximating polynomials.
4. prove convergence of Fourier series of a function of bounded variation.
5. establish orthogonality of Jacobi polynomials and predict zeros of orthogonal polynomials.
6. formulate recurrence relations of orthogonal polynomials.

Unit I: Approximation of periodic functions, Fejers theorem, Dirichlet Kernel, Lebesgue constant, approximation by algebraic polynomials, Weierstrass theorem, Bernstein polynomials, convergence of Bernstein polynomials Approximation in normed linear spaces, existence ,uniqueness, classical theory, alternation theorem. **15 Lectures**

Unit II: Interpolation: Algebraic Formulation of Finite Interpolation problem , Gram determinant, well posed problems, Lagrange interpolation, Taylor interpolation, Hermite interpolation; Lagrange Form, fundamental Lagrange polynomials, Cauchy relations, biorthonormal relations, error in Lagrange interpolation; Convergence of sequence of Lagrange interpolating polynomials, Extended Haar Subspaces and Hermite Interpolation, generalized Gram determinant; Hermite - Fejer Interpolation. **15 Lectures**

Unit III: Fourier Series: Introduction, Preliminaries, Riemann- Lebesgue lemma, Localization principle, Dini test, periodic integral of a function, Dirichlet- Jordan Test, functions of bounded variations, Bojanic theorem , Convergence of Fourier Series. **15 Lectures**

Unit IV: Orthogonal Polynomials: Introduction, Chebyshev polynomials, properties of Chebyshev polynomials, recurrence relation of Chebyshev polynomials, Chebyshev polynomials of second kind , Jacobi Polynomials: Elementary Properties, Legendre polynomials, ultraspherical polynomials, Asymptotic Properties.
15 Lectures

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Books:

1. Hrushikesh N. Mhaskar and DevidasV.Pai : Fundamentals of Approximation Theory, Narosa Publishing House.

References Books:

1. Theodore J. Rivlin : An Introduction to the Approximation of Functions, Dover Publications, Inc. New York.

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-303, CCS-304, CCS-305
Title of Paper: Dynamical Systems- I
Total Credits: 05

Course Outcomes : Upon successful completion of this course, the student will be able to:
1. Classify equilibrium points of the dynamical system
2. Construct bifurcation diagrams and analyze the system for different values of parameter.
3. Relate the qualitative properties of the system with the eigen values of coefficient matrix.
4. Estimate the solution of the system using the canonical form of coefficient matrix
5. Construct the exponential of a matrix and apply it to solve the dynamical system.
6. Examine the discrete dynamical systems.

Unit I: First order systems- Qualitative Analysis:
Introduction: First order linear systems, equilibrium points- classification, stability, bifurcation, phase portraits. Scalar autonomous non-linear systems, Stability (linearization, equilibrium points), phase portraits- slope fields, Examples, two-parameter family. **15 Lectures**

Unit II: Higher order linear systems
Higher order linear ODE as a system of first order ODEs, preliminaries from algebra, eigen-values and eigen-vectors, canonical forms, solution of linear systems.
Phase portraits for planar systems: Real distinct eigen-values, complex eigen-values, repeated eigen-values; Phase portraits for systems in 3 dimension; changing co-ordinates. **15 Lectures**

Unit III: Higher order linear systems (continued...)
Classification of planar systems: the trace-determinant plane. Yet another elegant way to find solution: The *Exponential of a Matrix* (Definition, properties of exponential of a matrix, application to the solution of a system).**Discrete dynamical systems:** Introduction to the discrete maps (iterative maps), orbit, periodic points, cobweb plots. Fixed points of a map. **15 Lectures**

Unit IV: Discrete dynamical systems (continued...)
Stability analysis of a fixed point (sink, source, saddle).Bifurcation and chaos; Standard examples (Logistic map, tent map, doubling map).Planar linear maps. **15 Lectures**

Unit V: Examples, seminars, group discussion on above four units. Applications of mathematical software "Winplot" in solving problems in dynamical systems. **15 Lectures**

Recommended Books:
1. M. Hirsch, S. Smale and R. L. Devaney, Differential Equations, Dynamical Systems, and an Introduction to Chaos,ElsevierAcademic Press, USA, 2004.
2. Hale and Kocak, Dynamics and Bifurcations, Springer, New York.

Reference Books:
1.Alligood, Sauer and Yorke, Chaos - An Introduction to Dynamical Systems, Springer, New York.
2. Perko, Differential Equations and Dynamical Systems, Springer, New York.

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-303, CCS-304, CCS-305
Title of Paper: Graph Theory-I
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:
1. classify the graphs and solve the related problems.
2. understand Euler Graph and Hamiltonian Graph to solve problems.
3. use matching's to solve optimal assignment problems.
4. solve network problems
5. solve graph theoretic problems and apply algorithms

Unit I : Trees and connectivity: Definitions and simple properties, Bridges, spanning trees, cut vertices and connectivity. Euler Tours: Eular graphs, Properties of Euler graph, The Chinese postman problem **15Lectures**

Unit II : Homiltonian Cycles: Hamiltonion graphs. The travelling salesman problem. Matchings : Matching's and Augmenting paths, The marriage problem, The Personal Assignment problem, 15 **Lectures**

Unit III : The Optimal Assignment problem, A chinese postman Problem, Postscript. Planer Graphs : Plane and Planar graphs, Eulers formula, Platonic bodies Kurotowskis theorem. Non Homiltonian plane graphs. The dual of a plane graph. **15Lectures**

Unit IV: Vertex coloring, vertex coloring algorithms, critical graphs, cliques, Edge coloring, map coloring. Directed graphs: Definition, Indegree and outdegree, Tournaments, traffic flow, Networks : Flows and Cuts, The Ford and Fulkerson Algorithm, Separating sets **15Lectures**

Unit V : Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Book:
1. John Clark and Derek Holton : A First Look at Graph Theory, Allied Publishers Ltd. Bombay.

References Books:
1. Douglas B.West : Introduction to Graph Theory, Pearson Education Asia.
2. F. Harary - Graph Theory, Narosa Publishing House (1989)
3. K. R. Parthsarthy : Basic Graph Theory, Tata McGraw Hill publishing Co.Ltd.New Delhi

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-303, CCS-304, CCS-305
Title of Paper: Differential Geometry
Total Credits: 05

Course Outcomes : Upon successful completion of this course, the student will be able to:

1. find the directional derivatives of the functions.
2. compare the unit-speed and arbitrary-speed curves.
3. apply the Frenet formulas to analyze the curves.
4. examine whether the given set in R^3 is a surface.
5. construct the parametrizations of different surfaces.
6. formulate different types of curvatures of given surface.

Unit I: Euclidean Space, Tangent Vectors, Directional Derivatives, Curves in R^3,and reparametrization of curves, standard curves, Speed of curve, length of curve, mappings. **15 Lectures**

Unit II: Mappings, The Frenet Formulas, Arbitrary-Speed Curves, Covariant Derivatives, Isometries of R^3, Orthogonal transformations. **15 Lectures**

Unit III: Coordinate patches, surface in R^3, simple surface, cylinder surface, surface of revolution, parametrization of a region, parametrization of cylinder and surface of revolution, smooth overlapping patches, tangent and normal vector fields on a surface. **15 Lectures**

Unit IV: The shape operator of surface M in R^3, normal curvature, principal curvatures, Gaussian and mean curvatures, Umbilic points, fundamental forms of a surface, computational techniques. **15 Lectures**

Unit V: Problem solving sessions, seminars and group discussion on the above four units. **15 Lectures**.

Recommended Books:

1. O'Neill, B., Elementary Differential geometry, Academic Press, Revised Edition 2006.

Reference Books:

1. D. Somasundaram, Differential Geometry- First Course, Narosa Publishing House, New Dehli, 2010.
2. Nirmala Prakash, Differential Geometry, Tata Mcgraw Hill, 1981.
3. K. S. Amur and et al., Differential Geometry, Narosa Publishing House, 2010.
4. Millman, R. and Parker, G. D. Elements of Differential Geometry, Prentice-Hall of India Pvt. Ltd. 1977.
5. Hicks, N. , Notes on Differential Geometry, Princeton University Press (1968)

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-303, CCS-304, CCS-305
Title of Paper: Combinatorics
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:
1. describe Pigeonhole principle and use it to solve problems.
2. use definitions and theorems from memory to construct solutions to problems
3. use Burnside Frobenius Theorem in counting's.
4. use various counting techniques to solve various problems.
5. apply combinatorial ideas to practical problems.
6. improve mathematical verbal communication skills.

Unit I: Basic Tools : The sum rule and product rule, permutations and combinations The Pigeonhole principle, Ramsay numbers, Catalan numbers, sterling numbers Further basic tools. **15 Lectures**

Unit II: Generalized permutations and combinations sequences and selections, The inclusion and Exclusion principle, Systems of distinct representatives, solved problems Derangements and other constrained arrangements combinatorial number Theory. **15 Lectures**

Unit III : The permanent of a matrix, Rook polynomials and Hit polynomials, SDR and coverings, (Sperners theorem and Symmetric chain decomposition, posets and Dilworth's theorem) Statements. Generating functions and Recurrence relations Ordinary and exponential Generating functions. **15 Lectures**

Unit IV: Partitions of a positive integer, Recurrence relations Algebraic solutions of linear Recurrence relations with constant coefficients with solutions of recurrence relations using generating functions. Group Theory in Combinatorics: The Burnside Frobenius theorem, permutation groups and their Cycle indices, Polyas enumeration theorems. **15 Lectures**

Unit – V Examples and student seminars on the above four units**.** **15 Lectures**

Recommended Books:

1. V. K. Balkrishnan: Combiactorics, Shaums Outlines Series, McGrow Hill Inc.

Reference Books:

1. Richard Brualdi - Introductory Combinatosics North Holland.

2. V. Krishnamurthy: Combinatorics, E. W. Press

3. A. Tucker: Combinatorics, John Wiley & Sons, Inc

4. C.Vasudev, Theory and Problems of Combinatorics, New Age International.

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-303, CCS-304, CCS-305

Title of Paper: Commutative Algebra – I

Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:
1. classify the ideals to solve the related problems.
2. understand various radicals.
3. know Hilbert basis theorem and apply it to other development.
4. use Nakayama Lemma for further development in Noetherion Rings.
5. Derive The Krull intersection theorem

Unit – I Minimal Prime and Primary Ideals : Examples and properties of Minimal, Prime and Primary Ideals. The nil radical of an ideal and its properties, semiprime ideals. The associated prime ideal of a primary ideal, Problems. (**No. of Lectures 15)**

Unit – II Minimal prime ideals of a ring. Certain Radicals of a Ring : Jacobson Radical, The definition of the idempotents of R/I can be raised or lifted into R and its properties, Primary rings, Quasiregular element and its properties, Problems. (**No. of Lectures 15)**

Unit – III Prime radicals, Modular ideals, J-radial of a ring. Boolean rings, Regular rings, Stone representation theorem. Direct sum of Rings, Birkhoff theorem , Rings with Chain conditions: Equivalence of three conditions of a ring with a.c.c., Problems.

(**No. of Lectures 15)**

Unit – IV Hilbert Basis Theorem, Levitsky Theorem, Wedderburn Theorem, Any semisimple Artinion ring R is the direct sum of a finite number of fields. Noetherion Rings : Noether theorem, A primary representation of an ideal, Cohens Theorem, Nakayama Lemma. The Krull intersection theorem, Problems. (**No. of Lectures 15)**

Unit – V Tutorials and Seminar by students. (**No. of Lectures 15)**

Recommended Book : Barton David M. : A first course in Rings and Ideals Addison Wesley Publishing Company 1970.

Reference Books :

1. Oscar Zoriskiand P. Samuel : Commutative Algebra, Vol.I, Affilioted East Press Pvt. Ltd., New Delhi.
2. M.Atiyah and I.C. McDonald : Commutative Algebra.
3. Motsumura : Commutative Algebra.
4. C. Musili : Rings and Modules.

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-303, CCS-304, CCS-305
Title of Paper: Space dynamics- I
Total Credits: 05

Course Outcomes : Upon successful completion of this course, the student will be able to:

1. formulate trajectory equations and classify trajectories
2. Calculate flight path angle
3. determine orbit from position vectors and from one ground based observation
4. Calculate time of flight and orbit propagation
5. use perturbation methods
6. calculate atmospheric drag.

Unit I : Two Body Orbital Mechanics: Introduction, Two Body Problem, Constants of Motion, Conservation of Angular Momentum, Conservation of Energy, Conic Sections, Trajectory Equation, Eccentricity Vector, Energy and Semi major Axis, Elliptical Orbit, Ellipse Geometry, Flight Path Angle and Velocity Components, Period of an Elliptical Orbit, Circular Orbit, Parabolic Trajectory, Hyperbolic Trajectory. **15 Lectures**

Unit II: Orbit Determination: Introduction, Coordinate Systems, Classical Orbital Elements, Transforming Cartesian Coordinates to Orbital Elements, Transforming Orbital Elements to Cartesian Coordinates, Coordinate Transformations, Ground Tracks, Orbit Determination from One Ground-Based Observation, Orbit Determination from Three Position Vectors. **15 Lectures**

Unit III: Time of Flight: Introduction, Kepler's Equation, Time of Flight Using Geometric Methods, Time of Flight Using Analytical Methods, Relating Eccentric and True Anomalies, Parabolic and Hyperbolic Time of Flight, Kepler's Problem, Orbit Propagation using Lagrangian coefficients, Lambert's Problem. **15 Lectures**

Unit IV: Non Keplerian Motion: Introduction, Special Perturbation Methods, Non Spherical Central Body, General Perturbation Methods, Lagrange's Variation of Parameters, Gauss' Variation of Parameters, Perturbation Accelerations for Earth Satellites, Non Spherical Earth, Atmospheric Drag, Solar Radiation Pressure. **15 Lectures**

Unit V: Examples, Seminars and group discussion on the above four units. **15 Lectures**

Recommended books :

1.CraigKluever , Space Flight Dynamics, Wiley 2018.

Reference Books :

1. William Tyrrell Thomson, Introduction to Space Dynamics, Dover publication , New York
2. Gerhard, Methods of Celestial Mechanics, Vol. II, Springer.
3. George W. Collins, The Foundations of Celestial Mechanics, Pachart Foundation dba Pachart Publishing House.

M.A./M. Sc. Mathematics (Part II) Semester-III
(Introduced from June 2020 onwards under CBCS)

Course Code: CCS-303, CCS-304, CCS-305
Title of Course: Theory of Computation
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:
1. derive The Myhill Nerode theorem .
2. understand context free grammars.
3. explain The pumping Lemma for context free Languages.
4. describe Churchs hypothesis.

Unit I **15 Lectures**
Review of strings, alphabets, languages, finite automata. Regular sets : The pumping lemma for regular sets , closure properties of regular sets, decision algorithm for regular sets, The Myhill Nerode theorem and minimization of finite automata.

Unit II **15 Lectures**
Context Free grammars Definition of a context free grammer, more examples including some familiar languages, unions concatinatins and *'s of CFLS Derivation trees and ambiguity, an unambiguous CFG for algebraic expressions, simplified forms and normal forms.

Unit III **15 Lectures**
Pushdown Automata: Introduction by way an example, definition of a pushdown automata, Deterministic pushdown automata .A PDA corresponding to a given context free former, A context free Grammer corresponding to a Given PDA, Parsing Context Free and Non context free Languages The pumping Lemma for context free Languages, Intersections and complements of context free languages,

Unit IV **15 Lectures**
Turing Machines : Introduction The turing machine models, Computable languages and functions, Techniques for turing machine construction, Modification to turing machines, Churchs hypothesis, Turing machines as enumeraturs, Restricted turing machines equivalent to the basic model.

Unit V: Tutorials and Seminar by students **15 Lectures**

Recommends Book

1. John C. Martin : Introduction to Languages and the theory of computation ,Tata McGraw Hill publishing company limited New Delhi 1998.

Reference Books

1. K.L.P. Mishra and N.Chandrashekharan : Theory of computer science,Prentice Hill of India Pvt.Ltd. 2001.
2. John Hopcroft and J.Ullman : Introduction to Automata theory, Languages and Computation ,Narosa Publishers 1993.

M.A./M.Sc. Mathematics (Part II, Semester III)
Choice Based Credit System
Introduced from June 2020 onwards

Course Code: CCS-303, CCS-304, CCS-305
Title of Course: Algebraic Topology
Total Credits: 05

Course Outcomes : Upon successful completion of this course, the student will be able to:

(i) develop the concept of homotopy of paths
(ii) combine the group theory and topology to define fundamental groups of curves and surfaces
(iii) determine the fundamental groups of various curves
(iv) build the concept of retraction and use to study homotopy
(v) evaluate the fundamental group of compact 2-manifolds by applying Seifert-van Kampen theorem.

Unit 1: **(15 Lectures)**
Homotopy of paths, The fundamental group, covering spaces, the fundamental group of the circle,

Unit 2: **(15 Lectures)**
retractions and fixed points, Borsuk-Ulam theorem, deformation retracts and homotopy type.

Unit 3: **(15 Lectures)**
The fundamental group of S^n, fundamental groups of some surfaces, the Jordan separation theorem, the Jordan curve theorem, direct sums of Abelian groups
Free products of groups,

Unit 4: **(15 Lectures)**
free groups, the Seifert-van Kampen theorem (Statement only), the fundamental group of a wedge of circles.

Unit 5: Examples, seminars, group discussion on above four units. **(15 Lectures)**

Recommended Book:
Topology by J.R. Munkers, Prentice Hall, (Second Edition)
Reference Book:
Croom F.H. : Basic concepts in Algebraic Topology, Springer Verlag 1978)

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-303, CCS-304, CCS-305
Title of Course: Probability and Stochastic Processes
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Apply the specialised knowledge in probability theory and random processes to solve practical problems.
2. Gain advanced and integrated understanding of the fundamentals of and interrelationship between discrete and continuous random variables and between deterministic and stochastic processes.
3. Create mathematical models for practical design problems and determine theoretical solutions to the created models.

Unit I: **Probability theory:** Probability, conditional probability and independence; Random variables and their distributions (discrete and continuous). **15 Lectures**

Unit II: **Probability theory:** bivariate and multivariate distributions; Laws of large numbers, central limit theorem (statement and use only). **15 Lectures**

Unit III: **Stochastic process:** Definition and examples of stochastic processes, weak and strong stationarity; Markov chains with finite and countable state spaces -classification of states.
15 Lectures

Unit IV: **Stochastic process:** Markov processes, Poisson processes, birth and death processes, branching processes, queuing processes.. **15 Lectures**

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Book:
Dimitri Bertsekas, John N. Tsitsiklis : Introduction To Probability, Athena Scientific; 2 edition

Reference Books
1. W. Feller: An Introduction to Probability Theory and its Applications (Volume I and II), 3rd ed. John Wiley, New York, 1973.
2. P. G. Hoel, S. C. Port and C. J. Stone: Introduction to Probability Theory, University Book Stall/ Houghton Mifflin, New Delhi/New York, 199811971. 15
3. K. L. Chung: Elementary Probability Theory and Stochastic Processes, Springer-Verlag, New York, 1974. 4. S. M. Ross: Stochastic Processes, John Wiley, New York, 1983.
5. H. M. Taylor: First Course in Stochastic Processes, 2nd ed. Academic Press, Boston, 1975.
6. H. M. Taylor: Second Course in Stochastic Processes, Academic Press, Boston, 1981.

M.A. / M.Sc. (Mathematics) Part -II (Semester IV)

Course Code	Title of course
CC-401	Field Theory
DSE -402	**Any one of the following:** 1. Integral Equations 2. Measure and Integration
CCS-403 CCS-404 CCS-405	**Any Three of the following:** 1. Algebraic Number Theory 2. Operations Research – II 3. Fuzzy Mathematics –II 4. Computational Fluid Dynamics 5. Fractional Differential Equations 6. General Relativity – II 7. Lattice Theory – II 8. Wavelet Analysis 9. Dynamical Systems – II 10. Graph Theory-II 11. Analysis on Manifolds 12. Theory of Distributions 13. Commutative Algebra - II 14. Space Dynamics- II 15. Automata Theory 16. Dynamic Equations on Time Scales 17. Automata, Languages and Computation
SEC-406	Fundamentals of Information Technology (FIT)-II
GE-407	Introduction to Latex

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CC- 401
Title of Paper: Field Theory
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:

1) determine the basis and degree of a field over its subfield.
2) construct splitting field for the given polynomial over the given field.
3) find primitive n^{th} roots of unity and n^{th} cyclotomic polynomial.
4) make use of Fundamental Theorem of Galois Theory and Fundamental Theorem of Algebra to solve problems in Algebra.
5) apply Galois Theory to constructions with straight edge and compass.

UNIT-I: Algebraic Extensions of fields
Adjunction of roots, Algebraic extensions, Algebraically closed fields. **15 Lectures**

UNIT-II: Normal and Seperable extensions
Splitting fields, Normal extensions, Multiple roots, Finite fields, Separable extensions.
15 Lectures

UNIT-III: Galois Theory
Automorphism groups and fixed fields, Fundamental theorem of Galois theory, Fundamental theorem of algebra, Roots of unity and cyclotomic polynomials, Cyclic extensions.
15 Lectures

UNIT-IV: Applications of Galois theory
Polynomials solvable by radicals, Symmetric functions, Constructions by ruler and compass.
15 Lectures

Unit- V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Book(s):

1. Bhattacharya, Jain and Nagpal, Basic Abstract Algebra, 2nd edition, Cambridge University Press, UK.(Asian edition) 2005.

Reference Books:

1. Nathan Jacobson, Basic Algebra I, second edition, W. H. Freeman and company, New York
2. I. N. Herstein, Topics in Algebra, Wiley Eastern Ltd.
3. U. M. Swamy, A. V. S. N. Murthy, Algebra: Abstract and Modern, Pearson Education, 2012
4. John Fraleigh, A first course in Abstract Algebra (3rd edition) Narosa publishing house, New Delhi
5. I. T. Adamson, Introduction to Field Theory, second edition, Cambridge University Press,1982.
6. M. Artin, Algebra, PHI, 1996.
7. Ian Stewart, Galois Theory, CRC Publication.

M. A. / M. Sc. Mathematics (Part II) (Semester IV)

(Choice Based Credit System)

(Introduced from June 2020 onwards)

Course Code: DSE- 402

Title of Paper: Integral Equations

Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. classify the linear integral equations and demonstrate the techniques of converting the initial and boundary value problem to integral equations and vice versa.
2. develop the technique to solve the Fredholm integral equations with separable kernel.
3. develop and demonstrate the technique of solving integral equations by successive approximations, using Laplace and Fourier transforms
4. to analyze the properties of symmetric kernel.
5. toprove Hilbert Schmidt Theorem and solve the integral equation by applying it.

UNIT– I **15 Lectures**

Classification of linear integral equations, conversion of initial value problem to Volterra integral equation, conversion of boundary value problem to Fredholm integral equation, separable kernel, Fredholm integral equation with separable kernel, Fredholm alternative. Homogeneous Fredholm equations and eigen functions.

UNIT –II **15 Lectures**

Solutions of Fredholm integral equations by: Successive approximations method, successive substitution method, Adomian decomposition method, modified decomposition method, resolvent kernel of Fredholm equations and its properties, solutions of Volterra integral equations ,successive approximations method, Neumann series, successive substitution method.

UNIT –III **15 Lectures**

Solution of Volterra integral equations by Adomian decomposition method and the modified decomposition method, resolvent kernel of Volterra equations and its properties, convolution type kernels, applications of Laplace and Fourier transforms to solutions of Volterra integral equations, symmetric kernels**,** fundamental properties of eigen values and eigen functions for symmetric kernels, expansion in eigen functions and bilinear form.

UNIT – IV **15 Lectures**

Hilbert Schmidt Theorem and its consequences, solution of symmetric integral equations, operator method in the theory of integral equations, solution of Volterra and Fredholm integro differential equations by Adomian decomposition method. Green’s function: Definition, construction of Green’s function and its use in solving boundary value problems.

Unit V **15 Lectures**

Examples, seminars, group discussions on the above four units.

Recommended Books:

1. R. P. Kanwal, Linear Integral Equation: Theory and Technique, Birkhauser 2012.
2. Abdul-Majid Wazwaz, Linear and Nonlinear Integral Equations**-**Methods and Applications, Springer, 2011

Reference Books:

1. L. G. Chambers, Integral Equations- A Short Course, International Text Book Company, 1976.
2. M. A, Krasnov, et.al. Problems and exercises in Integral equations, Mir Publishers, 1971.
3. J. A. Cochran, The Analysis of Linear Integral Equations, Mc Graw Hill Publications, 1972.
4. C. D. Green, Integral Equation Methods, Thomas Nelson and sons, 1969.

M. A. / M. Sc. Mathematics (Part II) (Semester IV)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: DSE- 402
Title of Course: Measure and Integration
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. generalise the concept of measure.
2. appreciate the properties of Lebesgue measurable sets.
3. demonstrate the measurable functions and their properties.
4. understand the concept of Lebesgue integration of general measurable functions.
5. apply Fubini and Tonelli theorem to interchange order of the integration.

UNIT I **15 Lectures**

Measures and measurable sets, signed measures: The Hahn and Jordan Decompositions, The Caratheodory measure induced by an outer measure, the construction of outer measures, The Caratheodory-Hahn Theorem, The Extension of a premeasure to a measure.

UNIT II **15 Lectures**

Integration over general measure spaces, measurable functions, integration of nonnegative measurable functions, integration of general measurable functions , The Radon-Nikodym Theorem.

UNIT III **15 Lectures**

General L^p Spaces: The completeness of $L^p(X,\mu), 1 \leq p \leq \infty$, Holder's Inequality, The Cauchy-Schwarz Inequality, The Riesz-Fischer Theorem, Rapidly Cauchy Sequence, The Riesz Representation Theorem for the Dual of $L^p\ (X,\mu)$, The Kantorovitch Representation Theorem for the Dual of $L^\infty(X,\mu)$.

UNIT IV **15 Lectures**

Product Measures: The theorems of Fubini and Tonelli, Lebesgue measure on Euclidean space R^n , Caratheodory outer measures and Hausdorff measures on a metric sp

Unit V **15 Lectures**

Examples, seminars, group discussions on above four units.

Recommended Books:

1. H. L. Royden, P.M. Fitzpatrick, Real Analysis, Fourth Edition, PHI Learning Pvt. Ltd., New Delhi, 2010.

Reference Books:

1.G. de Barra, Measure Theory and Integration, New Age International (P) Ltd., 1981.
2. I. K. Rana, An Introduction to Measure and Integration, Narosa Book Company, 1997.
3. S. K. Berberian, Measure and Integration, McMillan, New York, 1965.
4. P. K. Jain, V. P. Gupta, Lebesgue Measure and Integration, Wiley Easter Limited, 1986.
5. P. K. Halmos, Measure Theory, Van Nostrand, 1950.

M. A. / M. Sc. Mathematics (Part II) (Semester IV)

(Choice Based Credit System)

(Introduced from June 2020 onwards)

Course Code: CCS-403, CCS-404, CCS-405
Title of Paper: **Algebraic Number Theory**
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to

1. deal with algebraic numbers , algebraic integers and its applications,
2. concept of lattices and geometric representation of algebraic numbers.
3. Understand the concept of fractional ideals.
4. relate Finitely generated abelian groups and modules
5. derive Minkowski's theorem.
6. compute class groups and class numbers.

Unit I: Revision of basic module theory, Fundamental concepts and results, Free modules and matrices, Direct sums of modules, Finitely generated modules over a P.I.D., Equivalence of matrices with entries in a P.I.D., Structure theorem for finitely generated modules over a P.I.D. and applications to abelian groups.
15 Lectures

Unit II: Algebraic Numbers, Quadratic and cyclotomic fields, Factorization into irreducibles , Euclidean quadratic fields. **15 Lectures**

Unit III: Prime factorization of ideals, Lattices, Minkowski's theorem. **15 Lectures**

Unit IV: Geometric Representation of algebraic numbers, class groups and class numbers, computational methods. **15 Lectures**

Unit V: Examples, Seminars and group discussion on the above four units. **15 Lectures**

Recommended Books:
1. N. Jacobson, Basic Algebra - I, Hindustan Publishing Corporation (India), Delhi (Unit-I)
2. I.N. Stewart and D.O. Tall, Algebraic Number Theory and Fermat’s Last Theorem,2015,CRC press. (Chapters 2 to 10) (Unit-II to Unit-IV)

Reference Books:
1. Algebraic Number Theory : Mathematical Pamphlet, TIFR, Bombay .
2. Paulo Ribenboim, Classical Theory of Algebraic Numbers, Springer , New York(2001).
3. N. S. Gopalkrishnan, University Algebra, New Age International(P) Ltd. Publishers.
4. Ian Stewart, Galoi Theory, CRC press(2015).
5. Harry Pollard, The Theory of Algebraic Numbers, The Mathematical Association of America.

M. A. / M. Sc. Mathematics (Part II) (Semester IV)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-403, CCS-404, CCS-405
Title of Paper: Operations Research – II
Total Credits: 05

Course Outcome-: Upon successful completion of this course, the student will be able to:-

1.decide policy for replacement.
2.calculate economic lot size.
3.derivePoission distribution theorem and compute attributes of distribution model.
4.construct Shannon Fano codes.
5.identify optimal path by using CPM and PERT.

Unit I **15 Lectures**

Replacement problems: failure mechanism of items, replacement policy for items whose maintenance cost increases with time and money value is constant, Money value, Present worth Factor, Discount rate, replacement policy for items whose maintenance cost increases with time and money value changes with constant rate, group replacement of items that fail completely.

Unit II **15 Lectures**

Inventory : cost involved in inventory problems, variables in inventory problem, symbols in inventory, concept of EOQ , Model I (a) The economic lot size system with uniform demand, Model I (b) The economic lot size with different rates of demand in different cycles, Model I (c) The economic lot size with finite rate of replenishment ,(EOQ production model) EOQ model with shortages, Model II (a) The EOQ with constant rate of demand , scheduling , time constant, Model II (c) The production lot size model with shortages , probabilistic inventory models, instantaneous demand , no set up cost model, Model VI (a) Discrete case , Model VI (b) continuous case.

Unit III **15 Lectures**

Queuing theory, queuing systems, queuing problems, transient and steady states. traffic intensity, probability distributions in queuing system, Poisson process, properties , exponential process , classification of queuing models , Model I : (M/M/I) : (infinity / FCFS) Model II (a) : General Erlang Queuing model .

Unit IV **15 Lectures**

Information theory : Communication process, quantitative measure of information , a binary unit of information , measure of uncertainty: entropy , basic properties of entropy function (H), joint and conditional entropies , uniqueness theorem, channel capacity ,efficiency and redundancy , encoding , Shannon Fano encoding procedure ,PERT / CPM: Applications of PERT / CPM techniques , network diagram, representations, rules for constructing the network diagram, determination of the critical path.

Unit V: **15 Lectures**

Examples, seminars, group discussions on above four units.

Recommended Books :

1.S.D. Sharma : Operations Research , KedarNath Ram Nath and Co.
2.J K Sharma: Operations Research :Theory and Applications, Mac Millan Co.

Reference Books :

1. KantiSwarup ,P.K.Gupta and Manmohan : Operations Research , S. Chand & Co.
2. Hamady Taha : Operations Research : Mac Millan Co.
3. S.D. Sharma: Linear Programming ,KedarNath Ram Nath and Co.
4. S.D. Sharma : Nonlinear and Dynamic programming KedarNath Ram Nath and Co.Meerut.
5. R.K.Gupta : Operations Research, Krishna PrakashanMandir , Meerut.
6. G.Hadley : Linear Programming , Oxford and IBH Publishing Co.

M. A. / M. Sc. Mathematics (Part II) (Semester IV)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-403, CCS-404, CCS-405
Title of Paper: Fuzzy Mathematics-II
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:
1. acquire the concept of fuzzy relations.
2. understand the basic concepts of fuzzy logic and fuzzy algebra.
3. develop the skills of solving fuzzy relation equations.
4. construct approximate solutions of fuzzy relation equations.
5.solve problems in Engineering and medicine.

Unit I **15 Lectures**
Projections and cylindrical extensions, binary fuzzy relations on single set, fuzzy equivalence relations, fuzzy compatibility relations, fuzzy ordering relations, fuzzy morphisms sup-i composition and inf-w_i composition.

Unit II **15 Lectures**
Fuzzy relation equations, problem partitioning, solution methods, fuzzy relational equations based on sup-i and inf-wi compositions, approximate solutions.

Unit III **15 Lectures**
Fuzzy propositions, fuzzy quantifiers, linguistic hedges, inference from conditional fuzzy propositions, qualified and quantified propositions

Unit IV **15 Lectures**
Fuzzy algebra, fuzzy groups and fuzzy rings and their basic properties

Unit V **15 Lectures**
Examples, seminars, group discussions on the above four units.

Recommended Books:
1. George J Klir, Bo Yuan, Fuzzy Sets and Fuzzy Logic. Theory and applications,PHI.Ltd. (2000)
2. John Mordeson, Fuzzy Mathematics,Springer,2001

Reference Books:
1.M.Grabish, Sugeno, and Murofushi, Fuzzy Measures and Integrals: Theory and Applications PHI, 1999.
2. H.J.Zimmerermann, Fuzzy set :Theory and its Applications, Kluwer, 1984.
3.M. Ganesh, Introduction to Fuzzy sets & Fuzzy Logic; PHI Learning Private Limited, New Delhi. 2011.

M. A. / M. Sc. Mathematics (Part II) (Semester IV)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-403, CCS-404, CCS-405
Title of Paper: Computational Fluid Dynamics

Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. classify partial differential equations (PDEs) mathematically and physically.
2. apply separation of variables method for solving initial boundary value problems.
3. construct forward, backward and centered difference formulae.
4. test stability, convergence & consistency of finite difference schemes.
5. solve problems in CFD using computer software.

Unit I **15 Lectures**

Comparison of experimental, theoretical and numerical approaches, governing equations, continuity equation, momentum equation (inviscid, viscous flows) energy equation, incompressible viscous flow, laminar boundary layer flow. Introduction of Scilab to solve problems in CFD.

Unit II **15 Lectures**

Nature of a well posed problems, physical classification and mathematical classification of partial differential equations: hyperbolic, parabolic, elliptic partial differential equations (PDEs). Conversion of PDE to canonical form. Traditional solution method: separation of variables, transformation relationships, evaluation of transformation parameters, forward, backward, centered difference formulae, generalized co-ordinates structure of first and second order PDE.

Unit III **15 Lectures**

Stability, convergence and consistency of finite difference scheme, Explicit, Implicit and Crank- Nicolson methods for heat equation, Von Neumann analysis, Euler's explicit method, upstream differencing method, Lax method, Euler implicit method for wave equation. Finite difference representation of Laplace equation, five point method. Problem solving by Scilab: codes of explicit methods for heat and wave equations and five point method for Laplace equation.

Unit IV **15 Lectures**

Finite difference schemes for Burgers equation (inviscid): Lax method, implicit methods. Finite difference schemes for Burgers equation (viscous): FTCS method, Briley – Mc Donald method. convergence and stability, grid generation, orthogonal gird generation, order of magnitude analysis, Reduced Navier-Stokes equations, boundary layer flow, flow in a straight rectangular duct, flow in a curved rectangular duct. Introduction to Finite Element Methods (FEM).

Unit V **15 Lectures**

Examples, Seminars and group discussion on the above four units.

Recommended Books:

1. Dale A Anderson, John Tannelhill, R. H. Fletcher, Computational Fluid Mechanics and Heat Transfer, Hemisphere publishing corporation, 1984.
2. G D Smith, Numerical Solution of Partial Differential Equations: Finite Difference Methods, Oxford Applied Mathematics and Computing Science Series, Oxford University Press, 1985.
3. C. A.J. Fletcher, Computational Techniques for Fluid Dynamics Vol. I & II, Springer Verlag Berlin Heidelberg, 1988.

Reference Books:

1. T J Chung, Computational Fluid Dynamics, Cambridge University Press, 2002.

M. A. / M. Sc. Mathematics (Part II) (Semester IV)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-403, CCS-404, CCS-405
Title of Paper:Fractional Differential Equations
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. analyze existence and uniqueness of solution of fractional differential equations.
2. apply Mittag-Leffler functions to derive the solution of fractional differential equations.
3. analyse data dependency of solution of fractional differential equations.
4. examine the properties of solution of fractional differential equations with initial boundary conditions.
5. derive stability results for fractional differential equations.

Unit I **15 Lectures**
Existence and uniqueness theorems (Miller-Ross sequential fractional derivative approach): Linear fractional differential equations (FDE), fractional differential equation of a general form, existence and uniqueness theorem as a method of solution. Dependence of a solution on initial conditions, basics of Riemann-Liouville and Caputo fractional derivatives.

Unit II **15 Lectures**
Brief review of Mittag-Leffler functions, existence and uniqueness results for Riemann-Liouville fractional differential equations, single-term Caputo fractional differential equations-basic theory and fundamental results, existence of solutions, uniqueness of solutions.

Unit III **15 Lectures**
Influence of perturbed data, smoothness of the solutions, boundary value problems, single-term Caputo fractional differential equations- advanced results for special cases, initial value problems for linear equations.

Unit IV **15 Lectures**
Boundary value problems for linear equations, stability of fractional differential equations, singular equations, Multi-Term Caputo fractional differential equations.

Unit V **15 Lectures**
Examples, seminars, group discussions on the above four units.

Recommended Books:

1. Kai Diethelm, The Analysis of Fractional Differential Equations, Springer, 2010.
2. Igor Podlubny, Fractional differential equations. San Diego: Academic Press; 1999.

Reference Books:

1. A. Kilbas, H.M. Srivastava, J.J. Trujillo, Theory and Applications of Fractional Differential Equations, Elsevier, Amsterdam, 2006.
2. L. Debnath, D. Bhatta, Integral Transforms and Their Applications, CRC Press, 2010.
3. K. S. Miller, B. Ross An introduction to the fractional calculus and differential equations, Wiley, New York, 1993.
4. S. G. Samko, A. A. Kilbas, O. I. Marichev, Fractional Integrals and Derivatives, Theory and Applications, Gordon and Breach, New York, 1993.

M.Sc. Mathematics (Part II) (Semester IV)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-403, CCS-404, CCS-405

Title of Course: General Relativity – II

Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:
1. able to solve Einstein field equations under spherical symmetry.
2.understand calculating relativistic frequency shifts for the bending of light passing a spherical mass distribution.
3.understand energy moment tensor, stress energy moment tensor for perfect fluid.
4. understand exterior product, derivative and P-forms.
5. calculate Bianchi identities in tetrad form.

Unit I **15 Lectures**

The action Principle, Einstein's field equations from action principle and its Newtonian approximation, Poisson's equation as an approximation of Einstein's field equation, flat space-time and empty space-time, local conservation laws associated with perfect fluid distribution, the energy momentum tensor, the stress-energy momentum tensor for perfect fluid, electromagnetic field, Schwarzschild space-time, spherical symmetry, Einstein field equations under spherical symmetry, Schwarzschild exterior solution.

Unit II **15 Lectures**

Planetary orbits and kepler'slaws, relativistic analogues of Kepler's law. Three crucial tests for general theory of relativity: 1. Perihelion of the planet Mercury ,2.Bending of light ,3. Gravitational red shift, Isotropic co-ordinates, Related time, .Isotropic form of Schwarzschild exterior solution.

Unit III **15 Lectures**

The exterior calculus: The tangent space, transformation properties of vector components. The co-tangent space .Basic in co-tangent space. Transformation laws of dual basis .Basis vector and 1-form tensor product and components of tensor. The law of transformation of tensors, exterior product (wedge product),exterior Derivative, P-forms, Hodge's star operator , Maxwell's field equation in exterior form.

Unit IV **15 Lectures**

Frame components of Riemannian curvature tensor, covarient differentiation,Ricci's rotation coefficients , Cartan's first equation of structure ,Catran's second equation of structure, curvature 2-forms, Bianchi identities in tetrad form, calculation of tetrad components of Riemannian tensor and Ricci tensor of spherically and axially symmetric metrics .

Unit V **15 Lectures**

Examples ,Seminars ,Group discussions on the above four units.

Recommended Book:

1. L.N. Katkar : Mathematical Theory of General Relativity. Narosa publishing house, New Delhi, (2014)

Reference Books :

1.J.V. Narlikar : Lectures on General relativity and cosmology, The Mac Millan com.(1978).
2. R. Adler, M. Bazinand M. Schiffer : Introduction of General Relativity , McGraw-Hill Book com.(1975).
3. W. Israel: Defferential forms in General Relativity . Dublin University press(1970)
4. Flander: Defferential forms in General Relativity (1963)
5. F.De Felice and C .J.S. Clarke : Relativity on curved Manifold. Cambridge University Press ,(1990)

M.A./M. Sc. Mathematics (Part II) Semester-IV

(Introduced from June 2020 onwards under CBCS)

Course Code: CCS-403, CCS-404, CCS-405
Title of Course: Lattice Theory -II

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. analyze Congrunces and Ideals
2. check Modularity and semimodularity in given lattice
3. apply geometric closure operator
4. use Kurosh – Ore replacement property

Unit I: Congruences and Ideals: Week projective and congruences, Distributive, Standard and Neutral Ideals, Structure Theorems. (15 lectures)

Unit II: Modular and Semimodular Lattices: Modular lattices, Semimodular Lattices, Geometric lattices, Partition of Lattices, Complemented modular Lattices. (15 lectures)

Unit III: Direct decompositions, Kurosh – Ore theorem, Ore's theorem, sub group lattices Semimodular, Lattices with Finite Length: Rank and covering Inequalities, (15 lectures)

Unit IV: Geometric closure operators, Semimodular Lattices and selectors, consistent semimodular lattices, Pseudomodular lattices Local Distributivity and Modularity: The characterization of Dilworth and Crawley. (15 lectures)

Unit V: Tutorials and Seminar by students (15 lectures)

Recommended Books :

1) Lattice theory: George Gratzer, W. H. Freeman and company, San Francisco, 1971.

2)Semimodular Lattices Theory and Applications by Manfred Stern, Cambridge University Press, 1999

Reference Books :

1) Lattice theory by G. Birkhoff, Amer. Math. Soc. Coll. Publications, Third Edition 1973.

M. A. / M. Sc. Mathematics (Part II) (Semester IV)

(Choice Based Credit System)

(Introduced from June 2020 onwards)

Course Code: CCS-403, CCS-404, CCS-405
Title of Paper: Wavelet Analysis
Total Credits: 05

Course outcomes: Upon successful completion of this course, the student will be able to:
1. calculate Fourier transforms and wavelet transforms of functions.
2. carry out synthesis and analysis of time signal.
3. construct mother wavelets.
4. construct inverse of Gram operator in infinite dimensional space.
5. use orthogonal wavelets.

Unit I **15 Lectures**

Fourier analysis: Fourier series, Riemann Lebesgue lemma, Parseval's formula, variation of function, functions of bounded variation, Fourier transform on R, translational and scaling properties of Fourier transforms, convolution, convolution theorem, Parseval Plancherel formula, inverse Fourier transform, Fourier transforms of derivatives, derivatives of Fourier transforms, examples on Fourier transforms, the Heisenberg uncertainty principle, The Shannon sampling theorem.

Unit II **15 Lectures**

The continuous wavelet transform: Wavelet transform, definitions and examples, A Plancherel formula on H, A Plancherel formula on H', bilinearity of Plancherel formula, analysis and synthesis of time signals, inversion formulas, Regularization lemma, reconstruction formula for time signal, the kernel function, inverse wavelet transform, reproducing kernel, decay of the wavelet transform ,asymptotic properties of wavelet transform ,Hoelder continuity, moment of wavelet , r-click, decay estimates.

Unit III **15 Lectures**

Frames: Geometrical considerations, the general notion of a frame, adjointoperator , Gram operator, frame constants, tight frame ,examples of frames, orthogonal projections, dual frame, general notion of a frame, Riesz basis, inverse of Gram operator defined on infinite dimensional space, mother wavelet, general notion of tight frame.

Unit IV **15 Lectures**

Multiresolution analysis: Axiomatic description, pair wise orthogonal spaces, orthogonal components, orthonormal wavelet basis, orthonormal wavelets with compact support, basic idea, generating function, cutoff factor, binary interpolation , Daubechies wavelets.

Unit V **15 Lectures**

Examples, Seminars and group discussion on the above four units.

Recommended Book:

1. Christian Blatter ,Wavelets a primer ,Universities press 1998.

Reference Books:

1. Mark A. Pinsky : Introduction To Fourier Analysis and Wavelets.
2. Gerald Kaiser : A Friendly Guide to Wavelets , Springer 1994.

M. A. / M. Sc. Mathematics (Part II) (Semester IV)

(Choice Based Credit System)

(Introduced from June 2020 onwards)

Course Code: CCS-403, CCS-404, CCS-405
Title of Paper: Dynamical Systems- II
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. test for the existence and uniqueness of solution of nonlinear system.
2. relate the stability of the system with its linearization.
3. distinguish between stable and unstable sets corresponding to the given system.
4. construct the local stable manifolds for the nonlinear system.
5. identify the chaotic behavior in the system by using Lyapunov exponents.

Unit I: Existence and Uniqueness **15 Lectures**
Set and topological preliminaries, function space preliminaries, existence and uniqueness theorem, dependence on initial conditions and parameters, the maximal interval of existence.

Unit II: Dynamical Systems **15 Lectures**
Definitions, flows, global existence of solutions, linearization, stability and Lyapunov functions, topological conjugacy and equivalence, Hartman-Grobman theorem, Omega-limit sets.

Unit III: Invariant Manifolds **15 Lectures**
Stable and unstable sets, Heteroclinic orbits, stable manifolds, local stable manifold theorem, Poincare-Bendixson theorem.

Unit IV: Chaotic Dynamics **15 Lectures**
Chaos, Lyapunov Exponents, properties of Lyapunov exponents, computing exponents, use of computer softwares to solve problems in dynamical systems.

Unit V: **15 Lectures**
Examples, seminars, group discussion on the above four units.

Recommended Books:

1. Meiss, James D. Differential Dynamical Systems. Vol. 14.Siam, 2007.

Reference Books:

1. M. Hirsch, S. Smale and R. L. Devaney, Differential Equations, Dynamical Systems, and an Introduction to Chaos,ElsevierAcademic Press, USA, 2004.
2. Strogatz, Nonlinear Dynamics and Chaos, Perseus Books, New York.
3. Wiggins, Introduction to Applied nonlinear Dynamics and Chaos, Springer, New York.
4. Arrowsmith and Place, Dynamical Systems: Differential Equations, Maps and Chaotic Behavior, Chapman and Hall, London.
5. Perko,Differential Equations and Dynamical Systems, Springer, New York.
6. Alligood, Sauer and YorkeChaos ,An Introduction to Dynamical Systems, Springer, New York.

M. A. / M. Sc. Mathematics (Part II) (Semester IV)

(Choice Based Credit System)

(Introduced from June 2020 onwards)

Course Code: CCS-403, CCS-404, CCS-405
Title of Paper: Graph Theory-II

Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:
1. understand properties of graphs in terms of matrices.
2. use of matching of bipartite graph to solve various problems
3.compute Laplacian eigen values.
3. find energy of graph using its matrix .
4. classification of trees using properties of matrix.

Unit I **15 Lectures**
Preliminaries, incidence matrix: rank, minors, path matrix, integer generalized inverse, Moore-Perose inverse, 0-1 incidence matrix, matchings in bipartite graphs.

Unit II **15 Lectures**
Adjacency matrix, eigenvalues of some graphs, determinant, bounds, energy of graph, antiadjacency matrix of directed graph, nonsingular trees.

Unit III **15 Lectures**
Laplacian Matrix: Basic properties, computing Laplacian eigenvalues, matrix tree theorem, bounds for Laplacian special radius, Edge-Laplacian of a tree, cycles and cuts, fundamental cycles and fundamental cut, fundamental matrices, minors.

Unit IV **15 Lectures**
Regular Graphs: Perron –Frobinius theory, adjacency algebra of regular graphs, strongly regular graph and Friendship theorem, graphs with maximum energy, algebraic connectivity, classification of trees, distance matrix of tree, eigen values of distance matrix of tree

Unit V **15 Lectures**
Examples, Seminars and group discussion on the above four units.

Recommended Book:

1. R. B. Bapat : Graphs and Matrices, Hindustan Book Agency.

References Books:

1. Douglas B.West : Introduction to Graph Theory Pearson Education Asia.
2. F. Harary - Graph Theory, Narosa Publishing House (1989)
3. K. R. Parthsarthy : Basic Graph Theory, Tata McGraw Hill publishing Co.Ltd.New Delhi

M. A. / M. Sc. Mathematics (Part II) (Semester IV)

(Choice Based Credit System)

(Introduced from June 2020 onwards)

Course Code: CCS-403, CCS-404, CCS-405
Title of Paper: Analysis on Manifolds
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. develop the concept of integration of functions in higher dimensions.
2. give a geometric interpretation of the determinant function.
3. build the concept of manifold using curves and surfaces.
4. determine the volume of a parameterized manifold.
5. evaluate the integration of differential forms on manifolds.

Unit I **15 Lectures**
Change of variables theorem: Diffeomorphsims in R^n, proof of the change of variables theorem, application.

Unit II **15 Lectures**
Manifolds: the Volume of a parallelpiped, volume of a parametrized manifold, manifold in R^n , the boundary of a manifold, integration on a manifold.

Unit III **15 Lectures**
Differential forms: Multilinear algebra, alternating tensors, wedge product, tangent vectors and differential forms, the differential operator, action of differential map

Unit IV **15 Lectures**
Stokes theorem: Integrating forms over parametrized manifolds, orientable manifolds, integrals over orientable manifolds, Stokes theorem.

Unit V **15 Lectures**
Examples, seminars, group discussion on above four units.

Recommended Book:

1. J.R. Munkers, Analysis on Manifolds (AddisionWesely) Section 18-37.

Reference Book:

1. Michael Spivak ,Calculus on Manifolds: A Modern Approach To Classical Theorems of Advanced Calculus.

M. A. / M. Sc. Mathematics (Part II) (Semester IV)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-403, CCS-404, CCS-405
Title of Paper: Theory of Distributions
Total Credits: 05

Course outcomes: Upon successful completion of this course, the student will be able to:
1.construct test functions, approximate identity, distributions.
2.differentiate a generalized function.
3.limit of sequence of generalized functions.
4.analyze properties of support of generalized functions.
5.define directional derivatives of generalized functions.

Unit I **15 Lectures**

Locally convex spaces, topological vector spaces, seminorms, locally convex spaces, examples of locally convex spaces, generalized functions, test functions, distributions

Unit II **15 Lectures**

Test functions and distributions: space of test functions, Frechet space, balanced sets, distribution in Ω , linear mapping of distributions, functions and measures as distributions, differentiation of distributions, distribution derivatives of functions, examples

Unit III **15 Lectures**

Multiplication by smooth functions ,sequences of distributions, convergence of distributions, local properties of distributions, local equality, locally finite partition of unity distributions of finite order, distributions defined by powers of x.

Unit IV **15 Lectures**

Support of distribution, distribution with compact support, distributions as derivatives, convolutions, translation, reflexion, approximate identity, differential of convolutions, properties of convolutions, regularization of distributions.

Unit V **15 Lectures**

Examples, seminars, group discussions on the above four units.

Recommended Book:

1. M.A. AlGawaiz, Marcel Dekkar, Theory of Distributions, Inc New York 1992.

Reference Books:

1. Walter Rudin, Functional Analysis, Tata McGraw Hill publishing company 1986.
2. A.H. Zemanian, Distribution Theory and Transform Analysis, Dover publication 1987.

M. A. / M. Sc. Mathematics (Part II) (Semester IV)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-403, CCS-404, CCS-405

Title of Paper: Commutative Algebra – II

Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. understand Artirian and Noetherion modules.
2. study The Krull-Schmidt theorem.
3. know projective modules for further development in modules.
4. apply integral extensions for going up and going down theorem.
5. derive prime decomposition theorem.

Unit I **15 Lectures**

Operations on submodules, isomorphism theorem for modules, Artirian and Noetherion modules. Composition series for modules,

Unit II **15 Lectures**

The Krull-Schmidt theorem, Fittings lemma, completely reducible modules, Schur's lemma.free modules, injective modules.

Unit III **15 Lectures**

Projective modules, direct sum and tensor product of modules. Exact sequence and short exact sequence of modules,

Unit IV **15 Lectures**

Uniqueness Theorem for primary decomposition of modules.

Integral extensions: Integral extensions, integral elements, integrally closed sets, finiteness of integral closure, going up theorem, goning down theorem.

Unit V **15 Lectures**

Examples, seminars, group discussions on the above four units.

Recommended Book :

1. N. Jacobson: Basic Algebra – II, Hindustan publishing corporation (India).

Reference Books :

1. M. D. Larsen and P. J. McCarthy: Multiplicative Theory of Tdeals, Academic press, 1971.
2. D. G. Northcot, Ideal Theory, Cambridge University, press, 1953.

M.A./M. Sc. (Mathematics) (Part II) (Semester IV)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-403, CCS-404, CCS-405
Title of Course: Space dynamics II
Total Credits: 05

Course Outcomes : Upon successful completion of this course, the student will be able to:
1 construct Euler's momentum equations.
2. analyze stability of rotation about principle axes.
3. perform Spin stabilization of missiles and projectiles.
4. represent General Motion of a Symmetric Gyro and Rolling of a thin circular disk
5. calculate Inertial components of angle of attack and Attitude Drift of Space Vehicles.

Unit I **15 Lectures**

Gyro dynamics: Displacement of a rigid body, moment of momentum of a rigid body (about a fixed point or the moving center of mass), components of momentum, kinetic energy of a rigid body, moment of inertia about a rotated axis, principal axes, Euler's moment equation, Euler's equation for principal axes, body with $A = B$ and zero external moment (body coordinates), body of revolution with zero moment in terms of Euler's angles, retrograde precession C > A, direct precession C < A, steady precession, unsymmetrical body with zero external moment (Poinsot's geometric solution), poinsot ellipsoid, polhode curves, unequal moments of inertia with zero moment (analytic solution), stability of rotation about principal axes.

Unit II **15 Lectures**

General Motion of a Symmetric Gyro or Top: General Motion of a Symmetric Gyro or Top, Symmetric gyro-angular momentum about gimbals axes, Cubic equation representing motion of symmetric gyro, Initial conditions, Steady Precession of a Symmetric Gyro or Top, Limiting cases, Spin stabilization of missiles and projectiles, Precession and Nutation of the Earth's Polar Axis.

Unit III **15 Lectures**

General Motion of a Rigid Body: Rolling of a thin circular disk on a rough horizontal plane, rolling of a disk with plane of the disk nearly vertical, upright spinning of the disk, disk spinning nearly horizontally,

Unit IV **15 Lectures**

Space Vehicle Motion: General Equations in Body Coordinates, Thrust Misalignment, Rotations Referred to Inertial Coordinates, Velocity components in transverse plane tilted by angle θ., Inertial components of angle of attack θ. Near Symmetric Body of Revolution with Zero Moment, Despinning of Satellites, Attitude Drift of Space Vehicles, Dissipation of energy.

Unit V: **15 Lectures**

Examples, seminars, group discussions on the above four units.

Recommended Books :

1. Kluever , Space Flight Dynamics, January 2018, Wiley

References Books :

1. Gerhard Beutler, Methods of Celestial Mechanics, Vol.2 Springer NY 2005
2.George W Collin II, Foundations of Celestial Mechanics, Pachart Foundation, 2004
3.VictorBrumberg, Analytical Techniques of Celestial Mechanics, Springer 1995

M.A./M. Sc. Mathematics (Part II) Semester-IV
(Introduced from June 2020 onwards under CBCS)

Course Code: CCS-403, CCS-404, CCS-405
Title of Course: Automata Theory
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:
1. understand semigroup relation.
2. explain Mealy machine.
3. derive orthogonal partitions.
4. describe admissible subset system decomposition.

Unit I **15 Lectures**
Semigroup Relation, semigroup, group, permutation group, products and homomorphisms.

Unit II **15 Lectures**
Machine and semigroup : State machines, their semigroups, homomorphisms, quotients, Coverings, Mealy machine.

Unit III **15 Lectures** Decompositions : Orthogonal Partitions, admissible partitions, permutation reset machines, group machines
(15)

Unit IV **15 Lectures** Connected transformation semigroups, automorphism decompositions, Admissible subset system decomposition.

Unit V: Tutorials and Seminar by students **15 Lectures**

Recommended Book :
1. Holcombe M.L. : Algebraic automata theory, Cambridge University Press.

Reference Books :
1. Arbib M.A. : Theory of abstract automata, Prentice Hall 2. Eilenberg, S. : Automata, Languages and machine 3. Ginburg A. : Algebraic theory of automata, Academic press.

M. A. / M. Sc. Mathematics (Part II) (Semester IV)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-403, CCS-404, CCS-405

Title of Course: Dynamic Equations on Time Scales

Total Credits: 05

Learning outcome: Upon successful completion of this course, students will be able to:
1. demonstrate the concepts of time scales calculus and dynamic equations on time scales.
2. develop sophisticated skill in understanding unification of continuous and discrete theory.
3. analyze the qualitative and quantitative aspects of solutions of dynamic equations.
4. develop various techniques and apply them to solve certain dynamic equations.
5. develop and demonstrate the techniques to solve self-adjoint equations.
6. unify and extend the traditional study of differential equations and difference equations

UNIT– I
The Time Scales Calculus : Basic Definitions, Differentiation, Examples and Applications, Integration, Chain Rules, Polynomials, Further Basic Results. **15 Lectures**

UNIT –II
First Order Linear Equations: Hilger's Complex Plane, The Exponential Function, Examples of Exponential Functions, Initial Value Problems, Second Order Linear Equations: Wronskians, Hyperbolic and Trigonometric Functions, Reduction of Order. **15 Lectures**

UNIT –III
Method of Factoring, Nonconstant Coefficients, Hyperbolic and Trigonometric Functions , Euler-Cauchy Equations, Variation of Parameters, Annihilator Method, Laplace Transform. **15 Lectures**

UNIT – IV
Self-Adjoint Equations: Preliminaries and Examples, The Riccati Equation, Disconjugacy, Boundary Value Problems and Green's Function, Eigenvalue Problems. **15 Lectures**

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Book(s):
1. Martin Bohner, Allan Peterson, *Dynamic equations on time scales : An introduction with applications*, Birkhauser, Boston, 2001.
Reference Book(s):
1. Martin Bohner, Allan C. Peterson, *Advances in dynamic equations on time scales*, Birkhauser, Boston, 2003

M. A. / M. Sc. Mathematics (Part II) (Semester III)
(Choice Based Credit System)
(Introduced from June 2020 onwards)

Course Code: CCS-403, CCS-404, CCS-405

Title of Course: Automata, Languages and Computation
Total Credits: 05

Course Outcomes: Upon successful completion of this course, the student will be able to:
1. Model, compare and analyse different computational models using combinatorial methods.
2. Apply rigorously formal mathematical methods to prove properties of languages, grammars and automata.
3. Construct algorithms for different problems and argue formally about correctness on different restricted machine models of computation
4. Identify limitations of some computational models and possible methods of proving them.

Unit I: **Automata and Languages:** Finite automata, regular languages, regular expressions, equivalence of deterministic and non- deterministic finite automata, minimization of finite automata , closure properties, Kleene's theorem, pumping lemma and its application.

15 Lectures

Unit II: **Automata and Languages:** Myhill-Nerode theorem and its uses; Context-free grammars, context-free languages, Chomsky normal form, closure properties, pumping lemma for CFL, push down automata

15 Lectures

Unit III: **Computability:** Computable functions, primitive and recursive functions, universality, halting problem, recursive and recursively enumerable sets, parameter theorem, diagonalisation, reducibility.

15 Lectures

Unit IV: **Computability:** Rice's Theorem and its applications. Turing machines and variants; Equivalence of different models of computation and Church-Turing thesis.

15 Lectures

Unit V: Examples, seminars, group discussions on above four units. **15 Lectures**

Recommended Book:

M. Sipser: Introduction to The Theory of Computation, PWS Pub. Co., New York, 1999.

Reference Books

1. N. J. Cutland: Computability: An Introduction to Recursive Function Theory, Cambridge University Press, London, 1980.
2. M. D. Davis, R. Sigal and E. J. Weyuker: Complexity, Computability and Languages, Academic Press, New York, 1994.
3. J. E. Hopcroft and J. D. Ullman: Introduction to Automata Theory, Languages and Computation, Addison-Wesley, California, 1979.

7. Nature of the Theory Question Papers

1. There shall be 7 questions each carrying 18 marks
2. Question No.1 is compulsory. It consists of objective type questions.
3. Students have to attempt any four questions from Question No.2 to Question No.7.
4. Question No.2 shall contain short-answer type sub-questions
5. Question No.2 to Question No.7 shall contain descriptive-answer type sub-questions.

Department of Mathematics
M. Sc. (Part II) (Semester IV)
(Choice Based Credit System)
Generic Elective
(Introduced from June 2020 onwards)

Course Code:GE-407
Title of Course: Graph Theory
Total Credits: 02

Learning outcome: Upon successful completion of this course, the student will be able to:
1. classify the graphs and solve the related problems.
2. understand Euler Graph and Hamiltonian Graph to solve problems.
3. use algorithms to solve shortest path problems.
4. solve network problems .
5. solve graph theoretic problems and apply algorithms.

UNIT– I **15 Lectures**

An Introduction to Graphs: Definition, graphs as a models, more definitions, vertex degree, subgraphs, Paths and Cycles, matrix representation of graphs, operations on graphs. Trees and connectivity: Definition and simple properties

UNIT –II **15 Lectures**

Bridges, spanning trees, connector problem, Shortest path problems, cut vertices and Connectivity. Definition and some properties of Euler and Hamiltonian graph. Directed graphs, application of directed graphs.

Recommended Book(s):

1. A First Look at Graph Theory, John Clark and Derek Allan Holton, Allied Publishers LTD.

Reference Book(s):

1. Graph Theory with Applications to Engineering and computer Science, Narsingh Deo, Prentice Hall of India Private limited.
2. Introduction to Graph Theory: D.B. West (2001) Prentice Hall.
3. Graph Theory: F.Harary (1969) Addison-Wesley.

Department of Mathematics
M. Sc. (Part II) (Semester IV)
(Choice Based Credit System)
Generic Elective
(Introduced from June 2020 onwards)

Course Code:GE-407
Title of Course: Operations Research
Total Credits: 02

Learning outcome: Upon successful completion of this course, the student will be able to:
1. impart knowledge in concepts and tools of Operations Research.
2. understand mathematical models like Linear Programming, Transportation, Assignment, Sequencing used in Operations Research.
3. apply these techniques constructively to make effective business decisions.

UNIT– I **15 Lectures**

What is Operations Research (O. R.) ?: Introduction : The development of Operations Research. Definitions of O. R., Modeling in Operation Research : Iconic, Analogue, and Symbolic. Main characteristics (Features) of O. R., Main phases of O. R. study, Scope of Operations Research. Operations Research in India.

Linear Programming: Introduction, Linear programming formulation. General formulation of Linear Programming Problem. Standard form of the Linear Programming Problem. Some Important Definitions: Solution to linear programming problem, Feasible solution, Basic feasible solution, Non-degenerate solution, Degenerate solution, Optimum basic feasible solution, Unbounded solution. Graphical solution of Linear Programming Problem(LPP).

UNIT –II **15 Lectures**

Assignment Problem: Introduction, Mathematical formulation of the Assignment Problem, Method for solving Assignment Problem : Hungarian Assignment Method, Maximization Case in Assignment Problem, Unbalanced Assignment problem, Travelling Salesman Problem.

Transportation Problem: Introduction, Mathematical formulation, Tabular Representation, Definitions : Feasible Solution(FS), Basic Feasible Solution (BFS), Optimal Solution. Methods for Initial Basic Feasible Solutions : North-West Corner Rule, Lowest Cost Entry (Matrix Minima) Method , Vogel's Approximation Method (Unit Cost Penalty Method). Non-degenerate basic feasible solution, Optimality Test : MODI Method.

SEQUENCING: Introduction, Definition, Principal Assumptions, Solution of Sequencing problem, Processing n jobs through Two machines. Processing n jobs through Three machines.

Recommended Book(s):
1. S.D. Sharma : Operations Research -Theory Methods and Applications , Kedar Nath Ramnath and Co. Meerut, Delhi , Reprint 2015.
2. J.K.Sharma : Operations Research -Theory and Applications , Laxmi Publications, 2017.

Reference Book(s):
1. R. K. Gupta : Operations Research Krishna Prakashan Mandir , Meerut.
2. KantiSwarup ,P.K.Gupta and Manmohan : Operations Research , S. Chand & Co.
3. Hamady Taha : Operations Research : Mac Millan Co.
4. S.D. Sharma: Linear programming ,Kedar Nath Ram Nath and Co.
5. G.Hadley : Linear programming , Oxford and IBH Publishing Co.

Department of Mathematics
M. Sc. (Part II) (Semester IV)
(Choice Based Credit System)
Generic Elective
(Introduced from June 2020 onwards)

Course Code:GE-407
Title of Course: Numerical Methods
Total Credits: 02

Learning outcome: Upon successful completion of this course, the student will be able to:
1. Understand the various types of mathematical equations.
2. Apply the bisection and secant methods to find the roots of polynomial and transcendental equations.
3. Solve the simultaneous linear equations using various methods.
4. Analyze the process of data interpolation.
5. Derive various identities involving difference operators.

UNIT– I **10 Lectures**
Numerical Solutions Of Algebraic and Transcendental Equations:
1. Prerequisites: functions, polynomials, roots
2. Bisection Method
3. Secant Method

UNIT –II **10 Lectures**
Numerical Solution of linear simultaneous equations:
1. Introduction: Basic concepts of matrices
2. Gauss elimination method
3. Gauss-Jordan method
4. Jacobi's iteration method

UNIT –III **10 Lectures**
Interpolation:
1. Introduction
2. Newtons forward interpolation Formula
3. Newtons backward interpolation Formula

Recommended Book(s):
1. Numericals Methods by B. S. Grewal (Khanna Publication Delhi.)

Reference Book(s):
1.Higher Engineering Mathematics, by B. S. Grewal (Khanna Publication Delhi.)
2.Higher Engineering Mathematics, by B. V. Ramana (Tata McGraw-Hill)
3. Advanced Engineering Mathematics, by H. K. Das (S. Chand Publication.)
4.Mathematical Methods of Science and Engineering, by Kanti B. Datta (Cengage Learning.)

Department of Mathematics
M. Sc. (Part II) (Semester IV)
(Choice Based Credit System)
Generic Elective
(Introduced from June 2020 onwards)

Course Code:GE-407
Title of Course: Mathematics for Economics and Finance
Total Credits: 02

Learning outcome: Upon successful completion of this course, the student will be able to:

1. apply mathematics to financial aspects of market.
2. gain knowledge of applying Mathematics to calculation of GST. Income tax etc.
3. work out EMI calculations of loans and compare it with the offers made by Banking institutions.
4. Model market transactions and analyze the possible trends
5. Guide the investors in the market.

UNIT– I **15 Lectures**
Mathematical models in economics: Introduction, A model of the market, Market equilibrium, Excise tax. Mathematical terms and notations: Sets, Functions, composite functions, recurrences, limits: Sequences and graphs and equations.

UNIT –II **15 Lectures**
The elements of finance: Interest and capital growth, Income generation, The interval of compounding. The cobweb model: How stable is the market equilibrium?, The general linear case, Economic interpretation.

Recommended Book(s):

1. Martin Anthony and Norman Biggs, Mathematics for Economics and Finance: Methods and Modelling, Cambridge University Press, 2000.

Reference Book(s):

1. D.Bose, An Introduction to Mathematical Economics, Himalaya Publishing House.