SEMESTER SYSTEM COURSE STRUCTURE

FOR

M. SC. COURSE IN MATHEMATICS
(PURE AND APPLIED STREAMS)

Under Choice Based Credit System (CBCS)

Effective from the session 2021-23

DEPARTMENT OF MATHEMATICS
DIRECTORATE OF OPEN AND DISTANCE LEARNING
UNIVERSITY OF KALYANI
NADIA, WEST BENGAL

M.SC. IN MATHEMATICS

(PURE AND APPLIED STREAMS)

TOTAL CREDITS: 100, FULL MARKS: 1650

COMMON ABBREVIATIONS

COR: Core Course; **AECC**: Ability Enhancement Compulsory Course;
GEC: Generic Elective Course; **SEC**: Skill Enhancement Course; **DSE**: Discipline Specific Elective
SEE: Semester End Examination; **IA**: Internal Assessment

COURSE OUTLINE

SEMESTER I

TOTAL CREDITS: 26; DURATION: 6 Months;
LEARNER STUDY HOURS: 180 × 4 + 60 = 780 Hours
(Counselling + Self Study + Assignments = 78 + 657 + 45)

Course	Stream	Topics	SEE (80)	IA (20)	TOTAL	COUNSELLING HOURS	CREDITS
COR 1.1	COMMON TO BOTH STREAMS	• Real Analysis I • Complex Analysis I • Functional Analysis I	• 25 • 30 • 25	• 7 • 6 • 7	100	18	6
COR 1.2		• Ordinary Differential Equations • Partial Differential Equations	• 40 • 40	• 10 • 10	100	18	6
COR 1.3		• Potential Theory • Abstract Algebra I • Operations Research I	• 30 • 25 • 25	• 6 • 7 • 7	100	18	6
DSE 1.4	APPLIED	• Mechanics of Solids • Non-linear Dynamics	• 40 • 40	• 10 • 10	100	18	6
	PURE	• Differential Geometry I • Topology I	• 40 • 40	• 10 • 10	100	18	
AECC 1.5	COMMON	Computer Programming in C (Theory)	40	10	50	6	2
Total			**360**	**90**	**450**	**78**	**26**

SEMESTER II

TOTAL CREDITS: 26; DURATION: 6 Months;
LEARNER STUDY HOURS: 180 × 3 + 120 × 2 = 780 Hours
(Counselling + Self Study + Assignments = 78 + 657 + 45)

Course	Stream	Topics	SEE (80)	IA (20)	TOTAL	COUNSELLING HOURS	CREDITS
COR 2.1	COMMON TO BOTH STREAMS	• Real Analysis II • Complex Analysis II • Functional Analysis II	• 25 • 25 • 30	• 7 • 7 • 6	100	18	6

COR 2.2		• Classical Mechanics • Abstract Algebra II • Operations Research II	• 25 • 25 • 30	• 7 • 7 • 6	100	18	6
COR 2.3		• Numerical Analysis	• 40	• 10	50	12	4
DSE 2.4	APPLIED	• Mechanics of Fluids • Stochastic Processes	• 50 • 30	• 10 • 10	100	18	6
	PURE	• Differential Geometry II • Topology II	• 40 • 40	• 10 • 10	100	18	
GEC 2.5(CBCS)	OTHER DEPARTMENTS	• History of Mathematics • Operations Research • Matrices and Linear Algebra • Theory of Dynamical Systems	• 20 • 20 • 20 • 20	• 5 • 5 • 5 • 5	100	12	4
Total			**360**	**90**	**450**	**78**	**26**

SEMESTER III

TOTAL CREDITS: 22; DURATION: 6 Months;

LEARNER STUDY HOURS: 180 × 3 = 540 Hours

(Counselling + Self Study + Assignments =54 + 451 + 35)

Practical: 120 Hours

Course	Stream	Topics	SEE	IA	TOTAL	COUNSELLING HOURS	CREDITS
COR 3.1	COMMON TO BOTH STREAMS	• Linear Algebra • Special Functions • Integral Equations and Integral Transforms	• 30 • 20 • 30	• 10 • 5 • 5	100	18	6
COR 3.2		• Calculus of $\mathbb{R}^n$ • Fuzzy Set Theory • Calculus of Variations	• 40 • 20 • 20	• 10 • 5 • 5	100	18	6
DSE 3.3	APPLIED	• Modelling of Biological Systems • Dynamical Systems	• 40 • 40	• 10 • 10	100	18	6
	PURE	• Operator Theory • Measure Theory	• 40 • 40	• 10 • 10	100	18	
SEC 3.4	COMMON TO BOTH STREAMS	• Computer Programming in C (Practical)	50			120	4
Total			**240**	**60**	**350**	**174**	**22**

Marks Distribution for SEC 3.4 is as follows:

1. Practical Notebook – 10 marks;
2. Examination – 30 marks;
3. Viva-voce – 10 marks.

SEMESTER IV

TOTAL CREDITS: 26; DURATION: 6 Months;
LEARNER STUDY HOURS: 180 × 3 + 240 = 780 Hours
(Counselling + Self Study + Assignments = 72 + 672 + 30)

Course	Stream	Topics	SEE (80)	IA (20)	TOTAL	COUNSELLING HOURS	CREDITS
COR 4.1	COMMON TO BOTH STREAMS	• Discrete Mathematics • Probability and Statistical Methods	• 50 • 30	• 10 • 10	100	18	6
DSE4.2	TO BE OPTED	Optional Course**	80	20	100	18	6
DSE 4.3	TO BE OPTED	Optional Course**	80	20	100	18	6
PROJECT 4.4	COMMON TO BOTH STREAMS	Project Notebook + Seminar Presentation + Viva-voce	50+30+20		100	24	8
Total					**400**	**78**	**26**

Examination related course criteria (Project Work)

1. Each student has to carry out a project work under the supervision ofteacher(s) of the Department and on the basis of her/his subject interest in the advanced topics of Mathematics(subject to the availability of teacher). The same is to be submitted to the Department after getting it countersigned by the concerned teacher(s) and prior to the commencement of Viva-Voce.
2. All Projectrelated record shall be maintained by the Department.
3. Seminar presentation and Viva–Voce Examination shall be conducted by the Department.

****The list of Optional courses is furnished as follows and will be offered according to the availability of teachers.**

Applied Stream	Pure Stream
Advanced Operations Research I***	Advanced Operations Research I***
Advanced Operations Research –II***	Advanced Operations Research –II***
Fuzzy Sets and Systems***	Fuzzy Sets and Systems***
Advanced Solid Mechanics	Advanced Real Analysis
Advanced Fluid Mechanics	Advanced Complex Analysis I
Computational Fluid Mechanics	Advanced Complex Analysis II
Magneto-Fluid Mechanics	Advanced Functional Analysis
Plasma Physics	Abstract Harmonic Analysis
Mathematics of Finance & Insurance	Advanced General Topology
Seismology	Advanced Algebraic Topology
Computational Biology	Advanced Algebra I
Mathematical Biology	Advanced Algebra II
Dynamical Oceanography	Advanced Differential Geometry I
Applied Functional Analysis	Advanced Differential Geometry II
Advanced Numerical Analysis (Theory and Practical)	Functional Analysis and its Applications to PDEs
Compressible Fluid Dynamics	Ergodic Theory & Topological Dynamics

	Advanced Partial Differential Equations

***The syllabi for the optional courses on Advanced Operations Research I, Advanced Operations Research II and Fuzzy Sets and Systems are common to both the Pure and Applied Streams.

Semester I

COR 1.1

Marks: 100; Credits: 6

Unit	Topic	Counselling Duration
Block I: Real Analysis I; Marks 32 (SEE: 25; IA: 07)		
1	Cardinal number **:** Definition, Schröder-Bernstein theorem, Order relation of cardinal numbers, Arithmetic of cardinal numbers, Continuum hypothesis	54 Mins
2	Cantor's set **:** Construction and its presentation as an uncountable set of measure zero	54 Mins
3	Functions of bounded variation **:** Definition and basic properties, Lipschitz condition, Jordan decomposition,	54 Mins
4	Nature of points of discontinuity, Nature of points of non-differentiability, Convergence in variation (Helly's First theorem)	54 Mins
5	Absolutely continuous functions **:** Definition and basic properties, Deduction of the class of all absolutely continuous functions as a proper subclass of all functions of bounded variation,	54 Mins
6	Characterization of an absolutely continuous function in terms of its derivative vanishing almost everywhere	54 Mins
7	Riemann-Stieltjes integral **:** Existence and basic properties, Integration by parts, Integration of a continuous function with respect to a step function,	54 Mins
8	Convergence theorems in respect of integrand, convergence theorem in respect of integrator (Helly's Second theorem)	54 Mins
9	Gauge partition **:** Definition of a delta-fine tagged partition and its existence, Lebesgue's criterion for Riemann integrability,	54 Mins
10	Delta-fine free tagged partition and an equivalent definition of the Riemann integral	54 Mins
Block II: Complex Analysis I; Marks 36 (SEE: 30; IA: 06)		
11	Riemann's sphere, point at infinity and the extended complex plane	54 Mins
12	Functions of a complex variable, limit and continuity. Analytic functions, Cauchy-Riemann equations	54 Mins
13	Complex integration. Cauchy's fundamental theorem (statement only) and its consequences. Cauchy's integral formula. Derivative of an analytic function	54 Mins

14	Morera's theorem, Cauchy's inequality, Liouville's theorem, Fundamental theorem of classical algebra	54 Mins
15	Uniformly convergent series of analytic functions. Power series. Taylor's theorem. Laurent's theorem	54 Mins
Block III: Functional Analysis I; Marks 32 (SEE: 25; IA: 07)		
16	Metric spaces. Brief discussions of continuity, completeness, compactness. Hölder's and Minkowski's inequalities (statement only)	54 Mins
17	Baire's (category) theorem. The spaces and. Banach's fixed point theorem	54 Mins
18	Applications to solutions of certain systems of linear algebraic equations, Fredholm's integral equation of the second kind, implicit function theorem. Kannan's fixed point theorem	54 Mins
19	Real and Complex linear spaces. Normed induced metric. Banach spaces, Riesz's lemma	54 Mins
20	Finite dimensional normed linear spaces and subspaces, completeness, compactness criterion, equivalent norms	54 Mins
Total		18 Hours

References:

Block I:

I. P. Natanson**:** Theory of Integrals of a Real Variable (Vol. I and II).
2. B. K. Lahiri and K. C. Ray**:** Real Analysis.
3. W. Rudin**:** Principles of Mathematical Analysis.
4. A. G. Das**:** The Generalized Riemann Integral.
5. G. Das**:** Theory of Integration – The Riemann, Lebesgue and Henstock-Kurzweil Integrals.
6. W. Sierpinsky**:** Cardinal Number and Ordinal Number.
7. H. L. Royden**:** Real Analysis

Block II:

1. A. I. Markushevich**:** Theory of Functions of a Complex Variable (Vol. I, II and III).
2. R. V. Churchill and J. W. Brown**:** Complex Variables and Applications.
3. E. C. Titchmarsh**:** The Theory of Functions.
4. E. T. Copson**:** An Introduction to the Theory of Functions of a Complex Variable.
5. J. B. Conway**:** Functions of One Complex Variable.
6. L. V. Ahlfors**:** Complex Analysis.
7. H. S. Kasana**:** Complex Variables – Theory and Applications.
8. S. Narayan and P. K. Mittal**:** Theory of Functions of a Complex Variable.
9. A. K. Mukhopadhyay**:** Functions of Complex Variables and Conformal Transformation.
10. J. M. Howi**:** Complex Analysis.
11. S. Ponnusamy: Foundation of Complex Analysis.

12. H. A Priestly: Introduction to Complex Analysis, Clarendon Press, Oxford, 1990.
13. E. M. Stein and R. Shakrachi: Complex Analysis, Princeton University Press.

Block III:

1. E. Kreyszig**:** Introductory Functional Analysis with Applications.
2. W. Rudin**:** Functional Analysis.
3. N. Dunford and L. Schwart**:**Linear Operators (Part I).
4. A. E. Taylor**:** Introduction to Functional Analysis.
5. B. V. Limaye**:** Functional Analysis.
6. K. Yoshida**:** Functional Analysis.
7. B. K. Lahiri**:** Elements of Functional Analysis.

COR 1.2

Marks: 100; Credits: 6

Unit	Topic	Counselling Duration
Block I: Ordinary Differential Equations; Marks 50 (SEE: 40; IA: 10)		
1	Existence of solutions**:** Picard's Existence theorem for equation dy / dx = f(x,y), Gronwall's lemma, Picard-Lindelöf method of successive approximations.	54 Mins
2	Solutions of linear differential equations of nth order. Wronskian, Abel's identity.	54 Mins
3	Linear dependence and independence of the solution set, Fundamental set of solutions.	54 Mins
4	Green's function for boundary value problem and solution of non-homogenous linear equations.	54 Mins
5	Adjoint and self-adjoint equations. Lagrange's identity.	54 Mins
6	Sturm's separation and comparison theorems for second order linear equations. Regular Sturm-Liouville problems for second order linear equations.	54 Mins
7	Eigen values and eigen functions, expansion in eigen functions.	54 Mins
8	Solution of linear ordinary differential equations of second order in complex domain.	54 Mins
9	Existence of solutions near an ordinary point and a regular singular point.	54 Mins
10	Solutions of Hyper geometric equation and Hermite equation, Introduction to special functions.	54 Mins
Block II: Partial Differential Equations; Marks 50 (SEE: 40; IA: 10)		
11	Introduction and pre-requisite, Genesis and types of solutions of Partial Differential Equations.	54 Mins

12	First order Partial Differential Equations, Classifications of First Order Partial Differential Equations. Charpit's Method for the solution of First Order non-linear Partial Differential Equation.	54 Mins
13	Linear Partial Differential Equations of second and higher order, Linear Partial Differential Equation with constant coefficient, Solution of homogeneous irreducible Partial Differential Equations	54 Mins
14	Method of separation of variables, Particular integral for irreducible non-homogeneous equations	54 Mins
15	Linear partial Differential equation with variable coefficients, Cannonical forms, Classificatin of second order partial differential equations, Canonical transformation of linear second order partial differential equations	54 Mins
16	Parabolic equation, Initial and boundary conditions, Heat equation under Dirichlet's Condition, Solution of Heat equation under Dirichlet's Condition ,	54 Mins
17	Solution of Heat equation under Neuman Condition, Solution of Parabolic equation under non-homogeneous boundary condition	54 Mins
18	Hyperbolic equation, occurrence of wave equations, in Mathematical Physics, Initial and boundary conditions, Initial value problem	54 Mins
19	D' Alembert's solutions, vibration of a sting of finite length, Initial value problem for a non-homogeneous wave equation	54 Mins
20	Elliptic equations, Gauss Divergence Theorem, Green's identities, Harmonic functions, Laplace equation in cylindrical and spherical polar coordinates, Dirichlet's Problem, Neumann Problem	54 Mins
Total		18 Hours

References:

Block I:
1. G. F. Simmons**:** Differential Equations.
2. E. E. Coddington and N. Levinson**:** Theory of Ordinary Differential Equations.
3. M. Birkhoff and G. C. Rota**:** Ordinary Differential Equations.
4. M.D. Raisinghania: Advanced Differential Equations.
5. E. L. Ince**:** Ordinary Differential Equations

Block II:

1. A. K. Nandakumaran and P. S. Datti: Partial Differential equations, Cambridge University Press, 2020.
2. L. C. Evans: Partial Differential equations, Vol 19, AMS.
3. G. Evans: Analytic methods for partial differential equations, Springer, 2001.
4. Phoolan Prasad and RenukaRavindran: Partial differential Equations, New Age Int., 2011.
5. T. Amaranath: An elementary course in partial differential equations, Narosa, 2014.
6. K. Sankara, Rao: Introduction to partial differential equations, PHI, 2015.

7. I. N. Sneddon: Elements of partial differential equations, Mc Grew Hill, New York, 1957.
8. Robert C. McOwen: Partial differential equations, Pentice hall, 2013.

COR 1.3

Marks: 100; Credits: 6

Unit	Topic	Counselling Duration
Block I: Potential Theory; Marks 36 (SEE: 30; IA: 06)		
1	Concept of potential and attraction for line, surface and volume distributions of matter.	54 Mins
2	Laplace's equation, problems of attraction and potential for simple distribution of matter	54 Mins
3	Existence and continuity of first and second derivatives of potential within matter. Poisson's equation, work done by mutual attraction, problems	54 Mins
4	Integral theorem of potential theory (statement only) Green's identities, Gauss' average value theorem,	54 Mins
5	Continuity of potential and discontinuity of normal derivative of potential for a surface distribution, potential for a single and double layer, Discontinuity of potential	54 Mins
6	Boundary value problems of potential theory. Green's function, solution of Dirichlet's problem for a half-space	54 Mins
7	Solid and surface spherical harmonics	54 Mins
Block II: Abstract Algebra I; Marks 32 (SEE: 25; IA: 07)		
8	**Preliminaries**: Review of earlier related concepts-Groups and their simple properties	54 Mins
9	**Class equations on groups and related theories**: Conjugacy class equations, Cauchy's theorem,	54 Mins
10	p-Groups, Sylow theorems and their applications, simple groups	54 Mins
11	**Direct Product on groups**: Definitions, discussion on detailed theories with applications	54 Mins
12	**Solvable groups**: Related definitions and characterization theorems, examples	54 Mins
13	**Group action**: Definition and relevant theories with applications	54 Mins
Block III: Operations Research–I; Marks 32 (SEE: 25; IA: 07)		

14	**Extension of Linear Programming Methods :** Theory of Revised Simplex Method and algorithmic solution approaches to linear programs	54 Mins
15	Dual-Simplex Method, Decomposition principle and its use to linear programs for decentralized planning problems	54 Mins
16	**Integer Programming (IP) :** The concept of cutting plane for linear integer programs, Gomory's cutting plane method	54 Mins
17	Gomory's All-Integer Programming Method, Branch-and-Bound Algorithm for general integer programs	54 Mins
18	**Sequencing Models :** The mathematical aspects of Job sequencing and processing problems, Processing n jobs through Two machines, processing n jobs through m machines	54 Mins
19	**Nonlinear Programming (NLP) :** Convex analysis, Necessary and Sufficient optimality conditions, Cauchy's Steepest descent method,	54 Mins
20	Karush-Kuhn-Tucker (KKT) theory of NLP, Wolfe's and Beale's approaches to Quadratic Programs	54 Mins
Total		18 Hours

References:

Block I:

1. O. D. Kellog**:** Theory of Potential.
2. P. K. Ghosh**:** Theory of Potential.
3. A. S Ramsey**:** Newtonian Attraction.
4. T. M. Macrobert**:** Spherical Harmonics.

Block II:

1. M.K. Sen, S. Ghosh and P. Mukhopadhyay: Abstract Algebra, University Press.
2. Luthar&Passi: Algebra (Vol. 1).
3. John B. Fraleigh: A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
4. D. S. Dummit, R. M. Foote: Abstract Algebra, 2nd edition, Wiley Student edition.
5. J. A. Gallian: Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, 1999.
6. I. N. Herstein, Topics in Algebra: Wiley Eastern Ltd. New Delhi, 1975.
7. T. W. Hungerford: Algebra, Springer, 1980.
8. Joseph J. Rotman: An introduction to the theory of groups, Springer-Verlag, 1990.
9. M. Artin: Abstract Algebra, 2nd Ed., Pearson, 2011.
10. Malik, Mordeson and Sen: Fundamentals of Abstract Algebra, McGraw-Hill, 1997.
11. S. Lang: Algebra (2nd ed.), Addition-Wesley.
12. M. R. Adhikari and Abhishek Adhikari: Groups, Rings and Modules with Applications.
13. N. Jacobson: Lecturers in Abstract Algebra.

Block III:

1. Linear Programming – G. Hadley.
2. Mathematical Programming Techniques – N. S.Kambo.

3. Nonlinear and Dynamic Programming – G. Hadley.
4. Operations Research – K. Swarup, P. K. Gupta and Man Mohan.
5. Operations Research – H. A. Taha.
6. Operations Research – S. D. Sharma.
7. Introduction to Operations Research – A. Frederick, F. S. Hillier and G. J. Lieberman.
8. Optimization: Theory and Applications – S. S. Rao.
9. Nonlinear and Mixed-Integer Optimization – Christodoulos A. Floudas.

DSE 1.4 (Applied Stream)

Marks: 100; Credits: 6

Unit	Topic	Counselling Duration
Block I: Mechanics of Solids; Marks 50 (SEE: 40; IA: 10)		
1	Brief discussion of tensor transformation, symmetric tensor, alternating tensor. Analysis of strain, Normal strain, shearing strain and their geometrical interpretations	54 Mins
2	Strain quadratic of Cauchy, Principal strains, Invariants, Saint-Venant's equations of compatibility, equivalence of Eulerian and Lagrangian components of strain in infinitesimal deformation	54 Mins
3	Analysis of stress, stress tensor, Equations of equilibrium and motion. Stress quadric of Cauchy. Principal stress and invariants, strain energy function	54 Mins
4	Graphical representation of elastic deformation. Equations of elasticity. Generalized Hooke's law. Homogeneous isotropic media. Elastic modulii for isotropic media.	54 Mins
5	Equilibrium and dynamical equations for an isotropic elastic solid.Connections of the strain energy function with Hooke's Law, uniqueness of solutions. Clapeyron's Theorem, Beltrami-Michell compatibility equations, Saint-Venant's principle.	54 Mins
6	Equilibrium of isotropic elastic solid**:** Deformations under uniform pressure. Deformations of prismatical bar stretched by its own weight and a cylinder immersed in a fluid, twisting of circular bar by couples at the ends	54 Mins
7	Torsion **:** Torsion of cylindrical bars, Torsional rigidity, Torsion function, Lines of shearing stress, simple problems related to circle, ellipse and equilateral triangle	54 Mins
8	Two-dimensional problems**:** Plane strain, Plane stress, Generalised plane stress, Airy's stress function, General solution of biharmonic equation.	54 Mins
9	Stresses and displacements in terms of complex potentials. Simple problems, stress function appropriate to problems of plane stress	54 Mins
10	Waves**:** Propagation of waves in an isotropic elastic medium, waves of dilatation and distortion. Plane waves	54 Mins

Block II:Non-Linear Dynamics; Marks 50 (SEE: 40; IA: 10)		
11	**Linear autonomous systems**: Linear autonomous systems, existence, uniqueness and continuity of solutions, diagonalization of linear systems,	54 Mins
12	Fundamental theorem of linear systems, the phase paths of linear autonomous plane systems	54 Mins
13	Complex eigen values, multiple eigen values, similarity of matrices and Jordon canonical form, stability theorem	54 Mins
14	Reduction of higher order ODE systems to first order ODE systems, linear systems with periodic coefficients	54 Mins
15	Linearization of dynamical systems: Two, three and higher dimension.	54 Mins
16	Population growth. Lotka-Volterra system	54 Mins
17	**Stability**: Asymptotic stability (Hartman's theorem), Global stability (Liapunov's second method)	54 Mins
18	Limit set, attractors, periodic orbits, limit cycles	54 Mins
19	Bendixon criterion, Dulac criterion, Poincare-Bendixon Theorem.	54 Mins
20	**Stability and bifurcation**: Saddle-Node, transcritical and pitchfork bifurcations. Hopf- bifurcation	54 Mins
Total		18 Hours

References:

Block I:

1. S. Sokolnikoff: Mathematical Theory of Elasticity.
2. A. E. H. Love: A Treatise on the Mathematical Theory of Elasticity.
3. Y. C. Fung: Foundations of Solid Mechanics.
4. R.N. Chatterjee: Mathematical Theory of Continuum Mechanics. 7. H. L. Royden**:** Real Analysis

Block II:

1. D. W. Jordan and P. Smith (1998): Nonlinear Ordinary Equations- An Introduction to Dynamical Systems (Third Edition), Oxford Univ. Press.
2. L. Perko (1991): Differential Equations and Dynamical Systems, Springer Verlag.
3. F. Verhulust (1996): Nonlinear Differential Equations and Dynamical Systems, SpringerVerlag.
5. H. I. Freedman - Deterministic Mathematical Models in Population Ecology.
6. Mark Kot (2001): Elements of Mathematical Ecology, Cambridge Univ. Press.
7. W. G. Kelley and A. C. Peterson, Difference Equations- An Introduction with Applications, Academic Press.
8. S. Elaydi. An Introduction of Difference Equation, Springer.

DSE 1.4 (PureStream)

Marks: 100; Credits: 6

Unit	**Topic**	**Counselling Duration**
Block I: Differential Geometry I; Marks 50 (SEE: 40; IA: 10)		
1	Vector valued functions, Directional Derivatives, Total derivatives,	54 Mins
2	Statement of Inverse and Implicit Function Theorems, Curvilinear coordinate system in E3.	54 Mins
3	Reciprocal base system. Riemannian space. Reciprocal metric tensor, Christoffel symbols, Covariant differentiation of vectors and tensors of rank 1 and 2.	54 Mins
4	Riemannian curvature tensor, Rieci tensor and scalar curvature. Space of constant curvature, Einstein space	54 Mins
5	On the meaning of covariant derivative. Intrinsic differentiation. Parallel vector field.	54 Mins
6	Tensor Algebra on finite dimensional vector spaces, Inner product spaces, matrix representation of an inner product ,	54 Mins
7	Linear functional, r-forms, Exterior product, Exterior derivative	54 Mins
8	Regular curves, curvature, torsion, curves in plane, signed curvature, curves in spaces,	54 Mins
9	Serret Frenet formulae, Isoperimetric inequality, four vertex theorem	54 Mins
10	Introduction to surface, Definition example, first fundamental form of surfaces	54 Mins
Block II: Topology I; Marks 50 (SEE: 40; IA: 10)		
11	Definition and examples of topological spaces.	54 Mins
12	Basis for a given topology, necessary and sufficient condition for two bases to be equivalent,	54 Mins
13	Sub-base, topologizing of two sets from a sub base	54 Mins
14	Closed sets, closure and interior, their basic properties and their relations	54 Mins
15	Neighbourhoods, exterior and boundary, dense sets. Accumulation points and derived sets. Subspace topology	54 Mins
16	Continuous, open, closed mappings, examples and counter examples	54 Mins
17	Their different characterizations and basic properties	54 Mins
18	Pasting lemma, homeomorphism, topological properties.	54 Mins
19	The countability axioms	54 Mins
20	Separation axioms	54 Mins
Total		18 Hours

References:

Block I:

1. Munkres: Analysis on manifolds,
2. Andrew Pressley: Elementary Differential Geometry.
3. M. P. DoCarmo: Differential Geometry of curves and surfaces.
4. Christian Bar: Differential geometry.
5. Nirmala Prakash: Differential geometry
6. I. S. Sokolnikoff: Tensor Analysis, Theory and applications.
7. L. P. Eisenhart: Introduction to Differential Geometry.

Block II:

1. M. A. Armstrong, Basic Topology, Springer (India), 2004,
2. J.R. Munkres, Topology, 2nd Ed., PHI (India), 2002,
3. J. M. Lee: Introduction to topological Manifolds,
4. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw- Hill, New York, 1963.12. H. A Priestly: Introduction to Complex Analysis, Clarendon Press, Oxford, 1990.
13. E. M. Stein and R. Shakrachi: Complex Analysis, Princeton University Press.

AECC 1.5

Marks: 50; Credits: 2

Unit	Topic	Counselling Duration
Computer Programming in C (Theory); Marks 50 (SEE: 40; IA: 10)		
1	Fundamentals of 'C' Language : Basic structure of a 'C' program, Basic Data type, Constants and Variables,Identifier, Keywords, Constants, Basic data type, Variables, Declaration and Initialization, Statements and Symbolic constants. Compilation and Execution of a 'C' program.	1 Hour
2	Operators and Expressions : Arithmetic, Relational, Logical operators. Increment, Decrement, Control, Assignment, Bitwise, and Special operators. Precedence rules of operators, Type Conversion (casting), Modes of arithmetic expressions, Conditional expressions.	1 Hour
3	Input / Output Operations : Formatted I/O - Single character I/O (getchar(), putchar()), Data I/O (scanf(),printf()), String I/O (gets(), puts()). Programming problems. Decision Making Statements: Branching – if Statement, if-else Statement, Nested if-else Statement. else-if and switch Statements. Loop Control: for Statement, while Statement, do while Statement. break, continue and exit Statements. Programming problems.	1 Hour
4	Functions : Function declaration, Library functions, User defined	1 Hour

	function, Passing argument to a function,Recursion. Programming problems. Arrays : Array declaration and static memory allocation. One dimensional, two dimensional and multidimensional arrays. Passing arrays to functions. Sparse matrix.	
5	Pointers : Basic concepts of pointer, Functions and Pointers. Pointers and Arrays, Memory allocation,Passing arrays to functions, Pointer type casting. Programming problems. Structures and Unions : Declaring a Structure, Accessing a structure element, Storing methods of structure elements, Array of structures, Nested structure, Self – referential structure, Dynamic memory allocation, Passing arrays to function. Union and rules of Union. Programming problems.	1 Hour
6	File Operations: File Input / Output operations – Opening and Closing a file, Reading and Writing a file.Charactercounting, Tab space counting, File-Copy program, Text and Binary files.	1 Hour
Total		6 Hours

References:

1. Programming in ANSI C: E. Balaguruswamy.
2. Let Us C: Y. Kanetkar.
3. Programming in C Language: B. S. Gottfred.
4. Mastering Algorithmin C: K. Loudon.
5. The C Programming Language: B.W. Kernighan and D. Ritchie.

Semester II

COR 2.1

Marks: 100; Credits: 6

Unit	Topic	Counselling Duration
	Block I: Real Analysis II; Marks 32 (SEE: 25; IA: 07)	
1	The Lebesgue measure: Definition of the Lebesgue outer measure on the power set of R, countable subadditivity, Carathéodory's definition of the Lebesgue measure and basic properties. Measurability of an interval (finite or infinite),	54 Mins
2	Countable additivity, Characterizations of measurable sets by open sets, G_δ sets, closed sets and F_σ sets. Measurability of Borel sets, Existence of non-measurable sets.	54 Mins
3	Measurable functions : Definition on a measurable set in R and basic properties, Simple functions	54 Mins
4	Sequences of measurable functions, Measurable functions as the limits of sequences of simple functions	
5	Lusin's theorem on restricted continuity of measurable functions, Egoroff's theorem, Convergence in measure	54 Mins
6	The Lebesgue integral : Integrals of non-negative simple functions, The integral of non-negative measurable functions on arbitrary measurable sets in R using integrals of non-negative simple functions, Monotone convergence theorem and Fatou's lemma.	54 Mins
7	The integral of Measurable functions and basic properties, Absolute character of the integral, Dominated convergence theorem,	54 Mins
8	Inclusion of the Riemann integral, Riesz-Fischer theorem on the completeness of the space of Lebesgue integrable functions.	54 Mins
9	Lebesgue integrability of the derivative of a function of bounded variation on an interval. Descriptive characterization of the Lebesgue integral on intervals by absolutely continuous functions.	54 Mins
	Block II: Complex Analysis II; Marks 32 (SEE: 25; IA: 07)	
10	Contour integration. Conformal mapping, Bilinear transformation. Idea of analytic continuation.	54 Mins
11	Multivalued functions – branch point. Idea of winding number.	54 Mins

12	Zeros of an analytic function. Singularities and their classification.	54 Mins
13	Limit points of zeros and poles. Riemann's theorem. Weierstrass-Casorati theorem.	54 Mins
14	Theory of residues. Argument principle. Rouche's theorem. Maximum modulus theorem. Schwarz lemma. Behaviour of a function at the point at infinity.	54 Mins
Block III: Functional Analysis II; Marks 36 (SEE: 30; IA: 06)		
15	Linear operators, Linear operators on normed linear spaces, continuity	54 Mins
16	Bounded linear operators, norm of an operator, various expressions for the norm. Spaces of bounded linear operators. Inverse of an operator.	54 Mins
17	Linear functionals. Hahn-Banach theorem (without proof), simple applications. Normed conjugate space and separability of the space. Uniform boundedness principle, simple application.	54 Mins
18	Inner product spaces, Cauchy Schwarz's inequality, the induced norm, polarization identity, parallelogram law. Orthogonality, Pythagoras Theorem, orthonormality, Bessel's inequality and its generalisation.	54 Mins
19	Hilbert spaces, orthogonal complement, projection theorem.	54 Mins
20	The Riesz's representation theorem. Convergence of series corresponding to orthogonal sequence, Fourier coefficient, Perseval's identity.	
Total		18 Hours

References:

Block I:

1. G. de BARRA: Measure theory and integration.
2. I. P. Natanson**:** Theory of Integrals of a Real Variable (Vol. I and II).
3. B. K. Lahiri and K. C. Ray**:** Real Analysis.
4. W. Rudin**:** Principles of Mathematical Analysis.
5. A. G. Das**:** Theory of Integration – The Riemann, Lebesgue and Henstock-Kurzweil Integrals.
6. P. K..Jain, V. P. Gupta and P. Jain**:** Lebesgue measure and integration
7. H. L. Royden**:** Real Analysis

Block II:

1. A. I. Markushevich**:** Theory of Functions of a Complex Variable (Vol. I, II and III).
2. R. V. Churchill and J. W. Brown**:** Complex Variables and Applications.
3. E. C. Titchmarsh**:** The Theory of Functions.
4. E. T. Copson**:** An Introduction to the Theory of Functions of a Complex Variable.

5. J. B. Conway: Functions of One Complex Variable.
6. L. V. Ahlfors: Complex Analysis.
7. H. S. Kasana: Complex Variables – Theory and Applications.
8. S. Narayan and P. K. Mittal: Theory of Functions of a Complex Variable.
9. A. K. Mukhopadhyay: Functions of Complex Variables and Conformal Transformation.
10. J. M. Howie: Complex Analysis.
11. S. Ponnusamy: Foundation of Complex Analysis.
12. H. A Priestly: Introduction to Complex Analysis, Clarendon Press, Oxford, 1990.
13. E. M. Stein and R. Shakarchi: Complex Analysis, Princeton University Press.

Block III:

1. E. Kreyszig: Introductory Functional Analysis with Applications.
2. W. Rudin: Functional Analysis.
3. N. Dunford and L. Schwartz: Linear Operators (Part I).
4. A. E. Taylor: Introduction to Functional Analysis.
5. B. V. Limaye: Functional Analysis.
6. K. Yoshida: Functional Analysis.
7. B. K. Lahiri: Elements of Functional Analysis.

COR 2.2

Marks: 100; Credits: 6

Unit	Topic	Counselling Duration
Block I: Classical Mechanics; Marks 32 (SEE: 25; IA: 07)		
1	Lagrangian Formulation: Generalised coordinates. Holonomic and nonholonomic systems. Scleronomic and rheonomic systems. D'Alembert's principle. Lagrange's equations. Energy equation for conservative fields. Cyclic (ignorable) coordinates. Generalised potential.	54 Mins
2	Moving Coordinate System: Coordinate systems with relative translational motions. Rotating coordinate systems. The Coriolis force.	54 Mins
3	Motion on the earth. Effect of Coriolis force on a freely falling particle. Euler's theorem. Euler's equations of motion for a rigid body. Eulerian angles.	54 Mins
4	Variational Principle : Calculus of variations and its applications in shortest distance, minimum surface of revolution, Brachistochrone problem,	54 Mins
5	Geodesic. Hamilton's principle. Lagrange's undetermined multipliers. Hamilton's equations of motion.	54 Mins
6	Canonical Transformations: Canonical coordinates and canonical transformations. Poincaré theorem. Lagrange's	54 Mins

	and	
7	Poisson's brackets and their variance under canonical transformations, Hamilton's equations of motion in Poisson's bracket. Jacobi's identity. Hamilton-Jacobi equation.	54 Mins
8	Small Oscillations :General case of coupled oscillations. Eigen vectors and Eigen frequencies. Orthogonality of Eigen vectors. Normal coordinates. Two-body problem.	54 Mins
Block II: Abstract Algebra II; Marks 32 (SEE: 25; IA: 07)		
9	Preliminaries: Review of earlier related concepts-Rings, integral domains, fields and their simple properties.	54 Mins
10	Detailed discussion on rings: Classification of rings, their definitions and characterization theorem with examples and counter examples.	54 Mins
11	Polynomial rings, division algorithm, irreducible polynomials, Eisenstein's criterion for irreducibility.	54 Mins
12	Ideals in rings: Definitions, classifications with related theorems, examples and counter examples	54 Mins
13	Domains in rings: Classification, definitions and related theories with example and counter examples.	54 Mins
14	Field extensions: Definition and simple properties.	54 Mins
Block III: Operations Research II; Marks 36 (SEE: 30; IA: 06)		
15	Sensitivity Analysis: Changes in price vector of objective function, changes in resource requirement vector, addition of decision variable, addition of a constraint.	54 Mins
16	Parametric Programming : Variation in price vector, Variation in requirement vector	54 Mins
17	Replacement and Maintenance Models: Failure mechanism of items, General replacement policies for gradual failure of items with constant money value and change of money value at a constant rate over the time period, Selection of best item.	54 Mins
18	Dynamic Programming (DP): Basic features of DP problems, Bellman's principle of optimality, Multistage decision process with Forward and Backward recursive relations, DP approach to stage-coach problems.	54 Mins
19	Non-Linear Programming (NLP): Lagrange Function and Multipliers, Lagrange Multipliers methods for nonlinear programs with equality and inequality constraints.	54 Mins
20	Separable programming, Piecewise linear approximation solution approach, Linear fractional programming.	
Total		18 Hours

References:

Block I:

1. E. T. Whittaker**:** A Treatise of Analytical Dynamics of Particles and Rigid Dynamics.
2. Greenwood**:** Dynamics.
3. F. Chorlton**:** Dynamics.
4. Routh**:** Dynamics.
5. H. Lamb**:** Dynamics.
6. R. G. Takwale and P. S. Puranik**:** Introduction to Classical Mechanics.
7. H. Goldstein**:** Classical Mechanics.
8. Classical Mechanics: N. C. Rana and P.S. Joag.

Block II:

1. J. A. Gallian: Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, 1999.
2. M. R. Adhikari and Abhishek Adhikari: Groups, Rings and Modules with Applications.
3. Luthar&Passi: Algebra (Vol. 1).
4. I. N. Herstein: Topics in Algebra, Wiley Eastern Ltd. New Delhi, 1975.
5. D. S. Dummit, R. M. Foote: Abstract Algebra, 2nd edition, Wiley Student edition.
6. John B. Fraleigh: A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
7. M.K. Sen, S. Ghosh and P. Mukhopadhyay: Abstract Algebra, University Press.
8. T. W. Hungerford: Algebra, Springer, 1980.
9. Joseph J. Rotman: An introduction to the theory of groups, Springer-Verlag, 1990.
10. N. Jacobson: Lecturers in Abstract Algebra.
11. M. Artin: Abstract Algebra, 2nd Ed., Pearson, 2011.
12. Malik, Mordeson and Sen: Fundamentals of Abstract Algebra, McGraw-Hill, 1997.
13. S. Lang: Algebra (2nd ed.), Addition-Wesley.

Block III:

1. Linear Programming – G. Hadley.
2. Mathematical Programming Techniques – N. S. Kambo.
3. Nonlinear and Dynamic Programming – G. Hadley.
4. Operations Research – K. Swarup, P. K. Gupta and Man Mohan.
5. Operations Research – H. A. Taha
6. Introduction to Operations Research – A. Frederick, F. S. Hillier and G. J. Lieberman.
7. Engineering Optimization: Theory and Practice – S. S. Rao.
8. Principles of Operations Research – Harvey M. Wagner.
9. Operations Research – P. K. Gupta and D. S. Hira.
10. Nonlinear and Mixed-Integer Optimization – Christodoulos A. Floudas.
11. Operations Research: Theory and Applications – J. K. Sharma.

COR 2.3

Marks: 50; Credits: 4

Unit	Topic	Counselling

		Duration
Block I: Numerical Analysis; Marks 50 (SEE: 40; IA: 10)		
1	**Errors:** Floating-point approximation of a number, Loss of significance and error propagation, Stability in numerical computation.	52 Mins
2	**Interpolation:** Hermite's and spline interpolation. Interpolation by iteration –Aitken's and Neville's schemes.	52 Mins
3	**Approximation of Function:** Least square approximation. Weighted least square approximation. Orthogonal polynomials,	52 Mins
4	Gram –Schmidt orthogonalisation process, Chebysev polynomials, Mini-max polynomial approximation.	52 Mins
5	**Numerical Integration:** Gaussian quadrature formula and its existence. Euler-MacLaurin formula	52 Mins
6	Gregory-Newton quadrature formula. Romberg integration.	52 Mins
7	**Systems of Linear Algebraic Equations:** Direct methods, Factorization method.	52 Mins
8	**Eigenvalue and Eigenvector Problems:** Direct methods, Iterative method –Power method.	52 Mins
9	**Nonlinear Equations:** Fixed point iteration method, convergence and error estimation.	52 Mins
10	Modified Newton-Raphson method, Muller's method, Inverse interpolation method, error estimations and convergence analysis.	52 Mins
11	**Ordinary Differential Equations:** Initial value problems–Picard's successive approximation method, error estimation.	52 Mins
12	Single-step methods –Euler's method and Runge-Kutta method, error estimations and convergence analysis	52 Mins
13	Multi-step method –Milne's predictor-corrector method, error estimation and convergence analysis.	52 Mins
14	**Partial Differential Equations:** Finite difference methods for Elliptic and Parabolic differential equations.	52 Mins
Total		12 Hours

References:

1. K. E. Atkinson: An Introduction to Numerical Analysis, 2 nd Edition, Wiley-India, 1989.
2. S. D. Conte and C. de Boor:Elementary Numerical Analysis -An Algorithmic Approach, 3 rd Edition, McGraw-Hill, 1981.
3. R. L. Burden and J. D. Faires:Numerical Analysis, 7 th Edition, Thomson, 2001.
4. Froberg, C. E. :Introduction to Numerical Analysis.
5. Hildebrand, F.B. : Introduction to Numerical Analysis.
6. Ralston, A. and Rabinowits, P. : A First Course in Numerical Analysis.
7. Atkinson, K. and Cheney, W. : Numerical Analysis.
8. David, K. and Cheney, W. : Numerical Analysis.

9. Powell, M. :Approximation Theory and Methods.
10. Jain, M. F., Iyenger, S. R. K. and Jain, R.K.:Numerical Methods for Scientific and Engineering Computation.
11. Scheid, F.: Numerical Analysis.
12. Sanyal, D. C. and Das, K. : A Text Book of Numerical Analysis.
13. Reddy, J. N.: An Introduction to Finite Element Methods.
14. Sastry, S. S.: Introductory Methods of Numerical Analysis.

DSE 2.4 (AppliedStream)

Marks: 100; Credits: 6

Unit	Topic	Counselling Duration
Block I: Mechanics of Fluids; Marks 60 (SEE: 50; IA: 10)		
1	**Kinematics:** Real and ideal fluids. Streamlines and paths of particles. Steady and unsteady flows.	54 Mins
2	Lagrange's and Euler's methods of description of fluid motion. Accelerations. Boundary surface. Irrotational and rotational motions.	54 Mins
3	Equation of continuity. Equations of Motion**:** Lagrange's and Euler's equations of motion. Bernoulli's theorem. Cauchy's integrals. Impulsive action.	54 Mins
4	**Motion in Two Dimensions:** Stream function. Sources, sinks and doublets. Images. Image of a source (sink) with regard to a plane and a sphere.	54 Mins
5	Image of a doublet with regard to a sphere, Images in two dimensions. Milne-Thomson circle theorem. Blasius theorem.	54 Mins
6	**General Theory of Irrotational Motion:** Flow and circulation. Cyclic and acyclic motions.	54 Mins
7	Impulsive motion. Properties of irrotational motion. Kelvin's theorem of minimum kinetic energy.	54 Mins
8	Motion of a sphere. Liquid streaming past a fixed sphere. Equations of motion of a sphere**.**	54 Mins
9	**Vortex Motion:** Vortex motion and its simple properties. Motion due to circular and rectilinear vortices.	54 Mins
10	Vortex pair and doublet. Karman vortex street.	54 Mins
11	**Viscous Liquid Motion:** Stress components in real fluid. Rate of strain quadric. Stress analysis in fluid motion.	54 Mins
12	Relation between stress and rate of strain. Navier-Stokes' equations.	54 Mins
13	Plane Poiseuille and Couette flow between two parallel plates.	54 Mins

Block II: Stochastic Processes; Marks 40 (SEE: 30; IA: 10)		
14	Review of Probability: Random variables, conditional probability and independence,	54 Mins
15	Bivariate and multi-variate distributions.	54 Mins
16	Probability generating functions, characteristic functions, convergence concepts.	54 Mins
17	**Conditional Expectation:** Conditioning on an event, conditioning on a discrete random variable, conditioning on an arbitrary random variable, conditioning on a sigma-field.	54 Mins
18	**The Random Walk:** unrestricted random walk, types of stochastic processes, gambler's ruin problem, generalisation of the random walk model.	54 Mins
19	**Markov Chains:** Definitions, Chapman-Kolmogorov equation, Equilibrium distributions, Classification of states, Long-time behaviour. Stationary distribution. Branching process	54 Mins
20	Stochastic process in continuous time: Poisson process and Brownian motion.	54 Mins
Total		18 Hours

References:

Block I:

1. F. Chorlton: Textbook of Fluid Dynamics.
2. A.S. Ramsey: A Treatise on Hydromechanics Part II.
3. G. K. Batchelor**:** An Introduction to Fluid Dynamics.
4. L. D. Landau and E. M. Lipschitz**:** Fluid Mechanics.

Block II:

1. Modern Probability Theory: B. R. Bhat.
2. Elementary Probability Theory and Stochastic Processes: K. L. Chung.
3. An Outline of Statistical Theory (Vol 1 and 2): A. M. Goon, M. K. Gupta &B. Dasgupta.
4. An Introduction to Multivariate Statistical Analysis: T. W.Anderson.
5. Introduction to Stochastic Processes: Hoel, Port, Stone
6. Stochastic Processes: Sheldon M. Ross
7. Stochastic Processes: J. Medhi.

DSE 2.4 (PureStream)

Marks: 100; Credits: 6

Unit	Topic	Counselling

		Duration
Block I: Differential Geometry II; Marks 50 (SEE: 40; IA: 10)		
1	Curves in the plane and space, surfaces in three-dimension, Smooth surface	54 Mins
2	Tangents and derivatives, normal and orientability, Examples of surfaces.	54 Mins
3	The first fundamental form, Length of curves on surfaces	54 Mins
4	Isometries of surfaces, Conformal mapping of surfaces	54 Mins
5	Curvature of surfaces, The second fundamental form, The Gauss and Weingarten map	54 Mins
6	Normal and geodesic curvatures, Parallel transport and covariant derivative.	54 Mins
7	Gaussian, mean and principal curvatures	54 Mins
8	Gauss Theorem Egregium, Minimal surface	54 Mins
9	The Gauss Bonnet Theorem. Abstract differentiable manifolds and examples, Tangent Spaces	54 Mins
10	Continuation of Unit 9	54 Mins
Block II: Topology II; Marks 50 (SEE: 40; IA: 10)		
11	Connectedness: Examples, various characterizations and basic properties. Connectedness on the real line.	54 Mins
12	Components and quasi components. Path connectedness and path components.	54 Mins
13	Compactness: Characterizations and basic properties of compactness, Lebesgue, lemma. Sequential compactness	54 Mins
14	BW Compactness and countable compactness. Local compactness and Baire Category Theorem.	54 Mins
15	Identification spaces: Constructing a Mobius strip, identification topology, Orbit spaces.	54 Mins
16	Continuation of Unit 15	54 Mins
17	Some Matrix Lie Groups: Some elementary properties of topological groups.	54 Mins
18	*GL(n,R)* as a topological group and its subgroups.	54 Mins
19	Fundamental groups, calculation of fundamental group of S.	54 Mins
20	Continuation of Unit 19	54 Mins
Total		18 Hours

References:

Block I:

1. Munkres: Analysis on manifolds,
2. Andrew Pressley: Elementary Differential Geometry.
3. M. P. DoCarmo: Differential Geometry of curves and surfaces.
4. Christian Bar: Differential geometry.

5. Nirmala Prakash: Differential geometry.
6. L. W. Tu: Introduction to manifolds.
7. J. M. Lee: Differentiable manifoldfs.

Block II:

1. M. A. Armstrong, Basic Topology, Springer (India), 2004,
2. J.R. Munkres, Topology, 2nd Ed., PHI (India), 2002,
3. J. M. Lee: Introduction to topological Manifolds,
4. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw- Hill, New York, 1963.
5. A basic course in algebraic topology, Massey
6. Allen Hatcher, Algebraic topology.

GEC2.5

Marks: 100; Credits: 4

Unit	Topic	Counselling Duration
Block I: History of Mathematics; Marks 25 (SEE: 20; IA: 5)		
1	Babylonian and Egyptian mathematics, Greek mathematics, Pythagoras, Euclid and the elements of geometry, Archimedes, Apollonius	45 Mins
2	Development of Trigonometry, Development of Algebra, Development of Analytic Geometry	45 Mins
3	Development of Calculus, Development of Selected Topics of Modern Mathematics.	45 Mins
4	Development of Modern geometries, Modern algebra, Methods of real analysis.	45 Mins
Block II: Operations Research; Marks 25 (SEE: 20; IA: 5)		
5	Formulation of linear programming models. Graphical solution. Basic solution (BS) and Basic Feasible Solution (BFS), Degenerate and non-degenerate BFS, Convex set, convex hull, convex polyhedron, extreme points, hyper plane.	45 Mins
6	Standard form of LPP. Simplex method. Charnes' Big – M method.	45 Mins
7	Transportation and assignment problems.	45 Mins
8	A brief introduction to PERT and CPM, Components of PERT/CPM Network and precedence relationships, Critical	45 Mins

	path analysis.	
Block III: Matrices and Linear Algebra; Marks 25 (SEE: 20; IA: 5)		
9	Matrix: definition, order, symmetric and skew symmetric matrices.	45 Mins
10	Determinant of a matrix, elementary properties of determinants, inverse of a matrix, normal form of a matrix, rank of a matrix.	45 Mins
11	Elementary concept of a vector space, linear dependence and independence of vectors, basis of a vector space, row space, column space, solution of system of linear equations, Cramar's rule.	45 Mins
12	Eigen values and Eigen vectors of matrices, Cayley Hamilton Theorem, Diagonalization of matrices.	45 Mins
Block IV: Theory of Dynamical Systems; Marks 25 (SEE: 20; IA: 5)		
13	Linearization of dynamical systems: Two, three and higher dimension. Population growth. Lotka-Volterra system.	45 Mins
14	Stability: Asymptotic stability (Hartman's theorem), Global stability (Liapunov's second method).	45 Mins
15	Limit set, attractors, periodic orbits, limit cycles. Bendixon criterion, Dulac criterion, Poincare-Bendixon Theorem. Floquet's theorem.	45 Mins
16	Stability and bifurcation: Routh-Hurwitz criterion for nonlinear systems. Saddle-Node, transcritical and pitchfork bifurcations. Hopf- bifurcation.	45 Mins
Total		12 Hours

References:

Block I:

1. J.H. Eves: An Introduction to the History of Mathematics, Saunders, 1990.

2. Clifford A. Pickover: The Math Book: From Pythagoras to the 57th Dimension, 250 Milestones in the History of Mathematics (Sterling Milestones) Paperback –February 7, 2012.

3. Carl B. Boyer and Uta C. Merzbach: A History of Mathematics 3rd Edition.

4. Jacqueline Stedall: The History of Mathematics: A Very Short Introduction 1st Edition.

5. D.M. Burton: The History of Mathematics, Allyn and Bacon, 5th edition.

6. Dirk J. Struik: A Concise History of Mathematics: Fourth Revised Edition (Dover Books on Mathematics) 4th Edition.

7. Florian Cajori: A History of Mathematics (Paperback).

Block II:

1. H.A. Taha: Operations Research

2. J.G. Chakraborty and P.R. Ghosh: Linear Programming and Game Theory
3. P.K. Gupta and D.S. Hira: Operations Research
4. K. Swarup, P. K. Gupta and Man Mohan: Operations Research.

Block III:

1. I. N. Herstein: Topics in Algebra.

2. K. Hoffman and R. Kunze: Linear Algebra.

3. S. K. Mapa: Higher Algebra

4. Kumaresan: Linear Algebra

Block IV:

1. L. Perko: Differential Equations and Dynamical Systems, Springer Verlag.

2. F. Verhulust: Nonlinear Differential Equations and Dynamical Systems, Springer.

3. S.H. Strogatz: Nonlinear Dynamics and Chaos.

4. M. Lakshmanan, S. Rajasekar: Nonlinear Dynamics-Integrability, Chaos and Patterns.

Semester III

COR 3.1

Marks: 100; Credits: 6

Unit	Topic	Counselling Duration
Block I: Linear Algebra; Marks 40 (SEE: 30; IA: 10)		
1	**Matrices over a field:** Matric polynomial, eigen values and eigen vectors, minimal polynomial.	54 Mins
2	**Linear Transformation (L.T.):** Brief overview of L.T., Rank and Nullity of L.T.,	54 Mins
3	Dual space, dual basis, Representation of L.T. by matrices, Change of basis.	54 Mins
4	**Normal forms of matrices:** Triangular forms, diagonalization of matrices	54 Mins
5	Smith's normal form, Invariant factors and elementary divisors,	54 Mins
6	Jordan canonical form, Rational (or Natural Normal) form.	54 Mins
7	**Inner Product Spaces**: Inner product and Norms. Adjoint of a linear operator, Normal, self adjoint, unitary, orthogonal operators and their matrices.	54 Mins
8	**Bilinear and Quadratic forms**: Bilinear forms, quadratic forms,Reduction and classification of quadratic forms, Sylvester's law of Inertia.	54 Mins
Block II: Special Functions; Marks 25 (SEE: 20; IA: 05)		
9	**Legendre Polynomial**: Generating function, Recurrence relations, Rodrigue's formula, Orthogonal property. Schlafli's integral formula. Laplace's first and second integral formula. Construction of Legendre differential equation.	54 Mins
10	**Bessel's function**: Generating function, Recurrence relation, Representation for the indices ½, -1/2, 3/2 and -3/2. Bessel's integral equation. Bessel's function of second kind.	54 Mins
11	**Hermite Polynomial**: Generating function, Recurrence relations, Rodrigue's formula, Orthogonal property. Construction and solution of Hermite differential equation.	54 Mins
12	**Laguerre Polynomial**: Generating function, Recurrence relations, Rodrigue's formula, Orthogonal property. Construction and solution of Laguerre differential equation.	54 Mins
13	**Chebyshev Polynomial**: Definition, Series representation, Recurrence relations, Orthogonal property. Construction and solution of Chebyshev differential equation.	54 Mins
Block III: Integral Equations and Integral Transformations;		

Marks 35 (SEE: 30; IA: 05)		
14	**Integral Equation:** Symmetric, separable, iterated and resolvent kernel, Fredholm and Voltera integral equation & their classification, integral equation of convolution type, eigen value &eigen function, method of converting an initial value problem (IVP) into a Voltera integral equation, method of converting a boundary value problem (BVP) into a Fredholmintegral equation.	54 Mins
15	Homogeneous Fredholm integral equation of the second kind with separable or degenerate kernel; classical Fredholm theory-Fredholm alternative, Fredholm theorem.	54 Mins
16	**Method of successive approximations:** Solution of Fredholm and Voltera integral equation of the second kind by successive substitutions & Iterative method (Fredholm integral equation only), reciprocal function, determination of resolvent kernel and solution of Fredholm integral equation.	54 Mins
17	**Hilbert-Schmidt theory:** Orthonormal system of function, fundamental properties of eigen value and function for symmetric kernel, Hilbert theorem, Hilbert-Schmidt theorem.	54 Mins
18	**Integral Transform:** Laplace transforms of elementary functions & their derivatives and Dirac-delta function, Laplace integral, Lerch's theorem (statement only), property of differentiation, integration and convolution, inverse transform, application to the solution of ordinary differential equation, integral equation and BVP.	54 Mins
19	**Fourier Transform:** Fourier transform of some elementary functions and their derivatives, inverse Fourier transform, convolution theorem & Parseval's relation and their application, Fourier sine and cosine transform;	54 Mins
20	Hankel Transform**,** inversion formula and Finite Hankel transform, solution of two-dimensional Laplace and one-dimensional diffusion & wave equation by integral transform.	54 Mins
Total		18 Hours

References:

Block I:

1. I. N. Herstein**:** Topics in Algebra.
2. K. Hoffman and R. Kunze**:** Linear Algebra.
3. J. H. Kwak and S. Hong**:** Linear Algebra.
4. E. D. Nering: Linear Algebra and Matrix Theory.
5. T. S. Blyth: Module Theory.
6. I. S. Luthar and I. B. S. Passi**:** Modules.

Block II:

1. N. N. Lebedev**:** Special Functions and Their Applications.

2. I. N. Sneddon: Special Functions of Mathematical Physics and Chemistry.
3. E. D. Rainville: Special Function

Block III:

1. M. D. Raisinghania: Integral Equations and Boundary Value Problems.
2. R. P. Kanwal: Linear Integral Equations.
3. S. G. Michelins: Linear Integral Equations.
4. D. V. Wider: The Laplace Transforms.
5. P. J. Collins: Differential and Integral Equations.
6. H. S. Carslaw and J. C. Jaeger: Operational Methods in Applied Mathematics.
7. I. G. Petrovsky: Lectures on the Theory of Integral Equations.
8. R. V. Churchill: Operational Mathematics.
9. L. Debnath and D. Bhatta: Integral Transforms and Their Applications.
10. I. N. Sneddon: The Use of Integral Transforms.
11. B. Davies: Integral Transforms and Their Applications.
12. A. M. Wazwaz: A First Course in Integral Equations.
13. N. V. Mclachlan: Operational Calculus.

COR 3.2

Marks: 100; Credits: 6

Unit	Topic	Counselling Duration
Block I: Calculus of $\mathbb{R}^n$; Marks 50 (SEE: 40; IA: 10)		
1	Differentiation on R^n: Directional derivatives and continuity, the total derivative and continuity,	54 Mins
2	Total derivative in terms of partial derivatives, the matrix transformation of $T: R^n \to R^n$. The Jacobian matrix.	54 Mins
3	The chain rule and its matrix form. Mean value theorem for vector valued function. Mean value inequality.	54 Mins
4	A sufficient condition for differentiability. A sufficient condition for mixed partial derivatives.	54 Mins
5	Functions with non-zero Jacobian determinant, the inverse function theorem, the implicit function theorem as an application of Inverse function theorem.	54 Mins
6	Extremum problems with side conditions – Lagrange's necessary conditions as an application of Inverse function theorem.	54 Mins
7	Integration on R^n: Integral of $f: A \to R$when $A \subset R^n$is a closed rectangle.	54 Mins
8	Conditions of inerrability. Integrals of $f: C \to R, C \subset R^n$is not a rectangle, concept of Jordan measurability of a set in R^n.	54 Mins
9	Fubini'stheorem for integral of $f: A \times B \to R, A \subset R^n$, $B \subset R^n$are closed rectangles.	54 Mins

10	Fubini's theorem for $f: C \to R, C \subset A \times B,$ Formula for change of variables in an integral in R^n .	54 Mins
	Block II: Fuzzy Set Theory; Marks 25 (SEE: 20; IA: 05)	
11	Interval Arithmetic: Interval numbers, arithmetic operations on interval numbers, distance between intervals, two level interval numbers	54 Mins
12	Basic concepts of fuzzy sets: Types of fuzzy sets, -cuts and its properties, representations of fuzzy sets,	54 Mins
13	Decomposition theorems, support, convexity, normality, cardinality, standard set-theoretic operations on fuzzysets, Zadeh's extension principle.	54 Mins
14	Fuzzy Relations: Crisp versus fuzzy relations, fuzzy matrices and fuzzy graphs, composition of fuzzy relations,relational join, binary fuzzy relations.	54 Mins
15	Fuzzy Arithmetic: Fuzzy numbers, arithmetic operations on fuzzy numbers (multiplication and division on $\mathbb{R}^+$only), fuzzy equations.	54 Mins
	Block III: Calculus of Variations; Marks 25 (SEE: 20; IA: 05)	
16	**Variational Problems with fixed Boundaries:** Variation, Linear functional, Euler-Lagrange equation, Functionals dependent on higher order derivatives, Functionals dependent on functions of several variables	54 Mins
17	Applications of Calculus of variations on the problems of shortest distance, minimum surface of revolution, Brachistochrone problem, geodesic etc. Isoperimetric problem.	54 Mins
18	**Variational Problems with Moving Boundaries:** Transversality conditions, Orthogonality conditions, Functional dependent on two functions, One sided variations.	54 Mins
19	**Sufficient Conditions for an Extremum:** Proper field, Central field, Field of extremals, Embedding in a field of extremals and in a central field	54 Mins
20	Sufficient condition for extremum-Weirstrass condition, Legendre condition. Weak and strong extremum.	54 Mins
Total		18 Hours

References:

Block I:

1. T. M. Apostol**:** Mathematical Analysis.
2. M. Spivak**:** Calculus on Manifolds.
3. W. Rudin**:** Principles of Mathematical Analysis

Block II:

1. Fuzzy Sets and Fuzzy Logic *Theory and Applications*: G.J. Klir and B. Yuan.
2. Introduction to Fuzzy Arithmetic *Theory and Applications:* A. Kaufmann and M.M. Gupta.
3. Fuzzy Set Theory: R. Lowen.
4. Fuzzy Set Theory and Its Applications: H.-J. Zimmermann.
5. Fuzzy Set, Fuzzy Logic, Applications: G. Bojadziev and M. Bojadziev.

Block III:

1. A.S. Gupta: Calculus of Variations with Applications, Prentice –Hall of India.
2. I.M. Gelfand and S.V. Fomin, Calculus of Variations, Prentice Hall Inc.
3. L. Elsgolts: Differential equations and the Calculus of Variations.

DSE 3.3 (AppliedStream)

Marks: 100; Credits: 6

Unit	Topic	Counselling Duration
Block I: Modelling of Biological Systems; Marks 50 (SEE: 40; IA: 10)		
1	**Mathematical models in ecology:** Discrete and Continuous population models for single species. Logistic models and their stability analysis. Stochastic birth and death processes.	54 Mins
2	**Continuous models for two interacting populations:** Lotka-Volterra model of predator -prey system, Kolmogorov model. Trophic function. Gauss's Model.	54 Mins
3	Leslie-Gower predator-prey model. Analysis of predator-prey model with limit cycle behavior, parameter domains of stability. Nonlinear oscillations in predator-prey system.	54 Mins
4	**Deterministic Epidemic Models:** Deterministic model of simple epidemic, Infection through vertical and horizontal transmission, General epidemic- Kermack-Mckendrick Threshold Theorem.	54 Mins
5	**Delay Models**: Discrete and Distributed delay models. Stability of population steady states.	54 Mins
6	**Spatial Models**: Formulating spatially structured models. Spatial steady states: Linear and nonlinear problems. Models of spread of population.	54 Mins
7	**Blood flow models:** Basic concepts of blood flow and its special characteristics. Application of Poiseulle's law to the study of bifurcation in an artery.	54 Mins
8	Pulsatile flow of blood in rigid and elastic tubes. Aortic	54 Mins

	diastolic-systolic pressure waveforms. Moen-Korteweg expression for pulse wave velocity in elastic tube. Blood flow through artery with mild stenosis.	
9	**Models for other fluids:** Peristaltic motion in a channel and in a tube. Two dimensional flow in renal tubule. Lubrication of human joints.	54 Mins
10	**Models in Pharmacokinetics:** Compartments, Basic equations, single and two compartment models.	54 Mins
Block II: Dynamical Systems; Marks 50 (SEE: 40; IA: 10)		
11	**Autonomous and non-autonomous systems:** Orbit of a map, fixed point, equilibrium point, periodic point, circular map, configuration space and phase space.	54 Mins
12	Nonlinear oscillators-conservative system. Hamiltonian system. Various types of oscillators in nonlinear system viz. simple pendulum, and rotating pendulum.	54 Mins
13	**Limit cycles:** Poincaré-Bendixon theorem (statement only). Criterion for the existence of limit cycle for Liénard's equation.	54 Mins
14	**Stability:** Definition in Liapunov sense. Routh-Hurwitz criterion for nonlinear systems.	54 Mins
15	Liapunov's criterion for stability. Stability of periodic solutions. Floquet's theorem.	54 Mins
16	**Solutions of nonlinear differential equations by perturbation method:** Secular term. Nonlinear damping.	54 Mins
17	Solutions for the equations of motion of a simple pendulum, Duffing and Vanderpol oscillators.	54 Mins
18	**Bifurcation Theory:** Origin of Bifurcation, Bifurcation Value, Normalisation, Resonance, Stability of a fixed point.	54 Mins
19	Bifurcation of equilibrium solutions – the saddle node bifurcation, the pitch-fork bifurcation, Hopf-bifurcation.	54 Mins
20	**Randomness of orbits of a dynamical system:** The Lorentz equations, Chaos, Strange attractors.	54 Mins
Total		18 Hours

References:

Block I:

1. K. E. Watt**:** Ecology and Resource Management-A Quantitative Approach.
2. R. M. May**:** Stability and Complexity in Model Ecosystem.
3. Y. M. Svirezhev and D. O. Logofet**:** Stability of Biological Communities.
4. A. Segel**:** Modelling Dynamic Phenomena in Molecular Biology.
5. J. D. Murray**:** Mathematical Biology. Springer and Verlag.
6. N. T. J. Bailey**:** The Mathematical Approach to Biology and Medicine.

7. L. Perko (1991): Differential Equations and Dynamical Systems, Springer Verlag.
8. F. Verhulust (1996): Nonlinear Differential Equations and Dynamical Systems, Springer Verlag.
9. H. I. Freedman - Deterministic Mathematical Models in Population Ecology.
10. Mark Kot (2001): Elements of Mathematical Ecology, Cambridge Univ. Press
11. Fung, Y.C.: Biomechanics.

Block II:

1. D. W. Jordan and P. Smith: Nonlinear Ordinary Differential Equations.
2. F. Verhulst: Nonlinear Differential Equations and Dynamic Systems.
3. R. L. Davaney: An Introduction to Chaotic Dynamical Systems.
4. P. G. Drazin: Non-linear Systems.
5. K. Arrowsmith: Introduction to Dynamical Systems.
6. C. Havyshi: Nonlinear Oscillations in Physical Systems.
7. A. H. Nayfeh and D. T. Mook: Nonlinear Oscillations.
8. V. I. Arnold: Dynamical Systems V-Bifurcation Theory and Catastrophy Theory.
9. V. I. Arnold: Dynamical Systems III – Mathematical Aspects of Classical and Celestial Mechanics

DSE 3.3 (PureStream)

Marks: 100; Credits: 6

Unit	Topic	Counselling Duration
Block I: Operator Theory; Marks 50 (SEE: 40; IA: 10)		
1	**Conjugate Space:** Definition of conjugate space, determination of conjugate spaces of R^n, l_p for $1 \leq p < \infty$. Representation theorem for bounded linear functionals on C$[a, b]$(Statement only). Some idea about the spaces $BV[a, b]$ and $B[a, b]$ Determination of conjugate spaces of C$[a, b]$ and some other finite and infinite dimensional spaces.	54 Mins
2	**Weak convergence and weak* convergence**: Definition, characterization of weak convergence and weak* convergence, sufficient condition for the equivalence of weak* convergence and weak convergence in the dual space.	54 Mins
3	**Reflexive spaces:** Definition of reflexive space, canonical mapping, relation between reflexivity and separability, some consequences of reflexivity.	54 Mins
4	Bounded linear operator, uniqueness theorem, adjoint of an operator and its properties.	54 Mins
5	Self-adjoint, compact, normal, unitary and positive operators, norm of self -adjoint operator, group of unitary operator, square root of positive operator-characterization and basic properties,	54 Mins
6	Projection operator and their sum, product &permutability, invariant subspaces, closed linear transformation, closed graph theorem and open mapping theorem.	54 Mins
7	**Unbounded operator:** Basic properties, Cayley transform,	54 Mins

	change of measure principle, spectral theorem.	
8	**Compact map:** Basic properties, compact symmetric operator, Rayleigh principle, Fisher's principle, Courant's principle, Mercer's theorem, positive compact operator.	54 Mins
9	**Strongly continuous semigroup:** Strongly continuous semigroup of operator and contraction, infinitesimal generator,	54 Mins
10	Hille-Yosida theorem, Lumer-Phillips lemma, Trotter's theorem, Stone's theorem.	54 Mins
Block II: Measure Theory; Marks 50 (SEE: 40; IA: 10)		
11	**Measures:** Class of Sets, Measures, The extension Theorems and Lebesgue-Stieltjes measures,	54 Mins
12	Caratheodory extension of measure, Completeness of measure.	54 Mins
13	**Integrations:** Measurable transformations, Induced measures, distribution functions, Integration, More on Convergency.	54 Mins
14	Product of two measure spaces. Fubini's theorem.	54 Mins
15	Lp-spaces: Lp-Spaces, Dual spaces,	54 Mins
16	Banach and Hilbert spaces.	54 Mins
17	**Decomposition and Differentiations:** Signed and Complex Measures	54 Mins
18	The Lebesgue-Radon-Nikodym theorem	54 Mins
19	Differentiation on absolute Continuity, Lebesgue differentiation Theorem,	54 Mins
20	Functions of Bounded variations, Riesz representation Theorem.	54 Mins
Total		18 Hours

References:

Block I:

1. R. F. Bass: Functional Analysis.
2. A. E. Taylor: Introduction to Functional Analysis.
3. E. Kreyszing: Introductory Functional Analysis with Applications.
4. B. V. Limaye: Functional Analysis.
5. A. N. Kolmogorov and S. V. Fomin: Elements of the Theory of Functions and Functional Analysis.
6. P. K. Jain: Functional Analysis.
7. C. Bachman and L. Narici: Functional Analysis.
8. B. K. Lahiri: Elements of Functional Analysis.
9. W. Rudin: Functional Analysis.
10. S. K. Berbarian: Introduction to Hilbert Spaces.
11. G. F. Simons: Introduction to Topology and Analysis.

Block II:

1. K. B. Athreya and S. Lahiri: Measure Theory.
2. G. B. Folland: Real analysis, Mordern Techniques and their applications.

3. Stein and Sakarchy: Real Analysis,
4. T. Tao: Introduction to measure theory.

SEC 3.4

Computer Programming in C (Practical)

Marks: 50; Credits: 4

Sl No.	Topic
Group A	
1	Program to find the summation of natural numbers up to a given number
	Program to evaluate the factorial of a given number
	Program to generate all the terms of Fibonacci Series up to a certain number
	Program to test whether a number is prime or not
2	Program for computation of the exponential series
	Program for computation of the sine series
	Program for computation of the roots of a quadratic equation
	Program to compute addition of two matrices
	Program compute the multiplication of two matrices
	Program to find the bubble sorting of some given numbers
Group B	
3	Program to compute the least square approximate of a set of numbers
	Program to compute the root of a given real function by Newton Raphson method correct upto 5 decimal places
4	Program to compute a given integral using three point Gaussian Quadrature
	Program to compute a given integral using Romberg formula
5	Program to find the numerically largest eigen value and the corresponding eigen vector of a matrix
6	Program to find the solution of an initial value problem using Euler's Method
	Program to find the solution of an initial value problem using RK-4 Method
	Program to find the solution of first order ODE by Milne’s predictor-corrector method

Practical Examination Related Criteria:

(i) Laboratory clearance should be taken by the students prior to commencement of Practical Examination.

(ii) The Lab Assignment Dissertations of the students should be submitted prior to commencement of Practical Examination.

(iii) Duration of practical examination will be 3 (Three) hours.

(iv) One External Examiner will be appointed by the Department for the Practical Examination.

References:

Group A:

1. Programming in ANSI C: E. Balaguruswamy.
2. Let Us C: Y. Kanetkar.
3. Programming in C Language: B. S. Gottfred.
4. Mastering Algorithm in C: K. Loudon.
5. The C Programming Language:B.W. Kernighan and D. Ritchie.
6. C by Example: N. Kalicharan.

Group B:

1. Balagurusamy, E. – Programming in ANSI C
2. Y. Kanetkar – Let Us C
3. B. S. Gottfred – Programming in C Language
4. C. K. Loudon – Mastering Algorithm in.
5. B.W. Kernighan and D. Ritchie – The C Programming Language
6. N. Kalicharan – C by Example
7. F. Scheid – Theory and Problems of Numerical Analysis.
8. C. Xavier – C Language and Numerical Methods.
9. E. Balagurusamy – Computer Oriented Statistical and Numerical Methods.
10. D. C. Sanyal, and K. Das – A Text Book of Numerical Analysis.
11. A. K. Mukhopadhyay – Introduction to Numerical Methods with Computer Programming.
12. M. K. Jain, S. R. K. Iyengar and R. K. Jain,– Numerical Methods for Scientific and Engineering Computation.

Semester IV

COR 4.1

Marks: 100; Credits: 6

Unit	Topic	Counselling Duration
Block I: Discrete Mathematics; Marks 60 (SEE: 50; IA: 10)		
1	Graph Theory: Definition of graphs, circuits, cycles, Subgraphs, induced subgraphs, degree of a vertex, Connectivity.	54 Mins
2	Trees, Euler's formula for connected graphs, Spanning trees, Complete and complete bipartite graphs.	54 Mins
3	Planar graphs and their properties, Fundamental cut set and cycles. Matrix representation of graphs,	54 Mins
4	Kuratowski's theorem (statement only) and its use, Chromatic index, chromatic numbers and stability numbers.	54 Mins
5	Lattices: Lattices as partialordered sets. Their properties. Lattices as algebraic system.	54 Mins
6	Sublattices. Direct products and Homomorphism. Some special Lattices e.g. complete complemented and distributed lattices.	54 Mins
7	Boolean Algebra Basic Definitions, Duality, Basic theorems, Boolean algebra as lattices.	54 Mins
8	Boolean functions, Sum and Product of Boolean algebra, Minimal Boolean Expressions, Prime implicants Propositions and Truth tables.	54 Mins
9	Logic gates and circuits, Applications of Boolean Algebra to Switching theory (using AND, OR, & NOT gates), Karnaugh Map method.	54 Mins
10	Combinatorics: Introduction, Basic counting principles, Permutation and combination, pigeonhole principle, Recurrence relations and generating functions.	54 Mins
11	Grammar and Language: Introduction, Alphabets, Words, Free semi group, Languages,	54 Mins
12	Regular expression and regular languages. Finite Automata (FA). Grammars.	54 Mins
13	Finite State Machine. Non-deterministic and deterministic FA. Push Down Automation (PDA).	54 Mins
14	Equivalence of PDAs and Context Free Languages (CFLs), Computable Functions.	
Block II: Probability and Statistical Methods; Marks 40 (SEE: 30; IA: 10)		
15	Fields and σ-fields of events. Probability as a measure. Random variables. Probability distribution.	54 Mins
16	Expectation. Moments. Moment inequalities, Characteristic function. Convergence of sequence of random variables-weak convergence, strong convergence and convergence in distribution,	54 Mins

	continuity theorem for characteristic functions. Weak and strong law of large numbers. Central Limit Theorem.	
17	Definition and classification of stochastic processes. Markov chains with finite and countable state space, classification of states.	54 Mins
18	Statistical Inference, Estimation of Parameters, Minimum Variance Unbiased Estimator, Method of Maximum Likelihood for Estimation of a parameter.	54 Mins
19	Interval estimation, Method for finding confidence intervals, Statistical hypothesis, Level of significance; Power of the test.	54 Mins
20	Analysis of variance, One factor experiments, Linear mathematical model for ANOVA.	54 Mins
Total		18 Hours

References:

Block I:

1. J. P Tremblay and R. Manohar**:** Discrete Mathematical Structures with Applications to Computers.
2. J. L. Gersting**:** Mathematical Structures for Computer Sciences.
3. S. Lepschutz**:** Finite Mathematics.
4. S. Wiitala: Discrete Mathematics – A Unified Approach.
5. J. E. Hopcroft and J. D. Ullman**:** Introduction to Automata Theory, Languages and Computation.
6. C. L. Liu**:** Elements of Discrete Mathematics.
7. F. Harary**:** Graph Theory.
8. C. Berge**:** The Theory of Graphs and its Applications.
9. N. Deo**:** Graph Theory with Applications to Engineering and Computer Science.
10. K . D. Joshi**:** Foundation of Discrete Mathematics.
11. S. Sahani**:** Concept of Discrete Mathematics.
12. L. S. Levy**:** Discrete Structure in computer Science.
13. J. H. Varlist and R. M. Wilson**:** A course in Combinatorics.
14. J. E. Whitesitt**:** Boolean Algebra and its Applications.
15. G. E. Revesz**:** Introduction to Formal Languages.
16. G. Birkhoff and T. C. Bartee**:** Modern Applied Algebra.
17. K. L. P. Mishra and N. Chandrasekaran**:** Automata, Languages, and Computation
18. G. Gtratzer: Lattice Theory: Foundation.

Block II:

1. P. Billingsley:Probability and Measure, 3 rd Edition, John Wiley & Sons, New York, 1995.
2. J. Rosenthal:A First Look at Rigorous Probability, World Scientific, Singapore, 2000.
3. K. B. Atreya and S.N. Lahiri:Measure Theory and Probability Theory, springer, 2006.
4. A.N. Shiryayev:Probability, 2 nd Edition, Springer, New York, 1995.
5. K.L. Chung:A Course in Probability Theory, Academic Press, New York, 1974.
6. B. R. Bhat.: Modern Probability Theory.
7. K. L. Chung: Elementary Probability Theory and Stochastic Processes.
8. A. M. Goon, M. K. Gupta &B. Dasgupta: An Outline of Statistical Theory (Vol 1 and 2).
9. T. W.Anderson: An Introduction to Multivariate Statistical Analysis.
10. C. R. Rao: Linear Statistical Inference and its Applications:.

Detailed Syllabi for the Optional Courses

DSE4.2 & DSE4.3

Marks: 100; Credits: 6

Optional Courses for both Pure and Applied Streams

ADVANCED OPERATIONS RESEARCH I

Network Analysis– Network definitions, Minimal Spanning Tree Algorithm, Shortest Route Algorithms, Max-flow Min-cut theorem, Genaralized Max-flow Min-cut theorem, linear programming interpretation of Max-flow Min-cut theorem, minimum cost flows.A brief introduction to PERT and CPM, Components of PERT/CPM Network and precedence relationships, Critical path analysis, PERT analysis in controlling project.

Queueing Theory: Basic features of Queueing Systems, Operating characteristics of a Queueing System, Arrival and Departure (birth and death) distributions, Inter-arrival and service times distributions, Transient steady-state conditions in queueing process. Poisson queueing models **:** (M / M / 1) **:** (/ FIFO /) ; (M / M / 1) **:** (N / FIFO /) ; (M / M / C) **:** (/ FIFO /) ; (M / M / C) **:** (N / FIFO /), C N ; (M / M / R) **:** (K / GD / K), R < K– machine servicing model;

Simulation: A brief introduction to simulation, Advantages of simulations over traditional search methods, Limitations of simulation techniques, Computational aspects of simulating a system, random number generation in stochastic simulation, Monte-Carlo simulation and modelling aspects of a system, Simulation approaches to inventory and queueing systems.

Linear Multi-Objective Programming (LMOP) : Conversion of LMOP to linear programming, *Minsum*and *Priority based* Goal Programming (GP) approaches to LMOP problems, Fuzzy Set -Theoretic approaches to GP Problems.

Hierarchical Decision Analysis: Introduction to Bilevel Programming (BLP) and Multilevel Programming (MLP), Fuzzy Programming approaches to BLP problems.

Genetic Algorithms (GAs): Introduction to GAs, Robustness of GAs over traditional search methods. Binary encodings of candidate solutions, Schema Theorem and Building Block Hypothesis, Genetic operators – crossover and mutation, parameters for GAs, Reproduction mechanism for producing Offspring, Darwinian Principle in evaluating objective function, Simple GA schemes, GA approaches to optimization problems.

Reference:

1. Operations Research – K. Swarup, P. K. Gupta and Man Mohan.
2. Operations Research – H. A. Taha.
3. Operations Research – S. D. Sharma.
4. Introduction to Operations Research – A. Frederick, F. S. Hillier and G. J. Lieberman.
5. Optimization Theory and Applications – S. S. Rao.
6. Engineering Optimization**:** Theory and Practice – S. S. Rao
7. Optimization Methods in Operation Research – K. V. Mital.

8. Inventory Control – J. Jonson and D. Montogomer.
9. Analysis of Inventory Systems – G. Haddly and T. M. Within.
10. Queuing Theory – J. A. Panico.
11. Introduction to Theory of Queues – L. Takacs.
12. Linear Programming in Single and Multiple Objective System – J. P. Ignizio.
13. Decisions with Multiple Objectives – R. L. Keeney and H. Raiffs.
14. Linear Goal Programming – M. J. Schniederjans.
15. Linear Multiobjective Programming – M. Zeleny.
16. Multi-objective Programming and Goal Programming**:** *Theory and Applications* – T. Tanino, T. Tanaka and M. Inuiguchi.
17. Multi-objective Programming and Goal Programming**:** *Theory and Applications* – M. Tamiz.
18. Goal Programming and Extensions – J. P. Ignizio.
19. Handbook of Critical Issues in Goal Programming – C. Romero.
20. Fuzzy Multiple Objective Decision Making – Y. J. Lai and C. L. Hwang.
21. Fuzzy Set Theory and its Applications – H. J. Zimmermann.
22. Genetic Algorithms in Search, Optimization and Machine Learning – D. E. Goldberg.
23. An Introduction to Genetic Algorithms – M. Mitchell.
24. Genetic Algorithms – K. F. Man, K. S. Tang and S. Kwong.
25. Genetic Algorithms + Data Structures = Evolution Programs – Z. Michalewicz.
26. Adaptation in Natural and Artificial Systems - J. H. Holland.

ADVANCED OPERATIONS RESEARCH II

Information Theory: Information concept, expected information, Measure of information and characterisation, units of information, bivariate information theory, economic relations involving conditional probabilities, Entropy and properties of entropy function, units of entropy, Joint, conditional and relative entropy, Mutual information, Conditional Mutual information, Conditional relative entropy, Convex-concave function, Information inequality, Log-sum inequality, Channel capacity, Redundancy.

Coding theory: Communication system, encoding and decoding, Shannon-Fano encoding procedure, Haffman encoding procedure, noiseless coding theory, noisy coding, error detection and correction, minimum distance decoding, family of codes, Linear code, Hammimg code, cyclic code, Golay code, BCH codes, Reed-Muller code, perfect code, codes and design, Linear codes and their dual, weight distribution.

Markovian Decision Process: Markov chain, stochastic matrices, Power of stochastic matrices, regular matrices, Ergodic matrices, State transition diagram, imbedded Markov Chain method for Steady State solution.

Reliability theory: Elements of Reliability theory, failure rate, extreme value distribution, analysis of stochastically falling equipments including the reliability function, reliability and growth model, MTTF, Linear increasing hazard rate, System reliability, Series configuration, Parallel configuration, Mixed configuration, Redundancy.

Geometric Programming (GP): Posynomial, Signomial, Degree of difficulty, Unconstrained minimization problems, Solution using Differential Calculus, Solution seeking Arithmetic-Geometric inequality, Primal dual relationship & sufficiency conditions in the unconstrained case, Constrained minimization, Solution of a constrained Geometric Programming problem, Geometric programming with mixed inequality constrains, Complementary Geometric programming.

Theory of Inventory Control: A brief introduction to Inventory Control, Single-item deterministic models without shortages and with shortages, inventory models with price breaks. Dynamic Demand Inventory Models.

Single-item stochastic models without Set-up cost and with Set-up cost.

Multi-item inventory models with the limitations on warehouse capacity, Average inventory capacity, Capital investment.

References:

1. An Introduction to Information Theory – F. M. Reza.
2. Operations Research: An Introduction – P. K. Gupta and D.S. Hira.
3. Graph Theory with Applications to Engineering and Computer Science – N. Deo.
4. Operations Research –K. Swarup, P. K. Gupta and Man Mohan.
5. Coding and Information Theory – Steven Roman.
6. Coding Theory, A First Course – San Ling r choaping Xing.
7. Introduction to Coding Theory – J. H. Van Lint
8. The Theory of Error Correcting Codes – Mac William and Sloane.
9. Information and Coding Theory – Grenth A. Jones and J. Marry Jones.
10. Information Theory, Coding and Cryptography – Ranjan Bose.

FUZZY SETS AND SYSTEMS

Operations on Fuzzy Sets: Fuzzy complements, axioms of fuzzy complements, equilibrium, dual point, characterization theorem of fuzzy complements, increasing and decreasing generators. t-norms, t-conorms, their axioms and corresponding characterization theorems, dual triple.

Fuzzy Relations: Fuzzy equivalence relations, fuzzy Compatibility relations, fuzzy ordering relations, fuzzy morphisms, projections and cylindric extensions.

Defuzzification of Fuzzy Numbers: Definition, Different types of defuzzification techniques.

Fuzzy Logic: A brief review of Classical logic, fuzzy propositions, fuzzy quantifiers, fuzzy inference rules, inferences from fuzzy propositions.

Possibility Theory: Fuzzy measures, evidence theory, belief measures and plausibility measures, possibility theory, necessity measures, possibility measures, possibility distributions, fuzzy sets and possibility theory, possibility theory versus probability theory.

Fuzzy Decision Making: Introduction to decision- making in Fuzzy environment. Individual decision making, multi-person decision making, multicriteria decision making, fuzzy ranking methods, fuzzy linear programming, multiobjective fuzzy programming.

Variants of Fuzzy Sets: Concepts of non-membership, Intuitionistic Fuzzy Sets, Pythagorean Fuzzy Sets, q-rung orthopair fuzzy sets.

References:

1. The Importance of Being Fuzzy – A. Sangalli.
2. Fuzzy Sets and Fuzzy Logic *Theory and Applications* – G. J. Klir and B. Yuan.
3. Introduction to Fuzzy Arithmetic *Theory and Applications* – A. Kaufmann and M. M. Gupta.
4. Fuzzy Sets and Systems – D. Dubois and H. Prade.
5. Fuzzy Set Theory – R. Lowen.
6. A First Course in Fuzzy Logic – H. T. Nguyen and E. A. Walker.
7. Fuzzy Logic – J. E. Baldwin.
8. Fuzzy Set Theory and Its Applications – H. J. Zimmermann.
9. Fuzzy Set, Fuzzy Logic, Applications – G. Bojadziev, M. Bojadziev.
10. Fuzzy Logic for Planning and Decision Making – F. A. Lootsma.

Optional Courses for Applied Stream Only

ADVANCED SOLID MECHANICS

Elastostatics: Orthogonal curvilinear coordinates. Strain and rotation components, dilatation.Equations of motion in terms of dilatation and rotation. Stress equations of motion. Radial displacement.Spherical shell under internal and external pressures, gravitating sphere.Displacement symmetrical about an axis.Cylindrical tube under pressure, rotating cylinder.

Problems of semi-infinite solids with displacements or stresses prescribed on the plane boundary.

Variational methods.Theorems of minimum potential energy.Betti-Raylegh reciprocal theorem.Use of minimum principle in the case of deflection of elastic string of central line of a beam.

Equilibrium of thin plates.Boundary conditions.Approximate theory of thin plates.Application to thin circular plates.

Elastodynamics: Waves in isotropic elastic solid medium. Surface waves, e.g. Rayleigh and Love waves. Kinematical and dynamical conditions in relation to the motion of a surface of discontinuity.Poisson's and Kirchoff's solutions of the characteristic wave equation.

Radial and rotatory vibration of a solid and hollow sphere.Radial and torsional vibration of a circular cylinder.

Transverse vibration of plates, Basic differential equations. Vibration of a rectangular plate with simply supported edges. Free vibration of a circular plate.

Plasticity: Basic concepts and yield criteria. Prandtl-Reyss theory, Stress-strain relations of Von-Mises.Hencky's theory of small deformation.

Torsion of cylindrical bars of circular and oval sections.Bending of a prismatic bar of narrow rectangular cross-section by terminal couple.Spherical and cylindrical shell under internal pressure.Plastic deformation of flat rings.

Slip lines and plastic flow. Plastic mass pressed between two parallel planes.

References:

1. Sokolnikoff I. S**:** Mathematical Theory of Elasticity.
2. Love A.E. H. **:**A Treastise on the Mathematical Theory of Elasticity.
3. Fung Y.C.**:** Foundations of Solid Mechanics.
4. Timoshenko S. and Goodier N**:** Theory of Elasticity.
5. Ghosh. P.K**:** Waves and Vibrations.
6. Prager, N and Hodge, P.G. **:**Theory of Perfectly Plastic Solids.
7. Southwell, R. V**:** Theory of Elasticity.

ADVANCED FLUID MECHANICS

Incompressible fluid: Elementary theory of aerofoils**:** Kutta - Joukowski's theorem. Joukowski's hypothesis.Joukowski's, Karmann-Trefftz and Mises family of profiles.
Theory of discontinuous potential motion.Kirchhof's method of solving problems of two-dimensional motion with free streamlines.Levi - Cevita's method.Concept of a vortex sheet.Karmann's vortex sheet and its stability.Karmann's formula for resistance due to a vortex wake.

Prandtl boundary layer.Boundary layer equations.Blasius solution.Boundary layer parameters.

Compressible fluid: Polytropic gas and its entropy. Adiabatic and isentropic flow.Propagation of small disturbance. Bernoulli's integral. Isentropic flow of a perfect gas.Subsonic and supersonic flow.Mach numbers and critical speeds.Mach lines.Normal and oblique shock waves. Steady isentropic irrotational flow. Prandtl - Maye flow.Hodograph equations, characteristic of steady flow in the real and hodograph plane.

Viscous flow: Navier-Stokes equations in orthogonal curvilinear coordinates. Dissipation of energy.Hydrodynamical theory of lubrication.Principle of similitude.Two – dimensional motion of viscous liquid (equation satisfied by the stream function).Hamel's equation and its solution.Diffusion of vorticity from a line vortex.Stokes and Lamboseen's solutions.Prandtl equation of boundary layer. Steady plane and circular jets.

Turbulent flow: Mean values. Reynolds theory.Mixing length theories. Momentum transfer theory. Taylor's vorticity transfer theory. Karmann's similarity hypothesis.Applications to the solutions of (i) mixing zone between two parallel flows, (ii) motion in a 65 plane jet.Prandtl 1/7power law and its application to turbulent boundary layer over a flat- plate.

References:

1. Goldstein, A**:** Modern Development in Fluid Mechanics (Vol. I & II).
2. Lamb, H.**:** Hydrodynamics.
3. Milne-Thomson, L. M**:** Theoretical Hydrodynamics.
4. Pai, S. I.**:** Viscous Flow Theory (Vol. I & II).
5. Landau L. D. and Lifshitz E. M.: Fluid Mechanics.
6. Schlichting H.**:** Boundary Layer Theory.
7. Young, A. D**:** Boundary Layers.
8. Batchelor, G. K.**:** An Introduction to Fluid Mechanics.
9. Pai, S.I.: Theory of Jets, Turbulent Flow.

COMPUTATIONAL FLUID MECHANICS

A brief Introduction to Computational Fluid Mechanics.

Stationary convection: Diffusion equation (finite volume discretization schemes of positive type, upwind discretization).

Nonstationary convection: Diffusion equation**:** Stability. Discrete maximum principle.

Incompressible Navier-Stokes (NS) equations: Boundary conditions. Spatial and temporal discretization on collocated and on staggered grids.

Iterative method: Stationary methods. Krylov subspace methods. Multigrid methods. Fast position solvers. Iterative methods for incompressible NS equations.

Shallow water equations: One - and two-dimensional cases.

Scalar conservation laws: Godunov's order Barrier Theorem. Linear Schemes.

Euler equation in one space dimension: Analytic aspects. Approximate Riemann solver. Osher scheme. Flux splitting schemes. Stability.James-Schmidt-Turkel scheme. Higher order scheme.

Discretization in general domains: Boundary fitted grids. Equations of motion in general coordinates. Numerical solution of Euler equation in general coordinates. Numerical solution of NS equations in general domains.

Unified methods: computation of compressible and incompressible flow.

References:

1. Wesseling, P**:** Principle of Computational Fluid Dynamics.
2. Anderson, J. D.**:** Principle of Computational Fluid Dynamics;The Basics with Applications.
3. Wendt, J. F., Anderson J. D., Degrez G. and Dick E.**:** Principle of Computational Fluid Dynamics.
4. Ferziger, J. H. and Peric, M.**:** Computational Methods for Fluid Dynamics.

MAGNETO-FLUID MECHANICS

Fundamental equations: Maxwell’s electromagnetic field equations. Basic Magneto-Fluid Dynamics (MFD) equations.Energy conservation equation.Equations for infinitely conducting medium.Lundquist equations.Properties of MFD equations, Magnetic Reynolds number.Boundary conditions.Alfven’s wave.Magnetic body force.Ferraro’s law of isorotation.

Incompressible magneto-hydrodynamic flow: Parallel steady flow. One–dimensional steady viscous flow. Isentropic and homentropic flows. Hartmann and Couette flows.

Characteristics of MFD waves: Characteristic equation. Characteristic determinant.Magneto hydrodynamic waves. Fast, slow, transverse and entropy waves.

MFD shock waves, and Jump relation: The generalized Hugoniot condition. The compressive nature of magneto hydrodynamic shocks.Mach number, Subsonic and supersonic flows.Sub and super Alfvenic waves.

MFD Stability: Normal mode analysis of stability for infinitely conducting, inviscid and incompressible medium. Rayleigh-Taylor and Kelvin -Helmholtz instabilities in presence of horizontal magnetic field.Capillary instability of a jet in presence of axial magnetic field.Stability of pinch. Principle of exchange instability – marginal stability analysis of a layer of fluid heated from below in presence of uniform magnetic field and gravity perpendicular to the boundary.

References:

1. Jeffrey, A.**:** Magneto Hydrodynamics.
2. Cowling, T. G.**:** Magneto Hydrodynamics.
3. Ferraro, V. C. A. and Plumpton. C.**:** An Introduction to Magnetofluid Mechanics.
4. Pai, S. I**:** Magnetogas Dynamics and Plasma Dynamics.
5. Cramer, K. R. and Pai S. I.**:** Magnetofluid Dynamics for Engineers and Physicists.
6. Shercliff, J. A.**:** Magnetohydrodynamics.
7. Bansal, J. L.**:** Magnetofluid Dynamics of Viscous Fluids.

PLASMA PHYSICS

Field of a moving point charge: Radiation from an accelerated charge. Radiation power.Damping force of radiation.Lagrangian and Hamiltonian for the motion of a charge particle in electromagnetic field.

Non-relativistic motion: Non–relativistic motion of charged particles in electric and magnetic fields. Gradient and curvature drifts.

Basic Plasma properties: Waves in unmagnetized and cold magnetized Plasmas. Radiation from plasma-the Bremsstratilung and Synchrotron radiation.Stream instabilities in cold plasma.

Collision processes in plasmas: Two-body elastic collisions. Two-particle Coulomb interaction.Tomson and Rayleigh scattering.Cerencov radiation.

Small amplitude waves in plasmas: Linearized equations. Anisotropy of magnetized plasmas.Appleton-Hartree equation.Dielectric and conductivity tensors.Electromagnetic field in dissipative plasmas.

Kinetic approach-Linearized Vlasov equations: Small amplitude Oscillations- Landau damping.

Derivation of MHD equations: General properties, e.g. generalization of Bernoulli's and Kelvin's theorems, diamagnetic drifts and currents. Double-adiabatic theory for collisionless plasma- the Chew-Goldberger-low (CGL) equations.

Space and astrophysical plasmas: Structuring of plasmas in solar system and magnetospheres. Magnetic reconnections.Double layers and particle acceleration.Solar wind-magnetosphere-Ionosphere intersection.Solar wind intersection with smaller bodies.

Dusty plasmas: Dusty plasmas and the role of dust in stellar environment, galactic and planetary systems.

References:

1. Jackson, J. D**:** Classical Electrodynamics.
2. Jones, D. S**:** Theory of Electromagnetism.
3. Landau, L. D. and Lifshitz E. M**:** Classical Theory of Fields.
4. Panofsky, W. K. H. and Philips M**:** Classical Theory of Fields.
5. Kompanoyets, A.S**:** Theoretical Physics.
6. Alfven, H. and Falthamman, C. A**:** Cosmical Electrodynamics.
7. Chandrasekher, S**:** Plasma Physics.
8. Thomson, W.B**:** An Introduction to Plasma Physics.
9. Clemmow, P.C. and Dougherty J. P**:** Electrodynamics of Particles and Plasma.
10. Chakraborty, B**:** Principles of Plasma Mechanics.

MATHEMATICS OF FINANCE & INSURANCE

Mathematics of Finance (SEE: 40; IA: 10)

Financial derivatives: An introduction. Types of financial derivatives – forwards and futures.Option and its kinds; and SWAPS. The Arbitrage Theorem and Introduction to Portfolio selection and capital Market Theory**:** Static and Continuous – Time model.

Pricing by Arbitrage: A single –period option pricing model; Multi – period pricing model – Cox – Ross – Rubinstein model; Bounds on option prices. The Ito's lemma and the Ito's integral.

Dynamics of derivative prices: Stochastic differential equations (SDEs) –Major models of SDEs, Linear constant coefficient SDEs, Geometric SDEs, Square root process, Mean reverting process and Omstein- Uhlenbeck process.

Martingale measures and risk-neutral probabilities: Pricing of binomial options with equivalent martingle measures.

The Black-Scholes option pricing: Model with no arbitrage approach, limiting case of binomial option pricing and risk –neutral probabilities.

The American Option pricing: Extended trading strategies. Analysis of American put options; early exercise premium and relation of free boundary problem.

Mathematics of Insurance (SEE: 40; IA: 10):

Concepts from insurance: Introduction. The claim number process.The claim size process.Solvability of the portfolio. Reinsurance and ruin problem.

Premium and ordering of risks: Premium calculation principles and ordering distributions.

Distribution of aggregate claim amount: Individual and collective model. Compound distribution. Claim number of distribution. Recursive computation methods.Lundberg bounds and approximation by compound distributions.

Risk processes: Time-dependent risk models. Poisson arrival processes. Ruin probabilities and bounds asymptotic and approximation.

Time dependent risk models: Ruin problems and computations of ruin functions. Dual queuing models in continuous time and numerical evaluation of ruin functions.

References:

1. Hull, J. C. – Options, Futures and other Derivatives.
2. Ross, S. M. – An Introduction to Mathematical Finance.
3. Neftci, S. N. – An Introduction to Mathematical Financial Derivatives.
4. Elliott, R. J. and Kopp, P. E. – Mathematics of Financial Markets.

5. Merton, R. C. Continuous – Time Finance.
6. Daykin, C. D., Pentikainen, T. and Pesonen, M. – Practical Risk Theory for Actuaries.
7. Rolski, T., Schmidli, H., Schmidt, V. and Teugels, J. – Stochastic Processes for Insurance and Finance.

SEISMOLOGY

Vibrations and Waves: Theory of elastic waves in perfectly elastic media. Vibration and waves.Seismological considerations. Plane waves Standing waves. Dispersion of waves.Energy in plane wave motion.General solution of wave equation.

Bodily elastic waves: P wave (P-Wave) and Secondary wave (S- waves). The effect of gravity fluctuations.Effect of deviation from perfect elasticity.The Jeffereys–Lomnitz Law.

Surface elastic waves: Surface waves along the plane boundary between two homogeneous perfectly elastic media. Rayleigh waves. Love waves. Dispersion curves. Rayliegh waves in presence of a surface layer. Seismic surface waves.

Reflection and refraction of elastic waves: Laws of reflection and refraction. General equations for the two media.Case of incident Surface Horizontal (SH-wave), P-wave and Surface Vertical (SV-wave) incident against free plane boundary.Reflection and refraction of seismic waves. Lamb's problem-line load suddenly applied on elastic half-space. Refraction of dispersed waves.

Seismic rays in a spherically stratified earth model: The parameter p of a seismic ray. Relation between p, Δ,T for a given family of rays. Features of the relations between Δ and T corresponding to certain assigned types of variation with r. Derivation of the P-and S-velocity distributions from the (T, Δ) relations. Special velocity distributions, e.g. curvature of a seismic ray, rays in a homogeneous medium, circular rays.

Amplitude of the surface motion due to seismic waves: Energy per unit area of wave front in an emerging wave. Relation between energy and amplitude Movements of the outer surface arising from an incident wave of given amplitude. Amplitude as a function of Δ. Loss of energy.

Travel-time analysis: Parameters of earthquakes. Epicentral distance and azimuth of an observing station from an epicentre.Theory of the evolution of the main P travel-time table.

Seismology and the earth's upper layers and interior Positions: Theory of travel-times near earthquakes. Physical properties of earth's upper layers.Discontinuities within the earth.

References:
1. Byerlg, P.: Seismology.
2. Richter, C. F.: Elementary Seismology
3. Love, A. E. H.: Some Problems of Geodynamics.
4. Bullen, K. E.: An Introduction to the Theory of Seismology.
5. Bath, M.: Theory of Seismology.

COMPUTATIONAL BIOLOGY

A brief review of computational aspects molecular biology**.**

Basic concepts of molecular biology: DNA and proteins. The central dogma.Gene and Genome sequences.

Restriction maps: Graphs. Interval graphs. Measuring fragment sizes.

Algorithms for double digest problem (DDP): Algorithms, and complexity Analysis. Mathematical programming approaches to DDP**:** Integer programming. Partition problems.Travelling Salesman Problem (TSP).Simulated Annealing (SA).

Sequence assembly: Sequencing strategies. Assembly in practices, fragment overlap statistics, fragment alignment, sequence accuracy.

Sequence comparisons methods: Local and global alignment. Dynamic programming solution method.Multiple sequence alignment.

Stochastic Approach to sequence alignment and sequence pattern-Hidden: Markov chain method for biological sequences.

References:

1. Waterman, M. S.**:** Introduction to Computational Biology.
2. Baxevanis, A. and Ouelette, B.**:** Bioinformatics-A Practical Guide to the Analysis of Genes and Proteins.
3. Floudas, C. A.**:** Nonlinear and Mixed -Integer Optimization.
4. Bellman, R. and Krush, R.**:** Dynamic Programming – Biblography of Theory and Applications.
5. Bellman, R. and Dreyfus, S. E.**:** Applied Dynamic Programming.
6. Rao, S. S.**:** Engineering Optimization.
7. Devis, L.**:** Genetic Algorithms and Simulated Annealing.

MATHEMATICAL BIOLOGY

Diffusion Model: The general balance law, Fick's law, diffusivity of motile bacteria.

Models for Developmental Pattern Formation: Background, model formulation, spatially homogeneous and inhomogeneous solutions, Turing model, conditions for diffusive stability and instability, pattern generation with single species model.

Effect of Nutrients on autotroph-herbivore interaction: Introduction, Models on nutrient recycling and its stability, Effect of nutrients on autotroph herbivore stability, Models on herbivore nutrient recycling on autotrophic production. Models on phytoplankton-zooplankton system and its stability, Bio-control in plankton models with nutrient recycling.Leslie-Gower predator-prey model with different functional responses.

Continuous models for three or more interacting populations: Food chain models. Stability of food chains.Species harvesting in competitive environment, Economic aspects of harvesting in predator-prey systems.

Interaction of Ratio-dependent models: Introduction, May’s model, ratio-dependent models of two interacting species, two prey- one predator system with ratio-dependent predator influence- its stability and persistence.

Microbial population model: Microbial growth in a chemostat. Stability of steady states.Growth of microbial population.Product formation due to microbial action.Competition for a growth- rate limiting substrate in a chemostat.

Deterministic Epidemic Models: Recurrent epidemics, Seasonal variation in infection rate, allowance of incubation period. Simple model for the spatial spread of an epidemic. Proportional Mixing Rate in Epidemic: SIS model with proportional mixing rate, SIRS model with proportional mixing rate. Epidemic model with vaccination.

Stochastic Epidemic Models: Introduction, stochastic simple epidemic model, Yule-Furry model (pure birth process), expectation and variance of infective, calculation of expectation by using moment generating function.

Eco-Epidemiology: Predator-prey model in the presence of infection, viral infection on phytoplankton-zooplankton (prey-predator) system.

Models for Population Genetics: Introduction, basic model for inheritance of genetic characteristic, Hardy-Wienberg law, models for genetic improvement, selection and mutation- steady state solution and stability theory.

References:

1. J.D.Murray: Mathematical Biology, Springer and Verlag.

2. Mark Kot: Elements of Mathematical Ecology, Cambridge Univ. Press.

3. Leach Edelstein-Keshet: Mathematical Models in Biology, Birkhauser Mathematics Series.

4. F. Verhulust: Nonlinear Differential Equations and Dynamical Systems, Springer-Verlag.

5. R. M. May**:** Stability and Complexity in Model Ecosystem.

6. N.T.J.Bailey: The Mathematical Theory of Infectious Diseases and its Application, 2nd edn. London.

7. H. I. Freedman - Deterministic Mathematical Models in Population Ecology.

8. L.A.Segel (1984): Mpodelling Dynamical Phenomena in Molecular Biology, Cambridge University Press.

9. Vincenzo Capasso (1993): Lecture Notes in Mathematical Biology (Vol. No. 97)- Mathematical Structures of Epidemic Systems, Springer Verlag.

10. Eric Renshaw (1990): Modelling Biological Populations in Space and Time, Cambridge Univ. Press.

11. Busenberg and Cooke (1993): Vertically Transmitted Diseases- Models and Dynamics, Springer Verlag.

DYNAMICAL OCEANOGRAPHY

Hydrothermic equations of seawater.Gibbs relation, Gibbs-Duhem relation, heat capacities, Vaisala frequency, Determination of the thermodynamic properties of seawater.

Equations of motion of seawater.Conservation of mass and diffusion of salt.Kinematic free surface condition taking mass exchange into account. Equation of motion of seawater considered a viscous compressible fluid referred to a frame rotating with the earth. Energy transport equation. Thermodynamic energy equation. Entropy transfer equation. The closure problem and relation between thermodynamic fluxes and gradients of t, p, s. Properties and consequences of the adiabatic equations.Ertel's formula, potential vorticity and Rossby principle.Approximation of the basic equations - Boussinesq and linear -approximation, Quasi-geostrophic equations.

Wave motions in the ocean. General properties of plane and nearly plane waves.Linearised small-amplitude waves under gravity in rotating stratified ocean-simple gyroscopic and internal waves, internal gravity waves, plane waves, the energetic of plane waves. Long wave equation for a continuously stratified fluid.Wave reflection and wave trapping by lateral boundaries. Nonlinear surface waves**:** the Stokes approximation, finite-amplitude wave in shallow water. The solitary wave.

Turbulence**:** Basic concept. Time-averaged form of the momentum and continuity equations for incompressible flow. Eddy coefficients and their estimations. Elementary examples of the application of eddy coefficients.Salinity tongue in an ocean at rest.

Currents in the ocean.Quasi-static approximation.Geostrophic motion in a stratified ocean.Helland-Hansen formula. Stationary accelerate currents. Steady wind-driven currents in a homogeneous ocean. Wind-drift.Characterization of horizontal and vertical motion. Equation satisfied by the total flow function. Sverdrup's curl relation.Western boundary current.Munk's formula.Sverdrup's study of wind driven current in a baroclinic ocean.Munk's theory of wind-driven ocean circulation.

Tides and storm surges.Statistical theory of tides. Tidal harmonics channel theory of tides.

References:

1. P. H. Leblond and L. A. Mysak**:** Waves in the Ocean.
2. J. Pedlosky**:** Geophysical Fluid Dynamics.
3. V. M. Kamenkovch**:** Fundamentals of Ocean Dynamics.
4. O. M. Philips**:** Dynamics of the Upper Ocean.

APPLIED FUNCTIONAL ANALYSIS

Review of basic properties of Hilbert spaces.

Convex programming: Support functional of a convex set. Minkowski functional, Separation theorem.Kuhn-Tucker optimality theorem.Mini-Max theorem.Farkas theorem.

Spectral theory of operators: Spectral theory of compact operators. Operators on a separable Hilbert space.Krein factorization theorem for continuous kernels and its consequences.l2 spaces over Hilbert spaces. Multilinear forms. Analyticity theorem.Nonlinear Volterra operators.

Semigroups of linear operators: General properties of semigroups. Generation of semigroups.Dissipative semigroups.Compact semigroups.Holomorphic semigroups.Elementary examples of semigroups.Extensions.Differential equations.Cauchy problem.Controllability.State reduction.Observability.Stability and stabilizability.Evaluation equations.

Optional control theory: Linear quadratic regulator problems with finite and infinite time intervals. Concept of hard constraints.Final value control.Time optimal control problems.

References:

1. A. V. Balakrishnan**:** Applied Functional Analysis.
2. N. Dunford and J. T. Schwartz**:** Linear Operators, Vols. I & II.
3. S. G. Krein**:** Linear Differential Equations in a Banach Space.
4. K. Yosida**:** Functional Analysis.
5. M. Avriel**:** Nonlinear Programming – *Analysis and Methods.*
6. L. Mangasarian**:** Nonlinear Programming.
7. S, S. Rao**:** Optimization – *Theory and Applications*.
8. E. Kreyszing**:** Introductory Functional Analysis with Applications.
9. D. H. Grieffel**:** Applied Functional Analysis.
10. J. Zabczyk**:** Mathematical Control Theory – *An Introduction.*
11. W. L. Brogan**:** Modern Control Theory.
12. H. Kwakernaak and R. Sivan**:** Linear Optimal Control Systems.
13. A. Isidori**:** Nonlinear Control Systems.
14. S. G. Tzafestas**:** Methods and Applications of Intelligent Control.

ADVANCED NUMERICAL ANALYSIS
(THEORY & PRACTICAL)

Advanced Numerical Analysis: Theory (SEE: 50; IA: 12)

Interpolation: Newton's bivariate interpolation Triangular interpolation, Bilinear interpolation. Approximation**:** Rational approximation, Continued fraction approximation, Pade approximation. Solution of polynomial equation**:** Birge-Vieta method, Bairstaw method.

Solution of linear system of equations: Direct methods**:** Cholosky method, Partition method, error estimations. Iterative methods**:** Different iterative schemes, Optimal relaxation parameter for SOR method, Convergence analysis.

Eigen value problems of real symmetric matrices: Bounds of Eigenvalues, Householder's method, Given's method, Inverse power method.

Solution of nonlinear system of equations: Newton's method, Steepest- Descent method, Convergence analysis.

Numerical solution of boundary value problems of Ordinary differential equations: Finite-difference method, Newton-Raphson method (second order equation), error estimations.

Numerical solution of partial differential equations: Introduction to Elliptic, Parabolic and Hyperbolic equations. Explicit methods**:** Schmidt method, Dufort-Frankel method, Convergence and stability analysis. Implicit methods**:** Crank-Nicolson method, convergence and stability analysis, Matrix method.

Numerical solution of integral equations: Finite - difference method, Cubic spline method, Method using Generalized quadrature.

Finite Element Methods: Introduction to Finite Element methods. Weighted residual methods**:** Least square method, Partition method, Variational method**:** Ritz method.

Finite elements: Line segment element, Triangular element, Rectangular element, Curved-boundary element.

Finite element methods: Ritz finite element method, Least square finite element method, Convergence, Completeness and Compatibility analysis. Boundary value problems in ordinary differential equations**:** Mixed boundary conditions - Galerkin method.

References:

1. E. V. Krishnamurthy and S. K. Sen**:** Numerical Algorithms Computations in Science and Engineering.
2. Hildebrand, F. B**:** An Introduction to Numerical Analysis.
3. Atkinson, K. E.**:** An Introduction to Numerical Analysis.
4. Collatz, L.**:** Functional Analysis and Numerical Mathematics.
5. Fox, L.**:** Numerical Solution of Ordinary and Partial Differential Equations.
6. Ames, W. F.**:** Numerical Methods of Partial Differential Equations.
7. Strang, G., Fix, G.**:** An Analysis of the Finite Element Methods.
8. Zienkiewiez, O. C.**:** The Finite Element Methods in Structural and Continuum Mechanics.
9. Jain, M. K.,Iyengar, S. R. K., Jain, R. K.**:** Numerical Methods for Scientific and Engineering Computations.
10. Jain, M. K.**:** Numerical Solution of Differential Equations.
11. Baker, C. T. H. and Phillips, C.**:** The Numerical Solution of Non-linear Problems.
12. Row, S. S.**:** Finite Element Methods in Engineering.

Advanced Numerical Analysis: Practical (SEE: 30*; IA: 08)
(*Laboratory Assignment = 5 marks + Viva- Voce = 5 marks
+ Compilation and Execution of Two Problems = 20 marks)

1. Newton's method for finding real roots of simultaneous equations.

2. Graeffee’s Root-squaring method (up to biquadratic).

3. Bairstow’s method (up to biquadratic).

4. Q–D (Quotient-Difference) method.

5. Matrix inversion**:** Cholesky method.

6. Eigen value problems**:** Jacobi’s method, Inverse Power method.

7. Numerical Solution of ODEs**:** Explicit and implicit R–K (Runge–Kutta) methods, Predictor–Corrector methods, Adams’ method.

8. Boundary value problems**:** Finite- difference method.
9. Numerical solutions of PDEs**:** Crank – Nicolson method.
10. Cubic Spline interpolation using the General Form.
11. Integral equation**:** Monte – Carlo method.

Practical Examination Related Criteria:
(i) Laboratory clearance be taken by the students prior to commencement of practical examination.
(ii) The Lab. Assignment Dissertations of the students be submitted prior to commencement of practical examination.
(iii) Duration of practical examination will be 4 (Four) hours.
(iv) One external examiner be appointed for practical examination.

References:

1. Krishnamurthy, E. V. and S. K. Sen**:** Numerical Algorithms Computations in Science and Engineering.

2. Balaguruswamy, E.**:** Programming in ANSI C.

3. Xavier, C**:** C and Numerical Methods.

COMPRESSIBLE FLUID DYNAMICS

Compressible Fluid: Compressibility of Fluids, System and Control Volume, Thermodynamic Process and Cycle, Laws of Thermodynamics, Stored Energy and Energy in Transition, Entropy, Isothermal-Adiabatic and Isentropic process, Perfect gas.

Conservation Laws for Compressible Fluids: Extensive and intensive properties, Conservation of mass and Continuity equation, Conservation of Momentum and Momentum equation, Conservation of Energy and Energy equation.

Basic Concepts of Compressible Flow: Velocity of Sound, Mach Number, Subsonic and Supersonic Flow, Stagnation Condition, Relation between Stagnation and Static Properties, Kinetic form of Steady Flow Energy Equation, Critical Speed of Sound, Stream Thrust and Impulse Function.

Isentropic Flow: Governing equations, Effect of Area Variation, Nozzle, Diffuser, Choking, Isentropic Flow Relations, Differential Equations in terms of Area variation and Solution.

Normal Shock Waves: Compression Wave and Expansion Wave, Governing Equations for Normal Shock Waves, Hugonoit Curve, Prandtl-Meyer Equation, Mach Number Downstream of Normal Shock, Property Ratios across Normal Shock, Stagnation to Static Pressure Ratios, Change in Entropy across Normal Shock, Rankine-Hugonoit Relations.

Oblique Shock Waves: Compression Shock Wave and Expansion Fan, Upstream and Downstream Velocity Triangles, Oblique Shock Relations, Deflection and Wave Angle, Prandtl Velocity Equation for Oblique Shock Wave, Mach Lines, Prandtl-Meyer Flow, Prandtl-Meyer Angle.

Rocket Propulsion: Rocket Propulsion Parameters, Effective Jet Velocity, Characteristic Velocity, Exit Velocity of Jet, Design Parameters for Rocket Engine, Propellants, Combustion, Rocket Equation, Altitude Gain during Vertical Flight, Escape Velocity.

References:

1. P. A. Thompson: Compressible Fluid Dynamics.
2. A.H. Shaproo: Compressible Fluid Flow.
3. P. Niyogi: Inviscid Gas Dynamics.
4. K. Oswatitsch: Gas Dynamics.
5. S.M. Yahya: Fundamentals of Compressible Flow.

Optional Courses for Pure Stream Only

ADVANCED REAL ANALYSIS

Representation of real numbers by series of radix fractions.Sets of real numbers, Derivatives of a set.Points of condensation of a set.Structure of a bounded closed set.Perfect sets.Perfect kernel of a closed set. Cantor's nondense perfect set. Sets of first and second categories, residual sets.

Baire one functions and their basic properties. One-sided upper and lower limits of a function.Semicontinuous functions. Dini derivates of a function.Zygmund's monotonicity criterion.

Vitali's covering theorem. Differentiability of monotone functions and of functions of bounded variation. Absolutely continuous functions, Lusin's condition (N), characterization of AC functions in terms of VB functions and Lusin's condition.

Concepts of VB*, AC*, VBG*, ACG* etc. functions. Characterization of indefinite Lebesgue integral as an absolutely continuous function.

Generalized Integrals**:** Gauge function.Cousin's lemma.Role of gauge function in elementary real analysis.Definition of the Henstock integral and its fundamental properties.Reconstruction of primitive function.Cauchy criterion for Henstockintegrability.Saks-Henstock Lemma.The Absolute Henstock Integral.The McShane integral.Equivalence of the McShane integral, the absolute Henstock integral and the Lebesgue integral. Monotone and Dominated convergence theorems. The Controlled convergence theorem.

Definition and elementary properties of the Perron integral and its equivalence with the Henstock integral.

Definition of the (special) Denjoy integral and its equivalence with the Henstock integral (characterization of indefinite Henstock integral as a continuous ACG* function).

Density of arbitrary sets.Approximate continuity.Approximate derivative.

References:

1. E. W. Hobson**:** The Theory of Functions of a Real Variable (Vol. I and II).
2. I. P. Natanson**:** Theory of Functions of a Real Variable (Vol. I and II).
3. R. A. Gordon**:** The Integrals of Lebesgue, Denjoy, Perron and Henstock, Amer. Math. Soc. Graduate Studies in Math., Vol. 4, 1994.
4. W. F. Pfeffer**:** The Riemann Approach to Integration - Local Geometric Theory.
5. R. Henstock**:** Lectures on the Theory of Integration.
6. P .Y Lee**:** Lanzhou Lectures on Henstock Integration.
7. S. Schwabi**:** Generalized Ordinary Differential Equations.
8. E. J. McShane**:** Unified Integration.
9. S. Saks**:** Theory of the Integral.

ADVANCED COMPLEX ANALYSIS I

The functions- M(r) and A(r).Hadamard theorem on the growth of log M(r), Schwarz inequality, Borel-Caratheodory inequality, Open mapping theorem.

Dirichlet series, abscissa of convergence and abscissa of absolute convergence, their representations in terms of the coefficients of the Dirichlet series. The Riemann Zeta function, the product development and the zeros of the zeta functions.

Entire functions, growth of an entire function, order and type and their representations in terms of the Taylor coefficients, distribution of zeros.Schottky's theorem (no proof).Picard's first theorem.Weierstrass factor theorem, the exponent of convergence of zeros. Hadamard's factorization theorem, Canonical product, Borel's first theorem.Borel's second theorem (statement only).

Multiple-valued functions, Riemann surface for the functions, logz,$\sqrt{z}$

Analytic continuation, uniqueness, continuation by the method of power series, natural boundary, existence of singularity on the circle of convergence.

Conformal transformations, Riemann's theorems for circle, Schwarz principle of symmetry. Univalent functions, general theorems, sequence of univalent functions, sufficient conditions for univalence.

References:

1. E. T. Copson**:** An Introduction to the Theory of Functions of a Complex Variable.
2. E. C. Titthmarsh**:** The Theory of Functions.
3. A. I. Markushevich**:** Theory of Functions of a Complex Variable (Vol. I, II &III).
4. L. V. Ahlfors**:** Complex Analysis.
5. J. B. Conway**:** Functions of One Complex Variable.
6. A. I. Markushevich**:** The Theory of Analytic Functions, A Brief Course.
7. G. Valiron**:** Integral Functions.
8. C. Caratheodory**:** Theory of Functions of a Complex Variable.
9. R. P. Boas**:** Entire Functions.

ADVANCED COMPLEX ANALYSIS II

Harmonic functions, Characterisation of Harmonic functions by mean-value property.Poisson's integral formula.Dirichlet problem for a disc.

Doubly periodic functions.Weierstrass Elliptic function and its properties.

Entire functions, M(r, f) and its properties (statements only).Meromorphic functions. Expansions. Definition of the functions m (r, a), N(r, a) and T(r,f).

Nevanlinna's first fundamental theorem.Cartan's identity and convexity theorems.Orders of growth.Order of a meromorphic function.Comparative growth of logM(r) and T(r).Nevanlinna's second fundamental theorem. Estimation of S(r) (Statement only). Nevanlinna's theorem on deficient functions.Nevanlinna's five-point uniqueness theorem.Milloux theorem.

Functions of several complex variables.Power series in several complex variables.Region of convergence of power series.Associated radii of convergence. Analytic functions. Cauchy-Riemann equations.Cauchy's integral formula.Taylor's expansion.Cauchy's inequalities.Zeros and Singularities of analytic functions.

References:

1. E. C. Tittmarsh: The Theory of Functions.
2. E. T. Copson: An Introduction to the Theory of Functions of a Complex Variable.
3. A. I. Markushevich: Theory of Functions of a Complex Variable, (Vol. I, II, III).
4. W. Kaplan: An Introduction to Analytic Functions.
5. H. Cartan: Theory of Analytic Functions.
6. W. K. Hayman: Meromorphic Functions.
7. L. Yang: Value Distribution Theory.

8. R. C. Gunning and H. Rossi: Analytic Functions of Several Complex Variables.
9. B. A. Fuks: An Introduction to the Theory of Analytic Functions of Several Complex Variables.
10. Bochner and Martin: Several Complex Variables.

ADVANCED FUNCTIONAL ANALYSIS

Hilbert Space: Preliminary concept of Inner product space and Hilbert space. Generalized Bessel's inequality. Complete orthonormal sequence and separability in Hilbert spaces. Isometric isomorphism of every infinite dimensional separable Hilbert space with the space l_2, Grahm-Schimdtorthonormalization process. Stone-Weierstrass theorem.Approximation in normed linear spaces. Best approximation and uniqueness.

Conjugate Space: Preliminary ideas of conjugate space. Conjugate spaces of C, C_0andC[a,b] Representation theorem for bounded linear functional on C[a,b].

Reflexive Space: Definition of reflexive space. Canonical mapping.Subspaces of reflexive space, Bounded sequence contains a weakly convergent subsequence. Existence of an element of smallest norm.Relation between separability and reflexivity.Reflexivity of Hilbert spaces.Strictly convex and uniformly convex Banach spaces.Helley's theorem (statement only) and Milman and Pettis theorem for uniformly convex Banach spaces (statement only).

Spectral Theory of Operators: Spectrum of a bounded linear operator. Resolvent operator.Spectral radius.Spectral mapping theorem for polynomials.Spectrum of completely continuous operator and of self-adjoint operator.Spectral representation of self-adjoint operator.

Banach Algebra: Banach algebra with identity. Resolvent operator and Resolvent function. Topological divisor of zeros.Gelfand-Mazur theorem.Spectral mapping theorem.Complex homomorphism.Concept of Ideal in Banach algebra.

Derivative of an Operator: Gateaux derivative and its uniqueness. Representation of Gateaux derivative when domain and range are finite.Frechet derivative and its uniqueness.Relation between Gateaux derivative and Frechet derivative. Complete continuity of Frechet derivative.

References:
1. G. Bachman and L. Narici**:** Functional Analysis.
2. A. L. Brown and A. Pag**:** Elements of Functional Analysis.
3. J. B. Conway**:** A Course in Functional Analysis
4. E. Kreyszig**:** Introductory Functional Analysis with Applications
5. B. V. Limaye**:** Functional Analysis
6. W. Rudin**:** Functional Analysis.
7. B. K. Lahiri**:** Elements of Functional Analysis
8. E. Rickart**:** Banach Algebra

ABSTRACT HARMONIC ANALYSIS

Banach Algebra: Banach Algebras, basic concepts, Gelfand theory, The spectral Theorem, Spectral theory of *-representations.

Locally compact groups: Harr measure, Unimodular group, Homogeneous spaces.

Representation Theory: Unitary representation, Representation of a group and its group algebra, Functions of positive type.

Analysis on Locally compact groups: Dual group, Fourier transform,Potriagin duality.

Analysis on Compact groups: Representation of Compact groups, The Peter-Weyl Theorem.

References:

1. A Course in Abstract Harmonic Analysis, G. B. Folland
2. E. Hewitt and K. Ross**:** Abstract Harmonic Analysis, (Vol.1).
3. L. Loomis**:** An Introduction to Abstract Harmonic Analysis.
4. W. Rudin**:** Fourier Analysis on Groups.
5. G. Bachman**:** Elements of Abstract Harmonic Analysis.
6. W. Rudin**:** Real and Complex Analysis.

ADVANCED GENERAL TOPOLOGY

Locally Connected space, Various Disconnected spaces, and Quotient Spaces: Local Connected spaces, Zero-dimensional spaces, totally and extremally disconnected spaces, characterizations and their basic properties.Quotient spaces.

Nets and Filters: Inadequacy of sequence, Directed set, definition of net, convergence by net. Cluster point of a net, subnet, ultranet, Topological concepts via nets.

Definition of a filter.Free and fixed filter. Filter bases, image and inverse image of filter base and filter, induced filter. Ultrafilter and its existence and characterization.Convergence of filters.Properties of convergence of filters. Cluster point of a filter and its properties. Characterizations of compactness in terms of nets and filters.Alternative proof of Tychonoff product Theorem using ultranet / ultrafilter. Net based on filter, filter generated by net.

Compactification: Locally compact spaces**:** Examples and various characterizations, compactification of topological spaces. Alexandroff compactification.Stone-Cech compactification.Cardinality of N.

Paracompactness: Star refinement, barycentric refinement and their relation. Various characterizations of paracompactness.A. H. Stone’s theorem concerning paracompactness of metric spaces.Interconnection between paracompactness and (i) Hausdorffness, (ii) Regularity and (iii) Lindelöfness.Properties of paracompactness with regard to subspaces and product space.

Embedding and Metrization: Evaluation map, Embedding theorem for Tychonoff spaces, Urysohn'smetrization theorem.

Uniform spaces: Definition and examples of uniform spaces. Base and subbase of a uniformity, uniform topology. Uniformity and separation axioms.Uniformizable spaces.Uniform continuity and product uniformity.Uniform property. Uniformity of pseudometric spaces and uniformity generated by a family of pseudometric. Compactness of uniform spaces. Cauchy filter. Relation between completeness and compactness in uniform spaces.

Proximity spaces: Definition and examples. Topology induced by proximity. Alternate description of proximity (the concept of -neighbourhood).Separated proximities.Proximal neighbourhoods.p-map, p-isomorphism. Subspaces and product of proximity spaces. Proximities induced by uniformities. Compactness and proximities.

C(X) and C*(X)**:** The function rings C(X) and C*(X), C-embedded and C* embedded sets in X. Urysohn's extension theorem, Z-filters and Z-ultrafilters on X, their duality with ideals and maximal ideals of C(X). Fixed ideals and compact spaces.

References:

1. J. L. Kelley**:** General Topology.
2. S. Willard**:** General Topology.
3. J. Dugundji, Topology.
4. R. Engelking**:** Outline of General Topology.
5. S. A. Naimpally and B. D. Warrack**:** Proximity Space.
6. J. Nagata**:** Modern General Topology.
7. L. Gillman and M. Jerison**:** Rings of continuous functions.
8. J. Nagata**:** Modern Dimension Theory.

ADVANCED ALGEBRAIC TOPOLOGY

Covering spaces: Basic properties, Classification of covering spaces. Universal covering spaces.Applications – BorsukUlam Theorem.

Higher Homotopy Groups: Basic properties and examples. Homotopy Groups of Spheres.Relation between homology groups and homotopy groups.Lefschetz fixed point theorem. Brouwer fixed point theorem.

Singular Homology Theory: Singular Chain Complex. Singular Homology group. Chain map, induced map between homology groups. Chain homotopy, Mayer-Victoris sequences. Axioms for homology theorem.

Cohomology and Duality Theorems: Definitions and Calculation Theorems. Poincaré duality.Alexander duality and Lefschetz duality.

CW-complexes: Definition, Cellular maps. Homotopy groups of CW-complexes. Whitehead Theorem.Homology theory of CW-complexes.Betti number and Euler characteristics.Excision theorem and cellular homology, Hurewicz theorem.Fiber spaces.Presheaves. Fine presheaves. Application of cohomology to presheaves.

References:

1. Fred. H. Croom**:** Basic Concepts of Algebraic Topology.
2. C. R. F. Maunder**:** Algebraic Topology.
3. Edwin H. Spanier**:** Algebraic Topology.
4. J. Mayer**:** Algebraic Topology.
5. B. Gray**:** Homotopy Theory.
6. J. Dugundji**:** Topology.
7. Allen Hatcher**:** Algebraic Topology.

ADVANCED ALGEBRA I

Semi group: Regularity & primality of ideal and bi-ideal in semi group, left regular and intra-regular ordered semi group and their characterization in terms of semi-prime left ideal, poe-semigroup, ternary semigroup & its commutativity, regularity and intra-regularity, completely semi prime ideal in intra-regular ternary semi group, lateral ideal in ternary semi group, characterization of bi-ideal in ordered semi group and its connection with regularity, relationship between weakly regularity and interior ideal in semi group.

Ring: Bi-ideal of higher index, characterization property, principality and minimality of higher indexed bi-ideal, fuzzy and anti fuzzy algebraic treatment of bi-ideal in ring, simple and bi-ideal free ring- characterization theorem, left (right) ideal of a right (left) ideal in a regular ring and its relationship with bi-ideal, minimal bi-ideal in a divison ring, -ideal in a ring- necessary and sufficient condition in terms of higher indexed bi-ideal, meta ideal of finite index and k-ideal (k being a positive integer) in a ring, two sided ideal of a two sided ideal in Von Neumann regular ring.

Noetherian ring: Almost normal extension, Hilbert's basis theorem, semisimple ring and its centre, necessary and sufficient condition for semisimplicity in terms of ring endomorphism; quotient, opposite and simple &isotypic component of semisimple ring; degree, height & index of simple ring, Nakayama lemma, properties of Jacobson radical, Wedderburn-Artin theorem; radical and artinian ring- nilpotence, chain condition, computing some radical; annihilator and Jacobson radical, restriction functor.

Field extension: Review of simple, normal, separable, radical and cyclic extension; splitting field of polynomials- homomorphism from simple extension, multiple roots; Galois extension- group of automorphism of field, fundamental theorem, Galois group of polynomial, solvability of equation, action of Galois group on roots of polynomial; symmetric group Sp (p being prime) as Galois group over $\mathbb{Q}$, finite field and computing Galois group over $\mathbb{Q}$, primitive element theorem, normal basis theorem, Hilbert's theorem 90, Kummer theory, Galois's solvability theorem, algebraic closure- existence and uniqueness, separable closure; transcendental extension- algebraic independence, transcendence bases, Luroth's theorem, separating transcendence bases, transcendental Galois extension.

Geometric Construction: Constructible real numbers, trisection of 60º angle and square the circle by straight edge and compass, duplication of a cube, construction of a regular septagon, constructibility of regular 9-gon and regular 20-gon.

Coding theory: Definition- a probabilistic model, weight and code distance, generator and parity-check matrices, equivalence of codes, encoding messages in linear code, decoding linear code, bounds- sphere-covering lower bound, Hamming (sphere packing) upper bound, perfect code, binary Hamming code and its decoding, extended code, Golay code, singleton bound and maximum distance separable (MDS) code, Reed-Solomon code, digression – coding and communication complexity, Gilbert-Varshamov bound, Plotkin bound, Hadamard code, Walsh-Hadamard code; constructing code from other code- general rules for construction, Reed-Muller code.

References:

1. K. Sinha and S. Srivastava: Theory of Semigroups and Applications.
2. J. A. Gallian: Contemporary Abstract Algebra.
3. J. N. Mordeson, D. S. Malik and N. Kuroki: Fuzzy Semigroups.
4. S. T. Hu: Elements of Modern Algebra.
5. D. S. Malik, J. M. Mardeson and M. K. Sen: Fundamental of Abstract Algebra.
6. E. Artin: Galois Theory (2nd Edition).
7. D. S. Dummit and R. M. Foote: Abstract Algebra.
8. T. W. Hungerford: Algebra .
9. N. Jacobson: Lectures in Abstract Algebra (Vol. -I).
10. M. Nagata: Field Theory.
11. A. G. Kurosh: The Theory of Groups.
12. M. R.Adhikari and AvishekAdhikari: Groups, Rings, and Modules with Applications.
13. M. Auslander and D. A. Buchsbaum: Groups, Rings, Modules.
14. T. W. Hungerford: Algebra, Springer, 1980.
15. S. M. Moser and Po-Ning Chen: A Student’s Guide to Coding and Information Theory.
16. S. Ball: A course in Algebraic Error-Correcting Codes.
17. Monica Borda: Fundamentals in Information Theory and Coding.
18. Rajan Bose: Information Theory, Coding and Cryptography.
19. Raymond Hill: A First Course in Coding Theory.
20. ArijitSaha, Nilotpal Manna and SurajitMondal: Information Theory, Coding and Cryptography.
21. San Ling, Chaoping Xing: Coding Theory: A First Course.
22. G. A. Jones and J. M. Jones: Information and Coding Theory.

ADVANCED ALGEBRA II

Modules: Modules Homomorphisms. Exact sequences.Free modules, Projective and injective modules.Divisible abelian groups.Embedding of a module in an injective module.

Modules over PID, Torsion-free modules, Finitely generated modules over PID.

Tensor product of modules, Tensor product of free modules.

Commutative Rings and Modules: Noetherian and Artinian modules, Composition series in modules. Primary decomposition of a submodule of a module.

Noetherian rings, Cohen's theorem, Krull intersection theorem, Nakayama lemma. Hilbert basis theorem.

Extension of a ring, Integral extension of a ring, Integral closure, Lying-over and Going-up theorems.

Transcendence base of a field over a subfield.Algebraically independence subset of an extension field over a field. Algebraically closed field extensions of isomorphic fields with equal transcendence degree are isomorphic.

Affine varieties of algebraic sets.Noether normalization lemma, Hilbert Nullstellensatz.

Structure of Rings: Left artinian rings, Simple rings, Primitive rings, Jacobson density theorem, WedderburnArtin theorem on simple (left), Artinian rings.

The Jacobson radical, Jacobson semisimple rings, subdirect product of rings, Jacobson semisimple rings as subdirect products of primitive rings, Wedderburn-Artin theorem on Jacobson semisimple (left), Artinian rings.

Simple and Semisimple modules, Semisimple rings, Equivalence of semisimple rings with Jacobson (left) Artinian rings, Properties of semisimple rings, Characterizations of semisimple rings in terms of modules.

Group Representations: Group rings, Maschkke's theorem, Character of a representation, Regular representations, Orthogonality relations, Burnside's $p^a q^h$ theorem.

References:

1. Serge Lang**:** Algebra.
2. Nathan Jacobson**:** Basic Algebra (Vol. II).
3. M. Atiyah and I. G. MacDonald**:** Introduction to Commutative Algebra.
4. O. Zarisky and P. Samuel**:** Commutative Algebra (Vols. I and II).
5. D. S. Malik, John M. Mordeson, and M. K. Sen**:** Fundamentals of Abstract Algebra.
6. N. McCoy**:** Theory of Rings.
7. I. N. Herstein**:** Non-Commutative Rings.
8. T. Y. Lam**:** A First Course in Non-commutative Rings.
9. C. W. Curtis and I. Reiner**:** Representation Theory of Finite Groups and Associated Algebras.

ADVANCED DIFFERENTIAL GEOMETRY I

Riemannian geometry: Differentiable manifolds- definitions and examples, curves on manifolds, tangent spaces, basis theorem, directional derivative as tangent vector fields, Differentiable mapping, Tangent spaces, cotangent space, pull back and push forward map, Vector field, Integral curve of a vector field, Lie bracket, Immersion, Imbedding, rank of a mapping, f-related vector fields. Affine connections, Riemannian connections, semi symmetric connections, fibre bundle Basic definitions, Curvature tensor, Ricci tensor, Scalar curvature, Sectional curvature.

Properties of Riemann curvature, Bianchi's identities, Conformal curvature, Projective curvature, Jacobi equations Local Isometrics, Lie Derivatives and their elementary properties. Ricci flow, Ricci soliton.

Isometric immersions: The second fundamental form, The fundamental equations, Complete manifolds, HopfRinow Theorem, The Theorem of Hadamard, Lie Groups.

Structures on manifolds, almost contact structure, Sasakian structure, almost complex structure, Kaehler structure. Submanifolds with almost contact structures.

References:

1. Riemannian Geometry, M. P. Do carmo.
2. A course in Differential Geometry and Lie Groups, S. Kumaresan.
3. S. Kobayasi and K. Nomizu: Foundations of Differential Geometry (Vol. 1).
4. W. M. Boothby: An Introduction to Differentiable Manifold and Riemannian Geometry.
5. Barrett O'Neil: Riemannian Geometry.
6. L. W. Tu , Introduction to manifolds.
7. J. M. Lee, Differential geometry,
8. D. E. Blair, Riemannian geometry of contact and symplectic manifolds.
9. K. Yano and M. Kon: Structures on manifolds.

ADVANCED DIFFERENTIAL GEOMETRY II

Geometry of Contact Manifolds: Structure tensor, characteristic vector fields, definition and examples of almost contact manifolds, Neijenhuis tensor, contact manifolds. K-contact and Sasakian structures.Sasakian space forms. Nearly Sasakian structures. Quasi-Sasakian structure, trans-Sasakian structure, cosymplectic structures, generalized Sasakian-space forms.

Locally φ-symmetric spaces, Ricci symmetric spaces, semisymmetric spaces, submanifolds, Ricci flow and Ricci soliton of almost contact manifolds, submanifolds, invariant submanifolds, anti invariantsubmanifolds. Totally geodesic submanifolds of almost contact manifolds.

Geometry of Symplectic Manifolds: Drfinition and example of symplectic manifolds, Almost complex manifolds. Neijenhuis tensor. Complex manifolds. Contravariant almost analytic vector. Almost Hermite manifolds. Linear connection in an almost Hermite manifold.Kähler manifold.Almost Tachibana manifold.Tachibana manifold.Holomorphic sectional curvature.Almost product and almost decomposable manifold. Almost Einstein manifold., symmetry, semisymmetry and pseudo-symmetry of such spaces, Ricci flow and Ricci solitons on such spaces.

Applications of differential geometry in mechanics, relativity and cosmology.

References:

1. K. Yano and M. Kon: Structures on manifolds.
2. D. E. Balair: Riemannian geometry of contact and symplectic manifolds
3. H Geigs: Contact topology.
4. A. N. Matveev: Mechanics and Theory of Relativity.

FUNCTIONAL ANALYSIS AND ITS APPLICATIONS TO PDEs

Functional Analysis and Applications to PDES: Theory of distributions, Holder space, sobolev space, weak derivatives, approximation by smooth functions, extensions, traces, sobolev inequalities, Gagliardo-Nirenbarg-sobole inequality, Poincare inequality, Difference quotient, the space H-1, space involving time.

Elliptic equations, weak solutions, Lax Milgram theorem, energy estimates, Fredholm alternative, regularity, interior regularity, boundary regularity, weak maximum principle, strong maximum principle, Harnack's inequality, Eigen values of symmetric elliptic operator, eigenvalues of non-symmetric elliptic operator.

Linear evolution equation, second order parabolic equation, existence of weak solutions, regularity, maximum principle, second order hyperbolic equation, existence of weak solution, regularity, propagation of disturbances.

System of first order hyperbolic equations, symmetric hyperbolic system.

References:

1. G. Folland: Introduction to partial differential equations, Princton university press, 1976.
2. D. Gilbarg and N. Trudinger: Elliptic partial differential equations of second order, Springer, 1983.
3. L. Hormandu: The analysis of Linear partial differential equations operator, Springer, 1983.
4. L. C. Evans: Partial Differential equations, Vol 19, AMS
5. Robert C. McOwen: Partial differential equations, Pentic hall, 2013
6. I. N. Sneddon: Elements of partial differential equations, Mc Grew Hill, New York.
7. S. Kesavan: Topics in Functional Analysis and applications to PDEs.

ERGODIC THEORY & TOPOLOGICAL DYNAMICS

Measure Preserving Transformation: Definition and Examples, Recurrence, Ergodicity.

The Ergodic Theorem: Von Neumann's L2 -ergodic Theorem, Birkhoff's Ergodic Theorem.

Mixing Properties: Poincare Recurrence, Ergodicity of a mixing property, Weakly Mixing, A little spectral theory, Weakly mixing and eigenfunctions, Mixing.

Equivalence: The isomorphism problem; conjugacy, spectral equivalence.

Invariant Measures for Continuous Maps: Existence of Invariant Measures, Unique Ergodicity, Measure Rigidity and Equidistribution.

Conditional Measures and Algebras: Conditional Expectation, Conditional Measures.

Factors and Joinings: Relatively independent joining, Kroneker factor.

Topological Dynamics: Recurrent points, Uniform Recurrence and Minimal Systems, Multiple Birkhoff recurrence Theorem and its applications.

Entropy: Entropy, the Kolmogorov-Sinai theorem, calculation of entropy, the Shannon-McMillan Breiman theorem.

Appendix: Topological Group, monothetic group. Locally compact groups, Harr measure on locally compact groups.

Character on locally compact abelian (LCA) group, dual group, computation of dual groups of Z, R, T. Fourier transform of members of L1(G), Parseval Formula, Herglotz–Bochner Theorem, Inversion Theorem, Pontryagin Duality Theorem.

References:

1. H. Furstenberg, Recurrence in ergodic Theory and combinatorial applications

D. J. Rudolf, Fundamentals of Measurable dynamics.

3. Peter Walters, An introduction to ergodic theory.
4. M. Einsiedlert and Tomas Ward, Ergodic Theory with a view towards number theory.

PROJECT 4.4

Marks: 100; Credits: 8, Counselling Durations: 24 Hours

(For Applied & Pure Streams)

Project Notebook: 50; Seminar presentation: 30; Viva-voce: 20

Examination related course criteria (Project Work)

1. Each student has to carry out a project work under the supervision ofteacher(s) of the Department and on the basis of her/his subject interest in the advanced topics of Mathematics(subject to the availability of teacher). The same is to be submitted to the Department after getting it countersigned by the concerned teacher(s) and prior to the commencement of Viva-Voce.
2. All Project related record shall be maintained by the Department.
3. Seminar presentation and Viva–Voce Examination shall be conducted by the Department.