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**Co-ordinators : Prof. Ronnie Sebastian**

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**Co-ordinators : Dr. Joydeep Dutta**

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**NPTEL : Functional Analysis (Mathematics)**

**Co-ordinators : Prof. P.D. Srivastava**

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- Lecture 2 - Holder Inequality and Minkowski Inequality
- Lecture 3 - Various Concepts in a Metric Space
- Lecture 4 - Separable Metrics Spaces with Examples
- Lecture 5 - Convergence, Cauchy Sequence, Completeness
- Lecture 6 - Examples of Complete and Incomplete Metric Spaces
- Lecture 7 - Completion of Metric Spaces + Tutorial
- Lecture 8 - Vector Spaces with Examples
- Lecture 9 - Normed Spaces with Examples
- Lecture 10 - Banach Spaces and Schauder Basis
- Lecture 11 - Finite Dimensional Normed Spaces and Subspaces
- Lecture 12 - Compactness of Metric/Normed Spaces
- Lecture 13 - Linear Operators-definition and Examples
- Lecture 14 - Bounded Linear Operators in a Normed Space
- Lecture 15 - Bounded Linear Functionals in a Normed Space
- Lecture 16 - Concept of Algebraic Dual and Reflexive Space
- Lecture 17 - Dual Basis & Algebraic Reflexive Space
- Lecture 18 - Dual Spaces with Examples
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- Lecture 20 - Tutorial - II
- Lecture 21 - Inner Product & Hilbert Space
- Lecture 22 - Further Properties of Inner Product Spaces
- Lecture 23 - Projection Theorem, Orthonormal Sets and Sequences
- Lecture 24 - Representation of Functionals on a Hilbert Spaces
- Lecture 25 - Hilbert Adjoint Operator
- Lecture 26 - Self Adjoint, Unitary & Normal Operators
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- Lecture 29 - Total Orthonormal Sets And Sequences
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- Lecture 3 - Analysis of Single Step Methods
- Lecture 4 - Runge - Kutta Methods for IVPs
- Lecture 5 - Higher Order Methods/Equations
- Lecture 6 - Error - Stability - Convergence of Single Step Methods
- Lecture 7 - Tutorial - I
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- Lecture 9 - Multi-Step Methods (Explicit)
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- Lecture 11 - Convergence and Stability of multi step methods
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- Lecture 13 - Stability Analysis of Multi Step Methods
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- Lecture 15 - Some Comments on Multi - Step Methods
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- Lecture 17 - Linear/Non - Linear Second Order BVPs
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- Lecture 21 - Tutorial - III
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- Lecture 24 - Finite Difference Approximations to Parabolic PDEs
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- Lecture 27 - Other Numerical Methods for Parabolic PDEs
- Lecture 28 - Tutorial - IV
- Lecture 29 - Matrix Stability Analysis of Finite Difference Scheme
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- Lecture 31 - Finite Difference Approximations to Elliptic PDEs - I

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**NPTEL : Optimization (Mathematics)**

**Co-ordinators : Prof. A. Goswami, Dr. Debjani Chakraborty**

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Lecture 2 - Formulation of LPP

Lecture 3 - Geometry of LPP and Graphical Solution of LPP

Lecture 4 - Solution of LPP : Simplex Method

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Lecture 7 - Special Cases in Simple Applications

Lecture 8 - Introduction to Duality Theory

Lecture 9 - Dual Simplex Method

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Lecture 11 - Integer Programming - I

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**Co-ordinators : Prof. Somesh Kumar**

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**Co-ordinators : Dr. Soumen Maity**

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- Lecture 52 - Constrained Optimization
- Lecture 53 - Feasible Direction
- Lecture 54 - Penalty and barrier method
- Lecture 55 - Penalty method
- Lecture 56 - Penalty and barrier method
- Lecture 57 - Penalty and barrier method
- Lecture 58 - Dynamic programming
- Lecture 59 - Multi-Objective decision making
- Lecture 60 - Multi-Attribute decision making



Lecture 1 - Introduction to Matrix Algebra - I

Lecture 2 - Introduction to Matrix Algebra - II

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Lecture 4 - Determinant of a Matrix

Lecture 5 - Determinant of a Matrix (Continued...)

Lecture 6 - Gauss Elimination

Lecture 7 - Gauss Elimination (Continued...)

Lecture 8 - LU Decomposition

Lecture 9 - Gauss-Jordan Method

Lecture 10 - Representation of Physical Systems as Matrix Equations

Lecture 11 - Tridiagonal Matrix Algorithm

Lecture 12 - Equations with Singular Matrices

Lecture 13 - Introduction to Vector Space

Lecture 14 - Vector Subspace

Lecture 15 - Column Space and Nullspace of a Matrix

Lecture 16 - Finding Null Space of a Matrix

Lecture 17 - Solving  $Ax=b$  when A is Singular

Lecture 18 - Linear Independence and Spanning of a Subspace

Lecture 19 - Basis and Dimension of a Vector Space

Lecture 20 - Four Fundamental Subspaces of a Matrix

Lecture 21 - Left and right inverse of a matrix

Lecture 22 - Orthogonality between the subspaces

Lecture 23 - Best estimate

Lecture 24 - Projection operation and linear transformation

Lecture 25 - Creating orthogonal basis vectors

Lecture 26 - Gram-Schmidt and modified Gram-Schmidt algorithms

Lecture 27 - Comparing GS and modified GS

Lecture 28 - Introduction to eigenvalues and eigenvectors

Lecture 29 - Eigenvalues and eigenvectors for real symmetric matrix

Lecture 30 - Positive definiteness of a matrix

Lecture 31 - Positive definiteness of a matrix (Continued...)

- Lecture 32 - Basic Iterative Methods: Jacobi and Gauss-Siedel
- Lecture 33 - Basic Iterative Methods: Matrix Representation
- Lecture 34 - Convergence Rate and Convergence Factor for Iterative Methods
- Lecture 35 - Numerical Experiments on Convergence
- Lecture 36 - Steepest Descent Method: Finding Minima of a Functional
- Lecture 37 - Steepest Descent Method: Gradient Search
- Lecture 38 - Steepest Descent Method: Algorithm and Convergence
- Lecture 39 - Introduction to General Projection Methods
- Lecture 40 - Residue Norm and Minimum Residual Algorithm
- Lecture 41 - Developing computer programs for basic iterative methods
- Lecture 42 - Developing computer programs for projection based methods
- Lecture 43 - Introduction to Krylov subspace methods
- Lecture 44 - Krylov subspace methods for linear systems
- Lecture 45 - Iterative methods for solving linear systems using Krylov subspace methods
- Lecture 46 - Conjugate gradient methods
- Lecture 47 - Conjugate gradient methods (Continued...)
- Lecture 48 - Conjugate gradient methods (Continued...) and Introduction to GMRES
- Lecture 49 - GMRES (Continued...)
- Lecture 50 - Lanczos Biorthogonalization and BCG Algorithm
- Lecture 51 - Numerical issues in BICG and polynomial based formulation
- Lecture 52 - Conjugate gradient squared and Biconjugate gradient stabilized
- Lecture 53 - Line relaxation method
- Lecture 54 - Block relaxation method
- Lecture 55 - Domain Decomposition and Parallel Computing
- Lecture 56 - Preconditioners
- Lecture 57 - Preconditioned conjugate gradient
- Lecture 58 - Preconditioned GMRES
- Lecture 59 - Multigrid methods - I
- Lecture 60 - Multigrid methods - II

Lecture 1 - Set Theory

Lecture 2 - Set Operations

Lecture 3 - Set Operations (Continued...)

Lecture 4 - Set of sets

Lecture 5 - Binary relation

Lecture 6 - Equivalence relation

Lecture 7 - Mapping

Lecture 8 - Permutation

Lecture 9 - Binary Composition

Lecture 10 - Groupoid

Lecture 11 - Group

Lecture 12 - Order of an element

Lecture 13 - Subgroup

Lecture 14 - Cyclic Group

Lecture 15 - Subgroup Operations

Lecture 16 - Left Cosets

Lecture 17 - Right Cosets

Lecture 18 - Normal Subgroup

Lecture 19 - Rings

Lecture 20 - Field

Lecture 21 - Vector Spaces

Lecture 22 - Sub-Spaces

Lecture 23 - Linear Span

Lecture 24 - Basis of a Vector Space

Lecture 25 - Dimension of a Vector space

Lecture 26 - Complement of subspace

Lecture 27 - Linear Transformation

Lecture 28 - Linear Transformation (Continued...)

Lecture 29 - More on linear mapping

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- Lecture 2 - Mean Value Theorems
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- Lecture 4 - Indeterminate Forms - Part 2
- Lecture 5 - Taylor Polynomial and Taylor Series
- Lecture 6 - Limit of Functions of Two Variables
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- Lecture 8 - Continuity of Functions of Two Variables
- Lecture 9 - Partial Derivatives of Functions of Two Variables
- Lecture 10 - Partial Derivatives of Higher Order
- Lecture 11 - Derivative and Differentiability
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- Lecture 13 - Differentiability of Functions of Two Variables (Continued...)
- Lecture 14 - Differentiability of Functions of Two Variables (Continued...)
- Lecture 15 - Composite and Homogeneous Functions
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- Lecture 18 - Maxima and Minima of Functions of Two Variables (Continued...)
- Lecture 19 - Maxima and Minima of Functions of Two Variables (Continued...)
- Lecture 20 - Constrained Maxima and Minima
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- Lecture 22 - Improper Integrals (Continued...)
- Lecture 23 - Improper Integrals (Continued...)
- Lecture 24 - Improper Integrals (Continued...)
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- Lecture 27 - Differentiation Under Integral Sign
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- Lecture 31 - Integral Calculus Double Integrals in Polar Form

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- [Lecture 36 - System of Linear Equations](#)
- [Lecture 37 - System of Linear Equations Gauss Elimination](#)
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Lecture 2 - Partition, Riemann integrability and One example (Continued...)

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Lecture 26 - Rectification

Lecture 27 - Rectification (Continued...)

Lecture 28 - Surface Integral

Lecture 29 - Surface Integral (Continued...)

Lecture 30 - Surface Integral (Continued...)

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- Lecture 34 - Successive Differentiation
- Lecture 35 - Integration of Vector Function
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- Lecture 37 - Divergence and Curl
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- Lecture 42 - Directional Derivative (Concept and Few Results) (Continued...)
- Lecture 43 - Directional Derivatives, Level Surfaces
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- Lecture 45 - Equation of Tangent, Unit Tangent Vector
- Lecture 46 - Unit Normal, Unit binormal, Equation of Normal Plane
- Lecture 47 - Introduction and Derivation of Serret-Frenet Formula, few results
- Lecture 48 - Example on binormal, normal tangent, Serret-Frenet Formula
- Lecture 49 - Osculating Plane, Rectifying plane, Normal plane
- Lecture 50 - Application to Mechanics, Velocity, speed, acceleration
- Lecture 51 - Angular Momentum, Newton's Law
- Lecture 52 - Example on derivation of equation of motion of particle
- Lecture 53 - Line Integral
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- Lecture 57 - Volume integral, Gauss theorem
- Lecture 58 - Gauss divergence theorem
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- Lecture 60 - Overview of Course



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Lecture 3 - Shifting Properties of Laplace Transform

Lecture 4 - Laplace Transform of Derivatives and Integration of a Function - I

Lecture 5 - Laplace Transform of Derivatives and Integration of a Function - II

Lecture 6 - Explanation of properties of Laplace Transform using Examples

Lecture 7 - Laplace Transform of Periodic Function

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Lecture 10 - Bessel Function and its Laplace Transform

Lecture 11 - Introduction to Inverse Laplace Transform

Lecture 12 - Properties of Inverse Laplace Transform

Lecture 13 - Convolution and its Applications

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Lecture 31 - Change of Scale and Modulation Properties of Fourier Transform

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Lecture 35 - Fourier Transform of Convolution of two functions

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Lecture 37 - Evaluation of Definite Integrals using Properties of Fourier Transform

Lecture 38 - Fourier Transform of Dirac Delta Function

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Lecture 40 - Applications of Fourier Transform to Ordinary Differential Equations - I

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Lecture 53 - Solution of Boundary Value Problems using Finite Fourier Transform - II

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Lecture 55 - Properties of Mellin Transform

Lecture 56 - Examples of Mellin Transform - I

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Lecture 60 - Evaluation of Z-Transform of some functions

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Lecture 8 - Finding Estimators - II

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Lecture 25 - Sufficiency and Information - I

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Lecture 27 - Minimal Sufficiency, Completeness - I

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Lecture 3 - Solution of BVPs by Eigen function expansion

Lecture 4 - Solution of BVPs by Eigen function expansion (Continued...)

Lecture 5 - Solutions of linear parabolic, hyperbolic and elliptic PDEs with finite domain by Eigen function expansions

Lecture 6 - Solutions of linear parabolic, hyperbolic and elliptic PDEs with finite domain by Eigen function expansions (Continued...)

Lecture 7 - Green's Function for BVP and Dirichlet Problem

Lecture 8 - Green's Function for BVP and Dirichlet Problem (Continued...)

Lecture 9 - Numerical Techniques for IVP; Shooting Method for BVP

Lecture 10 - Numerical Techniques for IVP; Shooting Method for BVP (Continued...)

Lecture 11 - Finite difference methods for linear BVP; Thomas Algorithm

Lecture 12 - Finite difference methods for linear BVP; Thomas Algorithm (Continued...)

Lecture 13 - Finite difference method for Higher-order BVP; Block tri-diagonal System

Lecture 14 - Finite difference method for Higher-order BVP; Block tri-diagonal System (Continued...)

Lecture 15 - Iterative methods for nonlinear BVP; Control volume formulation

Lecture 16 - Iterative methods for nonlinear BVP; Control volume formulation (Continued...)

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- Lecture 34 - Direct sum and direct product of modules, free modules
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- Lecture 50 - Variational derivative and invariance of Euler's equation
- Lecture 51 - Invariance of Euler's equation and isoperimetric problem - I
- Lecture 52 - Isoperimetric problem - II
- Lecture 53 - Variational problem involving a conditional extremum - I
- Lecture 54 - Variational problem involving a conditional extremum - II
- Lecture 55 - Variational problems with moving boundaries - I
- Lecture 56 - Variational problems with moving boundaries - II
- Lecture 57 - Variational problems with moving boundaries - III
- Lecture 58 - Variational problems with moving boundaries; One sided variation
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Lecture 5 - Convex Programming Problems

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Lecture 14 - Dynamic Programming - I

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Lecture 16 - Dynamic programming approach to find shortest path in any network

Lecture 17 - Dynamic Programming - IV

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Lecture 1 - Introduction to error analysis and linear systems

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Lecture 6 - Introduction to Non-linear equations and Bisection method

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Lecture 17 - Interpolation - Part II ( Some basic operators and their properties)

Lecture 18 - Interpolation - Part III (Newton's Forward/ Backward difference and derivation of general error)

Lecture 19 - Interpolation - Part IV (Error in approximating a function by a polynomial using Newton's Forward and Backward difference formula)

Lecture 20 - Interpolation - Part V (Solving problems using Newton's Forward and Backward difference formula)

Lecture 21 - Interpolation - Part VI (Central difference formula)

Lecture 22 - Interpolation - Part VII (Lagrange interpolation formula with examples)

Lecture 23 - Interpolation - Part VIII (Divided difference interpolation with examples)

Lecture 24 - Interpolation - Part IX (Hermite's interpolation with examples)

Lecture 25 - Numerical differentiation - Part I (Introduction to numerical differentiation by interpolation formula)

Lecture 26 - Numerical differentiation - Part II (Numerical differentiation based on Lagrange's interpolation with examples)

Lecture 27 - Numerical differentiation - Part III (Numerical differentiation based on Divided difference formula with examples)

Lecture 28 - Numerical differentiation - Part IV (Maxima and minima of a tabulated function and differentiation errors)

Lecture 29 - Numerical differentiation - Part V (Differentiation based on finite difference operators)

Lecture 30 - Numerical differentiation - Part VI (Method of undetermined coefficients and Derivatives with unequal intervals)



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[Lecture 32 - Numerical Integration - Part II \(Quadrature formula and Trapezoidal rule with associated errors\)merical Integration Part-I \(Methodology of Numerical Integration and Rectangular rule \)](#)

[Lecture 33 - Numerical Integration - Part III \(Simpsons 1/3rd rule with associated errors\)](#)

[Lecture 34 - Numerical Integration - Part IV \(Composite Simpsons 1/3rd rule and Simpsons 3/8th rule with examples\)](#)

[Lecture 35 - Numerical Integration - Part V \(Gauss Legendre 2-point and 3-point formula with examples\)](#)

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[Lecture 39 - R-K Methods for solving ODEs](#)

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- Lecture 38 - Sensitivity Analysis - II
- Lecture 39 - Residual Theorem
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- Lecture 41 - Estimation of the Condition Number
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- Lecture 44 - Orthonormal Projections
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- Lecture 46 - SVD and their applications
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- Lecture 50 - Least square solutions - II
- Lecture 51 - Householder matrices
- Lecture 52 - Householder matrices and their applications
- Lecture 53 - Householder QR factorization - I
- Lecture 54 - Householder QR factorization - II
- Lecture 55 - Basic theorems on eigenvalues and QR method
- Lecture 56 - Power Method
- Lecture 57 - Rate of Convergence of Power Method
- Lecture 58 - Applications of Power Method with Shift
- Lecture 59 - Jacobi Method - I
- Lecture 60 - Jacobi Method - II

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Lecture 9 - Stability of Crank-Nicolson's scheme

Lecture 10 - Approximation of derivative boundary conditions

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Lecture 20 - Wendroff's method

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- Lecture 4 - Continuity of multivariable functions
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- Lecture 22 - Change of Variables in Multiple Integral
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Lecture 8 - Properties of Homogeneous Systems

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