Estd. 1962
"A++" Accredited by
NAAC(2021)
With CGPA 3.52

SHIVAJI UNIVERSITY, KOLHAPUR - 416 004, MAHARASHTRA

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शिवाजी विद्यापीठ, कोल्हापूर - ४१६ ००४,महाराष्ट्र

दूरध्वनी - ईपीएबीएक्स - २६०९०००, अभ्यासमंडळे विभाग दुरध्वनी ०२३१—२६०९०९३/९४

SU/BOS/Science/480 **Date: 01/07/2023**

To,

The Principal, All Concerned Affiliated Colleges/Institutions Shivaji University, Kolhapur	The Head/Co-ordinator/Director All Concerned Department (Science) Shivaji University, Kolhapur.

Subject: Regarding syllabi of M.Sc. Part-II (Sem. III & IV) as per NEP-2020 degree programme under the Faculty of Science and Technology.

Sir/Madam,

With reference to the subject mentioned above, I am directed to inform you that the university authorities have accepted and granted approval to the revised syllabi, nature of question paper and equivalence of M.Sc. Part-II (Sem. III & IV) as per NEP-2020 degree programme under the Faculty of Science and Technology.

M.Sc. Part-II (Sem. III & IV) as per NEP-2020			
1.	Mathematics	8.	Botany
2.	Mathematics (Distance Mode)	9.	Electronics
3.	Mathematics (Online Mode)	10.	Zoology
4.	M.Sc. Tech (Industrial Mathematics With Computer Application)	11.	Agro Chemical and Pest Management (AGPM)
5.	Geography	12.	Alcohol Technology
6.	Statistics	13.	Sugar Technology
7.	Applied Statistics and Informatics	14.	Geology

This syllabus, nature of question and equivalence shall be implemented from the academic year 2023-2024 onwards. A soft copy containing the syllabus is attached herewith and it is also available on university website **www.unishivaji.ac.in**)

The question papers on the pre-revised syllabi of above-mentioned course will be set for the examinations to be held in October /November 2023 & March/April 2024. These chances are available for repeater students, if any.

You are, therefore, requested to bring this to the notice of all students and teachers concerned.

Thanking you,

Dy Registrar
Dr. S. M. Kubal

Copy to:

1	The Dean, Faculty of Science & Technology	8	P.G. Admission/Seminar Section
2	Director, Board of Examinations and Evaluation	9	Computer Centre/ Eligibility Section
3	The Chairman, Respective Board of Studies	10	Affiliation Section (U.G.) (P.G.)
4	B.Sc. Exam/ Appointment Section	11	Centre for Distance Education

SHIVAJI UNIVERSITY, KOLHAPUR

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Accredited by NAAC: A++ Grade with CGPA 3.52

Choice Based Credit System with Multiple Entry and Multiple Exit Option
(NEP-2020)

Syllabus For

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

Semester III and IV

(Syllabus to be implemented from the AcademicYear2023-24)

Choice Based Credit System with Multiple Entry and Multiple Exit Option (NEP-2020)
M.A./ M.Sc.(Mathematics) Programme Structure
M.A./ M.Sc. (Mathematics) Part–I(Level-8)

SEMESTER-I(Duration-Six Month)											
	Sr. No.	Course Code	Teaching Scheme			Examination Scheme					
			Theory and Practical			University Assessment(UA)			Internal Assessment(IA)		
			Lectures +Tutorial (Per week)	Hours(Per week)	Credit	Maximum Marks	Minimum Marks	Exam. Hours	Maximum Marks	Minimum Marks	Exam. Hours
CGPA	1	CC-101	4+1	5	4	80	32	3	20	8	1
	2	CC-102	4+1	5	4	80	32	3	20	8	1
	3	CC-103	4+1	5	4	80	32	3	20	8	1
	4	CC-104	4+1	5	4	80	32	3	20	8	1
	5	CC-105	4+1	5	4	80	32	3	20	8	1
	6	OE-106	4+1	5	4	80	32	3	20	8	1
Total(A)			**--**	**--**	**24**	**480**	**--**	**--**	**120**	**--**	**--**
Non-CGPA	1	AEC-107	2	2	2	--	--	--	50	20	2
SEMESTER-II (Duration-Six Month)											
CGPA	1	CC-201	4+1	5	4	80	32	3	20	8	1
	2	CC-202	4+1	5	4	80	32	3	20	8	1
	3	CC-203	4+1	5	4	80	32	3	20	8	1
	4	CC-204	4+1	5	4	80	32	3	20	8	1
	5	CC-205	4+1	5	4	80	32	3	20	8	1
	6	OE-206	4+1	5	4	80	32	3	20	8	1
Total(B)			**--**	**--**	**24**	**480**	**--**	**--**	**120**	**--**	**--**
Non-CGPA	1	SEC-207	2	2	2	--	--	--	50	20	2
Total(A+B)					**48**	**960**	**--**	**--**	**240**	**--**	**--**

<table>
<tr><td>• Student contact hours per week:30Hours</td><td>• Total Marks for M.Sc.-I : 1200</td></tr>
<tr><td>• Theory and Tutorial Lectures:60 Minutes Each</td><td>• Total Credits for M.Sc.-I (Semester I&II):48</td></tr>
<tr><td>• CC-Core Course
• OE-Open Elective Course
• AEC-Mandatory Non-CGPA compulsory Ability Enhancement Course
• SEC-Mandatory Non-CGPA compulsory Skill Enhancement Course</td><td>• Separate passing is mandatory for Theory and Internal Examinations</td></tr>
<tr><td colspan="2">• Requirement for Entry at Level 8:
1) Completed the Bachelor of Science degree with principal / major subject Mathematics.
or
2) Completed the Bachelor of Science degree with Mathematics courses upto Second Year of Bachelor’s degree.
or
3) Completed the Bachelor’s degree (Level 7) with principal / major subject Mathematics.
or
4) Completed the Bachelor’s degree(Level 7)with Mathematics courses upto undergraduate Diploma(Level6)</td></tr>
<tr><td colspan="2">• Exit Option at Level 8:
Students can exit after completion of Level 8 with Post Graduate Diploma in Mathematics.</td></tr>
</table>

Choice Based Credit System with Multiple Entry and Multiple Exit Option (NEP-2020)
M.A./ M.Sc.(Mathematics) Programme Structure
M.A./ M.Sc.(Mathematics) Part–II (Level-9)

SEMESTER-III(Duration-Six Month)											
	Sr. No.	Course Code	Teaching Scheme			Examination Scheme					
			Theory and Practical			University Assessment(UA)			Internal Assessment(IA)		
			Lectures +Tutorial (Per week)	Hours(Per week)	Credit	Maximum Marks	Minimum Marks	Exam. Hours	Maximum Marks	Minimum Marks	Exam. Hours
CGPA	1	CC-301	4+1	5	4	80	32	3	20	8	1
	2	DSE-302	4+1	5	4	80	32	3	20	8	1
	3	CCS-303	4+1	5	4	80	32	3	20	8	1
	4	CCS-304	4+1	5	4	80	32	3	20	8	1
	5	CCS-305	4+1	5	4	80	32	3	20	8	1
	6	CCS-306	4+1	5	4	80	32	3	20	8	1
Total(C)			**--**	**--**	**24**	**480**	**--**	**--**	**120**	**--**	**--**
Non-CGPA	1	AEC-307	2	2	2	--	--	--	50	20	2
	2	EC (SWMMOOC)-308/ OE-308	Number of lectures and credit shall be as specified on SWAYAM-MOOC or as specified on OE								
SEMESTER-IV(Duration-Six Month)											
CGPA	1	CC-401	4+1	5	4	80	32	3	20	8	1
	2	DSE-402	4+1	5	4	80	32	3	20	8	1
	3	CCS-403	4+1	5	4	80	32	3	20	8	1
	4	CCS-404	4+1	5	4	80	32	3	20	8	1
	5	CCS-405	4+1	5	4	80	32	3	20	8	1
	6	CCS-406	4+1	5	4	80	32	3	20	8	1
Total(D)			**--**	**--**	**24**	**480**	**--**	**--**	**120**	**--**	**--**
Non-CGPA	1	SEC-407	2	2	2	--	--	--	50	20	2
	2	GE-408	2	2	2	--	--	--	50	20	2
Total(C+D)					**48**	**960**	**--**	**--**	**240**	**--**	**--**

• Student contact hours per week:**30** Hours	• Total Marks for M.Sc.-II : **1200**
• Theory and Tutorial Lectures:**60** Minutes Each	• Total Credits for M.Sc.-II (Semester III&IV):**48**
• ***Separate passing is mandatory for Theory and Internal Examination***	
• CC-CoreCourse • CCS-Core Course Specialization • 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-Multidisciplinary Generic Elective
• **Requirement for Entry at Level 9:** **1) Students of Shivaji University Kolhapur who have completed learning of Post Graduate Diploma (Level8)in Mathematics.** **2) Completed all requirements of the relevant Post Graduate Diploma (Level 8) in Mathematics.** **3) Bachelor's Degree (Honours/Research)(Level8)with principal/major subject Mathematics**	
• **ExitatLevel9:** **Students will exit after completion of Level 9 with Master's Degree in Mathematics.**	

	M.Sc.-I	**M.Sc.-II**	**Total**
Marks	**1200**	**1200**	**2400**
Credits	**48**	**48**	**96**

I. CGPA course:

1. There shall be 12CoreCourses(CC)of 48creditsperprogramme.
2. There shall be 08 Core Course Specialization (CCS) of 32creditsper programme.
3. There shall be 02 Discipline Specific Elective(DSE) courses of 08 credits per programme
4. There shall be 02 Open Elective Courses (OE) of 08 credits per programme.
5. Total credits for CGPA courses shall be of 96 credits per programme

II. Mandatory Non-CGPA Courses:

1. There shall be 02 Mandatory Non-CGPA compulsory Ability Enhancement Courses (AEC) of 02 credits per programme.
2. There shall be 02 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. If for a particular program there is no compatible SWAYAM-MOOC then for that program OE shall be offered.
5. There shall be one Multidisciplinary Generic Elective (GE) course of 02 credits per programme. Each student has to take generic elective from the department other than parent department.
6. For Non-CGP A courses the total credits shall be 10+ the credits of EC or OE as per availability.
7. The credits assigned to the course and the programmes are to be earned by the students and shall not have any relevance with the workload of the teacher.

M.A./M. Sc.(Mathematics)(Part-II/Level-9) (Semester III)

Course code	Title of course
CC-301	Functional Analysis
DSE-302	Any one of the following 1. Advanced Discrete Mathematics 2. Topological Vector Spaces
CCS-303, CCS-304, CCS-305, CCS-306	Any four of the following: 1. Non - Linear Optimization Techniques 2. Fuzzy Mathematics –I 3. Fluid Dynamics 4. Fractional Calculus 5. General Relativity–I 6. Lattice Theory–I 7. Approximation Theory 8. Dynamical Systems– I 9. Graph Theory-I 10. Differential Geometry 11. Combinatorics 12. Commutative Algebra-I 13. Space Dynamics-I 14. Theory of Computation 15. Algebraic Topology 16. Probability and Stochastic Processes 17. Coding Theory
AEC-307	Communicative English-II
EC(SWM MOOC)-308	

M. A. / M. Sc. Part-II (Mathematics) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code:CC-301
Title of Course: Functional Analysis
Total Credits: 04

Course Outcomes: Upon successful completion of this course, the student will be able to:
1. understand the fundamental topics, principles and methods of functional analysis.
2. demonstrate the knowledge of normed spaces, Banach spaces, Hilbert space.
3. define continuous linear transformations between linear spaces, bounded linear functionals.
4. apply finite dimensional spectral theorem.
5. identify normal, self adjoint, unitary, normal operators.

Unit I: Normed linear spaces, Banach spaces, quotient spaces, continuous linear transformations, equivalent norms, finite dimensional normed spaces and properties, conjugate space and separability, The Hahn-Banach theorem and its consequences. **15 Lectures**

Unit II: Second conjugate space, the natural embedding of the normed linear space in its second conjugate space, reflexivity of normed spaces, the open mapping theorem, projection on Banach space, the closed graph theorem, the conjugate of an operator, the uniform boundedness principle. **15 Lectures**

Unit III: Hilbert spaces: examples and elementary properties, orthogonal complements, the projection theorem, orthogonal sets, the Bessel's inequality, Fourier expansion and Perseval's equation, separable Hilbert spaces, the conjugate of Hilbert space, Riesz's theorem, the adjoint of an operator. **15 Lectures**

Unit IV: Self adjoint operators, normal and unitary operators, projections, eigen values and eigenvectors of an operator on a Hilbert space, the determinants and spectrum of an operator, the spectral theorem on a finite dimensional Hilbert space. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Book(s):
1. G. F. Simmons, Introduction to Topology and Modern Analysis, Tata McGraw Hill, 1963.

Reference Books:
1. Erwin Kreyszig, Introductory Functional Analysis with Applications, John Wiley and Sons, 1978.
2. A. E. Taylor, Introduction to Functional analysis, John Wiley and sons,1958.
3. J. B. Convey, A course in Functional Analysis, Springer-Verlag, 1985.
4. G. Bachman and L. Narici, Functional Analysis, Academic Press, 1972.
5. B. V. Limaye, Functioned Analysis, New age international, 1996.

M. A. / M. Sc. Part-II (Mathematics) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code :DSE-302
Title of Course: Advanced Discrete Mathematics
Total Credits: 04

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: 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.

15 Lectures

Unit II: Fusion, definition and simple properties of a tree, bridges, spanning trees, cut vertices, Euler tours and Hamiltonian cycles, Fleury's Algorithm, Hamiltonian graphs, plane and planar graphs.

15 Lectures

Unit III: 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.

15 Lectures

Unit IV: 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.

15 Lectures

Seminars, Tutorials, Problem solving session and group discussions on above 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.
4. J. Eldon Whitesitt, Boolean Algebra and Its Applications, Addison-Wesley PublishingCompany, Inc.,1961.

Reference books:

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

M. A. / M. Sc. Part-II (Mathematics) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code :DSE-302
Title of Paper: Topological Vector Spaces
TotalCredits:04

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 **15Lectures**

Unit II: Linear mappings on topological vector spaces, 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

15Lectures

Unit III: 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.

15Lectures

Unit IV: 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(Ω), C(Ω), differential operator, properties of differential operator. **15Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

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, NewYork1992

M. A. / M. Sc. Part-II (Mathematics) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-303, CCS-304, CCS-305, CCS-306
Title of Course: Non - Linear Optimization Techniques
Total Credits: 04

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

1. construct linear integer programming models and discuss the solution techniques.
2. formulate the nonlinear programming models.
3. propose the best strategy using decision making methods.
4. solve multi-level decision problems using dynamic programming method.

Unit I : Non – Linear Optimization Techniques : Introduction. Unconstrained Problems of Maxima and Minima. Constrained Problems of Maxima and Minima. Constraints in the form of Equations :Lagrangian method. Generalized to n – dimensional case. Sufficient condition for maximum (minimum) of objective function with single equality constraint. Sufficient condition for maximum (minimum) of objective function with more than one equality constraints, bondered Hessian matrix, sign definite matrix.

15 Lectures

Unit II : Sufficient condition for maximum and minimum. Constraints in the form of inequalities: Kuhn Tucker necessary and sufficient condition. **Non – Linear Programming Problem :** Practical solutions of of Non – inequalities. Formulation. General Non – Linear Programming Problem. Canonical form of Non – Linear Programming Problem. Graphical Solution.

15 Lectures

Unit III : Quadratic Programming : Introduction. Kuhn Tucker Conditions: Non – Negative Constraints. Wolfe's Modified Simplex Method. Important remarks on Wolfe's Method. Beale's Method. Simplex method for Quadratic Programming. **15 Lectures**

Unit IV : Dynamic programming: Introduction. Decision Tree and Bellman's Principle of Optimality. Solution of problem with a finite number of stages. Single additive constraints, multiplicative separable return, single multiplicative constraints, additively separable return, system involving more than one constraint. Application of dynamic programming in Linear programming.

15 Lectures

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Books :

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

Reference Books :

1. Kanti Swarup, P. K. Gupta and Manmohan : Operations Research , S. Chand & Co.
2. Hamady Taha : Operations Research : Mac Millan Co.
3. S. D. Sharma : Nonlinear and Dynamic Programming, KedarNath Ram Nath and Co. Meerut.
4. R. K. Gupta : Operations Research, Krishna Prakashan Mandir , Meerut.

M. A. / M. Sc. Part-II (Mathematics) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-303, CCS-304, CCS-305, CCS-306
Title of course: Fuzzy Mathematics-I
Total Credits: 04

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,extensionprinciple,propertiesofdirectandinverseimagesoffuzzysets.

20 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.

10 Lectures

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Books:

1. GeorgeJ.Klir,BoYuan,FuzzysetsandFuzzyLogic.TheoryandApplications,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 engineering Applications, Springer-Verlag Berlin Heidelberg 2005.
4. M. Ganesh, Introduction to Fuzzy Sets & Fuzzy Logic; PHIL earning Private Limited, New Delhi 2011.
5. Bojadev and M. Bojadev, Fuzzy Logic and Application,World Scientific Publication Pvt. Ltd. 2007.

M. A. / M. Sc. Part-II (Mathematics) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-303, CCS-304, CCS-305, CCS-306
Title of Course: Fluid Dynamics
Total Credits : 04

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, general orthogonal curvilinear co-ordinate system, stream lines, pathlines, 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, 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, circle theorem, sources and sinks, sources, sinks and doublets in two dimensional flows, methods of images. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Book(s):
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) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-303, CCS-304, CCS-305, CCS-306
Title of Course: Fractional Calculus
Total Credits: 04

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

1. analyse the properties of Grünwald-Letnikov, Riemann-Liouville, and Caputo fractional derivative.
2. evaluate fractional derivatives and fractional integrals
3. analyse the behaviour of fractional derivatives near and far from the lower terminal
4. evaluate Laplace and Fourier transforms of fractional derivatives and integrals.
5. solve fractional differential equations using Laplace and Fourier transforms.

Unit I: Brief review of special functions of the fractional calculus: Gamma function, Mittag-Leffler 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. **15 Lectures**

Unit III: Caputo's fractional derivative, 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. **15 Lectures**

Unit IV: Laplace transform of the Riemann-Liouville fractional derivative, Caputo derivative and Grünwald-Letnikov fractional derivative. Fourier transforms of fractional integrals and derivatives. Methods of solving FDE's: using Laplace transform and Fourier transforms-ordinary fractional differential equations, partial fractional differential equations, power series method: one term equation, equation with non-constant coefficients, two-term nonlinear equation.

15 Lectures

Seminars, Tutorials, Problem solving session and group discussions on above units.

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) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-303, CCS-304, CCS-305, CCS-306
Title of Course: General RelativityI
Total Credits: 04

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, Tensors, Algebra of tensors. 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. **15Lectures**

Unit III: Riemannian metric. Generalized Kronecker delta, alternating symbols and Levi-Civita tensor, Dual tensor. Parallel transport and Liederivative. 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**

Seminars, Tutorials, Problem solving session and group discussions on above units.

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 MacMillan com. (1978).

Reference Book:

1.R. Adler, M. Bazin and 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 Holl and 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 Coursein 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) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-303, CCS-304, CCS-305, CCS-306
Title of Course: Lattice Theory–I
Total Credits: 04

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

1. 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. To solve individually and creatively advanced problems of lattice theory and also problems connected with its applications to mathematics

Unit I : Posets: definition and examples, two definitions of lattices and their equivalence, examples of lattices, representation 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: Distributive lattices–properties and characterizations. Modular lattices–properties and characterizations, congruence relations, Boolean algebras– properties and characterizations. **15 lectures**

Unit III: Pseudo complementation, ideals and filters in lattices, lattice of all ideals I(L), Stone's theorem and its consequences, distributive, standard and neutral elements. **15 lectures**

Unit IV: Pseudo complemented lattices. S(L) and D(L) – special subsets of pseudo-complemented lattices, distributive pseudo complemented lattice, Stone lattices – properties and characterizations. **15lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Books:

1) George Grätzer, General Lattice Theory, Birkhäuser Verlag (SecondEdition).

Reference Books:

1) G. Birkhoff, Lattice Theory, Amer. Math. Soc. Coll. Publications, Third Edition1973.

M. A. / M. Sc. Mathematics (Part II) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic Year 2023-24)

CourseCode:CCS-303,CCS-304,CCS-305, CCS-306
Title of Course: Approximation Theory
Total Credits: 04

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**

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Book(s):
1. Hrushikesh N. Mhaskar and DevidasV.Pai: Fundamentals of Approximation Theory, Narosa Publishing House.

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

M. A. / M. Sc. Mathematics (Part II) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-303, CCS-304, CCS-305, CCS-306
Title of Course: Dynamical Systems- I
Total Credits: 04

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: 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: 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

Seminars, Tutorials, Problem solving session and group discussions onaboveunits.

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) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-303, CCS-304, CCS-305, CCS-306
Title of Course : Graph Theory-I
Total Credits: 04

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. Eulertours: Eulargraphs, properties of Eulergraph, the Chinese postman problem. **15 Lectures**

Unit II: Hamiltonian Cycles: Hamiltonian graphs, the travelling salesman problem, matching's and augmenting paths, the marriage problem. **15Lectures**

Unit III: The personal assignment problem, the optimal assignment problem, a Chinese postman problem postscript, plane and planar graphs, Eulers formula, platonic bodies, Kurotowskis theorem. **15 Lectures**

Unit IV: Vertex coloring, vertex coloring algorithms, critical graphs, cliques, edge coloring, map coloring, directed graphs: definition, indegree and outdegree, tournaments, traffic flow.
15 Lectures

Seminars, Tutorials, Problem solving session and group discussions on above units.

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) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-303, CCS-304, CCS-305, CCS-306
Title of Course: Differential Geometry
Total Credits: 04

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 R3 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 R3, 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 R3, orthogonal transformations. **15 Lectures**

Unit III: Coordinate patches, surface in R3, 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 R3, normal curvature, principal curvatures, Gaussian and mean curvatures, Umbilic points, fundamental forms of a surface, computational techniques. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

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) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-303, CCS-304, CCS-305, CCS-306
Title of Course: Combinatorics
Total Credits: 04

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: The sum rule and product rule, permutations and combinations, the Pigeonhole principle, Ramsay numbers, Catalan numbers, sterling numbers. **15 Lectures**

Unit II: Further basic tools, generalized permutations and combinations sequences and selections, the inclusion and exclusion principle, systems of distinct representatives, solved problems derangements and other constrain derangements. **15 Lectures**

Unit III: Combinatorial number theory, 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. **15 Lectures**

Unit IV: Generating functions and recurrence relations, ordinary and exponential generating functions, partitions of a positive integer, recurrence relations, algebraic solutions of linear recurrence relations with constant coefficients and solutions of recurrence relations using generating functions. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Books:

1. V. K. Balkrishnan: Combiactorics, Shaums Outlines Series, Mc Grow 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) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-303, CCS-304, CCS-305, CCS-306
Title of Course: Commutative Algebra–I
Total Credits:04

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. understand Boolean rings and Regular rings.
4. know Hilbert basis theorem and apply it to other development.
5. derive Wedderburn Theorem.

Unit–I : 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. **15 Lectures**

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. **15 Lectures**

Unit–III: Prime radicals, modular ideals, J-radial of a ring, Boolean rings, regular rings, Stone representation theorem, direct sum of rings, Birkhoff theorem , problems. **15 Lectures**

Unit–IV: Rings with Chain conditions: Equivalence of three conditions of a ring with ACC, Hilbert basis theorem, Levitsky theorem, Wedderburn theorem, any semi-simple Artinion ring R is the direct sum of a finite number of fields, problems. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Book:

1) Barton David M. : A first course in Rings and Ideals, Addison-Wesley Educational Publishers Inc 1970.

Reference Books:

1. Oscar Zoriski and P. Samuel: Commutative Algebra, Vol. I, Springer.

2. M. Atiyah and I. C. McDonald: Introduction to Commutative Algebra, Addison-Wesley Publishing Company (Series in Mathematics) .

3. Hideyuki Matsumura: Commutative Algebra, Revised and modernized edition by TEXromancers.

4. C.Musili: Rings and Modules, Narosa Publishing House.

M.A./M.Sc. Part –II (Mathematics)(Level-9) (Semester III)

(NEP-2020)

(Introduced from Academic year 2023-24)

CourseCode: CCS-303, CCS-304, CCS-305, CCS-306
Title of Course: Space dynamics- I
Total Credits: 04

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**

Seminars, Tutorials, Problem solving session and group discussions onaboveunits.

Recommended Book(s):

1. Craig Kluever , 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. Part –II (Mathematics)(Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic year 2023-24)

CourseCode:CCS-303,CCS-304,CCS-305, CCS-306
Title of Course: Theory of Computation
Total Credits: 04

Course Out comes: 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: 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. **15Lectures**

Unit II: Definition of a context free grammer, more example sincluding some familiar languages, unions, concatenations and *'s of CFLS derivation trees and ambiguity, anun ambiguous CFG for algebraic expressions. **15Lectures**

Unit III: Simplified forms and normal forms, Pushdown automata: introduction by way an example, definition, 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. **15Lectures**

Unit IV: The pumping lemma for context free languages, intersections and complements of context free languages, turing machines: introduction, theturingmachinemodels,computablelanguagesandfunctions,techniquesfor turing machine construction, Modification to turing machines, Churchs hypothesis, turing machines asenumeraturs. **15Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommends Book

1. John C. Martin: Introduction to Languages and the theory of computation, Tata McGraw Hill publishing company limited New Delhi1998.

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. Part –II (Mathematics) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic year 2023-24)

CourseCode:CCS-303,CCS-304,CCS-305, CCS-306
Title of Course: Algebraic Topology
Total Credits: 04

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

1. Develop the concept of homotopy of paths
2. combine the group theory and topology to define fundamental groups of curves and surfaces
3. determine the fundamental groups of various curves
4. build the concept of retraction and use to study homotopy
5. evaluate the fundamental group of compact 2-manifolds by applying Seifert-van Kampen theorem.

Unit I: Homotopy of paths, The fundamental group, covering spaces, the fundamental group of the circle. **15Lectures**

Unit II: Retractions and fixed points, Borsuk-Ulam theorem, deformation retracts and homotopy type. **15Lectures**

Unit III: 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 **15Lectures**

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

Seminars, Tutorials, Problem solving session and group discussions on above units.

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. Part –II (Mathematics) (Level-9) (Semester III)
(NEP-2020)
(Introduced from Academic year 2023-24)

CourseCode:CCS-303, CCS-304, CCS-305, CCS-306
Title of Course: Probability and Stochastic Processes
Total Credits: 04

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

1. Apply the specialized 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, conditional probability and independence; Random variables and their distributions (discrete and continuous). **15 Lectures**

UNIT –II: Bivariate and multivariate distributions; Laws of large numbers, central limit theorem (statement and use only).
15Lectures

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

UNIT – IV: Markov processes, Poisson processes, birth and death processes, branching processes, queuing processes. **15Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Book(s):

1. Dimitri Bertsekas, John N. Tsitsiklis : Introduction To Probability, Athena Scientific;2nd 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/ HoughtonMifflin, 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. Part –II (Mathematics) (Level-9) (Semester III)

(NEP-2020)

(Introduced from Academic year 2023-24)

CourseCode:CCS-303,CCS-304,CCS-305, CCS-306
Title of Paper: Coding Theory
Total Credits: 04
Course Outcomes: Upon successful completion of this course, the student will be able to:

1. design various codes.
2. decodes codes.
3. apply codes for secrete massages.

Unit – I Introduction to Coding Theory : Linear Codes : Block codes, linear codes, Humming codes, Majority logic decoding weight enumerates, the Lee Metric. Some good codes : Hadamard codes and generalizations, The Binary Golary codes, the Ternery Golary codes, constructing codes from other codes, reed Muller codes, Kerdock codes. **15 Lectures**

Unit – II Bounds on codes : The Gilbert bound, Upper bounds, the linear programming bound, Cyclic codes : Definitions Generator matrix and check polynomial, zeros of a cyclic code, The idempotent of a cyclic code, other representations of cyclic codes, BCH-codes Decoding BCH codes, Read soloman codes, Quadratic. **15 Lectures**

Unit – III Residue codes, Binary cyclic codes of length 2n (nodd) Generalised Reed muller codes.Perfect codes and uniformly packed codes Lioyds theorem, The characteristic polynomial of a code uniformly packed codes. **15 Lectures**

Unit – IV Examples of uniformly packed codes, Non existence theorems. Codes over Z4 Quaternary codes Binary codes derive from codes over Z4, Galuis rings over Z4 cyclic codes over, Z4. **15 Lectures**

N.B.: Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Books:

1. J. H. Van Lint : Introduction to coding theory, springer verlag 1998

References Books:-

1. Berle Kamp E.R.: Algebraic coding Theory, New york McGraw Hill,1968

M. A. / M. Sc. Part-II (Mathematics) (Level-9)

(Semester IV)(NEP-2020)

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, CCS-406	Any Four of the following: 1. Quantitative Techniques In Operations Research 2. Fuzzy Mathematics –II 3. Computational Fluid Dynamics 4. Fractional Differential Equations 5. General Relativity–II 6. Lattice Theory–II 7. Wavelet Analysis 8. Dynamical Systems– II 9. Graph Theory-II 10. Analysis on Manifolds 11. Theory of Distributions 12. Commutative Algebra- II 13. Space Dynamics-II 14. Algebraic Automata Theory 15. Dynamic Equations on Time Scales 16. Automata, Languages and Computation 17. Algebraic Number Theory
SEC-407	Fundamentals of Information Technology (FIT)-II
GE-408	

M. A. / M. Sc. Part-II (Mathematics) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code:CC-401
Title of Course: Field Theory
Total Credits: 04

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 nth roots of unity and nth 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 Separable 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 ofalgebra, Roots of unity and cyclotomic polynomials, Cyclic extensions.
15 Lectures

Unit IV: Applications of Galois Theory
Polynomials solvable by radicals, Symmetric functions, Ruler and compass constructions.
15 Lectures

Seminars, Tutorials, Problem solving session and group discussions onaboveunits.

Recommended Book(s):

1. Bhattacharya, Jain and Nagpaul, Basic Abstract Algebra, second edition, Cambridge University Press.

Reference Books:

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

M. A. / M. Sc. Part-II (Mathematics) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code :DSE-402
Title of Course: Integral Equations
Total Credits: 04
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 equation by Successive approximations, using Laplace and Fourier transforms.
4. to analyze the properties of symmetric kernel.
5. to prove Hilbert Schmidt theorem and solve the integral equation by applying it

UNIT– I 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 eigenfunctions. **15 Lectures**

UNIT –II 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.
15 Lectures

UNIT –III 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 eigenvalues and eigenfunctions for symmetric kernels, expansion in eigenfunctions and bilinear form.
15Lectures

UNIT – IV Hilbert Schmidt Theorem and its consequences, Solution of symmetric integral equations, Operator method in the theory of integral equations, Solution of Volterra and Fredholm integrodifferential equations by Adomian decomposition method, Green’s function: Definition, Construction of Green’s function and its use in solving boundary value problems. **15Lectures**

Seminars, Tutorials, Problem solving session and group discussions onaboveunits.

Recommended Book(s):

1. R. P. Kanwal, Linear Integral Equation: Theory and Technique, Academic Press, 1971.
2. Abdul-Majid Wazwaz, Linear and Nonlinear Integral Equations**:** Methods and Applications, Springer, 2011

Reference Books:

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

M. A. / M. Sc. Part-II (Mathematics) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code :DSE-402
Title of Course: Measure and Integration
Total Credits: 04

Course Outcomes: Upon successful completion of this course, the student will be able to:
1. generalize 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: 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. **15 Lectures**
Unit II: Integration over general measure spaces, measurable functions, integration of nonnegative measurable functions, integration of general measurable functions , The Radon-Nikodym Theorem. **15 Lectures**
Unit III: General L^P Spaces: The completeness of L^P (X, μ), $1 \leq p \leq \infty$, 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 $L^\infty(X, \mu)$. **15 Lectures**

Unit IV: Product Measures: The theorems of Fubini and Tonelli, Lebesgue measure on Euclidean space R^n, Caratheodory outer measures and Hausdorff measures on a metric space. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended books:

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

Reference books:

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

M. A. / M. Sc. Mathematics (Part II) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code:CCS-403, CCS-404, CCS-405, CCS-406
Title of Course: Algebraic Number Theory
Total Credits:04

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 ring and fields, factorization of polynomials and field extensions. Symmetric polynomials, modules, free abelian groups, algebraic numbers, conjugates and discriminates. **15Lectures**

Unit II: Integral bases, norms and traces, rings of integers. Quadratic and cyclotomic fields. Trivial factorization, factorization into irreducibles, examples of non-unique factorization into irreducibles, prime factorization, Euclidean domains, Euclidean quadratic fields. **15Lectures**

Unit III: Prime factorization of ideals, the norm of an ideal, non-unique factorization in cyclotomic fields. Lattices, the quotient torus, Minkowski's theorem, the two-square theorem, the four-square theorem. **15Lectures**

Unit IV: Geometric Representation of algebraic numbers. The class group, Existence theorem, finiteness of the class group. Factorization of a rational prime, Minkowski's constants, some class number calculations, tables. **15Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Books:

1. I. N. Stewartand D. O. Tall, Algebraic Number Theory and Fermat's Last Theorem, 2015, CRC press.

Reference Books:

1. Algebraic Number Theory: Mathematical Pamphlet, TIFR, Bombay.
2. N. Jacobson, Basic Algebra-I, Hindustan Publishing Corporation(India),Delhi(Unit-I)
3. Paulo Ribenboim, Classical Theory of Algebraic Numbers, Springer, New York(2001).
4. N. S. Gopalkrishnan, University Algebra, New Age International (P) Ltd. Publishers.
5. Ian Stewart, Galoi Theory, CRC press(2015).
6. Harry Pollard, The Theory of Algebraic Numbers, The Mathematical Association of America.

M. A. / M. Sc. Part-II (Mathematics) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-303, CCS-304, CCS-305, CCS-306
Title of Course: Quantitative Techniques in Operations Research
Total Credits : 04

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. derive Poisson distribution theorem and compute attributes of distribution model.
4. identify optimal path by using CPM and PERT.

Unit I : 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 (PWF) and Discount rate, replacement policy for items whose maintenance cost increases with time and money value changes with constant rate, individual replacement policy. Group replacement of items that fail completely (suddenly). **15 Lectures**

Unit II : Inventory : cost involved in inventory problems, variables in inventory problem, symbols in inventory, concept of Economic Ordering Quantity (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 (b) The EOQ with constant rate of demand, scheduling, time variable. Model II (c) The production lot size model with shortages. **15 Lectures**

Unit III : 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 . **15 Lectures**

Unit IV : Project Management By PERT / CPM : Introduction. Basic steps in PERT / CPM techniques. Network Diagram Representation. Rules for Drawing Network Diagram. Time Estimates and Critical Path in Network Analysis. Determination of Critical Path. Applications Areas of PERT / CPM.

15 Lectures

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Books :

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

Reference Books :

1. Kanti Swarup, P. K. Gupta and Manmohan : Operations Research , S. Chand & Co.
2. Hamady Taha : Operations Research : Mac Millan Co.
3. S. D. Sharma: Linear Programming, Kedar Nath Ram Nath and Co.
4. S. D. Sharma : Nonlinear and Dynamic programming Kedar Nath Ram Nath and Co. Meerut.
5. R. K. Gupta : Operations Research, Krishna Prakashan Mandir, Meerut.

M. A. / M. Sc. Part-II (Mathematics) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code:CCS-403, CCS-404, CCS-405, CCS-406
Title of Course: Fuzzy Mathematics-II
Total Credits: 04

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.
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 : 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-wi composition. **25 Lectures**

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

Unit III : Fuzzy propositions, fuzzy quantifiers, linguistic edges, inference from conditional fuzzy propositions, qualified and quantified propositions. **10 Lectures**

Unit IV: Approximate reasoning : fuzzy expert systems, fuzzy implications, selection of fuzzy implications, multi-conditional approximate reasoning, the role of fuzzy relation equations, internal valued approximate reasoning. **10Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Books:

1. George J Klir, BoYuan, 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. Ganesh, Introduction to Fuzzy sets & Fuzzy Logic; PHIL earning Private Limited, New Delhi. 2011.
4. John Mordeson, Fuzzy Mathematics, Springer,2001

M.A./M. Sc. (Mathematics) (Part II) (Semester III)
(NEP-2020)
(Introduced from June 2023 onwards)

Course Code: CCS-403,CCS-404,CCS-405, CCS-406
Title of Course: Computational Fluid Dynamics

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 Scilab software.

Unit I: Comparison of experimental, theoretical and numerical approaches, governing equations, continuity equation, momentum equation (inviscid, viscous flows) energy equation, incompressible viscous flow, laminar boundarylayer flow. Introduction of Scilab to solve problems in CFD.
15 Lectures

Unit II: 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.**15 Lectures**

Unit III: 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, Laxmethod, 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.
15 Lectures

Unit IV: 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. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Book(s):
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) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-403, CCS-404, CCS-405, CCS-406
Title of Course: Fractional Differential Equations
Total Credits: 04

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: Existence and uniqueness theorems (Miller-Ross sequential fractional derivative approach): Linear fractional differential equations, fractional differential equation of a general form, existence and uniqueness theorem as a method of solution. Dependence of a solution on initial conditions.
15 Lectures

Unit II: 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. **15 Lectures**

Unit III: 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. **15 Lectures**

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

Seminars, Tutorials, Problem solving session and group discussions on above 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. A. / M. Sc. Mathematics (Part II) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

CourseCode:CCS-403,CCS-404,CCS-405, CCS-406
Title of Course: General Relativity – II
Total Credits: 04

Course Outcomes: Upon successful completion of this course, the student will be able to:
1. solve Einstein field equations under spherical symmetry.
2. Understand calculating relativistic frequency shifts for the bending of light passing as pherical 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 : 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, Schwarz schild space-time, spherical symmetry, Einstein field equation sunder spherical symmetry, Schwarz schild exterior solute. **15Lectures**

Unit II: Planetary orbits and Kepler's laws, 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 Schwarz schild exterior solution. **15Lectures**

Unit III: The exterior calculus: The tangent space, transformation properties of vector components. Theco-tangent space. Bases in the co-tangent space. Transformation laws of dual basis. Basis vector and1-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. **15Lectures**

Unit IV: Frame components of Riemannian curvature tensor, covariant 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. **15Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above 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 MacMillan com. (1978).
2. R. Adler, M. Bazin and 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. DeFeliceand C. J. S. Clarke: Relativity on curved Manifold. Cambridge University Press ,(1990)

M. A. / M. Sc. Mathematics (Part II) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code:CCS-403, CCS-404, CCS-405, CCS-406
Title of Course: Lattice Theory–II
Total Credits: 04
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. **15 lectures**

Unit III: Partition of Lattices, Complemented modular Lattices Direct decompositions, Kurosh – Ore theorem, Ore's theorem, sub group lattices. **15 lectures**

Unit IV: Semimodular, Lattices with Finite Length: Rank and covering Inequalities, Geometric closure operators, Semimodular Lattices and selectors, consistent semimodular lattices. **15 lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Books:

1) Lattice Theory: George Gratzer, W. H. Freeman and company,SanFrancisco,1971.

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

Reference Books:

1)Lattice Theory: G. Birkhoff, Amer. Math. Soc. Coll. Publications, Third Edition 1973.

M. A. / M. Sc. Mathematics (Part II) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code:CCS-403, CCS-404, CCS-405, CCS-406
Title of Course: Wavelet Analysis
Total Credits: 04

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 : 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. **15 Lectures**

Unit II: 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. **15 Lectures**

Unit III: 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. **15 Lectures**

Unit IV: 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. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Book(s):
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) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-403, CCS-404, CCS-405, CCS-406
Title of Course: Dynamical Systems- II
Total Credits: 04

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

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

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

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

Seminars, Tutorials, Problem solving session and group discussions on above 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) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-403, CCS-404, CCS-405, CCS-406
Title of Course: Graph Theory –II
Total Credits: 04

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 eigenvalues.
4. find energy of graph using its matrix.
5. classification of trees using properties of matrix.

Unit I: Incidence matrix: rank, minors, path matrix, integer generalized inverse, Moore-Perose inverse, 0-1incidence matrix, matching's in bipartitegraphs. **15 Lectures**

Unit II: Adjacency matrix, eigenvalues of some graphs, determinant, bounds, energy of graph, anti-adjacency matrix of directed graph, non-singular trees. **15Lectures**

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

Unit IV: Cuts, fundamental cycles and fundamental cut, fundamental matrices, minors. 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. **15Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above 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) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-403, CCS-404, CCS-405, CCS-406
Title of Course: Theory of Distributions
Total Credits:04
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 function.
4. analyze properties of support of generalized functions.
5. define directional derivatives of generalized functions.

Unit I: Locally convex spaces, topological vector spaces, semi norms, locally convex spaces, examples of locally convex spaces, generalized functions, test functions, distributions. **15Lectures**

Unit II: 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. **15Lectures**

Unit III: 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. **15Lectures**

Unit IV: Support of distribution, distribution with compact support, distributions as derivatives, convolutions, translation, reflexion, approximate identity, differential of convolutions, properties of convolutions, regularization of distributions. **15Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above 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) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code:CCS-403,CCS-404,CCS-405, CCS-406
Title of Course: Commutative Algebra–II
Total Credits: 04
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. study tensor product of modules.
5. derive prime decomposition theorem.

Unit I: Operations on submodules, isomorphism theorem for modules, Artirian and Noetherion modules. Composition series for modules. **15Lectures**

Unit II: The Krull-Schmidt theorem, Fittings lemma, completely reducible modules, Schur'slemma. **15Lectures**

Unit III: Free modules, injective modules, Projective modules, direct summand tensor product of modules. **15Lectures**

Unit IV: Exact sequence and short exact sequence of modules, Uniqueness Theorem for primary decomposition of modules. **15Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above 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 Ideals, Academicpress,1971.
2. D. G. Northcot, Ideal Theory, Cambridge University, press,1953.

M. A. / M. Sc. Mathematics (Part II) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-403, CCS-404, CCS-405, CCS-406

Title of Course: Space dynamics- II
Total Credits:04

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 principal 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 : 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. **15 Lectures**

Unit II: 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. **15 Lectures**

Unit III: 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. **15 Lectures**

Unit IV: 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.
15 Lectures

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Book(s):
1. Kluever , Space Flight Dynamics, January 2018, Wiley

Reference 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) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-403, CCS-404, CCS-405, CCS-406

Title of Course: Algebraic Automata Theory
Total Credits: 04

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

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

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

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

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Book:
1. Holcombe M. L.: Algebraic Automata Theory, Cambridge University Press.

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

M. A. / M. Sc. Mathematics (Part II) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

CourseCode:CCS-403,CCS-404,CCS-405, CCS-406

Title of Course: Dynamic Equations on Time Scales
Total Credits: 04

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. unify and extend the traditional study of differential equations and difference equations

UNIT– I Definition of time scale, examples of time scale, forward and backward jump operators and their properties, classification of points, graininess function, Hilger derivative and its properties, Leibniz formula, regulated and rd-continuous intermediate functions, pre-differentiable functions and its existence, mean value theorems, value theorem. **15 Lectures**

UNIT –II Antiderivative and its existence, indefinite delta integral, Cauchy integral, properties of delta integrals, chain rules, change of variables, Taylor's formula, Hilger's complex plane and its properties, basic operations on Hilger's complex plane (circle plus addition, circle minus subtraction, circle dot multiplication, generalized square), regressive functions, generalized exponential function on time scales. Examples of generalized exponential functions. **15 Lectures**

UNIT –III First order linear dynamic equations, initial value problems on time scales, adjoint operators, Lagrange identity, variation of constants, second order linear dynamic equations, existence and uniqueness theorem, Wronskians, Abel's theorem. **15 Lectures**

UNIT – IV Hyperbolic and trigonometric functions on time scales, Solution of second order linear equation: by Reduction of order, by method of factoring, equations with non-constant coefficients, Hyperbolic and Trigonometric Functions-II , Euler-Cauchy dynamic Equations, Variation of Parameters, Annihilator Method, Laplace Transform. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions onaboveunits.

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) (Level-9) (Semester IV)
(NEP-2020)
(Introduced from Academic Year 2023-24)

Course Code: CCS-403, CCS-404, CCS-405, CCS-406
Title of Course: Automata, Languages and Computation
Total Credits: 04

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: Finite automata, regular languages, regular expressions, equivalence of deterministic and non-deterministic finite automata, minimization of finite automata, closure properties, Kleene's theorem. **15 Lectures**

Unit II: pumping lemma and its application, Myhill-Nerode theorem and its uses; Context-free grammars, context-free languages, Chomsky normal form, closure properties. **15 Lectures**

Unit III: pumping lemma for CFL, pushdown automata, Computable functions, primitive and recursive functions, universality, halting problem, recursive and recursively enumerable sets. **15 Lectures**

Unit IV: parameter theorem, diagonalisation, reducibility, Rice's Theorem and its applications. Turing machines and variants; Equivalence of different models of computation. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above units.

Recommended Book:

1. 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. Sigaland 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.

Nature of the Theory Question Papers:

1. There shall be 7questions eachcarrying16 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. QuestionNo.2 to Question No.7 shall consist of short/descriptive-answer type sub-questions.