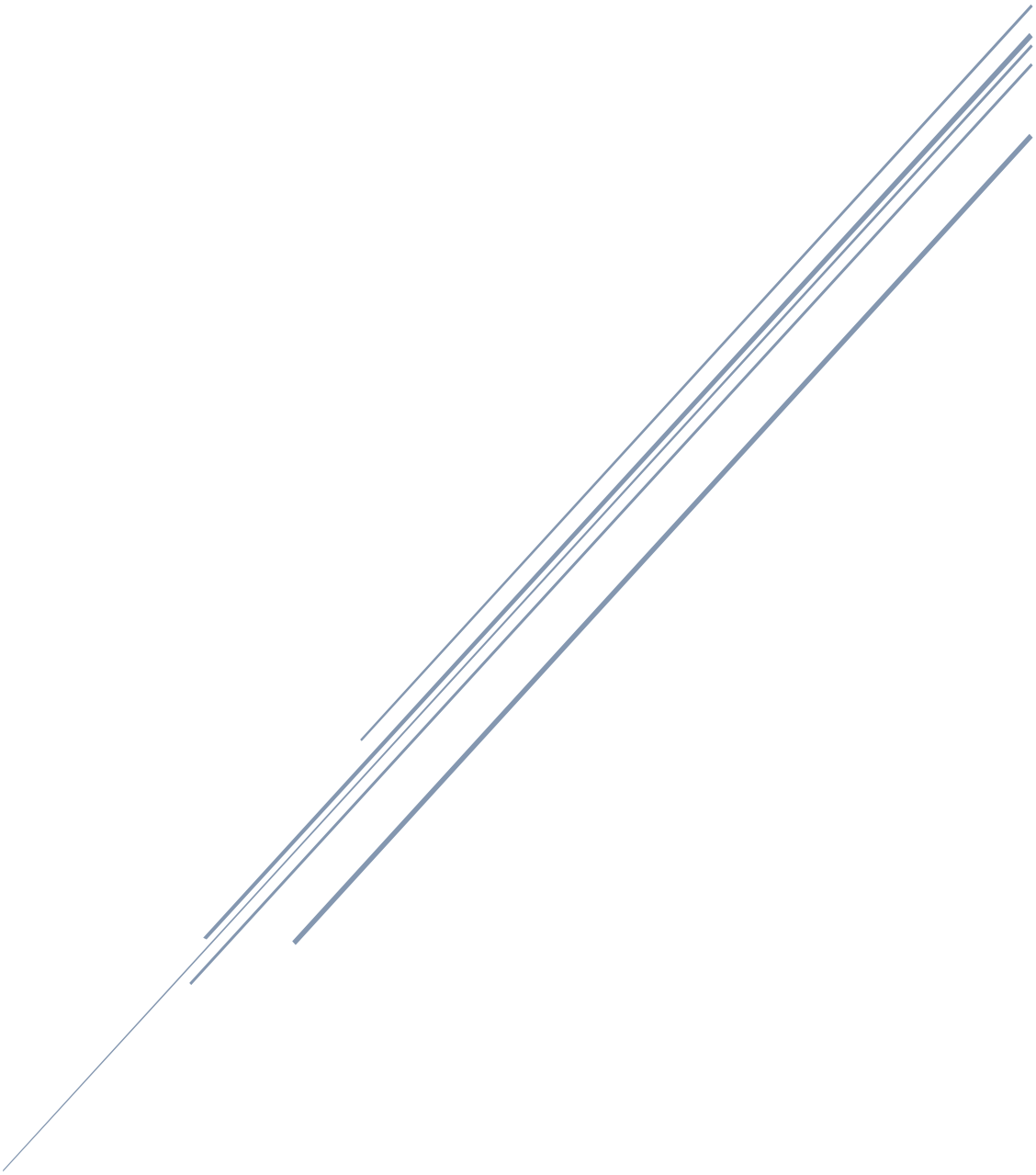
MASTER OF SCIENCE (MATHEMATICS)-ODL

PROGRAMME PROJECT REPORT (PPR)



School of Sciences

PPR of M. Sc. in Mathematics science approved by 39th Academic Council (vide memo no.: Reg/0322 dated 14.03.2023) for delivery of programme through Open Distance Learning mode.

i. Programme's mission and objectives:

Mathematics is an indispensable problem-solving and decision-making tool used in most of the advanced development in science, engineering and technology. Therefore, a significant increase of interest in mathematics has been grown among different disciplines as well as other areas of life in recent past. With that spirit in mind, NSOU started Post Graduate Mathematics course in the year of 2003 with the help of all its study centers. The main objectives of the course are:

- ✓ To democratize higher education in mathematics by providing access to large segments of the population, in particular the disadvantaged groups such as those living in remote and rural areas, including working people, women and other adults who wish to acquire and upgrade their mathematical knowledge and/or skills.
- ✓ To acquire knowledge about the nature, concepts, methods, techniques and objectives of advanced fields of Algebra, Analysis, Geometry and Topology, and Applied Mathematics, together with some historical perspective of their development.
- ✓ To develop an enhanced skill set that will put the learners at an advantage in careers as diverse as mathematics, education, computer science, economics, engineering and finance.
- ✓ To train learners to learn in an autonomous manner and know how to tackle research in mathematical sciences.
- ✓ To mitigate the need of qualified professional having specialized knowledge in mathematics for better cognitive and socio-economic development of the country.
- ✓ To augment the grasp and exposure of the learners towards advanced mathematics through specialization into Pure or Applied Mathematics based on their choice

ii. Relevance of the program with HEI's Mission and Goals:

The Post Graduate Mathematics course has a great relevance with the Mission and Goal set by the university. At present more than 1000 aspirants who are interested in mathematics are going through the programme in different study centers/regional centers across different geographic location of West Bengal.

There are three main reasons for offering this program –

- ✓ Persistent requests from study centers, local and regional students for PG mathematics program to be offered by NSOU in distance mode to meet educational and career needs of students.
- ✓ NSOU has already marked a significant footprint in mathematics teaching and research by educating a large no of learners in Mathematics at postgraduate as well as under graduate level. The Department of Mathematics has a collaborative association with other reputed universities/institutes in West Bengal. Thisaugments the teaching learning process by utilizing the expertise offaculties from other university as and when required.
- ✓ This course will help the economic and social growth of the country by supplying more qualified mathematician, which is basic need in today's competitive environment

iii. Nature of prospective target group of learners:

The target group of learners for the Post Graduate level are the Graduate students interested in studying Mathematics at a higher level.

To cater to the increasing pressure of employability demands of an ever-increasing population, many of whom choose to enroll in Mathematics, the programme is designed to provide opportunities to prospective learners who hope to seek employment as research scholars, educators, college/university teachers, administrators and journalists. Besides those interested in seeking professions as an archivist, archaeologist, art curator, museologist or librarian and above all a historian are the prospective target group of learners.

iv. Appropriateness of programme to be conducted in Open and Distance Learning and/or Online mode to acquire specific skills and competence:

This programme is suitable in the ODL system to acquire skills and competence with the quality education. As the state and national level, the higher educational institutions are expected to provide quality education, education for all, strategic plans for an institution that defines targets and measures of the programmes to be achieved by the institution. Apart from physical infrastructure, administrative policy and code of behaviour, school of sciences is actively engaged in its academic development of respective subjects. The School of Sciences has been designed its curriculum by the help of the Board of Studies (BOS), several learning resource materials, and feedback system through the BOS and an expert committee. Learning material through print-media named Self-Learning Materials (SLMs) is developed with the self-explanatory, self-contained and self-motivating approach following the UGC guideline.

- ✓ It tries to ensure quality service to the learners of the subject through development of good and appropriate standard Study Learning Material (SLMs), integration of modern methods of teaching learning process.
- ✓ Hands on practice during the Practical Sessions will help the learners to acquire knowledge in the practical domain of computer programming.
- ✓ Online support services, PCPs, tutorial classes are also provided.
- ✓ It also includes the usage of ICT and credibility of evaluation procedures.
- ✓ Organization of inter and intra Schools/ Institutional workshops, seminars on quality related themes and promotion of quality circles
- ✓ Arrangement for feedback responses from learners, parents and other stakeholders on quality related institutional processes will help to maintain the quality of the programme.

v. Instructional Design:

a. Introduction: The curriculum is adapted from the post graduate mathematics course recommended by UGC. The curriculum has been developed consulting with internal and external subject matter experts to avoid any disparity between the similar programs offered by other state and central universities. The entire syllabus has been divided into two parts. Each part comprised of 5 papers. To give an advanced level exposure to the trend of modern mathematics, learners are offered **special papers** either from **Pure Mathematics** group or from **Applied Mathematics** group **according to their choice**

b. Course Structure: (Please see the detailed table below):

	Paper	Paper Code	Paper Type	Weightage for Assignment	Weightage for Term End	Full Marks
1st Year	Abstract Algebra	PGMT -1A	Theory	20%	80%	100
	Linear Algebra	PGMT -1B				
	Real Analysis & Metric Spaces	PGMT -2A	Theory	20%	80%	100
	Complex Analysis	PGMT -2B				
	Ordinary Differential Equations	PGMT -3A	Theory	20%	80%	100
	Partial Differential Equations & Special Function	PGMT -3B				

	Numerical Analysis	PGMT -4A	Theory	20%	80%	100
	[1]Computer Programming & its application to Numerical Analysis	PGMT -4B				
	Principles of Mechanics	PGMT -5A	Theory	20%	80%	100
	Elements of Continuum Mechanics & Special Theory of relativity	PGMT -5B				
2nd Year	General topology	PGMT -6A	Theory	20%	80%	100
	Functional Analysis	PGMT -6B				
	Differential Equations, Integral Transformations	PGMT -7A	Theory	20%	80%	100
	Integral Equations	PGMT -7B				
	Differential Geometry	PGMT -8A	Theory	20%	80%	100
	Graph Theory	PGMT -8B				
	(i) Advanced Complex Analysis / (ii) Operational Research	PGMT-9A(i)/ (ii)	Theory	20%	80%	100
	(i) Advanced Topology / (ii) Mathematical models in ecology	PGMT-9B(i)/ (ii)	Theory	20%	80%	100
	(i) Advanced Differential Geometry/ (ii) Fluid Mechanics	PGMT-10A(i)/ (ii)	Theory	20%	80%	100
	(i) Advanced Functional Analysis/ (ii) Mechanics of Solids	PGMT-10B(i)/ (ii)	Theory	20%	80%	100

Note: A learner may choose any one of the following groups for Paper 9 & 10 as Special Papers:

A. Pure Mathematics-9A(i), 9B(i), 10A(i),10-B(i)

B. Applied Mathematics-9A(ii), 9B(ii), 10A(ii), 10B(ii)

(c) Detailed Syllabus:

Part- 1

Paper -I: Algebra

Group - A : Abstract Algebra (50 Marks)

General Concept: Classical Algebraic System, Algebraic structures , Morphisms. **Group:** Morphisms of groups, normal sub-groups and quotient Groups, fundamental homomorphism theorem, isomorphism theorem s of groups, Conjugacy. Permutation groups.

Ring: Ideals of a Ring, Quotient Ring, Prime and Maxi mal ideals in a commutative ring with unity. Isomorphism of rings. Characteristic of a ring.
Fields: Integral domain and Quotient field s. Prime fields, Euclidean domain. Polynomial rings, Principal ideal domain. Extension of fields. Finite fields. Root fields of Polynomials, Splitting fields.

References:

1. I. N. Herstein - Topics in Algebra, VikasPub.

[1] Computer training is integral part of PGMT Course in Paper-4B and its successful completion is mandatory.

2. G. Birkhoff and S. Maclane - A survey of ModernAlgebra.
3. Serge Lang - Algebra, Addition - Westeypub.
4. G. Birkhoffand T. C. Bartee-Modern Applied Algebra, Mc-GrawHill.
5. D. S. Malik, J. N. Mordeson, M. K. Sen - Fundamentals of AbstractAlgebra, Mc-Graw Hill.
6. P. B. Bhattacharya, S. K. Jain, S. R. Noyapai - Basic Abstract Algebra Cambridge.

Group- B: Linear Algebra (50 Marks)

Vector space: Normal and Unitary vector spaces. Euclidean vector space. Orthonormal basis. Isomorphism and inversion of Linear transformations, Dimension of a vector.
Inner Product Spaces: Inner product function, Norm of a vector, Pythagoras theorem, Gram-Schmidt Orthogonalization.
Linear transformations: Linear map and linear functional. Matrix representation of Linear transformations. Similar and Congruent matrices. Reduction of a matrix to Normal form. Jordan Canonical form. Characteristic polynomial. Minimal polynomial. Calley - Hamilton Theorem. Diagonalization of real symmetric matrices. Kernel and Image. Space spanned by Eigen vectors.
Reductions of matrices: Characterization of real quadratic form. Rank and Nullity. Invariant subspace. Equivalent Quadratic forms. Reduction to Canonical forms- Reduction of matrices to Diagonal or Normal Form
Quadratic Forms: Sylvester law. Simultaneous reduction of two quadratic forms and Classification of quadrics.

References:

1. T. M. Apostol - Linear Algebra. John Wiley andSons.
2. K. Hoffman & R. Kunze - Linear Algebra,Prentice-Hall.
3. V. A. Iyin&Poznyak - Linear Algebra, MirPublication.
4. S. Lang - Linear Algebra,Springer-Verlag.
5. G. Hadly - Linear Algebra,Narosa.
6. A. Kurosh - Higher Algebra, MirPublication.
7. A. R. Rao and P. Bhimasankaram -Linear Algebra,McGraw-Hill.

Paper -II: Analysis

Group - A: Real Analysis and Metric Spaces (Marks 50)

Real Analysis: Open sets and closed sets and their properties. Bolzano-Weirstrass theorem. Heine- Borel Property. Monotone functions and Nature of their discontinuities. Functions of bounded variations. Lebesgue Measure of a bounded set. Measurable sets and their properties. Measurable functions. Convergence in Measure. Lebesgue theorem. Lebesgue integral of bounded measurable functions an d their proper ties. Comparison with Riemann-Integral. Lebesgue's criteria for Riemann integrability. Riemann - Stieltjes integrals, Simple properties. Fourier Series.

Metric space: Examples, c, S, c[a , b], Algebra of open and closed sets, closure, Interior and boundary of a set. Limit point, Housdroff property, Completeness. Connectedness. Important theorems in a metric space. Heine- Borel theorem. Continuous Functions over metric space –with applications. Uniform Continuity. Contraction theorem. Construction mappings Approximation theorem. Completeness in Matric spaces, examples, Baire theorem and Equivalent matrices. Compactness and Connectedness in metric space.

References:

1. G.F. Simmons- Modern Analysis
2. J. L.Kelley-Topology
3. P. Nathanson- Theory of functions of Real variable-I,II
4. Brown and Page - FunctionalAnalysis
5. C. Goffman - Realfunctions

Group - B: Complex Analysis (50 Marks)

Complex Field: The algebra of complex numbers, extended complex plane, Riemann Sphere and Stereographic projection. Lines. Circles, Cross-ratio, Bilinear transformation.

ComplexFunctions: Functions of a complex variable, limit,continuity,

differentiability, Cauchy-Riemann Equations, Sufficient condition for differentiability.

Harmonic functions, Analytic functions.

Integration: Line integrals of a complex function, Cauchy's fundamental theorem and its consequences, Cauchy's integral formula. Maximum modulus theorem and its consequences, Morera's theorem, Liouville's theorem, Fundamental theorem of algebra .

Sequence and Series: Sequence and Series of Complex numbers and Complex functions, Uniform Convergence, Weierstrass' M-test, Weierstrass theorem on uniform convergence on Compact sets (statement only), term wise integration and differentiation. Power series. Cauchy-Hadamard theorem. Uniqueness theorem.

Elementary Functions: Exponential function s, trigonometric functions, logarithm function. Many-valued functions. Branch Point.

Analytic Functions: Taylor's theorem, zeros of an analytic function, form of an analytic function near a zero, zeros are isolated point s, Schwarz's lemma. Open mapping theorem. Laurent series. Singularities: Pole, Essential singularity, Removable singularity. Form and behavior of a function near a pole, Casorati-Weierstrass theorem, Riemann's theorem on Removable singularity, Simple examples.

Calculus of residues: Residue, Residue theorem, Meromorphic functions, Argument principle, Rouche's theorem. Contour integration.

References:

1. Theory of functions of a Complex variable-Vol I & II, A. I. Markushevich, Prentice-Hall,1965.
2. Functions of one Complex Variable - J B. Conway, Springer-Verlag,1973.
3. Complex variables and applications - R. V. Churchill & J. W. Brown, McGraw-Hill, International Edition (5th Edition),1990.
4. Complex Analysis -1. V. Ahlfors, McGrow-Hill,1953.
5. Foundations of Complex Analysis - S. Ponnusamy, NarosaPublishing House,1995.

Paper – III: Differential Equations

Group A: Ordinary Differential Equations and Special Functions (50 Marks)

Existence and Nature of Solutions: Introduction, Order, Degree and Exactnessof Differential equation, Principle of Duality, Picard'stheorem.

General Theory of Linear Differential Equation: Basic concepts. Linear Differential Equation and its Properties, Existence and uniqueness theorems; Variation of parameters; Ordinary

points: Regular singular points; Tw oSpace System; Autonomous System; Critic al points; Limitcycles.

System of linear differential equations: System of linear differential equations in Normal form, Homogeneous linear system. Wronskian; Characteristic Equation and Characteristic Values, Stability of solution of ordinary differential equation.

Second order linear differential equations: Uniqueness Theorem, Characteristic Equation and Characteristic Values, Boundary Conditions. Stourm-Liouville Systems, Fourier's Convergence Theorem.

Green's function: Green's functions and its properties, Sturm-Liouville theory; Boundary value problems.

Plain Autonomous Systems: Path of the system. Integral curves, Singular point. Critical point Node, Saddle point, Damped linear Oscillator.

Special Functions: Equation of Fuchsian type; Series solution by Frobeniusmethod; Bessel , Legendre, Hermite, Laguerre and Hypergeometric differential equations: Simple properties of solutions; Asymptotic Expansions; Solutions in terms of contourintegration.

Non-linear differential Equations: Fundamental Existence Theorem;Stability; Lyapunov's function; Differential Equations with periodic solutions; Method of Bogoliubev andKrylov.

References:

1. G. F. Simmons - DifferentialEquations
2. I. N. Sneddon - Special functions of mathematicalphysics
3. E. L. Ince — Ordinary DifferentialEquations
4. E A. Coddington and N. Levinson - Theory of Ordinary Differential Equations

Group — B: Partial Differential Equations (50 Marks)

Linear partial differential equations of the first order: Charpit method and Jacobi' s method or solutions; Lagrange's equation and its solution; Quasilinear partial differential equation of second order; Cauchy problem; Characteristic directions; Classification of equations; Normal form of equations; Adjoint and self- adjoint operators. Some important partial differential equations and their classifications; Wave equation: D'Alembert's solution, Riemann's method of solution of hyperbolic equations: Heat equation; Elementary solutions; Laplace's equation: Elementary solutions; Dirichlet and Neumann problems; The theory of Green's function for Laplace's equation

Elliptic differential equations: Laplace's equation, Poisson equation, Boundary value problems, Laplace's equation in spherical polar and cylindrical co-ordinates, Heat equation, Harmonic function and Mean value theorem.

Parabolic differential equations: Diffusion equation. Boundary conditions, Solution by method of separation of variables, Maxima-Minima Principle, Uniqueness Theorem.

Hyperbolic differential Equations: Wave equation and Helmholtz equation in spherical polar coordinates; Solution by the method of separation of variables: Solution by the method of Fourier series.

Green's function: Green's function method for solution of Laplace's equation, Green's functions for solving Diffusion equation, Green's functions for Wave equation-Helmholtz theorem.

References:

1. I. N. Sneddon - Elements of Partial DifferentialEquations

2. K. S. Rao - Introduction to Partial DifferentialEquations
3. H.F. Weinberg - A first Course in Partial DifferentialEquations
4. F. John - Partial DifferentialEquations

Paper – IV: Numerical Analysis & Computer Programming

Group - A: Numerical Analysis (50 Marks)

Introduction: Round-off errors an d Instability - inherent and induced, Control of Round-off errors, Hazards in Approximate Computations.

Solving System of n Linear Equations in n unknowns: LU Decomposition Methods, Determinant of a Matrix and Matrix Inversion, Least-Squares Solution Over-determined Linear Systems, ill- conditioned Matrix.

Eigen pair of annxn Numerical Matrix: Power Method for Extreme Eigen values and Related Eigen vectors, Power Method with shifting.

Solution of Non- Linear Equations: Isolation or Bracketing of a Root (With odd multiplicity), Fixed Point Iteration, Newton-Raphson Meth od and Modified Newton-Raphson Method (for Real Roots only), Roots of Polynomial Equations with real Numerical Coefficients, Evaluation of Polynomials and their Derivatives. Bairstow's Method for Quadratic Factors of Polynomials, Quotient — Difference Algorithm forPolynomial Roots, Nonlinear Systems, Newton 's Method, Quasi-Newton Method.

Polynomial Interpolation: Inverse Interpolation, Roots by Inverse Interpolation, Central Difference Interpolation Formulas - Gauss, Hermite Interpolation, Piecewise nominal Interpolation Cubic Spline Interpolation.

Approximation: Least Square Approximation to Discrete Data, Chebyshev Polynomials, Economized Power Series Approximation of Functions.

Numerical Integration: Newton-Cotes Integration formula. Romberg Method.

Gaussian Quadrature Rules

Numerical Solution of Ordinary Differential Equations-Initial Value Problems: Taylor Series Method, Euler and Modified Euler Methods, Runge-Kutta Methods, Linear Multistep Methods: Adams-Bashforth, A darns-Moulton and Milne Formulae. **Two-point Boundary Value Problems of Ordinary Differential Equations:** Finite Difference Method, Passage Method.

Elements of Finite Difference Method of Numerical Solution of Partial Differential Equations: Poisson Equation on a RectangularRegion,ParabolicEquation in One- space Dimension (Heat Equation) - Explicit Finite Difference Method, Crank- Nicolson Method(ImplicitMethod) Hyperbolic Equation in One- space Dimension (Wave Equation): Finite Difference Method, Method ofCharacteristics.

References:

1. H. R. Schwarz - Numerical Analysis, John Wiley and Sons,1989.
2. C.E-Froberg -Introduction to Numerical Analysis, Addition Westley Publ.Co., Reading,1979.
3. K.E.Atkinson -A n Introduction to Numerical Analysis. John Wiley and Sons,New

York,1978.
4. S, D. Conte, C. d e-Boor - Elementary Numeric al Analysis: An Algorithmic Approach, McGraw-Hill,1981.
5. F. B. Hildebrand - Introduction to Numerical Analysis, McGraw-Hill, New York, 1982.
6. J. B. Scarborough - Numerical Mathematical analysis. Johns-Hopkins,1978.
7. A. Ralston and P. Rabinowitz - A First Course in Numerical Analysis, McGraw-Hill, NewYork
8. L. Collate - The Numeric al treatment of differential equations. Springer, NewYork.

Group-B: Computer Programming and its Applications to Problems of Numerical Analysis (50 Marks)

Algorithms and Flowcharts: Algorithms, Objectives, Definition and Examples of Algorithms, Flowchart

Programming with C: Introduction to C Programming, Constants and variables, Operators and Expressions, Input and Output Statements, Control Statements, Arrays, Functions, Pointers: Address operators, pointer Declaration, Void Pointer, Passing Pointers to a Function, Pointers and One-Dimensional Array, Dynamic Memory Allocation. String Manipulation, Structure and Unions: Definition of Structure, accessing a Structure, Nested Structure, Array of Structure, User Defined data type, Structure and pointers, Passing Structure and Function, Union. File Processing: File Pointer, Opening and Closing a File, File Handling Function, Writing to a File, Reading from a file, Operations on Data Files. Macro and Preprocessor: Macros, Macros with Arguments, The C Preprocessor.

Problems on Numerical Analysis: Solution of Algebraic and Transcendental Equations: Bisection method, Iteration Method or Fixed Point Iteration, Newton-Raphson Method or Method of Tangent, Solution of System of Linear Equations: Jacobi's Iteration Method, Gauss-seidal's Iteration method, LU Decomposition Method. Integration: Trapezoidal rule,

Simpson's 1/3 Rule. Ordinary Differential Equations: Euler's Method, Runge-Kutta Methods. Fitting of a Straight Line.

Data Structure: Asymptotic Notations, Time and Space Complexities, Data Structure, Arrays, Stacks, Evaluation of Expression: Postfix expression, Queues, Linked Lists.

References:

1. E. Balagurusamy, Programming in ANSI C, 4thEdition, The Mcgraw-Hill Companies, New Delhi(2009).
2. B.Gottfried, Programming with C, Schaum's Outlines, The Mcgraw-Hill Companies, New Delhi(2001).
3. Horowitz and sahani, Fundamental of Data Structure, Galgotia, New Delhi(1995).

Paper-V: Mechanics

Group- A: Principles of Mechanics (50 Marks)

Preliminaries: Concepts of Inertial frame, Newton's law s of motions, Conservative forces. Conservation laws. Equations of motion of a particle in different systems of co-ordinates. Motion of a particle on smooth and rough surfaces.

D'Alembert's principle: Generalized co-ordinates. Constraints. Classification ofHamilton's canonical equations of motion, Integral of energy. Poisson Bracket and its proper ties. Poisson bracket relations concerning linear and angular momentum. Action Principles: Hamilton's principle and the principle of least action. Verification of Hamilton's principle by D 'Alembert 's principle. Derivation of Lagrange's equations and Hamilton's equations from Hamilton's principle.

SymmetriesandConstants of Motion: Noether' s theorem, applicationson important physical problems like Brachistochrone. Shortest distance, Laws of Reflection andRefraction.

Canonical transformation: Concept of Phase space, Different kinds of Canonical transformations. Configuration space. Point Transformation and equivalency of Lagrangianmechanics. Hamilton-Jacobi equation, application to action-angle variables.

References:

1. Classic al Mechanics : H. Goldstein, N arosa, 1980.
2. Classic al Mechanics : J. R. Taylor, University Science Bo oks,2005.
3. Classic al Mechanics : Rana andJoag
4. Mathematical Methods of Classical Mechanics : V. I. Arnold, Springer-Verlag,1978.
5. Principles of Mechanics : J. L. Synge and B. A. Griffith

Group-B: Elements of Continuum Mechanics and Special Theory of Relativity (without tensor) (50Marks)

Special Theory of Relativity: Galilean transformation. Postulates of special theory of relativity. Lorentz transformation. Time Dilation. Length contraction and dilation. Velocity addition theorem. Einstein's Mass-Energy relation. Transformation formula for mass.

Kinematics of fluids: Lagrangian and Eulerian methods. The equation of continuity. Streamlines. Velocity potential.Rotational and irrotational motion. Euler's dynamical equations of motion. Integration of Euler's equation s. Steady motion. Bernoulli's theorem. Motion in two dimensions. Source Sink and Doublets. Constancy of circulation. Kelvin's theorem on minimum kinetic energy. Viscous flow theory.

Navier-Stoke's equation. Circulation in viscous flow. Flow between parallel plates.

Deformation of Solid: Deformation of Elastic Solid, Strain tensor. Equations of compatibility. Analysis of stress. Stress equations of equilibrium and motion. Stress- strain relations. Generalized Hooke's law. Equilibrium equations for an isotropic elastic solid. Simple applications. Strain energy function. Saint Venant's principle.

Wave propagation. Isotropic elastic solid.

References:

1. Dynamics Part II: A. S. Ramsey (Cambridge UniversityPress)
2. An Introduction to the Theory of Relativity-: P.Bergmann
3. Theory of Relativity : Special and General: M. Ray (S. Chand &Co)
4. Treatise on Hydrodynamics : A. S. Ramsey (G. Bell & SonsLondon)
5. Theoretical Hydrodynamics : L M . Milne-Thomson(Macmillan)
6. A Treatise on the Mathematical Theory of Elasticity : A. E. K. Love(Dover)
7. Mathematical Theory of Elasticity : I. S. Sokolnikoff (McGraw Hill)

8. Mathematical Methods of the Theory of Elasticity : V. Z. Parton & P. I.Perlin (MIR)

Part 2

Paper–VI: Topology & Functional Analysis

Group - A: General Topology (50 Marks)

Topological spaces. Examples, Base for a Topology. Sub-base. Neighbourhood system of a point, Neighbourhood base. Limit point of a set. Closed sets. Closure of a set, Kuratowski closure operator; Interior and boundary of a set, Sub -space Topology,

First and Second Countable spaces. Continuous function over a Topological space. Homeomorphism; Nets, Filters, Their convergence, Product spaces, Projection function.Open and Closed function, Quotient spaces.

Separation axiom s T0 T1; T2; T3; T4 in Topological spaces. Product of T2-SPACES. Urysohn's Lemma in Normal spaces, Tietze extension Theorem, Embedding in cube. Embed ding Lemma. Urysohn'smetrization Lemma.

Open cover, Sub-cover, Compactness, Countable open cover, Lindeloff space, Compact sets, Finite Intersection property, Tychonoff Theorem on product of compact

spaces, Continuous image of a comp act space s, Locally compact spaces, One point compactification.

Connected spaces, Separate d sets, Disconnection of a space, Union of connected sets, Closure of a connected sets, Connected sets of reals, Continuous image of connected spaces, Topological product of connected spaces, components, Totally disconnected spaces, Locally connected spaces. Uniformity in a set, Base, Sub-base of a Uniformity, Uniform space. Uniform Topology. T2—property of a Uniformity, Interior and closure of a set in terms of uniformity, Uniformly continuous function. Product Uniformity.

References:

1. Modern Analysis and Topology : Simons
2. General Topology : Kelley
3. Topological structure : Thron
4. Topology : Du gundji
5. General Topology : Adhikary, Chatterjee, Ganguly
6. General Topology : K. K. Jha
7. General Topology : Vaidyanathaswami

Group-B : Functional Analysis (50 Marks)

Metric spaces: Metric Topology, Complete metric spaces, examples G, C [a, b]; Separable metric spaces, Continuous functions; Homeomorphism,
Isometry; Compact metric spaces, Sequential compactness, Banach Contraction Principle Theorem, Ascoli-Arzela Theorem.

Normed Linear space (N LS) : Ban ach space. C [a, b] a s a Banach space. Quotient space of a NLS, Algebra of convex sets. Bounded Linear operators, their continuity, Unboundable Lin ear operator, Norm || T || if a bounded Linear operator T one NLS. Formulae for || T ||.
Equivalent norms, Riesz Lemma. Finite Dimensionality of NLS by compact unit ball, Boundedness

of Linear operators over finite dimensional NLS, space BdL (X , Y) of bounded Linear operators ; its completeness. Bounded Linear Functional, Hahn - Banach Theorem; its applications, conjugate s paces of NLS; Canonical mapping; Embed ding of a NLS into its second conjugate spaces under a Linear Isometry; Reflexive Banach spaces; Open map ping Theorem; Closed Graph Theorem.
Inner product s paces (I.P.S.): Cauchy - Schwarz inequality, I.P. spaces as NLS, Law of Parallelogram, orthogonal (orthonormal) system of vectors; Hilbert spaces; Project ion Theorem in a Hilbert spaces H, Riesz representation for a bounded linear functional, Complete orthonormal system in H. Adjoint of bounded Linear operatorin a Hilbert space H. Algebra of adjoint operators. Self-adjoint operators in H; their norms, every bounded Linear operator in H as a sum of self-adjoint operators; eigen- values and eigen vectors of self-adjointoperators.

References:

1. B.K.Lahiri : Elements of FunctionalAnalysis
2. Leierstermise and Sobolev : Introduction to FunctionalAnalysis
3. BrownandPage : FunctionalAnalysis
4. Kreyszig : FunctionalAnalysis
5. GoffmanandPedrick : FunctionalAnalysis
6. Taylor: FunctionalAnalysis

Paper -VII: Integral Transformations & Equations

Group-A: Differential Equation s & Integral Transformations (50 Marks) Fourier Transform: Its property if Continuity and Differentiability, Fourier transform derivatives. Riemann - Labesgue Theorem. Fourier Inversion Theorem; ConvolutionTheorem and Parseval's relation for Fourier Transform; Fourier Sine and cosine

transform. Some applications like (i) Heat conduction in solids (ii) Waveequation.
Laplace's Transform: Laplace Transform of derivatives, Properties of Laplaces Transform, like (i) Linearity (ii) Shifting (iii) Translation (iv) ConvolutionTheorem. Differentiation and Integration of Laplace Tranform. Inverse Laplace Transform: Inversion by (i) use of linear and shifting property, (ii) use of formulas for derivative and Integral if a Laplaces Transform, (iii) use of convolution. Theorem. Heaviside series expansion. Applications in Linear ordinary and partial differentialequations.
Hankel Transforms: Its inversion formula. Hankel Transform of derivatives. Finite Hankel transform and inversion formula. Finite Hankel Transform of derivatives.
Applications in problem of (i) free symmetric vibration of a stretched circular membrane (ii) conduction of heat in an infinite circular cylinder.

References:

1. I.N. Sneddon– The use of Integral Transforms, McGraw-Hill. Singapore1972.
2. R.R. Goldberg, Fourier transforms, Cambridge University Press, Cambridge, 1961.
3. D. Brain- Integral Transformation and their applications. Springer-Verlag, New York,2002.
4. R. Brace wall- The Fourier transform and its applications, McGraw-Hill, New York,1999.

Group-B: Integral Equations and Generalized Functions (50 marks)

Preliminary concepts: Integral Equation, Special types of kernels - symmetric kernel, kernel producing convolution integral, separable or degenerate kernel. Integral operator. Resolvent,

resolvent kernel and resovent equation. Function space. Orthonormal system of functions. Gram-Schmidt orthogonalisation. Approximation and convergence in the mean. The Riesz Fisher theorem.

Method of successive approximations: Neumann series, Iterated kernel. L_2— kernels and functions.

Fredholm Theory: TheFredholmtheorems.Degenerate kernels. Method of approximation by degenerate kernels. Continuouskernels.
Hilbern-Schmidtkernel: expansion theorem, the Hilbert-Schmidt theorem, Hilbert s' formula, applications of Hilbert-Schmidt theorem. Expansion of the resolvent kernel. Positive kernels. Mercer's theorem. Fredholm integral equationof the firstkind.

References:

1. Lectures on the theory of Integral Equations, MirPub.
2. First course in Functional Analysis,PHI.
3. A course in Mathematical Analysis, Vol-III, Part-II DoverPub.
4. Integral Equations, Wiley, New York

Paper-VIII: Differential Geometry & Graph Theory

Group - A: Differential Geometry (50 Marks)

Tensors: Transformation of Co-ordinates; Summation conventions; dummy index, free index, Kronecker delta; Contravariant and Covariant vector. Invariants; Second order tensors and higher order tensors; Algebra of Tensors;

Contraction; Symmetric and skew symmetric tensors. Quotient Law; Conjugate symmetric tensor. Curvilinear Co-ordinates.
Metric tensor: Linear element ds, Riemannian metric. Fundamental metric tensor, Riemannian space. Associated vectors, magnitude of vectors, angles. Christoffel symbols. First and Second kind; Relations
Covariant differentiation of vectors and Tensors. Riemann - Christof elf Tensor and its proper ties; Riemann - Christoffel tensor of first kind; Ricci Tensor; Scalar Curvature, Einstein space.

Curves and Surfaces in spaces: Serret-Frenet formula; Helices, Surfaces: The element of length and metric tensor. First Fundamental form; Angle between two intersecting curves on a surface; Geodesies on a surface: Gaussian Curvature: Geodesic curvature. Necessary and sufficient condition for a curve on a surface to be geodesic.
Tensor derivative: Gauss formula: Weingarten's formula: Third Fundamental form of the surface. Equations of Gauss and Codazzi, Mensner's theorem; Principal curvatures, line of curvature.

References:

1. M. C. Chak i: A text book of Tensor Calculus
2. Sokolnicoff: Tensor Analysis
3. Weatherburn: Tensor Analysis
4. Eisenhart: Riemannian Geometry
5. S. Pain: Tensor Calculus
6. W. B. Boothby: An Introduction to Differentiable manifold and Riemannian Geometry

Group - B: Graph Theory (50 Marks)

Graphs and Directed Graphs (Digraph): Parallel edges. Adjacent edges. Loop; Simple Graph; Degree of a vertex; Regular Graph, Odd and Even vertex; Pendant vertex. Properties of a graph like: sum of degrees of vertices in a graph equals to twice the number of edges in G, Simple Graph has a pair of vertices of equal degrees. Directed Graphs (Digraph), Representation of binary relations on finite sets by Digraphs.

Subgraphs: isomorphism of graphs, walks, paths and cycles; length of a walk; closed walk; Circuits and cycles.

Connected Graphs: Components of a graph; A simple Graph of n vertices and m components has at most l/2 (n–m) (n – m + 1) edges ; Complete Graph, Complement of a graph ; A Complete Graph of n vertices contain s 1/2 n (n –1) edges,

Eulerian and Hamiltonian Graphs : Eulerian graph, Hamiltonian Graphs, A

Connected Graph of even degree vertices is Eulerian, Konigsberg Bridge problem; Hamiltonian Path.

Tree: Definition of Tree, Important properties like A tree of n vertices has (n - 1) edges; A connected n - vertex graph with (n - 1) edges is a tree. Minimally connected tree; Spanning tree ; Every connected graph has a spanning tree. Minimal s panning tree; Kruskal's algorithm f or a minim al spanning tree; Rooted tree, Binary tree.

Planar Graph: Imbedding of a Graph on a surface, Faces of a Planar Graph; Euler's polyhedral equation, Kuratowski's first Graph K_5 and Kuratowski second Graph $K_{3.3}$. Their properties.

Matrix representation of Graphs: Adjacency matrix of a Graph, Incidence matrix ofa Graph.

References:

1. F.Harrary: GraphTheory
2. N. Deo: GraphTheorywithapplicationstoEngineeringand ComputerScience
3. M. K. SenandB.C.Chakraborty: Introduction to Discrete Mathematics
4. M. K. Sen and D. S. Malik: Discrete MathematicalStructures
5. J. G ross andJ.Yellen: Graph Theory and itsapplications

Paper-IXA (i): Advanced Complex Analysis (50 M arks)

Analytic continuation – The idea of analytic continuation. The analytic continuation of the exponential, trigonometric and hyperbolic functions. Direct analytic continuation. Complete analytic function. Natural Boundary. Analytic continuation by power series. F unction el. Analytic continuation along a path. Monodromy theorem.

Conformal Mapping – I – Definition. Basic properties of con formal mapping. Conformal map pings by elementary functions. Schwarz Principal mappings by elementary functions. Schwarz cristoffel transformation. Some applications.

Entire function – Infinite product. Uniform convergence of infinite products. Basic propriety's entire function s. Factorization of entire functions.

Meromorphic function – Mittag – Leffler theorem. Gamma function. Jensen's theorem. Poisson – Jensen theorem.

Conformal Mapping – II – Univalent function. Normal families. The Riemann mapping theorem. The class Y.

Many valued function – The function log z. The power function. Branch points of an analytic function. Regular b ranches of analytic functions.

Riemann Surface – A few examples.

Paper IXB (i): Advanced Topology (50 Marks)

Compactness: More facts about nets and filters-subnets, clusters point, filter,ultrafilter. Characterization of compactness. Countable, Frechet, Sequential compactness, interrelationships, compactness in metric spaces, equivalence of the four types of compactness.

Compactification: More on Locally compact spaces, properties, compactification, more on one-point compactification, embedding Lemma, stone-Cech compactification, ordering in Hausdorff compactifications, Wallman's compactification.

Paracompactness: Locally finite family, paracompactness, basic properties, star operation, equivalent condition of paracompactness in respect of star operation, fully normal space, partition of unity.

Metrization: Metrization of topological space, Metrization of the product space R^j, Uryshon'smetrization theorem, Nagata-Smirnov metrization theorem, Cartesian product of metrizable spaces, Two important results, namely, Arzela-Ascoli's theorem, Stone- Weirstrass.

Uniform space and proximity spaces: Definition of uniform spaces, basis, sub basis of a uniformity, topology induced by uniformity, uniformizable spaces, Metrizable spaces, uniformly continuous maps, Cauchy nets and filters, completeness in a uniform space, total boundedness and compactness.

Paper–XA (i): Advanced Differential Geometry (50 Marks)

Differentiable Manifold: Differentiable mapping, Differentiable curves; Integral Curve, Differential of a mapping, f-related vector field. One parameter group of transformations on a manifold. Co- tangent space, r-form and Exterior Product.
Exterior differentiations, its existence and uniqueness. Pullback differential form.
Lie Group: Left translation, right translation, Invariant Vector field. Lie algebra of the Lie Group G. Invariant Differential Form: Automorphism. Inner automorphism. One- parameter Sub Group of a Lie Group. Lie Transformation Group (Action of a Lie Group on a Manifold). Fundamental Vector field, Fundamental map.

Linear connection; Torsion tensor field and curvature tensor field on a Linear connection. Ricci Identity:

(i) fora1-formw:$(\nabla x\nabla yw-\nabla Y\nabla X^w-\nabla[X,Y]^w)=-W(R(X,Y),Z,P)$

(ii) fora2-formw:$(\nabla X\nabla Y^w-\nabla Y\nabla X^w-\nabla[X,Y]^w)(Z,P)=$

$-W(R(X,Y)Z,P)-W(Z,R(X,Y)P)$

Riemanian Metric: Riemanian Connection (Levi- Civita Connection). Every Riemannian manifold (M, g) a of a unique. Riemannian Connection Manifold of constant curvature is an Einstein Manifold. A 3-dimensional Einstein manifold is a manifold of constant curvature.
Semi-symmetric Metric Connection. Weyl Conformal Curvature tensor. Goldberg's result:If (M, g) is a Riemannian manifold and A is the field of symmetric endom orphism corresponding to Ricci tensor S i.e., g (AX, Y) = S (X, Y) for every Vector fields X, Y on M, then C (X, Y) Z = R (X, Y) Z- 1/n-2 {g (Y , Z) AX– g (X, Z) AY +
S (Y, Z) X–S (X, Z) Y] + r/(n- 1) (n-2) {g(Y, Z) X– g) X, Z) Y}.
Conformallysym metric. Ri emannian Manifold, A conformallysym metric man ifoldisofconstantscalarcurvatureif$(\nabla zS)(Y,W)=(\nabla wS)(Y,Z)$forallY,Z,W.

References:

1. N.J.Hicks: DifferentialManifold
2. W.M. Boothby: Int. to Differential Manifolds and RiemannianGeometry
3. Y. Matsushima: DifferentiableManifold
4. P. M.Cohn:LieGroups
5. B. B.Sinha:Int. to modern Differential Geometry
6. S.Helgason:Differential Geometry, Lie Group and SymmetricSpaces

Paper – XB (i) : Advanced Functional Analysis (50 Marks)

Convex hull of a set in a vector space: Its representation Theorem; Symmetric sets, balanced sets, absorbing sets in a vector space; Isomorphism in vector spaces.

Topological vector spaces (TVS), translation and multiplication operators as self-homeomorphism, Bounded sets in TVS; basic properties in TVS. Separation Theorem in TV S ; Linea r operators and their continuity in TV S ; Locally compact TVS, Minkowski functionals, semi-norms, Kolmogorov theorem on normability of a TVS.

Bounded Linear functionals and their representation over Rn, l_p ($1< p <\infty$) and C [0,1]. Banach Steinhaus Theorem, Weak convergence in Normed Linear Space (NLS). Best approximation in N LS, strictly convex norms, uniqueness criterion of best approximation.
Resolvant set r(T) and spectrum s(T) of a bounded linear operator T over NLS,
compact linear o perators, spectral properties of a bounded self-adjoin t operators T over Hilbert space, spectral radius formula; Projection operators, their algebra and properties.

Eigen value, eigen vector of a linear operator over NLS X with Dim (X) <¥, characteristic equation: finite dimensional spectral theorem ; Banach algebra X, identity element; invertible and non - invertible elements o f X, Topological divisor of zero in X. Gelfand-Mazur Theorem.
Weak and weak* topology in conjugate space X* of a NL S X; their properties, weak* compactness, Banach-Alaogulu Theorem.

References:

1. W. Rudin: Functional Analysis
2. B. K. Lahiri: FunctionalAnalysis
3. Brown and Page: FunctionalAnalysis
4. Bachman and Narici: FunctionalAnalysis
5. Kreyszig: FunctionalAnalysis

IXA (ii): Operations Research (50Marks)

Classical Optimization techniques: Multivariable Optimization with no Constraints, equality constraint and inequality constraints. Method of constrained variation, Method of Lagrange multipliers. Kuhn-Tucker conditions. Revised Simplex meth od, Dual simplex method and modified dual simplex method.

Post optimality Analysis: Discrete changes in the Cost vector and Requirement vector. Addition of a single variable, Deletion of a variable and Addition of a new constraint.

Quadratic Programming: Wolfe's and Beale's method.

Integer Programming: Gomory's cutting Plane method, Branch and bound method.

One dimensional minimization method: Fibonacci method and Golden section method. **Unconstrained optimization technique**: Steepest descent method, Quadratically convergent method, Newton's method & Dairdon-Fletcher-Powell method.

Constrained optimization technique: Cutting plane method.

Paper IX B (ii): Mathematical Models in Ecology (50 Marks)

Introduction: Basic concept of ecology ecological systems. Mathematical models. Variables, Deterministic and Stochastic models. Modelling in discrete time and continuous time.
Continuous Sing e-Species Population Models: Basic Postulates, General Model equation. Malthus growth model, Logistic growth model, Allce effect. Qualitative analysis, Harvard model. Exercises.

Discrete Single-Species Population Models: Discrete models and difference equations. Differential Vs Difference equations. Equilibrium points and Stability. Graphical solution of Difference equations. Density dependent population growth. Equilibrium points and Criterion of Stability. Rabbit problem. Fibonacci sequence. Exercises.
Delay Differential equations Models: Introduction, Types of Delay equations, Discrete time Delay model, Distribute d Delay models of population.

Interacting Population Models: Qualitative analysis, Generalization and Stability. Periodic solutions and limit cycles. Classical Prey-Predator models. Realistic Lotka-voltera models. Co-operative systems. Ecosystem models. Functional groups and Nutrient Flows. Food-Chain model. Logistic primary production, Material cycling.

Paper – XA (ii): Fluid Mechanics (50 Marks)

Irrotational motion in 3D: motion of a sphere, flow around an ellipsoid, stream functio n for axis- symmetric flow, method of source and sinks, motion of a rigid body in an unbounded fluid, inertial motion of a body. Boundary conditions, motion of a circular cylinder, the unsteady flow, hydrodynamic

reactions in a steady flow, Blastius-Chaplygin formulae, Kutta-Jouko uskii transformation, method of conformal mapping. Schwartz- Christofell formulae, Joukouskii's profile, flow around a flat plate and an elliptic cylinder. Vortex lines,vortex filaments, rectilinear and circular vortex, Stoke's formulae, Helmholtz's theorems, formulation of vortices, vortex layer, Karman vortex street.

Wave motion: plane waves, wave components, steady waves, progressive waves, energy of waves, group velocity, rate of trans mission of energy in simple harmonic surface waves, water at the common surface of two liquids, Long wave, capillary waves. Flow through pipes of circular, annular and elliptic cross-section s, boundary layer equations on a plane wall, Blasius solution for a flat plate.

References:

1. Milne-Thomson, L. M., Theoretical Hydrodynamics, Macmillan and Co.Ltd, London,1955.
2. Ramsey, A. S., A Treatise On Hydromechanics, CBS Publishers andDistributors, New Delhi,2000.
3. Chorlton, F., Textbook Of Fluid Dynamics, CBS Publishers and Distributors,New Delhi,2003.

4. Lamb, H. Hydrodynamics, Cambridge University Press,1932.
5. Kundu, P , K., Fluid Mechanic s. Academic Press, San Diego,1990.
6. Landau. L. D., Liftshitz, E. M, Fluid Mechanics, Pergamon Press, London,1959.
7. Kochin, N. E., KibeL I. A. &Roze, N. V. Theoretical Hydrodynamics,Interscience Publishers,1964.

Paper X B (ii): Mechanics of Solids (50 Marks)

Two Dimensional Elastostatic Problems: Introduction, Plane strain, Plane stress and Generalized plan stress, Plane elastotalic problem, Airy's stress function.

Extension and Torsion: Axial Extension of a Beam, Beam stretched by its own weight, Bending of a beam by terminal couples, Torsion of cylindrical bars of circular cross-section, Torsion of a cylindrical bar of any given section, Solution of the torsion problem for certain particular cases.

Semi- Infinite Solids With prescribed Displacements or Stresses on the Boundary: Semi-infinite solid with prescribed Displacements on the plane Boundary, Semi-infinite solid with prescribed surface traction on the plane boundary, Simple Solutions.

Variational Methods: Euler's Equation, Theorem of minimum potential energy, Theorem of minimum complementary energy, Reciprocal theorem of bethi and Rayleigh, Examples

Elastic Waves: Body Waves: Waves of dilatation and waves if distortion, Plane Waves, Surface Waves: Rayleigh wave, Love waves.

Transverse Vibration of Thin Elastic Plates: Basic Preliminaries, Differential equation of transverse vibration of thin plate, Vibration of a rectangular plate with simply supported edge, Free vibration of a circular plate: Clamped edge, Simply supported edge, Symmetrical vibration of a thin circular plate.

Plasticity: Basic Concepts: Relation between the stress and strain deviators, Stress-strain curve. Yield Criterion, Equation of Plasticity: Prandtl- Reuss Theory, Stress-strain relation of Von- Mises, Elasto-plastic problems.

Duration of the programme:
The duration of post graduate mathematics course is 2 years which could be extended up to maximum 5 (five) years. Thereafter, students need to re-register freshly to complete the course

c. Faculty & Support Staff requirement:

Sl. No.	Faculty	Name of the Faculty	Work at (HQ/RC)	Number
1	Professor	Prof. Kajal De	On Lien	
2	Associate Professor	Mr. Ratanes Misra	RC - 1	1
3	Associate Professor	Dr. Nemai Chand Dawn	RC - 1	1
4	Assistant Professor	Mr. Mrinal Nath	RC - 1	1
5	Assistant Professor	Dr. Ushnish Sarkar	RC - 1	1
6	Assistant Professor	Dr. Chandan Kumar Mondal	RC - 1	1

d. Support Staffs:

Sl. No.	Office Staff (Designation)	Work at (HQ/RC)	Number

1	Junior Assistant	HQ - 1	1
2	Junior Assistant Cum Typist	RC - 1	1

e. Instructional Delivery Mechanisms:

Mode of Delivery type	Delivery Mechanism	Provided (Yes/No)	Detailed Information (Please Mention the Activity Hour)
Face to face mode	PCP	Yes	18 hrs. PCP for each 50 marks of Theory paper
	Tutorial/Special Class/ Remidial Classes/ECP	Yes	e- Tutorials are offered through LMS platform for at least 5 hours each 50 marks' theory paper
	Seminar /Research Colloquium	Yes	As per requirements
	Laboratory Based Practical	Yes	Computer training (practical) session (18 hours) is done in state-of-the-art laboratories of Kalyani & Durgapur RCs as well as selected study centers with well-equipped laboratories. LMS platform is also used innovatively to augment our learners' programming skill.
Self-Learning	SLMs	Yes	The printed SLMs are provided to the students during the counselling of admission. The e-SLMs are also available in the University website
	Reference Books	Yes	Reference books are distributed through library. Lists of references are available in each and every SLM. Moreover, some references are also suggested during the PCPs
ICT/ Digital Wellness of Students	Online (Web driven/Mobile App)	Yes	AVL, question bank are given to students through online; NSOU mobile app and Zoom platform are also used.
	Offline DVD/SD card?USB Drive	Yes	A number of AVL on PG Mathematics topic has been developed and further will be done within due course
	Telecommunications	yes	ICT cell gives support through telecommunication
Blended	Smart Classrooms	Yes	Smart classroom is used for delivering lectures at RCs
	Flipped Learning	Yes	ODL is based of SLMs. The Learners attend the PCPs after studying the content to clarify their doubts.

SLM:

NSOU has major focus on SLM or print based material and their continuous upgradation by eminent teachers/scholars both from NSOU and other reputed universities/institutes. Since text is still the dominant form of information in a distance environment, print-based instruction has a critical role in NSOU distance learning initiatives. Print offers compelling strengths as a distance education medium. It is easy to reproduce, portable, ideal for self-study, and a familiar medium to learners.

Audio-Visual Material Aids:

The learning package contains audio and video programmes which have been produced by NSOU, for better clarification and enhancement of understanding of the course material given to the student. A video programme is normally of 25-30 minutes' duration. The video programmes are delivered using laptop/desktop or a mobile app. NSOU has several mathematical modules already developed by the experts in different topics of post graduate mathematics course like Topology, Numerical Analysis, Graph Theory, Programming, Complex Analysis, Differential and Integral calculus.

Face to Face Counselling Sessions:

Normally, counselling sessions are held as per a schedule drawn before**h**and by the Study Centre Coordinator. They are held on Sunday. There are 6 counselling sessions of 3 hours duration for each course in face to face mode. Eminent teachers from NSOU and other institutes drive these sessions with their vast experience and help the learners to understand the subject better.

Computer training sessions:

NSOU has two state-of-the-art laboratories**in Kalyani and Durgapur Regional Centers** where modern computing techniques are practiced while solving different mathematical problems. Each of the laboratories in Kalyani and Durgapur RCs have capacity of 50 learners and well equipped with different programming language software like C, C++, Python, R which is the basic needs of modern days mathematical programming for PG level. Computer trainingsessions are also offered in some selected study centers with well equipped laboratories to cater the need of the learners. LMS platform is also used innovatively to augment our learners' programming skill.

Multimedia Based material:

NSOU developed several lectures on rigorous mathematical topics which comprised of words, pictures/Diagrams along with relevant automation for better clarity and visualization. CD-ROM and DVDs have been used as storage for this lecture which will be distributed to the learners as per their needs.

Online/Virtual Classes:

Additionally, NSOU, conducts live/virtual classes using technology. These are pre-calendared classes where the faculty or external experts are invited to conduct live sessions for students. Students are able to ask questions and the instructor is able to answer questions after the lecture using technology.

Mobile App:

NSOU provides a mobile app to each and every student using which students can go through entire learning material at their convenience. The mobile app has the capability to make the entire content (Video, Textual, Quizzes etc.) in off-line mode too. This is a unique offering of NSOU which has made the learning process convenient and very effective for the learners.

vi. Procedure for admissions, curriculum transaction and evaluation:

University frames its policy related to admission entry criteria, method of admission, conduction of admission through the Admission Committee (statutory body) following the guideline of the UGC (Open and Distance Learning and Online Programmes) Regulations, 2020 and Department of Higher Education, Govt. of West Bengal. Admissions are conducted entirely through Online mode centrally by the University.

Information Circulation Policy:

All information related to the programme like admission policy, eligibility, fee structure, course curriculum, medium of instruction, method of instruction, evaluation method, SLMs etc. are transacted through prospectus, brochure, official notification etc.

Learner Support Services:

Learner support services are provided by the University at three level of functioning of the Open University architecture i.e. Learner Support Centre (LSC), Regional Centre and Head Quarter.

Following the UGC (Open and Distance Learning and Online Programmes) Regulations, 2020 LSCs are provide various learner support services in order to facilitate the acquisition of teaching-learning experience for its enrolled learners throughout at various phases of learners' study life cycle. LSC also main contact points for access by the learners, responsive and facilitating information centres, arranging contact sessions and other operations like processing of assignments etc.

University has constituted Learner's Facilitation Centre (LFC) at each Regional Centres to provide various support services. Beside that University has also provided learners support services through web based platform/ telephone/ email/ instant messaging services.

Transaction of Curriculum and Academic Planner:

The University employs a variety of strategies to maximize the exposure of students to course material and each instructional programme. Initially, printed SLMs/SIMs (Self Learning Materials/Self Instructional Materials) packages and contact programmes including face-to-face engagement with academic counsellors are offered. Ultimately, audio materials, audio-visual presentations, teleconferences, and sporadic discussion sessions through webcasting and online radio may be implemented. The following instructional Learning Methodologies and Student Support Services are utilised to improve the Open and Distance learning environment:

- SLM in Print
- eSLM on the University Website
- Live AV Lectures Using LMS platform integrating App based education
- AV Lectures in DVD Mode; subsequently integrated on NSOU android app (Over 40 hrs run time)
- Blended Learning through PCP at LSC and online instruction
- SLP

Curriculum transaction is through Online and or Offline modes as detailed above and all academic activities are conducted following the programme is following the below mentioned activity planner during the academic session:

Name of the Activity	**Tentative months schedule (specify months) during Year**	
	From (Month)	**To (Month)**
Admission	Nov	Jan
Distribution of SLM	Jan	Mar
Contact Programmes (counselling, practical, etc.)	Apr	Nov
Assignment Submission	Oct	Nov
Evaluation of Assignment	Nov	Dec
Examination	Dec	Jan
Declaration of Result	Mar	Apr

Name of the Activity	Tentative months schedule (specify months) during Year	
	From (Month)	To (Month)
Renewal/ Re–registration	Jan	Feb

Evaluation:

Evaluation is on a 2-tier basis, divided into Assignment submission (online mode) and Term End Examinations (Offline mode). The weightage is as follows:
Assignment – 20 marks
Term End Examination – 80 marks
Total marks for each course – 100

A**ssignment / Internal Assessment/ Continuous Assessment / Formative Assessment:** Assignment submission is the first interaction between the learner and the teacher. It has a very important role to play in the teaching-learning process in distance education. So, submission of Assignment is mandatory for all learners. The assignment responses reflect what the learners have understood and learnt. The assignment answer scripts are returned to the learners so that the assignment answers serve the purpose of providing feedback to the learners and inform them their strengths and weaknesses. Learners will be required to submit assignment for each course and the marks obtained on evaluation of those assignment courses will be entered into his/her individual record of performance. This will constitute 30% (maximum) of the Full marks in the course as per University Grants Commission (Open and Distance Learning Programmes and Online Programmes) regulations, 2020. All the Marks secured by the learners will be progressively entered into the result card. Every learner is required to submit the assignment courses before each Term-End Examination. In practical course of Science stream, there is no assignment.

Term-End Examinations: Minimum 80% of the total credit points of the course (except practical course where it is 100%) would be reserved for Term-End Examination as per University Grants Commission (Open and Distance Learning Programmes and Online Programmes) Regulations, 2020. Minimum qualifying marks in each course is 20% (Term End Examination Marks + Assignment Marks).

Waive of Programme Fee:

University waive of full course fee for transgender learners.

vii. Requirement of the laboratory support and Library Resources:

NSOU has developed state-of-the-art laboratory in Kalyani and Durgapur Regional Centers for computer programming, which is used for postgraduate mathematics course. The laboratory has capacity of 50 learners and equipped with hardware and software required for mathematical programming. Other laboratories in different study centers are also used for practical sessions.
Library facility is one of important services in any higher educational institution. In addition to the Self Learning Materials (SLMs) and other learning resources the University provides library facility to all of its registered learners. The Library Department, Netaji Subhas Open University is located at Kalyani Campus.
Further, to cater to the needs of huge number of registered students, the University needs unlimited libraries to provide educational support to everyone. To cope with the situation, the University has initiated the process of setting up a strategic partnership with the existing network of Public Libraries that are available in the State of West Bengal to offer educational support to our learners all over the State. This initiative taken by NSOU is the first of its kind in the country.

viii. Cost estimate of the programme and the provisions:

Total course fee is Rs. 10,400/- (Excluding Examination and Studentship Renewal Fees). An approximate distribution of expenditure is given below to get prior view:

Assigned Head	Sub Head	% of Expenditure
Development	SLM Preparation and Development Cost	7
	SLM Printing	44
Maintenance & Programme Delivery	Maintenances Grant	5
	Counselling/ PCP/ Lab Counselling	25
	Delivery Charges	4
	Other Overhead Expenses	8
ICT Support	Admission Processing	1
	ICT Support Services	5
	Computer Training	1

ix. Quality assurance mechanism and expected programme outcomes:

University is supported with a strong group of Board of Studies (BOS) members. All highly competent and esteemed professors have constantly supported this programme to cater to equitable quality education. They are engaging their self in time-to-time reviewing of syllabus. They do moderation and in such a way this BOS is responsible to check and maintain the quality of this program. NSOU has constituted the "Centre for Internal Quality Assurance (CIQA) as per UGC (Open and Distance Learning and Online Programmes) Regulations, 2020 to ensure the delivery of high quality programmes to its learners.

Board of Studies (BOS): Board of Studies ensure quality of the Curriculum of Post Graduate Programme in Mathematics as per University norms. BOS plays a vital role as the following

- ✓ Curriculum review and development of quality Self Learning Materials (SLMs) in print. The curriculum is reviewed regularly to ensure that it is up-to-date and relevant to the needs of learners.
- ✓ Learner's assessment and evaluation process through a variety of methods, including exams, assignments. This helps to ensure that Learners are meeting the learning outcomes of the Programme.

Expected Programme outcomes:

After successful completion the students may increase their knowledge with the new tools and techniques of Mathematics. A student after completing this course may go either for various government jobs such as school service or research programme in various institutes and universities in India or abroad.