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NPTEL : Measure and Integration (Mathematics)

Co-ordinators : Prof. Inder K Rana

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- Lecture 4 - Path Homotopy
- Lecture 5 - Composition of paths
- Lecture 6 - Fundamental group π_1
- Lecture 7 - Computation of Fund. Group of a circle
- Lecture 8 - Computation (Continued...)
- Lecture 9 - Computation concluded
- Lecture 10 - Van-Kampen's Theorem
- Lecture 11 - Function Spaces
- Lecture 12 - Quotient Maps
- Lecture 13 - Group Actions
- Lecture 14 - Examples of Group Actions
- Lecture 15 - Assorted Results on Quotient Spaces
- Lecture 16 - Quotient Constructions Typical to Alg. Top
- Lecture 17 - Quotient Constructions (Continued...)
- Lecture 18 - Relative Homotopy
- Lecture 19 - Construction of a typical SDR
- Lecture 20 - Generalized construction of SDRs
- Lecture 21 - A theoretical application
- Lecture 22 - The Harvest
- Lecture 23 - NDR pairs
- Lecture 24 - General Remarks
- Lecture 25 - Basics of Geometry
- Lecture 26 - Abstract Simplicial Complex
- Lecture 27 - Geometric Realization
- Lecture 28 - Topology on $|K|$
- Lecture 29 - Simplicial maps
- Lecture 30 - Polyhedrons
- Lecture 31 - Point Set topological Aspects

- Lecture 32 - Barycentric Subdivision
- Lecture 33 - Finer Subdivisions
- Lecture 34 - Simplicial Approximation
- Lecture 35 - Sperner Lemma
- Lecture 36 - Invariance of domain
- Lecture 37 - Proof of controled homotopy
- Lecture 38 - Links and Stars
- Lecture 39 - Homotopical Aspects of Simplicial Complexes
- Lecture 40 - Homotopical Aspects
- Lecture 41 - Covering Spaces and Fund. Groups
- Lecture 42 - Lifting Properties
- Lecture 43 - Homotopy Lifting
- Lecture 44 - Relation with the fund. Group
- Lecture 45 - Regular covering
- Lecture 46 - Lifting Problem
- Lecture 47 - Classification of Coverings
- Lecture 48 - Classification
- Lecture 49 - Existence of Simply connected coverings
- Lecture 50 - Construction of Simply connected covering
- Lecture 51 - Properties Shared by total space and base
- Lecture 52 - Examples
- Lecture 53 - G-coverings
- Lecture 54 - Pull-backs
- Lecture 55 - Classification of G-coverings
- Lecture 56 - Proof of classification
- Lecture 57 - Pushouts and Free products
- Lecture 58 - Existence of Free Products, pushouts
- Lecture 59 - Free Products and free groups
- Lecture 60 - Seifert-Van Kampen Theorems
- Lecture 61 - Applications
- Lecture 62 - Applications (Continued...)

Lecture 1 - Introduction

Lecture 2 - Attaching cells

Lecture 3 - Subcomplexes and Examples

Lecture 4 - More examples

Lecture 5 - More Examples

Lecture 6 - Topological Properties

Lecture 7 - Coinduced Topology

Lecture 8 - Compactly generated topology on Products

Lecture 9 - Product of Cell complexes

Lecture 10 - Product of Cell complexes (Continued...)

Lecture 11 - Partition of Unity on CW-complexes

Lecture 12 - Partition of Unity (Continued...)

Lecture 13 - Homotopical Aspects

Lecture 14 - Homotopical Aspects (Continued...)

Lecture 15 - Cellular Maps

Lecture 16 - Cellular Maps (Continued...)

Lecture 17 - Homotopy exact sequence of a pair

Lecture 18 - Homotopy exact sequence of a fibration

Lecture 19 - Categories-Definitions and Examples

Lecture 20 - More Examples

Lecture 21 - Functors

Lecture 22 - Equivalence of Functors (Continued...)

Lecture 23 - Universal Objects

Lecture 24 - Basic Homological Algebra

Lecture 25 - Diagram-Chasing

Lecture 26 - Homology of Chain Complexes

Lecture 27 - Euler Characteristics

Lecture 28 - Singular Homology Groups

Lecture 29 - Basic Properties of Singular Homology

Lecture 30 - Excision

Lecture 31 - Examples of Excision-Mayer Vietoris

- Lecture 32 - Applications
- Lecture 33 - Applications (Continued...)
- Lecture 34 - The Singular Simplicial Homology
- Lecture 35 - Simplicial Homology
- Lecture 36 - Simplicial Homology (Continued...)
- Lecture 37 - CW-Homology and Cellular Singular Homology
- Lecture 38 - Construction of CW-chain complex
- Lecture 39 - CW structure and CW homology of Lens Spaces
- Lecture 40 - Assorted Topics
- Lecture 41 - Some Applications of Homology
- Lecture 42 - Applications of LFT
- Lecture 43 - Jordan-Brouwer
- Lecture 44 - Proof of Lemmas
- Lecture 45 - Relation between π_1 and H_1
- Lecture 46 - All Postponed Proofs
- Lecture 47 - Proofs (Continued...)
- Lecture 48 - Definitions and Examples
- Lecture 49 - Paracompactness
- Lecture 50 - Manifolds with Boundary
- Lecture 51 - Embeddings and Homotopical Aspects
- Lecture 52 - Homotopical Aspects (Continued...)
- Lecture 53 - Classification of 1-manifolds
- Lecture 54 - Classification of 1-manifolds (Continued...)
- Lecture 55 - Triangulation of Manifolds
- Lecture 56 - Pseudo-Manifolds
- Lecture 57 - One result due to Poincaré and another due to Munkres
- Lecture 58 - Some General Remarks
- Lecture 59 - Classification of Compact Surface
- Lecture 60 - Final Reduction-Completion of the Proof
- Lecture 61 - Proof of Part B
- Lecture 62 - Orientability

NPTEL : NOC:Partial Differential Equations (Mathematics)

Co-ordinators : Prof. Sivaji Ganesh

- Lecture 1 - Partial Differential Equations - Basic concepts and Nomenclature
- Lecture 2 - First Order Partial Differential Equations- How they arise? Cauchy Problems, IVPs, IBVPs
- Lecture 3 - First order Partial Differential Equations - Geometry of Quasilinear equations
- Lecture 4 - FOPDE's - General Solutions to Linear and Semilinear equations
- Lecture 5 - First order Partial Differential Equations- Lagrange's method for Quasilinear equations
- Lecture 6 - Relation between Characteristic curves and Integral surfaces for Quasilinear equations
- Lecture 7 - Relation between Characteristic curves and Integral surfaces for Quasilinear equations
- Lecture 8 - FOPDE's - Method of characteristics for Quasilinear equations - 1
- Lecture 9 - First order Partial Differential Equations - Failure of transversality condition
- Lecture 10 - First order Partial Differential Equations - Tutorial of Quasilinear equations
- Lecture 11 - FOPDE's - General nonlinear equations 1 - Search for a characteristic direction
- Lecture 12 - FOPDE's - General nonlinear equations 2 - Characteristic direction and characteristic strip
- Lecture 13 - FOPDE's - General nonlinear equations 3 - Finding an initial strip
- Lecture 14 - FOPDE's - General nonlinear equations 4 - Local existence and uniqueness theorem
- Lecture 15 - First order Partial Differential Equations - Tutorial on General nonlinear equations
- Lecture 16 - First order Partial Differential Equations - Initial value problems for Burgers equation
- Lecture 17 - FOPDE's - Conservation laws with a view towards global solutions to Burgers equation
- Lecture 18 - Second Order Partial Differential Equations - Special Curves associated to a PDE
- Lecture 19 - Second Order Partial Differential Equations - Curves of discontinuity
- Lecture 20 - Second Order Partial Differential Equations - Classification
- Lecture 21 - SOPDE's - Canonical form for an equation of Hyperbolic type
- Lecture 22 - SOPDE's - Canonical form for an equation of Parabolic type
- Lecture 23 - SOPDE's - Canonical form for an equation of Elliptic type
- Lecture 24 - Second Order Partial Differential Equations - Characteristic Surfaces
- Lecture 25 - SOPDE's - Canonical forms for constant coefficient PDEs
- Lecture 26 - Wave Equation - A mathematical model for vibrating strings
- Lecture 27 - Wave Equation in one space dimension - d'Alembert formula
- Lecture 28 - Tutorial on One dimensional wave equation
- Lecture 29 - Wave Equation in d space dimensions - Equivalent Cauchy problems via Spherical means
- Lecture 30 - Cauchy problem for Wave Equation in 3 space dimensions - Poisson-Kirchhoff formulae
- Lecture 31 - Cauchy problem for Wave Equation in 2 space dimensions - Hadamard's method of descent

- Lecture 32 - Nonhomogeneous Wave Equation - Duhamel principle
- Lecture 33 - Wellposedness of Cauchy problem for Wave Equation
- Lecture 34 - Wave Equation on an interval in? - Solution to an IBVP from first principles
- Lecture 35 - Tutorial on IBVPs for wave equation
- Lecture 36 - IBVP for Wave Equation - Separation of Variables Method
- Lecture 37 - Tutorial on Separation of variables method for wave equation
- Lecture 38 - Qualitative analysis of Wave equation - Parallelogram identity
- Lecture 39 - Qualitative analysis of Wave equation - Domain of dependence, domain of influence
- Lecture 40 - Qualitative analysis of Wave equation - Causality Principle, Finite speed of propagation
- Lecture 41 - Qualitative analysis of Wave equation - Uniqueness by Energy method
- Lecture 42 - Qualitative analysis of Wave equation - Huygens Principle
- Lecture 43 - Qualitative analysis of Wave equation - Generalized solutions to Wave equation
- Lecture 44 - Qualitative analysis of Wave equation - Propagation of waves
- Lecture 45 - Laplace equation - Associated Boundary value problems
- Lecture 46 - Laplace equation - Fundamental solution
- Lecture 47 - Dirichlet BVP for Laplace equation - Green's function and Poisson's formula
- Lecture 48 - Laplace equation - Weak maximum principle and its applications
- Lecture 49 - Laplace equation - Dirichlet BVP on a disk in R^2 for Laplace equations
- Lecture 50 - Tutorial 1 on Laplace equation
- Lecture 51 - Laplace equation - Mean value property
- Lecture 52 - Laplace equation - More qualitative properties
- Lecture 53 - Laplace equation - Strong Maximum Principle and Dirichlet Principle
- Lecture 54 - Tutorial 2 on Laplace equation
- Lecture 55 - Cauchy Problem for Heat Equation - 1
- Lecture 56 - Cauchy Problem for Heat Equation - 2
- Lecture 57 - IBVP for Heat equation Subtitle: Method of Separation of Variables
- Lecture 58 - Maximum principle for heat equation
- Lecture 59 - Tutorial on heat equation
- Lecture 60 - Heat equation Subheading : Infinite speed of propagation, Energy, Backward Problem

Lecture 1 - Introduction

Lecture 2 - Introduction

Lecture 3 - Introduction

Lecture 4 - Introduction

Lecture 5 - Introduction

Lecture 6 - Introduction

Lecture 7 - Introduction

Lecture 8 - Introduction

Lecture 9 - Introduction

Lecture 10 - Introduction

Lecture 11 - Introduction

Lecture 12 - Introduction

Lecture 13 - Introduction

Lecture 14 - Introduction

Lecture 15 - Introduction

Lecture 16 - Introduction

Lecture 17 - Introduction

Lecture 18 - Introduction

Lecture 19 - Introduction

Lecture 20 - Introduction

Lecture 21 - Introduction

Lecture 22 - Creating New Spaces

Lecture 23 - Creating New Spaces

Lecture 24 - Creating New Spaces

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Lecture 26 - Creating New Spaces

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[Lecture 52 - Largeness properties](#)

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[Lecture 54 - Largeness properties](#)

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Lecture 1 - Welcome Speech

Lecture 2 - Preliminaries from Banach spaces

Lecture 3 - Differentiation on Banach spaces

Lecture 4 - Preliminaries from one-variable real analysis

Lecture 5 - Implicit and Inverse function theorems

Lecture 6 - Compact Hausdorff spaces

Lecture 7 - Local Compactness

Lecture 8 - Local Compactness (Continued...)

Lecture 9 - The retraction functor $k(X)$

Lecture 10 - Compactly generated spaces

Lecture 11 - Paracompactness

Lecture 12 - Partition of Unity

Lecture 13 - Paracompactness (Continued...)

Lecture 14 - Paracompactness (Continued...)

Lecture 15 - Various Notions of Compactness

Lecture 16 - Total Boundedness

Lecture 17 - Arzel'a- Ascoli Theorem

Lecture 18 - Generalities on Compactification

Lecture 19 - Alexandroff's compactification

Lecture 20 - Proper maps

Lecture 21 - Stone-Cech compactification

Lecture 22 - Stone-Weierstrass's Theorems

Lecture 23 - Real Stone-Weierstrass Theorem

Lecture 24 - Complex and extended Stone-Weierstrass theorem

Lecture 25 - (Missing)

Lecture 26 - Urysohn's Metrization theorem

Lecture 27 - Nagata Smyrnov Metrization theorem

Lecture 28 - Nets

Lecture 29 - Cofinal families subnets

Lecture 30 - Basics of Filters

Lecture 31 - Convergence Properties of Filters

- Lecture 32 - Ultrafilters and Tychonoff's theorem
- Lecture 33 - Ultraclosed filters
- Lecture 34 - Wallman compactification
- Lecture 35 - Wallman compactification (Continued...)
- Lecture 36 - Global Separation of Sets
- Lecture 37 - More examples
- Lecture 38 - Knaster-Kuratowski Example
- Lecture 39 - Separation of Sets (Continued...)
- Lecture 40 - Definition of dimension and examples
- Lecture 41 - Dimensions of subspaces and Unions
- Lecture 42 - Sum theorem for higher dimensions
- Lecture 43 - Analytic Proof of Brouwer's Fixed Point Theorem
- Lecture 44 - Local Separation to Global Separation
- Lecture 45 - Partially Ordered sets
- Lecture 46 - Principle of Transfinite Induction
- Lecture 47 - Order topology
- Lecture 48 - Ordinals
- Lecture 49 - Ordinal Topology (Continued...)
- Lecture 50 - The Long Line
- Lecture 51 - Motivation and definition
- Lecture 52 - The Exponential Correspondence
- Lecture 53 - An Application to Quotient Maps
- Lecture 54 - Groups of Homeomorphisms
- Lecture 55 - Definition and Examples of Manifolds
- Lecture 56 - Manifolds with Boundary
- Lecture 57 - Homogeneity
- Lecture 58 - Homogeneity (Continued...)
- Lecture 59 - Classification of 1-dim. manifolds
- Lecture 60 - Classification of 1-dim. Manifolds (Continued...)
- Lecture 61 - Surfaces
- Lecture 62 - Connected Sum

- Lecture 1 - Genesis and a little history
- Lecture 2 - Basic convergence theorem
- Lecture 3 - Riemann Lebesgue Lemma
- Lecture 4 - The ubiquitous Gaussian
- Lecture 5 - Jacobi theta function identity
- Lecture 6 - The Riemann zeta function
- Lecture 7 - Bessel's functions of the first kind
- Lecture 8 - Least square approximation
- Lecture 9 - Parseval formula. Isoperimetric theorem
- Lecture 10 - Dirichlet problem for a disc
- Lecture 11 - The Poisson kernel
- Lecture 12 - Cesaro summability and Fejer's theorem
- Lecture 13 - Fejer's theorem (Continued...)
- Lecture 14 - Kronecker's theorem
- Lecture 15 - Weyl's equidistribution theorem
- Lecture 16 - Borel's theorem and beyond
- Lecture 17 - Fourier transform and Schwartz space
- Lecture 18 - Hermite's differential equation
- Lecture 19 - Fourier inversion theorem Riemann Lebesgue lemma
- Lecture 20 - Plancherel's Theorem
- Lecture 21 - Heat equation. The heat kernel
- Lecture 22 - The Airy's function
- Lecture 23 - Exercises on Fourier Transform
- Lecture 24 - Principle of equipartitioning of energy
- Lecture 25 - A formula of Srinivasa Ramanujan
- Lecture 26 - Sturm Liouville problems. Orthogonal systems
- Lecture 27 - Vibrations of a circular membrane
- Lecture 28 - Fourier Bessel Series
- Lecture 29 - Properties of Legendre Polynomials
- Lecture 30 - Properties of Legendre polynomials (Continued...)
- Lecture 31 - Legendre polynomials - interlacing of zeros

Lecture 32 - Laplace's integrals for Legendre polynomials

Lecture 33 - Regular Sturm-Liouville problems

Lecture 34 - Variational properties of eigen-values

Lecture 35 - The Dirichlet principle

Lecture 36 - Regular Sturm-Liouville problems - Existence of eigen-values

Lecture 37 - The Bergman space

Lecture 38 - The Banach Steinhaus' Theorem

Lecture 39 - Hilbert space basics

Lecture 40 - Completeness of Hermite functions

Lecture 41 - Hermite, Laguerre and Tchebycheff's polynomials

Lecture 42 - Orthonormal bases in Hilbert spaces

Lecture 43 - Non-separable Hilbert-spaces. Almost periodic functions

Lecture 44 - Hilbert-Schmidt operators. Green's functions

Lecture 45 - Spectrum of a bounded linear operator

Lecture 46 - Weak (sequential) compactness of the closed unit ball

Lecture 47 - Compact self-adjoint operators. Existence of eigen values

Lecture 48 - Compact self-adjoint operators. Existence of eigen values (Continued...)

Lecture 49 - Celestial Mechanics

Lecture 50 - Inverting the Kepler equation using Fourier series

Lecture 51 - Odds and Ends

Lecture 52 - Dirichlet's Theorem on Fourier Series

Lecture 53 - Dirichlet's Theorem on Fourier Series (Continued...)

Lecture 54 - Topology on the Schwartz space

Lecture 55 - Examples of tempered distributions

Lecture 56 - Operations on distributions

Lecture 57 - Fourier Transform of tempered distribution

Lecture 58 - Support of a Distribution. Distributions with point support

Lecture 59 - Distributional solutions of ODEs. Continuity of the Fourier transform and differentiation

Lecture 60 - The Poisson summation formula

Lecture 1 - Introduction

Lecture 2 - Mathematical Preliminaries: Taylor Approximation

Lecture 3 - Mathematical Preliminaries: Order of Convergence

Lecture 4 - Arithmetic Error: Floating-point Approximation

Lecture 5 - Arithmetic Error: Significant Digits

Lecture 6 - Arithmetic Error: Condition Number and Stable Computation

Lecture 7 - Tutorial Session-1: Problem Solving

Lecture 8 - Python Coding: Introduction

Lecture 9 - Linear Systems: Gaussian Elimination Method

Lecture 10 - Linear Systems: LU-Factorization (Doolittle and Crout)

Lecture 11 - Linear Systems: LU-Factorization (Cholesky)

Lecture 12 - Linear Systems: Operation Count for Direct Methods

Lecture 13 - Tutorial Session-2: Python Coding for Naive Gaussian Elimination Method

Lecture 14 - Tutorial Session-3: Python Coding for Thomas Algorithm

Lecture 15 - Matrix Norms: Subordinate Matrix Norms

Lecture 16 - Matrix Norms: Condition Number of a Matrix

Lecture 17 - Iterative Methods: Jacobi Method

Lecture 18 - Iterative Methods: Convergence of Jacobi Method

Lecture 19 - Iterative Methods: Gauss-Seidel Method

Lecture 20 - Iterative Methods: Convergence Analysis of Iterative Methods

Lecture 21 - Iterative Methods: Successive Over Relaxation Method

Lecture 22 - Tutorial Session-4: Python implementation of Jacobi Method

Lecture 23 - Eigenvalues and Eigenvectors: Power Method (Construction)

Lecture 24 - Eigenvalues and Eigenvectors: Power Method (Convergence Theorem)

Lecture 25 - Eigenvalues and Eigenvectors: Gerschgorin's Theorem and Applications

Lecture 26 - Eigenvalues and Eigenvectors: Power Method (Inverse and Shifted Methods)

Lecture 27 - Nonlinear Equations: Overview

Lecture 28 - Nonlinear Equations: Bisection Method

Lecture 29 - Tutorial Session-5: Implementation of Bisection Method

Lecture 30 - Nonlinear Equations: Regula-falsi and Secant Methods

Lecture 31 - Nonlinear Equations: Convergence Theorem of Secant Method

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[Lecture 33 - Nonlinear Equations: Newton-Raphson's method \(Convergence Theorem\)](#)

[Lecture 34 - Nonlinear Equations: Fixed-point Iteration Methods](#)

[Lecture 35 - Nonlinear Equations: Fixed-point Iteration Methods \(Convergence\) and Modified Newton's Method](#)

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[Lecture 38 - Polynomial Interpolation: Existence and Uniqueness](#)

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[Lecture 41 - Polynomial Interpolation: Mathematical Error in Interpolating Polynomial](#)

[Lecture 42 - Polynomial Interpolation: Arithmetic Error in Interpolating Polynomials](#)

[Lecture 43 - Polynomial Interpolation: Implementation of Lagrange Form as Python Code](#)

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[Lecture 46 - Polynomial Interpolation: Cubic Spline Interpolation](#)

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Lecture 1 - Definition and examples of topological spaces

Lecture 2 - Examples of topological spaces

Lecture 3 - Basis for topology

Lecture 4 - Subspace Topology

Lecture 5 - Product Topology

Lecture 6 - Product Topology (Continued...)

Lecture 7 - Continuous maps

Lecture 8 - Continuity of addition and multiplication maps

Lecture 9 - Continuous maps to a product

Lecture 10 - Projection from a point

Lecture 11 - Closed subsets

Lecture 12 - Closure

Lecture 13 - Joining continuous maps

Lecture 14 - Metric spaces

Lecture 15 - Connectedness

Lecture 16 - Connectedness (Continued...)

Lecture 17 - Connectedness (Continued...)

Lecture 18 - Connected components

Lecture 19 - Path connectedness

Lecture 20 - Path connectedness (Continued...)

Lecture 21 - Connectedness of $GL(n, \mathbb{R})^+$ (math symbol)

Lecture 22 - Connectedness of $GL(n, \mathbb{C})$, $SL(n, \mathbb{C})$, $SL(n, \mathbb{R})$

Lecture 23 - Compactness

Lecture 24 - Compactness (Continued...)

Lecture 25 - Compactness (Continued...)

Lecture 26 - Compactness (Continued...)

Lecture 27 - $SO(n)$ is connected

Lecture 28 - Compact metric spaces

Lecture 29 - Lebesgue Number Lemma

Lecture 30 - Locally compact spaces

Lecture 31 - One point compactification

[Lecture 32 - One point compactification \(Continued...\)](#)

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[Lecture 36 - Part 3 : Grassmannian](#)

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NPTEL : Stochastic Processes (Mathematics)

Co-ordinators : Dr. S. Dharmaraja

Lecture 1 - Introduction to Stochastic Processes

Lecture 2 - Introduction to Stochastic Processes (Continued.)

Lecture 3 - Problems in Random Variables and Distributions

Lecture 4 - Problems in Sequences of Random Variables

Lecture 5 - Definition, Classification and Examples

Lecture 6 - Simple Stochastic Processes

Lecture 7 - Stationary Processes

Lecture 8 - Autoregressive Processes

Lecture 9 - Introduction, Definition and Transition Probability Matrix

Lecture 10 - Chapman-Kolmogorov Equations

Lecture 11 - Classification of States and Limiting Distributions

Lecture 12 - Limiting and Stationary Distributions

Lecture 13 - Limiting Distributions, Ergodicity and Stationary Distributions

Lecture 14 - Time Reversible Markov Chain, Application of Irreducible Markov Chain in Queueing Models

Lecture 15 - Reducible Markov Chains

Lecture 16 - Definition, Kolmogorov Differential Equations and Infinitesimal Generator Matrix

Lecture 17 - Limiting and Stationary Distributions, Birth Death Processes

Lecture 18 - Poisson Processes

Lecture 19 - M/M/1 Queueing Model

Lecture 20 - Simple Markovian Queueing Models

Lecture 21 - Queueing Networks

Lecture 22 - Communication Systems

Lecture 23 - Stochastic Petri Nets

Lecture 24 - Conditional Expectation and Filtration

Lecture 25 - Definition and Simple Examples

Lecture 26 - Definition and Properties

Lecture 27 - Processes Derived from Brownian Motion

Lecture 28 - Stochastic Differential Equations

Lecture 29 - Ito Integrals

Lecture 30 - Ito Formula and its Variants

Lecture 31 - Some Important SDE's and Their Solutions

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[Lecture 34 - Markov Renewal and Markov Regenerative Processes](#)

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[Lecture 36 - Non Markovian Queues Cont.,](#)

[Lecture 37 - Application of Markov Regenerative Processes](#)

[Lecture 38 - Galton-Watson Process](#)

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Lecture 2 - Probability space and conditional probability

Lecture 3 - Random variable and cumulative distributive function

Lecture 4 - Discrete Uniform Distribution, Binomial Distribution, Geometric Distribution, Continuous Uniform Distribution, Exponential Distribution, Normal Distribution and Poisson Distribution

Lecture 5 - Joint Distribution of Random Variables

Lecture 6 - Independent Random Variables, Covariance and Correlation Coefficient and Conditional Distribution

Lecture 7 - Conditional Expectation and Covariance Matrix

Lecture 8 - Generating Functions, Law of Large Numbers and Central Limit Theorem

Lecture 9 - Problems in Random variables and Distributions

Lecture 10 - Problems in Random variables and Distributions (Continued...)

Lecture 11 - Problems in Random variables and Distributions (Continued...)

Lecture 12 - Problems in Random variables and Distributions (Continued...)

Lecture 13 - Problems in Sequences of Random Variables

Lecture 14 - Problems in Sequences of Random Variables (Continued...)

Lecture 15 - Problems in Sequences of Random Variables (Continued...)

Lecture 16 - Problems in Sequences of Random Variables (Continued...)

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Lecture 18 - Classification of Stochastic Processes

Lecture 19 - Examples of Classification of Stochastic Processes

Lecture 20 - Examples of Classification of Stochastic Processes (Continued...)

Lecture 21 - Bernoulli Process

Lecture 22 - Poisson Process

Lecture 23 - Poisson Process (Continued...)

Lecture 24 - Simple Random Walk and Population Processes

Lecture 25 - Introduction to Discrete time Markov Chain

Lecture 26 - Introduction to Discrete time Markov Chain (Continued...)

Lecture 27 - Examples of Discrete time Markov Chain

Lecture 28 - Examples of Discrete time Markov Chain (Continued...)

Lecture 29 - Introduction to Chapman-Kolmogorov equations

Lecture 30 - State Transition Diagram and Examples

Lecture 31 - Examples

Lecture 32 - Introduction to Classification of States and Periodicity

Lecture 33 - Closed set of States and Irreducible Markov Chain

Lecture 34 - First Passage time and Mean Recurrence Time

Lecture 35 - Recurrent State and Transient State

Lecture 36 - Introduction and example of Classification of states

Lecture 37 - Example of Classification of states (Continued...)

Lecture 38 - Example of Classification of states (Continued...)

Lecture 39 - Example of Classification of states (Continued...)

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Lecture 41 - Example of Limiting Distribution and Ergodicity

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Lecture 45 - Definition of Reducible Markov Chains and Types of Reducible Markov Chains

Lecture 46 - Stationary Distributions and Types of Reducible Markov chains

Lecture 47 - Type of Reducible Markov Chains (Continued...)

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Lecture 49 - Introduction to Continuous time Markov Chain

Lecture 50 - Waiting time Distribution

Lecture 51 - Chapman-Kolmogorov Equation

Lecture 52 - Infinitesimal Generator Matrix

Lecture 53 - Introduction and Example Of Continuous time Markov Chain

Lecture 54 - Limiting and Stationary Distributions

Lecture 55 - Time reversible CTMC and Birth Death Process

Lecture 56 - Steady State Distributions, Pure Birth Process and Pure Death Process

Lecture 57 - Introduction to Poisson Process

Lecture 58 - Definition of Poisson Process

Lecture 59 - Superposition and Deposition of Poisson Process

Lecture 60 - Compound Poisson Process and Examples

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- Lecture 58 - Simpson's 3/8 Rule for Numerical Integration
- Lecture 59 - Method of Undetermined Coefficients
- Lecture 60 - Octave Code for Trapezoidal and Simpson's Rule
- Lecture 61 - Taylor Series Method for Ordinary Differential Equations
- Lecture 62 - Linear Multistep Method (LMM) for Ordinary Differential Equations
- Lecture 63 - Convergence and Zero Stability for LMM
- Lecture 64 - Matlab/Octave Code for Initial Value Problems

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Lecture 1 - Binary Operation and Groups

Lecture 2 - Vector Spaces

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Lecture 4 - Some Examples of Vector Spaces (Continued...)

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Lecture 6 - Spanning Set

Lecture 7 - Properties of Subspaces

Lecture 8 - Properties of Subspaces (Continued...)

Lecture 9 - Linearly Independent and Dependent Vectors

Lecture 10 - Linearly Independent and Dependent Vectors (Continued...)

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Lecture 12 - Properties of Linearly Independent and Dependent Vectors (Continued...)

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Lecture 1 - Random experiment, sample space, axioms of probability, probability space

Lecture 2 - Random experiment, sample space, axioms of probability, probability space (Continued...)

Lecture 3 - Random experiment, sample space, axioms of probability, probability space (Continued...)

Lecture 4 - Conditional probability, independence of events

Lecture 5 - Multiplication rule, total probability rule, Bayes's theorem

Lecture 6 - Definition of Random Variable, Cumulative Distribution Function

Lecture 7 - Definition of Random Variable, Cumulative Distribution Function (Continued...)

Lecture 8 - Definition of Random Variable, Cumulative Distribution Function (Continued...)

Lecture 9 - Type of Random Variables, Probability Mass Function, Probability Density Function

Lecture 10 - Type of Random Variables, Probability Mass Function, Probability Density Function (Continued...)

Lecture 11 - Distribution of Function of Random Variables

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Lecture 13 - Mean and Variance (Continued...)

Lecture 14 - Higher Order Moments and Moments Inequalities

Lecture 15 - Higher Order Moments and Moments Inequalities (Continued...)

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Lecture 19 - Common Discrete Distributions (Continued...)

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Lecture 21 - Common Continuous Distributions (Continued...)

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Lecture 23 - Applications of Random Variable (Continued...)

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- Lecture 44 - Law of Large Numbers
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- Lecture 47 - Descriptive Statistics and Sampling Distributions
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- Lecture 49 - Descriptive Statistics and Sampling Distributions (Continued...)
- Lecture 50 - Point estimation
- Lecture 51 - Methods of Point estimation
- Lecture 52 - Interval Estimation
- Lecture 53 - Testing of Statistical Hypothesis
- Lecture 54 - Nonparametric Statistical Tests
- Lecture 55 - Analysis of Variance
- Lecture 56 - Correlation
- Lecture 57 - Regression
- Lecture 58 - Logistic Regression

Lecture 1 - Random Experiment, Sample Space and Sigma Field

Lecture 2 - Axiomatic Definition of Probability

Lecture 3 - Properties of Axiomatic Definition of Probability and Classical Definition of Probability

Lecture 4 - Conditional Probability, Independent Events and Baye's Rule

Lecture 5 - Definition of Random Variable

Lecture 6 - Cumulative Distribution Function

Lecture 7 - Discrete and Continuous Type Random Variables

Lecture 8 - Mixed Type Random Variable

Lecture 9 - Function of a Random Variable

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Lecture 12 - Inequalities of Markov and Chebyshev

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Lecture 18 - Definition and Joint Distribution of a Random Vector

Lecture 19 - Joint Probability Mass Function

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Lecture 21 - Independent Random Vector

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Lecture 23 - Distribution of Functions of Random Variables (Continuous Type)

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Lecture 29 - Conditional Expectation

Lecture 30 - Modes of Convergence

Lecture 31 - Modes of Convergence (Continued...)

- Lecture 32 - Law of Large Numbers
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- Lecture 34 - Definition and Classification of Stochastic Processes
- Lecture 35 - Properties of Stochastic Processes
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- Lecture 37 - Standard Simple Stochastic Processes
- Lecture 38 - Definition of Discrete Time Markov Chain (DTMC)
- Lecture 39 - Chapman-Kolmogorov Equation
- Lecture 40 - Classification of States
- Lecture 41 - Classification of States (Continued...)
- Lecture 42 - Limiting Distribution
- Lecture 43 - Stationary Distribution
- Lecture 44 - Reducible Markov Chains
- Lecture 45 - Definition of Continuous Time Markov Chain (CTMC)
- Lecture 46 - Infinitesimal Generator Matrix
- Lecture 47 - Kolmogorov Differential Equations
- Lecture 48 - Limiting Distribution and Steady-State Distribution
- Lecture 49 - Birth Death Processes
- Lecture 50 - Introduction to Queueing Models and Kendall Notation
- Lecture 51 - Single-Server Queueing Models
- Lecture 52 - Single-Server Queueing Models (Continued...)
- Lecture 53 - Multi-Server Queueing Models

Lecture 1 - Introduction

Lecture 2 - Alphabet, Strings, Languages

Lecture 3 - Finite Representation

Lecture 4 - Grammars (CFG)

Lecture 5 - Derivation Trees

Lecture 6 - Regular Grammars

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Lecture 8 - Nondeterministic Finite Automata

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Lecture 11 - Minimization

Lecture 12 - RE \Rightarrow FA

Lecture 13 - FA \Rightarrow RE

Lecture 14 - FA \Leftrightarrow RG

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Lecture 24 - Turing Machines

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Lecture 26 - Combining Turing Machines

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Lecture 3 - de Moivre's Formula and Stereographic Projection

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Lecture 5 - Topology of the Complex Plane - Part-II

Lecture 6 - Topology of the Complex Plane - Part-III

Lecture 7 - Introduction to Complex Functions

Lecture 8 - Limits and Continuity

Lecture 9 - Differentiation

Lecture 10 - Cauchy-Riemann Equations and Differentiability

Lecture 11 - Analytic functions; the exponential function

Lecture 12 - Sine, Cosine and Harmonic functions

Lecture 13 - Branches of Multifunctions; Hyperbolic Functions

Lecture 14 - Problem Solving Session I

Lecture 15 - Integration and Contours

Lecture 16 - Contour Integration

Lecture 17 - Introduction to Cauchy's Theorem

Lecture 18 - Cauchy's Theorem for a Rectangle

Lecture 19 - Cauchy's theorem - Part-II

Lecture 20 - Cauchy's Theorem - Part-III

Lecture 21 - Cauchy's Integral Formula and its Consequences

Lecture 22 - The First and Second Derivatives of Analytic Functions

Lecture 23 - Morera's Theorem and Higher Order Derivatives of Analytic Functions

Lecture 24 - Problem Solving Session II

Lecture 25 - Introduction to Complex Power Series

Lecture 26 - Analyticity of Power Series

Lecture 27 - Taylor's Theorem

Lecture 28 - Zeroes of Analytic Functions

Lecture 29 - Counting the Zeroes of Analytic Functions

Lecture 30 - Open mapping theorem - Part-I

Lecture 31 - Open mapping theorem - Part-II

[Lecture 32 - Properties of Mobius Transformations - Part-I](#)

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[Lecture 34 - Problem Solving Session III](#)

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[Lecture 39 - Residue Theorem and Applications](#)

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Lecture 1 - Introduction to Financial Markets and Bonds

Lecture 2 - Introduction to Stocks, Futures and Forwards and Swaps

Lecture 3 - Introduction to Options

Lecture 4 - Interest Rates and Present Value

Lecture 5 - Present and Future Values, Annuities, Amortization and Bond Yield

Lecture 6 - Price Yield Curve and Term Structure of Interest Rates

Lecture 7 - Markowitz Theory, Return and Risk and Two Asset Portfolio

Lecture 8 - Minimum Variance Portfolio and Feasible Set

Lecture 9 - Multi Asset Portfolio, Minimum Variance Portfolio, Efficient Frontier and Minimum Variance Line

Lecture 10 - Minimum Variance Line (Continued), Market Portfolio

Lecture 11 - Capital Market Line, Capital Asset Pricing Model

Lecture 12 - Performance Analysis

Lecture 13 - No-Arbitrage Principle and Pricing of Forward Contracts

Lecture 14 - Futures, Options and Put-Call-Parity

Lecture 15 - Bounds on Options

Lecture 16 - Derivative Pricing in a Single Period Binomial Model

Lecture 17 - Derivative Pricing in Multiperiod Binomial Model

Lecture 18 - Derivative Pricing in Binomial Model and Path Dependent Options

Lecture 19 - Discrete Probability Spaces

Lecture 20 - Filtrations and Conditional Expectations

Lecture 21 - Properties of Conditional Expectations

Lecture 22 - Examples of Conditional Expectations, Martingales

Lecture 23 - Risk-Neutral Pricing of European Derivatives in Binomial Model

Lecture 24 - Actual and Risk-Neutral Probabilities, Markov Process, American Options

Lecture 25 - General Probability Spaces, Expectations, Change of Measure

Lecture 26 - Filtrations, Independence, Conditional Expectations

Lecture 27 - Brownian Motion and its Properties

Lecture 28 - Itô Integral and its Properties

Lecture 29 - Itô Formula, Itô Processes

Lecture 30 - Multivariable Stochastic Calculus, Stochastic Differential Equations

Lecture 31 - Black-Scholes-Merton (BSM) Model, BSM Equation, BSM Formula

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[Lecture 33 - Girsanov Theorem, Risk-Neutral Pricing of Derivatives, BSM Formula](#)

[Lecture 34 - MRT and Hedging, Multidimensional Girsanov and MRT](#)

[Lecture 35 - Multidimensional BSM Model, Fundamental Theorems of Asset Pricing](#)

[Lecture 36 - BSM Model with Dividend-Paying Stocks](#)

NPTEL : NOC:Mathematical Portfolio Theory (Mathematics)

Co-ordinators : Prof. Siddhartha Pratim Chakrabarty

Lecture 1 - Probability space and their properties, Random variables

Lecture 2 - Mean, variance, covariance and their properties

Lecture 3 - Linear regression; Binomial and normal distribution; Central Limit Theorem

Lecture 4 - Financial markets

Lecture 5 - Bonds and stocks

Lecture 6 - Binomial and geometric Brownian motion (gBm) asset pricing models

Lecture 7 - Expected return, risk and covariance of returns

Lecture 8 - Expected return and risk of a portfolio; Minimum variance portfolio

Lecture 9 - Multi-asset portfolio and Efficient frontier

Lecture 10 - Capital Market Line and Derivation of efficient frontier

Lecture 11 - Capital Asset Pricing Model and Single index model

Lecture 12 - Portfolio performance analysis

Lecture 13 - Utility functions and expected utility

Lecture 14 - Risk preferences of investors

Lecture 15 - Absolute Risk Aversion and Relative Risk Aversion

Lecture 16 - Portfolio theory with utility functions

Lecture 17 - Geometric Mean Return and Roy's Safety-First Criterion

Lecture 18 - Kataoka's Safety-First Criterion and Telser's Safety-First Criterion

Lecture 19 - Semi-variance framework

Lecture 20 - Stochastic dominance; First order stochastic dominance

Lecture 21 - Second order stochastic dominance and Third order stochastic dominance

Lecture 22 - Discrete time model and utility function

Lecture 23 - Optimal portfolio for single-period discrete time model

Lecture 24 - Optimal portfolio for multi-period discrete time model; Discrete Dynamic Programming

Lecture 25 - Continuous time model; Hamilton-Jacobi-Bellman PDE

Lecture 26 - Hamilton-Jacobi-Bellman PDE; Duality/Martingale Approach

Lecture 27 - Duality/Martingale Approach in Discrete and Continuous Time

Lecture 28 - Interest rates and bonds; Duration

Lecture 29 - Duration; Immunization

Lecture 30 - Convexity; Hedging and Immunization

Lecture 31 - Quantiles and their properties

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[Lecture 34 - Asset allocation](#)

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[Lecture 36 - Portfolio optimization with constraints, Value-at-Risk: Estimation and backtesting](#)

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Lecture 3 - Review of Basic Probability - III

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Lecture 5 - Definition of Markov Chain and Transition Probabilities

Lecture 6 - Markov Property and Chapman-Kolmogorov Equations

Lecture 7 - Chapman-Kolmogorov Equations: Examples

Lecture 8 - Accessibility and Communication of States

Lecture 9 - Hitting Time - I

Lecture 10 - Hitting Time - II

Lecture 11 - Hitting Time - III

Lecture 12 - Strong Markov Property

Lecture 13 - Passage Time and Excursion

Lecture 14 - Number of Visits

Lecture 15 - Class Property

Lecture 16 - Transience and Recurrence of Random Walks

Lecture 17 - Stationary Distribution - I

Lecture 18 - Stationary Distribution - II

Lecture 19 - Stationary Distribution - III

Lecture 20 - Limit Theorems - I

Lecture 21 - Limit Theorems - II

Lecture 22 - Some Problems - I

Lecture 23 - Some Problems - II

Lecture 24 - Time Reversibility

Lecture 25 - Properties of Exponential Distribution

Lecture 26 - Some Problems

Lecture 27 - Order Statistics

Lecture 28 - Poisson Processes

Lecture 29 - Poisson Thinning - I

Lecture 30 - Poisson Thinning - II

Lecture 31 - Conditional Arrival Times

[Lecture 32 - Independent Poisson Processes](#)

[Lecture 33 - Some Problems](#)

[Lecture 34 - Compound Poisson Processes](#)

Lecture 1 - Queueing Systems, System Performance Measures

Lecture 2 - Characteristics of Queueing Systems, Kendall's Notation

Lecture 3 - Little's Law, General Relationships

Lecture 4 - Laplace and Laplace-Stieltjes Transforms, Probability Generating Functions

Lecture 5 - An Overview of Stochastic Processes

Lecture 6 - Markov Chains: Definition, Transition Probabilities

Lecture 7 - Classification Properties of Markov Chains

Lecture 8 - Long-Term Behaviour of Markov Chains

Lecture 9 - Exponential Distribution and its Properties, Poisson Process

Lecture 10 - Poisson Process and its Properties, Generalizations

Lecture 11 - Continuous-Time Markov Chains, Generator Matrix, Kolmogorov Equations

Lecture 12 - Stationary and Limiting Distributions of CTMC, Balance Equations, Birth-Death Processes

Lecture 13 - Birth-Death Queues: General Theory, M/M/1 Queues and their Steady State Solution

Lecture 14 - M/M/1 Queues: Performance Measures, PASTA Property, Waiting Time Distributions

Lecture 15 - M/M/c Queues, Erlang Delay Formula

Lecture 16 - M/M/c/K Queues

Lecture 17 - Erlang's Loss System, Erlang Loss Formula, Infinite-Server Queues

Lecture 18 - Finite-Source Queues, Engset Loss System, State-Dependent Queues, Queues with Impatience

Lecture 19 - Transient Solutions: M/M/1/1, Infinite-Server and M/M/1 Queues, Busy Period Analysis

Lecture 20 - Queues with Bulk Arrivals

Lecture 21 - Queues with Bulk Service

Lecture 22 - Erlang and Phase-Type Distributions

Lecture 23 - Erlangian Queues: Erlangian Arrivals, Erlangian Service Times

Lecture 24 - Nonpreemptive Priority Queues

Lecture 25 - Nonpreemptive and Preemptive Priority Queues

Lecture 26 - M/M/1 Retrial Queues

Lecture 27 - Discrete-Time Queues: Geo/Geo/1 (EAS), Geo/Geo/1 (LAS)

Lecture 28 - Introduction to Queueing Networks, Two-Node Network

Lecture 29 - Burke's Theorem, General Setup, Tandem Networks

Lecture 30 - Queueing Networks with Blocking, Open Jackson Networks

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[Lecture 37 - Regenerative Processes, Semi-Markov Processes](#)

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[Lecture 40 - M/G/1 Queues: Waiting Times and Busy Period](#)

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[Lecture 42 - M/G/c, M/G/∞ and M/G/c/c Queues](#)

[Lecture 43 - G/M/1 Queues](#)

[Lecture 44 - G/G/1 Queues: Lindley's Integral Equation](#)

[Lecture 45 - G/G/1 Queues: Bounds](#)

[Lecture 46 - Vacation Queues: Introduction, M/M/1 Queues with Vacations](#)

[Lecture 47 - M/G/1 Queues with Vacations](#)

Lecture 1 - Prologue

Lecture 2 - Basic concepts on multivariate distribution

Lecture 3 - Basic concepts on multivariate distribution

Lecture 4 - Multivariate normal distribution – I

Lecture 5 - Multivariate normal distribution – II

Lecture 6 - Multivariate normal distribution – III

Lecture 7 - Some problems on multivariate distributions – I

Lecture 8 - Some problems on multivariate distributions – II

Lecture 9 - Random sampling from multivariate normal distribution and Wishart distribution - I

Lecture 10 - Random sampling from multivariate normal distribution and Wishart distribution - II

Lecture 11 - Random sampling from multivariate normal distribution and Wishart distribution - III

Lecture 12 - Wishart distribution and its properties - I

Lecture 13 - Wishart distribution and its properties - II

Lecture 14 - Hotelling's T^2 distribution and its applications

Lecture 15 - Hotelling's T^2 distribution and various confidence intervals and regions

Lecture 16 - Hotelling's T^2 distribution and Profile analysis

Lecture 17 - Profile analysis - I

Lecture 18 - Profile analysis - II

Lecture 19 - MANOVA - I

Lecture 20 - MANOVA - II

Lecture 21 - MANOVA - III

Lecture 22 - MANOVA & Multiple Correlation Coefficient

Lecture 23 - Multiple Correlation Coefficient

Lecture 24 - Principal Component Analysis

Lecture 25 - Principal Component Analysis

Lecture 26 - Principal Component Analysis

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Lecture 28 - Cluster Analysis

Lecture 29 - Cluster Analysis

Lecture 30 - Cluster Analysis

Lecture 31 - Discriminant Analysis and Classification

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NPTEL : Calculus of Variations and Integral Equations (Mathematics)

Co-ordinators : Dr. Malay Banerjee, Prof. D. Bahuguna

Lecture 1 - Calculus of Variations and Integral Equations

Lecture 2 - Calculus of Variations and Integral Equations

Lecture 3 - Calculus of Variations and Integral Equations

Lecture 4 - Calculus of Variations and Integral Equations

Lecture 5 - Calculus of Variations and Integral Equations

Lecture 6 - Calculus of Variations and Integral Equations

Lecture 7 - Calculus of Variations and Integral Equations

Lecture 8 - Calculus of Variations and Integral Equations

Lecture 9 - Calculus of Variations and Integral Equations

Lecture 10 - Calculus of Variations and Integral Equations

Lecture 11 - Calculus of Variations and Integral Equations

Lecture 12 - Calculus of Variations and Integral Equations

Lecture 13 - Calculus of Variations and Integral Equations

Lecture 14 - Calculus of Variations and Integral Equations

Lecture 15 - Calculus of Variations and Integral Equations

Lecture 16 - Calculus of Variations and Integral Equations

Lecture 17 - Calculus of Variations and Integral Equations

Lecture 18 - Calculus of Variations and Integral Equations

Lecture 19 - Calculus of Variations and Integral Equations

Lecture 20 - Calculus of Variations and Integral Equations

Lecture 21 - Calculus of Variations and Integral Equations

Lecture 22 - Calculus of Variations and Integral Equations

Lecture 23 - Calculus of Variations and Integral Equations

Lecture 24 - Calculus of Variations and Integral Equations

Lecture 25 - Calculus of Variations and Integral Equations

Lecture 26 - Calculus of Variations and Integral Equations

Lecture 27 - Calculus of Variations and Integral Equations

Lecture 28 - Calculus of Variations and Integral Equations

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[Lecture 40 - Calculus of Variations and Integral Equations](#)

NPTEL : Linear programming and Extensions (Mathematics)

Co-ordinators : Prof. Prabha Sharma

Lecture 1 - Introduction to Linear Programming Problems

Lecture 2 - Vector space, Linear independence and dependence, basis

Lecture 3 - Moving from one basic feasible solution to another, optimality criteria

Lecture 4 - Basic feasible solutions, existence & derivation

Lecture 5 - Convex sets, dimension of a polyhedron, Faces, Example of a polytope

Lecture 6 - Direction of a polyhedron, correspondence between bfs and extreme points

Lecture 7 - Representation theorem, LPP solution is a bfs, Assignment 1

Lecture 8 - Development of the Simplex Algorithm, Unboundedness, Simplex Tableau

Lecture 9 - Simplex Tableau & algorithm ,Cycling, Bland's anti-cycling rules, Phase I & Phase II

Lecture 10 - Big-M method,Graphical solutions, adjacent extreme pts and adjacent bfs

Lecture 11 - Assignment 2, progress of Simplex algorithm on a polytope, bounded variable LPP

Lecture 12 - LPP Bounded variable, Revised Simplex algorithm, Duality theory, weak duality theorem

Lecture 13 - Weak duality theorem, economic interpretation of dual variables, Fundamental theorem of duality

Lecture 14 - Examples of writing the dual, complementary slackness theorem

Lecture 15 - Complementary slackness conditions, Dual Simplex algorithm, Assignment 3

Lecture 16 - Primal-dual algorithm

Lecture 17 - Problem in lecture 16, starting dual feasible solution, Shortest Path Problem

Lecture 18 - Shortest Path Problem, Primal-dual method, example

Lecture 19 - Shortest Path Problem-complexity, interpretation of dual variables, post-optimality analysis-changes in the cost vector

Lecture 20 - Assignment 4, postoptimality analysis, changes in b, adding a new constraint, changes in $\{a_{ij}\}$, Parametric analysis

Lecture 21 - Parametric LPP-Right hand side vector

Lecture 22 - Parametric cost vector LPP

Lecture 23 - Parametric cost vector LPP, Introduction to Min-cost flow problem

Lecture 24 - Mini-cost flow problem-Transportation problem

Lecture 25 - Transportation problem degeneracy, cycling

Lecture 26 - Sensitivity analysis

Lecture 27 - Sensitivity analysis

Lecture 28 - Bounded variable transportation problem, min-cost flow problem

Lecture 29 - Min-cost flow problem

Lecture 30 - Starting feasible solution, Lexicographic method for preventing cycling ,strongly feasible solution

Lecture 31 - Assignment 6, Shortest path problem, Shortest Path between any two nodes, Detection of negative cycles

Lecture 32 - Min-cost-flow Sensitivity analysis Shortest path problem sensitivity analysis

Lecture 33 - Min-cost flow changes in arc capacities , Max-flow problem, assignment 7

Lecture 34 - Problem 3 (assignment 7), Min-cut Max-flow theorem, Labelling algorithm

Lecture 35 - Max-flow - Critical capacity of an arc, starting solution for min-cost flow problem

Lecture 36 - Improved Max-flow algorithm

Lecture 37 - Critical Path Method (CPM)

Lecture 38 - Programme Evaluation and Review Technique (PERT)

Lecture 39 - Simplex Algorithm is not polynomial time- An example

Lecture 40 - Interior Point Methods

NPTEL : Convex Optimization (Mathematics)

Co-ordinators : Dr. Joydeep Dutta

Lecture 1 - Convex Optimization

Lecture 2 - Convex Optimization

Lecture 3 - Convex Optimization

Lecture 4 - Convex Optimization

Lecture 5 - Convex Optimization

Lecture 6 - Convex Optimization

Lecture 7 - Convex Optimization

Lecture 8 - Convex Optimization

Lecture 9 - Convex Optimization

Lecture 10 - Convex Optimization

Lecture 11 - Convex Optimization

Lecture 12 - Convex Optimization

Lecture 13 - Convex Optimization

Lecture 14 - Convex Optimization

Lecture 15 - Convex Optimization

Lecture 16 - Convex Optimization

Lecture 17 - Convex Optimization

Lecture 18 - Convex Optimization

Lecture 19 - Convex Optimization

Lecture 20 - Convex Optimization

Lecture 21 - Convex Optimization

Lecture 22 - Convex Optimization

Lecture 23 - Convex Optimization

Lecture 24 - Convex Optimization

Lecture 25 - Convex Optimization

Lecture 26 - Convex Optimization

Lecture 27 - Convex Optimization

Lecture 28 - Convex Optimization

Lecture 29 - Convex Optimization

Lecture 30 - Convex Optimization

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[Lecture 41 - Convex Optimization](#)

[Lecture 42 - Convex Optimization](#)

NPTEL : Foundations of Optimization (Mathematics)

Co-ordinators : Dr. Joydeep Dutta

Lecture 1 - Optimization

Lecture 2 - Optimization

Lecture 3 - Optimization

Lecture 4 - Optimization

Lecture 5 - Optimization

Lecture 6 - Optimization

Lecture 7 - Optimization

Lecture 8 - Optimization

Lecture 9 - Optimization

Lecture 10 - Optimization

Lecture 11 - Optimization

Lecture 12 - Optimization

Lecture 13 - Optimization

Lecture 14 - Optimization

Lecture 15 - Optimization

Lecture 16 - Optimization

Lecture 17 - Optimization

Lecture 18 - Optimization

Lecture 19 - Optimization

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[Lecture 37 - Optimization](#)

[Lecture 38 - Optimization](#)

NPTEL : Probability Theory and Applications (Mathematics)

Co-ordinators : Prof. Prabha Sharma

Lecture 1 - Basic principles of counting

Lecture 2 - Sample space, events, axioms of probability

Lecture 3 - Conditional probability, Independence of events

Lecture 4 - Random variables, cumulative density function, expected value

Lecture 5 - Discrete random variables and their distributions

Lecture 6 - Discrete random variables and their distributions

Lecture 7 - Discrete random variables and their distributions

Lecture 8 - Continuous random variables and their distributions

Lecture 9 - Continuous random variables and their distributions

Lecture 10 - Continuous random variables and their distributions

Lecture 11 - Function of random variables, Moment generating function

Lecture 12 - Jointly distributed random variables, Independent r. v. and their sums

Lecture 13 - Independent r. v. and their sums

Lecture 14 - Chi χ^2 square r. v., sums of independent normal r. v., Conditional distr

Lecture 15 - Conditional distri, Joint distr. of functions of r. v., Order statistics

Lecture 16 - Order statistics, Covariance and correlation

Lecture 17 - Covariance, Correlation, Cauchy- Schwarz inequalities, Conditional expectation

Lecture 18 - Conditional expectation, Best linear predictor

Lecture 19 - Inequalities and bounds

Lecture 20 - Convergence and limit theorems

Lecture 21 - Central limit theorem

Lecture 22 - Applications of central limit theorem

Lecture 23 - Strong law of large numbers, Joint mgf

Lecture 24 - Convolutions

Lecture 25 - Stochastic processes: Markov process

Lecture 26 - Transition and state probabilities

Lecture 27 - State prob., First passage and First return prob

Lecture 28 - First passage and First return prob. Classification of states

Lecture 29 - Random walk, periodic and null states

Lecture 30 - Reducible Markov chains

Lecture 31 - Time reversible Markov chains

Lecture 32 - Poisson Processes

Lecture 33 - Inter-arrival times, Properties of Poisson processes

Lecture 34 - Queuing Models: M/M/I, Birth and death process, Little's formulae

Lecture 35 - Analysis of L , L_q , W and W_q , M/M/S model

Lecture 36 - M/M/S, M/M/I/K models

Lecture 37 - M/M/I/K and M/M/S/K models

Lecture 38 - Application to reliability theory failure law

Lecture 39 - Exponential failure law, Weibull law

Lecture 40 - Reliability of systems

Lecture 1 - Numbers

Lecture 2 - Functions-1

Lecture 3 - Sequence-1

Lecture 4 - Sequence-2

Lecture 5 - Limits and Continuity-1

Lecture 6 - Limits and Continuity-2

Lecture 7 - Limits And Continuity-3

Lecture 8 - Derivative-1

Lecture 9 - Derivative-2

Lecture 10 - Maxima And Minima

Lecture 11 - Mean-Value Theorem And Taylors Expansion-1

Lecture 12 - Mean-Value Theorem And Taylors Expansion-2

Lecture 13 - Integration-1

Lecture 14 - Integration-2

Lecture 15 - Integration By Parts

Lecture 16 - Definite Integral

Lecture 17 - Riemann Integration-1

Lecture 18 - Riemann Integration-2

Lecture 19 - Functions Of Two Or More Variables

Lecture 20 - Limits And Continuity Of Functions Of Two Variable

Lecture 21 - Differentiation Of Functions Of Two Variables-1

Lecture 22 - Differentiation Of Functions Of Two Variables-2

Lecture 23 - Unconstrained Minimization Of Funtions Of Two Variables

Lecture 24 - Constrained Minimization And Lagrange Multiplier Rules

Lecture 25 - Infinite Series-1

Lecture 26 - Infinite Series-2

Lecture 27 - Infinite Series-3

Lecture 28 - Multiple Integrals-1

Lecture 29 - Multiple Integrals-2

Lecture 30 - Multiple Integrals-3

Lecture 1 - Basic Probability

Lecture 2 - Interesting Problems In Probability

Lecture 3 - Random variables, distribution function and independence

Lecture 4 - Chebyshev inequality, Borel-Cantelli Lemmas and related issues

Lecture 5 - Law of Large Number and Central Limit Theorem

Lecture 6 - Conditional Expectation - I

Lecture 7 - Conditional Expectation - II

Lecture 8 - Martingales

Lecture 9 - Brownian Motion - I

Lecture 10 - Brownian Motion - II

Lecture 11 - Brownian Motion - III

Lecture 12 - Ito Integral - I

Lecture 13 - Ito Integral - II

Lecture 14 - Ito Calculus - I

Lecture 15 - Ito Calculus - II

Lecture 16 - Ito Integral In Higher Dimension

Lecture 17 - Application to Ito Integral - I

Lecture 18 - Application to Ito Integral - II

Lecture 19 - Black Scholes Formula - I

Lecture 20 - Black Scholes Formula - II

Lecture 1 - Introduction to Several Variables and Notion Of distance in R^n

Lecture 2 - Countinuity And Compactness

Lecture 3 - Countinuity And Connectdness

Lecture 4 - Derivatives: Possible Definition

Lecture 5 - Matrix Of Linear Transformation

Lecture 6 - Examples for Differentiable function

Lecture 7 - Sufficient condition of differentiability

Lecture 8 - Chain Rule

Lecture 9 - Mean Value Theorem

Lecture 10 - Higher Order Derivatives

Lecture 11 - Taylor's Formula

Lecture 12 - Maximum And Minimum

Lecture 13 - Second derivative test for maximum, minimum and saddle point

Lecture 14 - We formalise the second derivative test discussed in Lecture 2 and do examples

Lecture 15 - Specialisation to functions of two variables

Lecture 16 - Implicit Function Theorem

Lecture 17 - Implicit Function Theorem -a

Lecture 18 - Application of IFT: Lagrange's Multipliers Method

Lecture 19 - Application of IFT: Lagrange's Multipliers Method - b

Lecture 20 - Application of IFT: Lagrange's Multipliers Method - c

Lecture 21 - Application of IFT: Inverse Function Theorem - c

- Lecture 1 - Level curves and locus, definition of parametric curves, tangent, arc length, arc length parametrisation
- Lecture 2 - How much a curve is 'curved', signed unit normal and signed curvature, rigid motions, constant curvature
- Lecture 3 - Curves in \mathbb{R}^3 , principal normal and binormal, torsion
- Lecture 4 - Frenet-Serret formula
- Lecture 5 - Simple closed curve and isoperimetric inequality
- Lecture 6 - Surfaces and parametric surfaces, examples, regular surface and non-example of regular surface, transition maps.
- Lecture 7 - Transition maps of smooth surfaces, smooth function between surfaces, diffeomorphism
- Lecture 8 - Reparameterization
- Lecture 9 - Tangent, Normal
- Lecture 10 - Orientable surfaces
- Lecture 11 - Examples of Surfaces
- Lecture 12 - First Fundamental Form
- Lecture 13 - Conformal Mapping
- Lecture 14 - Curvature of Surfaces
- Lecture 15 - Euler's Theorem
- Lecture 16 - Regular Surfaces locally as Quadratic Surfaces
- Lecture 17 - Geodesics
- Lecture 18 - Existence of Geodesics, Geodesics on Surfaces of revolution
- Lecture 19 - Geodesics on surfaces of revolution; Clairaut's Theorem
- Lecture 20 - Pseudosphere
- Lecture 21 - Classification of Quadratic Surface
- Lecture 22 - Surface Area and Equiareal Map

Lecture 1 - Basic Fundamental Concepts Of Modelling

Lecture 2 - Regression Model - A Statistical Tool

Lecture 3 - Simple Linear Regression Analysis

Lecture 4 - Estimation Of Parameters In Simple Linear Regression Model

Lecture 5 - Estimation Of Parameters In Simple Linear Regression Model (Continued...) : Some Nice Properties

Lecture 6 - Estimation Of Parameters In Simple Linear Regression Model (Continued...)

Lecture 7 - Maximum Likelihood Estimation of Parameters in Simple Linear Regression Model

Lecture 8 - Testing of Hypothesis and Confidence Interval Estimation in Simple Linear Regression Model

Lecture 9 - Testing of Hypothesis and Confidence Interval Estimation in Simple Linear Regression Model (Continued...)

Lecture 10 - Software Implementation in Simple Linear Regression Model using MINITAB

Lecture 11 - Multiple Linear Regression Model

Lecture 12 - Estimation of Model Parameters in Multiple Linear Regression Model

Lecture 13 - Estimation of Model Parameters in Multiple Linear Regression Model (Continued...)

Lecture 14 - Standardized Regression Coefficients and Testing of Hypothesis

Lecture 15 - Testing of Hypothesis (Continued...) and Goodness of Fit of the Model

Lecture 16 - Diagnostics in Multiple Linear Regression Model

Lecture 17 - Diagnostics in Multiple Linear Regression Model (Continued...)

Lecture 18 - Diagnostics in Multiple Linear Regression Model (Continued...)

Lecture 19 - Software Implementation of Multiple Linear Regression Model using MINITAB

Lecture 20 - Software Implementation of Multiple Linear Regression Model using MINITAB (Continued...)

Lecture 21 - Forecasting in Multiple Linear Regression Model

Lecture 22 - Within Sample Forecasting

Lecture 23 - Outside Sample Forecasting

Lecture 24 - Software Implementation of Forecasting using MINITAB

Lecture 1 - How to Learn and Follow the Course

Lecture 2 - Why R and Installation Procedure

Lecture 3 - Introduction _Help_ Demo examples _packages_ libraries

Lecture 4 - Introduction _Command line_ Data editor _ Rstudio

Lecture 5 - Basics in Calculations

Lecture 6 - Basics of Calculations _ Calculator _Built in Functions Assignments

Lecture 7 - Basics of Calculations _Functions _Matrices

Lecture 8 - Basics Calculations: Matrix Operations

Lecture 9 - Basics Calculations: Matrix operations

Lecture 10 - Basics Calculations: Missing data and logical operators

Lecture 11 - Basics Calculations: Logical operators

Lecture 12 - Basics Calculations: Truth table and conditional executions

Lecture 13 - Basics Calculations: Conditional executions and loops

Lecture 14 - Basics Calculations: Loops

Lecture 15 - Data management - Sequences

Lecture 16 - Data management - sequences

Lecture 17 - Data management - Repeats

Lecture 18 - Data management - Sorting and Ordering

Lecture 19 - Data management - Lists

Lecture 20 - Data management - Lists (Continued...)

Lecture 21 - Data management - Vector indexing

Lecture 22 - Data management - Vector Indexing (Continued...)

Lecture 23 - Data management - Factors

Lecture 24 - Data management - factors (Continued...)

Lecture 25 - Strings - Display and Formatting, Print and Format Functions

Lecture 26 - Strings - Display and Formatting, Print and Format with Concatenate

Lecture 27 - Strings - Display and Formatting, Paste Function

Lecture 28 - Strings - Display and Formatting, Splitting

Lecture 29 - Strings - Display and Formatting, Replacement_ Manipulations _Alphabets

Lecture 30 - Strings - Display and Formatting, Replacement and Evaluation of Strings

Lecture 31 - Data frames

[Lecture 32 - Data frames \(Continued...\)](#)

[Lecture 33 - Data frames \(Continued...\)](#)

[Lecture 34 - Data Handling - Importing CSV and Tabular Data Files](#)

[Lecture 35 - Data Handling - Importing Data Files from Other Software](#)

[Lecture 36 - Statistical Functions - Frequency and Partition values](#)

[Lecture 37 - Statistical Functions - Graphics and Plots](#)

[Lecture 38 - Statistical Functions - Central Tendency and Variation](#)

[Lecture 39 - Statistical Functions - Boxplots, Skewness and Kurtosis](#)

[Lecture 40 - Statistical Functions - Bivariate three dimensional plot](#)

[Lecture 41 - Statistical Functions - Correlation and Examples of Programming](#)

[Lecture 42 - Examples of Programming](#)

[Lecture 43 - Examples of More Programming](#)

Lecture 1 - Introduction to R Software

Lecture 2 - Basics and R as a Calculator

Lecture 3 - Calculations with Data Vectors

Lecture 4 - Built-in Commands and Missing Data Handling

Lecture 5 - Operations with Matrices

Lecture 6 - Objectives, Steps and Basic Definitions

Lecture 7 - Variables and Types of Data

Lecture 8 - Absolute Frequency, Relative Frequency and Frequency Distribution

Lecture 9 - Frequency Distribution and Cumulative Distribution Function

Lecture 10 - Bar Diagrams

Lecture 11 - Subdivided Bar Plots and Pie Diagrams

Lecture 12 - 3D Pie Diagram and Histogram

Lecture 13 - Kernel Density and Stem - Leaf Plots

Lecture 14 - Arithmetic Mean

Lecture 15 - Median

Lecture 16 - Quantiles

Lecture 17 - Mode, Geometric Mean and Harmonic Mean

Lecture 18 - Range, Interquartile Range and Quartile Deviation

Lecture 19 - Absolute Deviation and Absolute Mean Deviation

Lecture 20 - Mean Squared Error, Variance and Standard Deviation

Lecture 21 - Coefficient of Variation and Boxplots

Lecture 22 - Raw and Central Moments

Lecture 23 - Sheppard's Correction, Absolute Moments and Computation of Moments

Lecture 24 - Skewness and Kurtosis

Lecture 25 - Univariate and Bivariate Scatter Plots

Lecture 26 - Smooth Scatter Plots

Lecture 27 - Quantile-Quantile and Three Dimensional Plots

Lecture 28 - Correlation Coefficient

Lecture 29 - Correlation Coefficient Using R Software

Lecture 30 - Rank Correlation Coefficient

Lecture 31 - Measures of Association for Discrete and Counting Variables - Part 1

[Lecture 32 - Measures of Association for Discrete and Counting Variables - Part 2](#)

[Lecture 33 - Least Squares Method - One Variable](#)

[Lecture 34 - Least Squares Method - R Commands and More than One Variables](#)

- Lecture 1 - Vectors in plane and space
- Lecture 2 - Inner product and distance
- Lecture 3 - Application to real world problems
- Lecture 4 - Matrices and determinants
- Lecture 5 - Cross product of two vectors
- Lecture 6 - Higher dimensional Euclidean space
- Lecture 7 - Functions of more than one real-variable
- Lecture 8 - Partial derivatives and Continuity
- Lecture 9 - Vector-valued maps and Jacobian matrix
- Lecture 10 - Chain rule for partial derivatives
- Lecture 11 - The Gradient Vector and Directional Derivative
- Lecture 12 - The Implicit Function Theorem
- Lecture 13 - Higher Order Partial Derivatives
- Lecture 14 - Taylor's Theorem in Higher Dimension
- Lecture 15 - Maxima and Minima for Several Variables
- Lecture 16 - Second Derivative Test for Maximum and Minimum
- Lecture 17 - Constrained Optimization and The Lagrange Multiplier Rule
- Lecture 18 - Vector Valued Function and Classical Mechanics
- Lecture 19 - Arc Length
- Lecture 20 - Vector Fields
- Lecture 21 - Multiple Integral - I
- Lecture 22 - Multiple Integral - II
- Lecture 23 - Multiple Integral - III
- Lecture 24 - Multiple Integral - IV
- Lecture 25 - Cylindrical and Spherical Coordinates
- Lecture 26 - Multiple Integrals and Mechanics
- Lecture 27 - Line Integral - I
- Lecture 28 - Line Integral - II
- Lecture 29 - Parametrized Surfaces
- Lecture 30 - Area of a surface Integral
- Lecture 31 - Area of parametrized surface

[Lecture 32 - Surface Integrals](#)

[Lecture 33 - Green's Theorem](#)

[Lecture 34 - Stoke's Theorem](#)

[Lecture 35 - Examples of Stoke's Theorem](#)

[Lecture 36 - Gauss Divergence Theorem](#)

[Lecture 37 - Facts about vector fields](#)

Lecture 1 - Notations, Motivation and Definition

Lecture 2 - Matrix: Examples, Transpose and Addition

Lecture 3 - Matrix Multiplication

Lecture 4 - Matrix Product Recalled

Lecture 5 - Matrix Product (Continued...)

Lecture 6 - Inverse of a Matrix

Lecture 7 - Introduction to System of Linear Equations

Lecture 8 - Some Initial Results on Linear Systems

Lecture 9 - Row Echelon Form (REF)

Lecture 10 - LU Decomposition - Simplest Form

Lecture 11 - Elementary Matrices

Lecture 12 - Row Reduced Echelon Form (RREF)

Lecture 13 - Row Reduced Echelon Form (RREF) (Continued...)

Lecture 14 - RREF and Inverse

Lecture 15 - Rank of a matrix

Lecture 16 - Solution Set of a System of Linear Equations

Lecture 17 - System of n Linear Equations in n Unknowns

Lecture 18 - Determinant

Lecture 19 - Permutations and the Inverse of a Matrix

Lecture 20 - Inverse and the Cramer's Rule

Lecture 21 - Vector Spaces

Lecture 22 - Vector Subspaces and Linear Span

Lecture 23 - Linear Combination, Linear Independence and Dependence

Lecture 24 - Basic Results on Linear Independence

Lecture 25 - Results on Linear Independence (Continued...)

Lecture 26 - Basis of a Finite Dimensional Vector Space

Lecture 27 - Fundamental Spaces associated with a Matrix

Lecture 28 - Rank - Nullity Theorem

Lecture 29 - Fundamental Theorem of Linear Algebra

Lecture 30 - Definition and Examples of Linear Transformations

Lecture 31 - Results on Linear Transformations

- Lecture 32 - Rank-Nullity Theorem and Applications
- Lecture 33 - Isomorphism of Vector Spaces
- Lecture 34 - Ordered Basis of a Finite Dimensional Vector Space
- Lecture 35 - Ordered Basis (Continued...)
- Lecture 36 - Matrix of a Linear Transformation
- Lecture 37 - Matrix of a Linear Transformation (Continued...)
- Lecture 38 - Matrix of a Linear Transformation (Continued...)
- Lecture 39 - Similarity of Matrices
- Lecture 40 - Inner Product Space
- Lecture 41 - Inner Product (Continued...)
- Lecture 42 - Cauchy Schwartz Inequality
- Lecture 43 - Projection on a Vector
- Lecture 44 - Results on Orthogonality
- Lecture 45 - Results on Orthogonality (Continued...)
- Lecture 46 - Gram-Schmidt Orthonormalization Process
- Lecture 47 - Orthogonal Projections
- Lecture 48 - Gram-Schmidt Process: Applications
- Lecture 49 - Examples and Applications on QR-decomposition
- Lecture 50 - Recapitulate ideas on Inner Product Spaces
- Lecture 51 - Motivation on Eigenvalues and Eigenvectors
- Lecture 52 - Examples and Introduction to Eigenvalues and Eigenvectors
- Lecture 53 - Results on Eigenvalues and Eigenvectors
- Lecture 54 - Results on Eigenvalues and Eigenvectors (Continued...)
- Lecture 55 - Results on Eigenvalues and Eigenvectors (Continued...)
- Lecture 56 - Diagonalizability
- Lecture 57 - Diagonalizability (Continued...)
- Lecture 58 - Schur's Unitary Triangularization (SUT)
- Lecture 59 - Applications of Schur's Unitary Triangularization
- Lecture 60 - Spectral Theorem for Hermitian Matrices
- Lecture 61 - Cayley Hamilton Theorem
- Lecture 62 - Quadratic Forms
- Lecture 63 - Sylvester's Law of Inertia
- Lecture 64 - Applications of Quadratic Forms to Analytic Geometry

[Lecture 65 - Examples of Conics and Quartics](#)

[Lecture 66 - Singular Value Decomposition \(SVD\)](#)

Lecture 1 - Introduction: Computation and Algebra

Lecture 2 - Background

Lecture 3 - GCD algorithm and Chinese Remainder Theorem

Lecture 4 - Fast polynomial multiplication

Lecture 5 - Fast polynomial multiplication (Continued...)

Lecture 6 - Fast integer multiplication and division

Lecture 7 - Fast integer arithmetic and matrix multiplication

Lecture 8 - Matrix Multiplication Tensor

Lecture 9 - Polynomial factoring over finite fields: Irreducibility testing

Lecture 10 - Equi-degree factorization and idea of Berlekamp's algorithm

Lecture 11 - Berlekamp's algorithm as a reduction method

Lecture 12 - Factoring over finite fields: Cantor-Zassenhaus algorithm

Lecture 13 - Reed Solomon Error Correcting Codes

Lecture 14 - List Decoding

Lecture 15 - Bivariate Factorization - Hensel Lifting

Lecture 16 - Bivariate polynomial factoring (Continued...)

Lecture 17 - Multivariate Polynomial Factorization

Lecture 18 - Multivariate Factoring - Hilbert's Irreducibility Theorem

Lecture 19 - Multivariate factoring (Continued...)

Lecture 20 - Analysis of LLL algorithm

Lecture 21 - Analysis of LLL algorithm (Continued...)

Lecture 22 - Analysis of LLL-reduced basis algorithm and Introduction to NTRU cryptosystem

Lecture 23 - NTRU cryptosystem (Continued...) and Introduction to Primality testing

Lecture 24 - Randomized Primality testing: Solovay-Strassen and Miller-Rabin tests

Lecture 25 - Deterministic primality test (AKS) and RSA cryptosystem

Lecture 26 - Integer factoring: Smooth numbers and Pollard's rho method

Lecture 27 - Pollard's p-1, Fermat, Morrison-Brillhart, Quadratic and Number field sieve methods

- Lecture 1 - Real numbers and Archimedean property
- Lecture 2 - Supremum and Decimal representation of Reals
- Lecture 3 - Functions
- Lecture 4 - Functions continued and Limits
- Lecture 5 - Limits (Continued...)
- Lecture 6 - Limits (Continued...) and Continuity
- Lecture 7 - Continuity and Intermediate Value Property
- Lecture 8 - Differentiation
- Lecture 9 - Chain Rule
- Lecture 10 - Nth derivative of a function
- Lecture 11 - Local extrema and Rolle's theorem
- Lecture 12 - Mean value theorem and Monotone functions
- Lecture 13 - Local extremum tests
- Lecture 14 - Concavity and points of inflection
- Lecture 15 - Asymptotes and plotting graph of functions
- Lecture 16 - Optimization and L'Hospital Rule
- Lecture 17 - L'Hospital Rule continued and Cauchy Mean value theorem
- Lecture 18 - Approximation of Roots
- Lecture 19 - Antiderivative and Riemann Integration
- Lecture 20 - Riemann's criterion for Integrability
- Lecture 21 - Integration and its properties
- Lecture 22 - Area and Mean value theorem for integrals
- Lecture 23 - Fundamental theorem of Calculus
- Lecture 24 - Integration by parts and Trapezoidal rule
- Lecture 25 - Simpson's rule and Substitution in integrals
- Lecture 26 - Area between curves
- Lecture 27 - Arc Length and Parametric curves
- Lecture 28 - Polar Co-ordinates
- Lecture 29 - Area of curves in polar coordinates
- Lecture 30 - Volume of solids
- Lecture 31 - Improper Integrals

[Lecture 32 - Sequences](#)

[Lecture 33 - Algebra of sequences and Sandwich theorem](#)

[Lecture 34 - Subsequences](#)

[Lecture 35 - Series](#)

[Lecture 36 - Comparison tests for Series](#)

[Lecture 37 - Ratio and Root test for series](#)

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[Lecture 39 - Revision - I](#)

[Lecture 40 - Revision - II](#)

[Lecture 1](#)

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Lecture 1 - Data Science - Why, What, and How?

Lecture 2 - Installation and Working with R

Lecture 3 - Installation and Working with R Studio

Lecture 4 - Calculations with R as a Calculator

Lecture 5 - Calculations with Data Vectors

Lecture 6 - Built-in Commands and Bivariate Plots

Lecture 7 - Logical Operators and Selection of Sample

Lecture 8 - Introduction to Probability

Lecture 9 - Sample Space and Events

Lecture 10 - Set Theory and Events using Venn Diagrams

Lecture 11 - Relative Frequency and Probability

Lecture 12 - Probability and Relative Frequency - An Example

Lecture 13 - Axiomatic Definition of Probability

Lecture 14 - Some Rules of Probability

Lecture 15 - Basic Principles of Counting - Ordered Set, Unordered Set, and Permutations

Lecture 16 - Basic Principles of Counting - Combination

Lecture 17 - Conditional Probability

Lecture 18 - Multiplication Theorem of Probability

Lecture 19 - Bayes' Theorem

Lecture 20 - Independent Events

Lecture 21 - Computation of Probability using R

Lecture 22 - Random Variables - Discrete and Continuous

Lecture 23 - Cumulative Distribution and Probability Density Function

Lecture 24 - Discrete Random Variables, Probability Mass Function and Cumulative Distribution Function

Lecture 25 - Expectation of Variables

Lecture 26 - Moments and Variance

Lecture 27 - Data Based Moments and Variance in R Software

Lecture 28 - Skewness and Kurtosis

Lecture 29 - Quantiles and Tschebyschev's Inequality

Lecture 30 - Degenerate and Discrete Uniform Distributions

Lecture 31 - Discrete Uniform Distribution in R

[Lecture 32 - Bernoulli and Binomial Distribution](#)

[Lecture 33 - Binomial Distribution in R](#)

[Lecture 34 - Poisson Distribution](#)

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Co-ordinators : Prof. Abhijit Pal

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Co-ordinators : Prof. Suprio Bhar

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Co-ordinators : Prof. P.D. Srivastava

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- 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
- Lecture 27 - Tutorial - III
- Lecture 28 - Annihilator in an IPS
- Lecture 29 - Total Orthonormal Sets And Sequences
- Lecture 30 - Partially Ordered Set and Zorns Lemma
- Lecture 31 - Hahn Banach Theorem for Real Vector Spaces

[Lecture 32 - Hahn Banach Theorem for Complex V.S. & Normed Spaces](#)

[Lecture 33 - Baires Category & Uniform Boundedness Theorems](#)

[Lecture 34 - Open Mapping Theorem](#)

[Lecture 35 - Closed Graph Theorem](#)

[Lecture 36 - Adjoint Operator](#)

[Lecture 37 - Strong and Weak Convergence](#)

[Lecture 38 - Convergence of Sequence of Operators and Functionals](#)

[Lecture 39 - LP - Space](#)

[Lecture 40 - LP - Space \(Continued.\)](#)

Lecture 1 - Motivation with few Examples

Lecture 2 - Single - Step Methods for IVPs

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

Lecture 8 - Tutorial - II

Lecture 9 - Multi-Step Methods (Explicit)

Lecture 10 - Multi-Step Methods (Implicit)

Lecture 11 - Convergence and Stability of multi step methods

Lecture 12 - General methods for absolute stability

Lecture 13 - Stability Analysis of Multi Step Methods

Lecture 14 - Predictor - Corrector Methods

Lecture 15 - Some Comments on Multi - Step Methods

Lecture 16 - Finite Difference Methods - Linear BVPs

Lecture 17 - Linear/Non - Linear Second Order BVPs

Lecture 18 - BVPS - Derivative Boundary Conditions

Lecture 19 - Higher Order BVPs

Lecture 20 - Shooting Method BVPs

Lecture 21 - Tutorial - III

Lecture 22 - Introduction to First Order PDE

Lecture 23 - Introduction to Second Order PDE

Lecture 24 - Finite Difference Approximations to Parabolic PDEs

Lecture 25 - Implicit Methods for Parabolic PDEs

Lecture 26 - Consistency, Stability and Convergence

Lecture 27 - Other Numerical Methods for Parabolic PDEs

Lecture 28 - Tutorial - IV

Lecture 29 - Matrix Stability Analysis of Finite Difference Scheme

Lecture 30 - Fourier Series Stability Analysis of Finite Difference Scheme

Lecture 31 - Finite Difference Approximations to Elliptic PDEs - I

[Lecture 32 - Finite Difference Approximations to Elliptic PDEs - II](#)

[Lecture 33 - Finite Difference Approximations to Elliptic PDEs - III](#)

[Lecture 34 - Finite Difference Approximations to Elliptic PDEs - IV](#)

[Lecture 35 - Finite Difference Approximations to Hyperbolic PDEs - I](#)

[Lecture 36 - Finite Difference Approximations to Hyperbolic PDEs - II](#)

[Lecture 37 - Method of characteristics for Hyperbolic PDEs - I](#)

[Lecture 38 - Method of characteristics for Hyperbolic PDEs - II](#)

[Lecture 39 - Finite Difference Approximations to 1st order Hyperbolic PDEs](#)

[Lecture 40 - Summary, Appendices, Remarks](#)

NPTEL : Optimization (Mathematics)

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

Lecture 1 - Optimization - Introduction

Lecture 2 - Formulation of LPP

Lecture 3 - Geometry of LPP and Graphical Solution of LPP

Lecture 4 - Solution of LPP : Simplex Method

Lecture 5 - Big - M Method

Lecture 6 - Two - Phase Method

Lecture 7 - Special Cases in Simple Applications

Lecture 8 - Introduction to Duality Theory

Lecture 9 - Dual Simplex Method

Lecture 10 - Post Optimality Analysis

Lecture 11 - Integer Programming - I

Lecture 12 - Integer Programming - II

Lecture 13 - Introduction to Transportation Problems

Lecture 14 - Solving Various types of Transportation Problems

Lecture 15 - Assignment Problems

Lecture 16 - Project Management

Lecture 17 - Critical Path Analysis

Lecture 18 - PERT

Lecture 19 - Shortest Path Algorithm

Lecture 20 - Travelling Salesman Problem

Lecture 21 - Classical optimization techniques : Single variable optimization

Lecture 22 - Unconstrained multivariable optimization

Lecture 23 - Nonlinear programming with equality constraint

Lecture 24 - Nonlinear programming KKT conditions

Lecture 25 - Numerical optimization : Region elimination techniques

Lecture 26 - Numerical optimization : Region elimination techniques (Continued.)

Lecture 27 - Fibonacci Method

Lecture 28 - Golden Section Methods

Lecture 29 - Interpolation Methods

Lecture 30 - Unconstrained optimization techniques : Direct search method

Lecture 31 - Unconstrained optimization techniques : Indirect search method

[Lecture 32 - Nonlinear programming : constrained optimization techniques](#)

[Lecture 33 - Interior and Exterior penalty Function Method](#)

[Lecture 34 - Separable Programming Problem](#)

[Lecture 35 - Introduction to Geometric Programming](#)

[Lecture 36 - Constrained Geometric Programming Problem](#)

[Lecture 37 - Dynamic Programming Problem](#)

[Lecture 38 - Dynamic Programming Problem \(Continued.\)](#)

[Lecture 39 - Multi Objective Decision Making](#)

[Lecture 40 - Multi attribute decision making](#)

NPTEL : Probability and Statistics (Mathematics)

Co-ordinators : Prof. Somesh Kumar

Lecture 1 - Algebra of Sets - I

Lecture 2 - Algebra of Sets - II

Lecture 3 - Introduction to Probability

Lecture 4 - Laws of Probability - I

Lecture 5 - Laws of Probability - II

Lecture 6 - Problems in Probability

Lecture 7 - Random Variables

Lecture 8 - Probability Distributions

Lecture 9 - Characteristics of Distribution

Lecture 10 - Special Distributions - I

Lecture 11 - Special Distributions - II

Lecture 12 - Special Distributions - III

Lecture 13 - Special Distributions - IV

Lecture 14 - Special Distributions - V

Lecture 15 - Special Distributions - VI

Lecture 16 - Special Distributions - VII

Lecture 17 - Functions of a Random Variable

Lecture 18 - Joint Distributions - I

Lecture 19 - Joint Distributions - II

Lecture 20 - Joint Distributions - III

Lecture 21 - Joint Distributions - IV

Lecture 22 - Transformations of Random Vectors

Lecture 23 - Sampling Distributions - I

Lecture 24 - Sampling Distributions - II

Lecture 25 - Descriptive Statistics - I

Lecture 26 - Descriptive Statistics - II

Lecture 27 - Estimation - I

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[Lecture 33 - Testing of Hypothesis - I](#)

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[Lecture 35 - Testing of Hypothesis - III](#)

[Lecture 36 - Testing of Hypothesis - IV](#)

[Lecture 37 - Testing of Hypothesis - V](#)

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[Lecture 39 - Testing of Hypothesis - VII](#)

[Lecture 40 - Testing of Hypothesis - VIII](#)

NPTEL : Regression Analysis (Mathematics)

Co-ordinators : Dr. Soumen Maity

Lecture 1 - Simple Linear Regression

Lecture 2 - Simple Linear Regression (Continued...1)

Lecture 3 - Simple Linear Regression (Continued...2)

Lecture 4 - Simple Linear Regression (Continued...3)

Lecture 5 - Simple Linear Regression (Continued...4)

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Lecture 7 - Multiple Linear Regression (Continued...1)

Lecture 8 - Multiple Linear Regression (Continued...2)

Lecture 9 - Multiple Linear Regression (Continued...3)

Lecture 10 - Selecting the BEST Regression model

Lecture 11 - Selecting the BEST Regression model (Continued...1)

Lecture 12 - Selecting the BEST Regression model (Continued...2)

Lecture 13 - Selecting the BEST Regression model (Continued...3)

Lecture 14 - Multicollinearity

Lecture 15 - Multicollinearity (Continued...1)

Lecture 16 - Multicollinearity (Continued...2)

Lecture 17 - Model Adequacy Checking

Lecture 18 - Model Adequacy Checking (Continued...1)

Lecture 19 - Model Adequacy Checking (Continued...2)

Lecture 20 - Test for Influential Observations

Lecture 21 - Transformations and Weighting to correct model inadequacies

Lecture 22 - Transformations and Weighting to correct model inadequacies (Continued...1)

Lecture 23 - Transformations and Weighting to correct model inadequacies (Continued...2)

Lecture 24 - Dummy Variables

Lecture 25 - Dummy Variables (Continued...1)

Lecture 26 - Dummy Variables (Continued...2)

Lecture 27 - Polynomial Regression Models

Lecture 28 - Polynomial Regression Models (Continued...1)

Lecture 29 - Polynomial Regression Models (Continued...2)

Lecture 30 - Generalized Linear Models

Lecture 31 - Generalized Linear Models (Continued.)

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[Lecture 33 - Regression Models with Autocorrelated Errors](#)

[Lecture 34 - Regression Models with Autocorrelated Errors \(Continued.\)](#)

[Lecture 35 - Measurement Errors & Calibration Problem](#)

[Lecture 36 - Tutorial - I](#)

[Lecture 37 - Tutorial - II](#)

[Lecture 38 - Tutorial - III](#)

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- Lecture 1 - Introduction and Motivation
- Lecture 2 - Basic Concepts of Point Estimations - I
- Lecture 3 - Basic Concepts of Point Estimations - II
- Lecture 4 - Finding Estimators - I
- Lecture 5 - Finding Estimators - II
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- Lecture 7 - Properties of MLEs
- Lecture 8 - Lower Bounds for Variance - I
- Lecture 9 - Lower Bounds for Variance - II
- Lecture 10 - Lower Bounds for Variance - III
- Lecture 11 - Lower Bounds for Variance - IV
- Lecture 12 - Sufficiency
- Lecture 13 - Sufficiency and Information
- Lecture 14 - Minimal Sufficiency, Completeness
- Lecture 15 - UMVU Estimation, Ancillarity
- Lecture 16 - Invariance - I
- Lecture 17 - Invariance - II
- Lecture 18 - Bayes and Minimax Estimation - I
- Lecture 19 - Bayes and Minimax Estimation - II
- Lecture 20 - Bayes and Minimax Estimation - III
- Lecture 21 - Testing of Hypotheses : Basic Concepts
- Lecture 22 - Neyman Pearson Fundamental Lemma
- Lecture 23 - Applications of NP lemma
- Lecture 24 - UMP Tests
- Lecture 25 - UMP Tests (Continued.)
- Lecture 26 - UMP Unbiased Tests
- Lecture 27 - UMP Unbiased Tests (Continued.)
- Lecture 28 - UMP Unbiased Tests : Applications
- Lecture 29 - Unbiased Tests for Normal Populations
- Lecture 30 - Unbiased Tests for Normal Populations (Continued.)
- Lecture 31 - Likelihood Ratio Tests - I

[Lecture 32 - Likelihood Ratio Tests - II](#)

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[Lecture 35 - Invariant Tests](#)

[Lecture 36 - Test for Goodness of Fit](#)

[Lecture 37 - Sequential Procedure](#)

[Lecture 38 - Sequential Procedure \(Continued.\)](#)

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Lecture 1 - Rational Numbers and Rational Cuts

Lecture 2 - Irrational numbers, Dedekind's Theorem

Lecture 3 - Continuum and Exercises

Lecture 4 - Continuum and Exercises (Continued.)

Lecture 5 - Cantor's Theory of Irrational Numbers

Lecture 6 - Cantor's Theory of Irrational Numbers (Continued.)

Lecture 7 - Equivalence of Dedekind and Cantor's Theory

Lecture 8 - Finite, Infinite, Countable and Uncountable Sets of Real Numbers

Lecture 9 - Types of Sets with Examples, Metric Space

Lecture 10 - Various properties of open set, closure of a set

Lecture 11 - Ordered set, Least upper bound, greatest lower bound of a set

Lecture 12 - Compact Sets and its properties

Lecture 13 - Weiersstrass Theorem, Heine Borel Theorem, Connected set

Lecture 14 - Tutorial - II

Lecture 15 - Concept of limit of a sequence

Lecture 16 - Some Important limits, Ratio tests for sequences of Real Numbers

Lecture 17 - Cauchy theorems on limit of sequences with examples

Lecture 18 - Fundamental theorems on limits, Bolzano-Weiersstrass Theorem

Lecture 19 - Theorems on Convergent and divergent sequences

Lecture 20 - Cauchy sequence and its properties

Lecture 21 - Infinite series of real numbers

Lecture 22 - Comparison tests for series, Absolutely convergent and Conditional convergent series

Lecture 23 - Tests for absolutely convergent series

Lecture 24 - Raabe's test, limit of functions, Cluster point

Lecture 25 - Some results on limit of functions

Lecture 26 - Limit Theorems for functions

Lecture 27 - Extension of limit concept (one sided limits)

Lecture 28 - Continuity of Functions

Lecture 29 - Properties of Continuous Functions

Lecture 30 - Boundedness Theorem, Max-Min Theorem and Bolzano's theorem

Lecture 31 - Uniform Continuity and Absolute Continuity

- Lecture 32 - Types of Discontinuities, Continuity and Compactness
- Lecture 33 - Continuity and Compactness (Continued.), Connectedness
- Lecture 34 - Differentiability of real valued function, Mean Value Theorem
- Lecture 35 - Mean Value Theorem (Continued.)
- Lecture 36 - Application of MVT , Darboux Theorem, L Hospital Rule
- Lecture 37 - L'Hospital Rule and Taylor's Theorem
- Lecture 38 - Tutorial - III
- Lecture 39 - Riemann/Riemann Stieltjes Integral
- Lecture 40 - Existence of Reimann Stieltjes Integral
- Lecture 41 - Properties of Reimann Stieltjes Integral
- Lecture 42 - Properties of Reimann Stieltjes Integral (Continued.)
- Lecture 43 - Definite and Indefinite Integral
- Lecture 44 - Fundamental Theorems of Integral Calculus
- Lecture 45 - Improper Integrals
- Lecture 46 - Convergence Test for Improper Integrals

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Lecture 2 - Laws of Probability

Lecture 3 - Random Variables

Lecture 4 - Moments and Special Distributions

Lecture 5 - Moments and Special Distributions (Continued...)

Lecture 6 - Special Distributions (Continued...)

Lecture 7 - Special Distributions (Continued...)

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Lecture 9 - Parametric Methods - I

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Lecture 11 - Parametric Methods - III

Lecture 12 - Parametric Methods - IV

Lecture 13 - Parametric Methods - V

Lecture 14 - Parametric Methods - VI

Lecture 15 - Parametric Methods - VII

Lecture 16 - Multivariate Analysis - I

Lecture 17 - Multivariate Analysis - II

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Lecture 1 - Sets, Classes, Collection

Lecture 2 - Sequence of Sets

Lecture 3 - Ring, Field (Algebra)

Lecture 4 - Sigma-Ring, Sigma-Field, Monotone Class

Lecture 5 - Random Experiment, Events

Lecture 6 - Definitions of Probability

Lecture 7 - Properties of Probability Function - I

Lecture 8 - Properties of Probability Function - II

Lecture 9 - Conditional Probability

Lecture 10 - Independence of Events

Lecture 11 - Problems in Probability - I

Lecture 12 - Problems in Probability - II

Lecture 13 - Random Variables

Lecture 14 - Probability Distribution of a Random Variable - I

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Lecture 17 - Characteristics of Distributions - I

Lecture 18 - Characteristics of Distributions - II

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Lecture 20 - Special Discrete Distributions - II

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Lecture 22 - Poisson Process - I

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Lecture 24 - Special Continuous Distributions - I

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- Lecture 32 - Problems on Special Distributions - II
- Lecture 33 - Function of a random variable - I
- Lecture 34 - Function of a random variable - II
- Lecture 35 - Joint Distributions - I
- Lecture 36 - Joint Distributions - II
- Lecture 37 - Independence, Product Moments
- Lecture 38 - Linearity Property of Correlation and Examples
- Lecture 39 - Bivariate Normal Distribution - I
- Lecture 40 - Bivariate Normal Distribution - II
- Lecture 41 - Additive Properties of Distributions - I
- Lecture 42 - Additive Properties of Distributions - II
- Lecture 43 - Transformation of Random Variables
- Lecture 44 - Distribution of Order Statistics
- Lecture 45 - Basic Concepts
- Lecture 46 - Chi-Square Distribution
- Lecture 47 - Chi-Square Distribution (Continued...), t-Distribution
- Lecture 48 - F-Distribution
- Lecture 49 - Descriptive Statistics - I
- Lecture 50 - Descriptive Statistics - II
- Lecture 51 - Descriptive Statistics - III
- Lecture 52 - Descriptive Statistics - IV
- Lecture 53 - Introduction to Estimation
- Lecture 54 - Unbiased and Consistent Estimators
- Lecture 55 - LSE, MME
- Lecture 56 - Examples on MME, MLE
- Lecture 57 - Examples on MLE - I
- Lecture 58 - Examples on MLE - II, MSE
- Lecture 59 - UMVUE, Sufficiency, Completeness
- Lecture 60 - Rao - Blackwell Theorem and Its Applications
- Lecture 61 - Confidence Intervals - I
- Lecture 62 - Confidence Intervals - II
- Lecture 63 - Confidence Intervals - III
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[Lecture 72 - Large Sample Test for Variance and Two Sample Problem](#)

[Lecture 73 - Paired t-Test](#)

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[Lecture 78 - Testing for Independence in rxc Contingency Table - I](#)

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Lecture 1 - Introduction to Multivariate Statistical Modeling

Lecture 2 - Introduction to Multivariate Statistical Modeling: Data types, models, and modeling

Lecture 3 - Statistical approaches to model building

Lecture 4 - Statistical approaches to model building (Continued...)

Lecture 5 - Univariate Descriptive Statistics

Lecture 6 - Univariate Descriptive Statistics (Continued...)

Lecture 7 - Normal Distribution and Chi-squared Distribution

Lecture 8 - t-distribution, F-distribution, and Central Limit Theorem

Lecture 9 - Univariate Inferential Statistics: Estimation

Lecture 10 - Univariate Inferential Statistics: Estimation (Continued...)

Lecture 11 - Univariate Inferential Statistics: Hypothesis Testing

Lecture 12 - Hypothesis Testing (Continued...): Decision Making Scenarios

Lecture 13 - Multivariate Descriptive Statistics: Mean Vector

Lecture 14 - Multivariate Descriptive Statistics: Covariance Matrix

Lecture 15 - Multivariate Descriptive Statistics: Correlation Matrix

Lecture 16 - Multivariate Descriptive Statistics: Relationship between correlation and covariance matrices

Lecture 17 - Multivariate Normal Distribution

Lecture 18 - Multivariate Normal Distribution (Continued...)

Lecture 19 - Multivariate Normal Distribution (Continued...): Geometrical Interpretation

Lecture 20 - Multivariate Normal Distribution (Continued...): Examining data for multivariate normal distribution

Lecture 21 - Multivariate Inferential Statistics: Basics and Hotelling T-square statistic

Lecture 22 - Multivariate Inferential Statistics: Confidence Region

Lecture 23 - Multivariate Inferential Statistics: Simultaneous confidence interval and Hypothesis testing

Lecture 24 - Multivariate Inferential Statistics: Hypothesis testing for equality of two population mean vectors

Lecture 25 - Analysis of Variance (ANOVA)

Lecture 26 - Analysis of Variance (ANOVA): Decomposition of Total sum of squares

Lecture 27 - Analysis of Variance (ANOVA): Estimation of Parameters and Model Adequacy tests

Lecture 28 - Two-way and Three-way Analysis of Variance (ANOVA)

Lecture 29 - Tutorial ANOVA

Lecture 30 - Tutorial ANOVA (Continued...)

Lecture 31 - Multivariate Analysis of Variance (MANOVA): Conceptual Model

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Lecture 32 - Multivariate Analysis of Variance (MANOVA): Assumptions and Decomposition of total sum square and cross products (SSCP)

Lecture 33 - Multivariate Analysis of Variance (MANOVA): Decomposition of total sum square and cross products (SSCP) (Continued...)

Lecture 34 - Multivariate Analysis of Variance (MANOVA): Estimation and Hypothesis testing

Lecture 35 - MANOVA Case Study

Lecture 36 - Multiple Linear Regression: Introduction

Lecture 37 - Multiple Linear Regression: Assumptions and Estimation of model parameters

Lecture 38 - Multiple Linear Regression: Sampling Distribution of parameter estimates

Lecture 39 - Multiple Linear Regression: Sampling Distribution of parameter estimates (Continued...)

Lecture 40 - Multiple Linear Regression: Model Adequacy Tests

Lecture 41 - Multiple Linear Regression: Model Adequacy Tests (Continued...)

Lecture 42 - Multiple Linear Regression: Test of Assumptions

Lecture 43 - MLR-Model diagnostics

Lecture 44 - MLR-case study

Lecture 45 - Multivariate Linear Regression: Conceptual model and assumptions

Lecture 46 - Multivariate Linear Regression: Estimation of parameters

Lecture 47 - Multivariate Linear Regression: Estimation of parameters (Continued...)

Lecture 48 - Multiple Linear Regression: Sampling Distribution of parameter estimates

Lecture 49 - Multivariate Linear Regression: Model Adequacy Tests

Lecture 50 - Multiple Linear Regression: Model Adequacy Tests (Continued...)

Lecture 51 - Regression modeling using SPSS

Lecture 52 - Principal Component Analysis (PCA): Conceptual Model

Lecture 53 - Principal Component Analysis (PCA): Extraction of Principal components (PCs)

Lecture 54 - Principal Component Analysis (PCA): Model Adequacy and Interpretation

Lecture 55 - Principal Component Analysis (PCA): Model Adequacy and Interpretation (Continued...)

Lecture 56 - Factor Analysis: Basics and Orthogonal factor models

Lecture 57 - Factor Analysis: Types of models and key questions

Lecture 58 - Factor Analysis: Parameter Estimation

Lecture 59 - Factor Analysis: Parameter Estimation (Continued...)

Lecture 60 - Factor Analysis: Model Adequacy tests and factor rotation

Lecture 61 - Factor Analysis: Factor scores and case study

Lecture 1 - Introduction to PDE

Lecture 2 - Classification of PDE

Lecture 3 - Principle of Linear Superposition

Lecture 4 - Standard Eigen Value Problem and Special ODEs

Lecture 5 - Adjoint Operator

Lecture 6 - Generalized Sturm - Liouville Problem

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Lecture 8 - Separation of Variables: Rectangular Coordinate Systems

Lecture 9 - Solution of 3 Dimensional Parabolic Problem

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Lecture 11 - Solution of 4 Dimensional Parabolic Problem (Continued...)

Lecture 12 - Solution of Elliptical PDE

Lecture 13 - Solution of Hyperbolic PDE

Lecture 14 - Orthogonality of Bessel Function and 2 Dimensional Cylindrical Coordinate System

Lecture 15 - Cylindrical Co-ordinate System - 3 Dimensional Problem

Lecture 16 - Spherical Polar Coordinate System

Lecture 17 - Spherical Polar Coordinate System (Continued...)

Lecture 18 - Example of Generalized 3 Dimensional Problem

Lecture 19 - Example of Application Oriented Problems

Lecture 20 - Examples of Application Oriented Problems (Continued...)

Lecture 1 - Countable and Uncountable sets

Lecture 2 - Properties of Countable and Uncountable sets

Lecture 3 - Examples of Countable and Uncountable sets

Lecture 4 - Concepts of Metric Space

Lecture 5 - Open ball, Closed ball, Limit point of a set

Lecture 6 - Tutorial-I

Lecture 7 - Some theorems on Open and Closed sets

Lecture 8 - Ordered set, Least upper bound, Greatest lower bound of a set

Lecture 9 - Ordered set, Least upper bound, Greatest lower bound of a set (Continued...)

Lecture 10 - Compact Set

Lecture 11 - Properties of Compact sets

Lecture 12 - Tutorial-II

Lecture 13 - Heine Borel Theorem

Lecture 14 - Weierstrass Theorem

Lecture 15 - Cantor set and its properties

Lecture 16 - Derived set and Dense set

Lecture 17 - Limit of a sequence and monotone sequence

Lecture 18 - Tutorial-III

Lecture 19 - Some Important limits of sequences

Lecture 20 - Ratio Test Cauchy's theorems on limits of sequences of real numbers

Lecture 21 - Fundamental theorems on limits

Lecture 22 - Some results on limits and Bolzano-Weierstrass Theorem

Lecture 23 - Criteria for convergent sequence

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Lecture 25 - Criteria for Divergent Sequence

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Lecture 29 - Convergence Criteria for Series of Positive Real Numbers

Lecture 30 - Tutorial-V

Lecture 31 - Comparison Test for Series

- Lecture 32 - Absolutely and Conditionally Convergent Series
- Lecture 33 - Rearrangement Theorem and Test for Convergence of Series
- Lecture 34 - Ratio and Integral Test for Convergence of Series
- Lecture 35 - Raabe's Test for Convergence of Series
- Lecture 36 - Tutorial-VI
- Lecture 37 - Limit of Functions and Cluster Point
- Lecture 38 - Limit of Functions (Continued...)
- Lecture 39 - Divergence Criteria for Limit
- Lecture 40 - Various Properties of Limit of Functions
- Lecture 41 - Left and Right Hand Limits for Functions
- Lecture 42 - Tutorial-VII
- Lecture 43 - Limit of Functions at Infinity
- Lecture 44 - Continuous Functions (Cauchy's Definition)
- Lecture 45 - Continuous Functions (Heine's Definition)
- Lecture 46 - Properties of Continuous Functions
- Lecture 47 - Properties of Continuous Functions (Continued...)
- Lecture 48 - Tutorial-VIII
- Lecture 49 - Boundness Theorem and Max-Min Theorem
- Lecture 50 - Location of Root and Bolzano's Theorem
- Lecture 51 - Uniform Continuity and Related Theorems
- Lecture 52 - Absolute Continuity and Related Theorems
- Lecture 53 - Types of Discontinuities
- Lecture 54 - Tutorial-IX
- Lecture 55 - Types of Discontinuities (Continued...)
- Lecture 56 - Relation between Continuity and Compact Sets
- Lecture 57 - Differentiability of Real Valued Functions
- Lecture 58 - Local Max. - Min. Cauchy's and Lagrange's Mean Value Theorem
- Lecture 59 - Rolle's Mean Value Theorems and Its Applications
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Lecture 1 - Preliminary concepts: Fluid kinematics, stress, strain

Lecture 2 - Cauchy's equation of motion and Navier-Stokes equations

Lecture 3 - Reduced forms of Navier-Stokes equations and Boundary conditions

Lecture 4 - Exact solutions of Navier-Stokes equations in particular cases

Lecture 5 - Dimensional Analysis – Non-dimensionalization of Navier-Stokes's equations

Lecture 6 - Stream function formulation of Navier-Stokes equations

Lecture 7 - Stokes flow past a cylinder

Lecture 8 - Stokes flow past a sphere

Lecture 9 - Elementary Lubrication Theory

Lecture 10 - Hydrodynamics of Squeeze flow

Lecture 11 - Solution of arbitrary Stokes flows

Lecture 12 - Mechanics of Swimming Microorganisms

Lecture 13 - Viscous flow past a spherical drop

Lecture 14 - Migration of a viscous drop under Marangoni effects

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Co-ordinators : Dr. T.E. Venkata Balaji

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Lecture 20 - Numerical Integration - 3 Error in Simpson's Rule Composite in Trapezoidal Rule, Error

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Lecture 25 - Numerical Solution Of ODE-2 Stability , Single-Step Methods - 1 Taylor Series Method

Lecture 26 - Numerical Solution Of ODE-3 Examples of Taylor Series Method Euler's Method

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Lecture 29 - Numerical Solution Of Ordinary Differential Equations - 6 Predictor-Corrector Methods (Adam-Moulton)

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- Lecture 32 - Numerical Solution of Ordinary Differential Equations - 9
- Lecture 33 - Numerical Solution of Ordinary Differential Equations - 10
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- Lecture 35 - Root Finding Methods - 1 The Bisection Method - 1
- Lecture 36 - Root Finding Methods - 2 The Bisection Method - 2
- Lecture 37 - Root Finding Methods - 3 Newton-Raphson Method - 1
- Lecture 38 - Root Finding Methods - 4 Newton-Raphson Method - 2
- Lecture 39 - Root Finding Methods - 5 Secant Method, Method Of false Position
- Lecture 40 - Root Finding Methods - 6 Fixed Point Methods - 1
- Lecture 41 - Root Finding Methods - 7 Fixed Point Methods - 2
- Lecture 42 - Root Finding Methods - 8 Fixed Point Iteration Methods - 3
- Lecture 43 - Root Finding Methods - 9 Practice Problems
- Lecture 44 - Solution Of Linear Systems Of Equations - 1
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- Lecture 50 - Solution Of Linear Systems Of Equations - 7
- Lecture 51 - Solution Of Linear Systems Of Equations - 8 Iterative Method - 1
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Lecture 6 - Bipartite Graph

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Lecture 8 - Diameter of a graph; Isomorphic graphs

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Lecture 11 - Minimum Spanning Trees (Continued...)

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Lecture 2 - Fourier series - Examples

Lecture 3 - Complex Fourier series

Lecture 4 - Conditions for the Convergence of Fourier Series

Lecture 5 - Conditions for the Convergence of Fourier Series (Continued...)

Lecture 6 - Use of Delta function in the Fourier series convergence

Lecture 7 - More Examples on Fourier Series of a Periodic Signal

Lecture 8 - Gibb's Phenomenon in the Computation of Fourier Series

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Lecture 10 - Properties of Fourier transform (Continued...)

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Lecture 13 - Definition of Fourier transforms

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Lecture 16 - Evaluation of an integral- Recall of complex function theory

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- Lecture 36 - Solving first order PDE's by Laplace transform
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Lecture 5 - Describing Categorical data (Continued...)

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Lecture 9 - Association between categorical variables (Continued...)

Lecture 10 - Association between numerical variables

Lecture 11 - Association between numerical variables (Continued...)

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Lecture 20 - Examples of quotient groups

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Lecture 10 - Symmetries of plane and wallpapers

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Lecture 12 - GAP through Rubik's cube

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Lecture 14 - A quick introduction to group representations

Lecture 15 - Rotations and quaternions

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NPTEL : NOC:Laplace Transform (Mathematics)

Co-ordinators : Prof. Indrava Roy

Lecture 1 - Introduction and Motivation for Laplace transforms - Part 1

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Lecture 3 - Improper Riemann integrals: Definition and Existence - Part 1

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Lecture 5 - Existence of Laplace transforms and Examples

Lecture 6 - Properties of Laplace transforms-I - Part 1

Lecture 7 - Properties of Laplace transforms-I - Part 2

Lecture 8 - Existence of Laplace transforms for functions with vertical asymptote at the Y-axis - Part 1

Lecture 9 - Existence of Laplace transforms for functions with vertical asymptote at the Y-axis - Part 2

Lecture 10 - Properties of Laplace transforms-II - Part 1

Lecture 11 - Properties of Laplace transforms-II - Part 2

Lecture 12 - Laplace transform of Derivatives - Part 1

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Lecture 19 - Methods of finding Inverse Laplace transform-I- Partial Fractions

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Lecture 23 - Applications of Laplace Transform to physical systems

Lecture 24 - Solving Linear ODE's with polynomial coefficients

Lecture 25 - Integral and Integro-differential equation

Lecture 26 - Further application of Laplace transforms - Part 1

Lecture 27 - Further application of Laplace transforms - Part 2

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Lecture 2 - Infinite Sets and the Banach-Tarski Paradox - Part 1

Lecture 3 - Infinite Sets and the Banach-Tarski Paradox - Part 2

Lecture 4 - Elementary Sets and Elementary measure - Part 1

Lecture 5 - Elementary Sets and Elementary measure - Part 2

Lecture 6 - Properties of elementary measure - Part 1

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Lecture 14 - Examples of Jordan measurable sets-II - Part 2

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Lecture 16 - Jordan measure under Linear transformations - Part 2

Lecture 17 - Connecting the Jordan measure with the Riemann integral - Part 1

Lecture 18 - Connecting the Jordan measure with the Riemann integral - Part 2

Lecture 19 - Outer measure - Motivation and Axioms of outer measure

Lecture 20 - Comparing Inner Jordan measure, Lebesgue outer measure and Jordan Outer measure

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Lecture 22 - Finite additivity of outer measure on Separated sets, Outer regularity - Part 2

Lecture 23 - Lebesgue measurable class of sets and their Properties - Part 1

Lecture 24 - Lebesgue measurable class of sets and their Properties - Part 2

Lecture 25 - Equivalent criteria for lebesgue measurability of a subset - Part 1

Lecture 26 - Equivalent criteria for lebesgue measurability of a subset - Part 2

Lecture 27 - The measure axioms and the Borel-Cantelli Lemma

Lecture 28 - Properties of the Lebesgue measure: Inner regularity, Upward and Downward Monotone convergence theorem, and Dominated convergence theorem for sets - Part 1

Lecture 29 - Properties of the Lebesgue measure: Inner regularity, Upward and Downward Monotone convergence theorem, and Dominated convergence theorem for sets - Part 2

Lecture 30 - Lebesgue measurability under Linear transformation, Construction of Vitali Set - Part 1

Lecture 31 - Lebesgue measurability under Linear transformation, Construction of Vitali Set - Part 2

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Lecture 33 - Abstract measure and Caratheodory Measurability - Part 1

Lecture 34 - Abstract measure and Caratheodory Measurability - Part 2

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Lecture 35 - Joint Probability Mass Function, Marginal Probability Mass Function, Examples

Lecture 36 - Numerical Examples on Bivariate Discrete Random Variables and the Concept of Joint Probability

Lecture 37 - Marginal Probability Density Function, Independence, and Examples

Lecture 38 - Numerical Examples on Probability Density Function

Lecture 39 - Conditional Probability Mass Function

Lecture 40 - Conditional Probability Density Function

Lecture 41 - Moments for Bivariate Random Variables

Lecture 42 - Association Between Two Random Variables

Lecture 43 - Numerical Examples on Moments for Bivariate Random Variables

Lecture 44 - Conditional Mean and Variance for Discrete Random Variables

Lecture 45 - Conditional Mean and Variance for Continuous Random Variables

Lecture 46 - Numerical Examples on Conditional Mean and Variance

Lecture 47 - Multivariate Random Variables

Lecture 48 - Multivariate Probability Density Function and Independence

Lecture 49 - Moments of a Multivariate Random Variable

Lecture 50 - Numerical Examples on Joint Probability Mass Functions

Lecture 51 - Numerical Examples on Joint Probability Density Functions

Lecture 52 - Multinomial Distribution and Multivariate Normal Distribution

Lecture 53 - Transformation of Random Variables

Lecture 54 - Theorem on Transformation of Random Variables

Lecture 55 - Transformation of Multivariate Random Variables

Lecture 56 - Examples of Transformation of Bivariate Random Variables

Lecture 57 - Convolution and Example on Transformation of n-variate Random Variables

Lecture 58 - Transformation of Discrete Random Variables

Lecture 59 - Moment Generating Functions

Lecture 60 - Example of Moment Generating Functions

Lecture 61 - Moment Generating Functions for the Transformation of Random Variables

Lecture 62 - Chebyshev's Inequality

Lecture 63 - Notions of Convergence, Law of Large Numbers, and the Central Limit Theorem

Lecture 1 - Introduction to the theory of sets

Lecture 2 - Set operation and laws of set operation

Lecture 3 - The principle of inclusion and exclusion

Lecture 4 - Application of the principle of inclusion and exclusion

Lecture 5 - Fundamentals of logic

Lecture 6 - Logical Inferences

Lecture 7 - Methods of proof of an implication

Lecture 8 - First order logic (1)

Lecture 9 - First order logic (2)

Lecture 10 - Rules of inference for quantified propositions

Lecture 11 - Mathematical Induction (1)

Lecture 12 - Mathematical Induction (2)

Lecture 13 - Sample space, events

Lecture 14 - Probability, conditional probability

Lecture 15 - Independent events, Bayes theorem

Lecture 16 - Information and mutual information

Lecture 17 - Basic definition

Lecture 18 - Isomorphism and sub graphs

Lecture 19 - Walks, paths and circuits operations on graphs

Lecture 20 - Euler graphs, Hamiltonian circuits

Lecture 21 - Shortest path problem

Lecture 22 - Planar graphs

Lecture 23 - Basic definition

Lecture 24 - Properties of relations

Lecture 25 - Graph of relations

Lecture 26 - Matrix of relation

Lecture 27 - Closure of relation (1)

Lecture 28 - Closure of relation (2)

Lecture 29 - Warshall's algorithm

Lecture 30 - Partially ordered relation

Lecture 31 - Partially ordered sets

[Lecture 32 - Lattices](#)

[Lecture 33 - Boolean algebra](#)

[Lecture 34 - Boolean function \(1\)](#)

[Lecture 35 - Boolean function \(2\)](#)

[Lecture 36 - Discrete numeric function](#)

[Lecture 37 - Generating function](#)

[Lecture 38 - Introduction to recurrence relations](#)

[Lecture 39 - Second order recurrence relation with constant coefficients \(1\)](#)

[Lecture 40 - Second order recurrence relation with constant coefficients \(2\)](#)

[Lecture 41 - Application of recurrence relation](#)

Lecture 1 - Introduction to linear differential equations

Lecture 2 - Linear dependence, independence and Wronskian of functions

Lecture 3 - Solution of second-order homogenous linear differential equations with constant coefficients - I

Lecture 4 - Solution of second-order homogenous linear differential equations with constant coefficients - II

Lecture 5 - Method of undetermined coefficients

Lecture 6 - Methods for finding Particular Integral for second-order linear differential equations with constant coefficients - I

Lecture 7 - Methods for finding Particular Integral for second-order linear differential equations with constant coefficients - II

Lecture 8 - Methods for finding Particular Integral for second-order linear differential equations with constant coefficients - III

Lecture 9 - Euler-Cauchy equations

Lecture 10 - Method of reduction for second-order linear differential equations

Lecture 11 - Method of variation of parameters

Lecture 12 - Solution of second order differential equations by changing dependent variable

Lecture 13 - Solution of second order differential equations by changing independent variable

Lecture 14 - Solution of higher-order homogenous linear differential equations with constant coefficients

Lecture 15 - Methods for finding Particular Integral for higher-order linear differential equations

Lecture 16 - Formulation of Partial differential equations

Lecture 17 - Solution of Lagrange's equation - I

Lecture 18 - Solution of Lagrange's equation - II

Lecture 19 - Solution of first order nonlinear equations - I

Lecture 20 - Solution of first order nonlinear equations - II

Lecture 21 - Solution of first order nonlinear equations - III

Lecture 22 - Solution of first order nonlinear equations - IV

Lecture 23 - Introduction to Laplace transforms

Lecture 24 - Laplace transforms of some standard functions

Lecture 25 - Existence theorem for Laplace transforms

Lecture 26 - Properties of Laplace transforms - I

Lecture 27 - Properties of Laplace transforms - II

Lecture 28 - Properties of Laplace transforms - III

Lecture 29 - Properties of Laplace transforms - IV

Lecture 30 - Convolution theorem for Laplace transforms - I

Lecture 31 - Convolution theorem for Laplace transforms - II

- Lecture 32 - Initial and final value theorems for Laplace transforms
- Lecture 33 - Laplace transforms of periodic functions
- Lecture 34 - Laplace transforms of Heaviside unit step function
- Lecture 35 - Laplace transforms of Dirac delta function
- Lecture 36 - Applications of Laplace transforms - I
- Lecture 37 - Applications of Laplace transforms - II
- Lecture 38 - Applications of Laplace transforms - III
- Lecture 39 - Z-Transform and inverse Z-transform of elementary functions
- Lecture 40 - Properties of Z-transforms - I
- Lecture 41 - Properties of Z-transforms - II
- Lecture 42 - Initial and final value theorem for Z-transforms
- Lecture 43 - Convolution theorem for Z-transforms
- Lecture 44 - Applications of Z-transforms - I
- Lecture 45 - Applications of Z-transforms - II
- Lecture 46 - Applications of Z-transforms - III
- Lecture 47 - Fourier series and its convergence - I
- Lecture 48 - Fourier series and its convergence - II
- Lecture 49 - Fourier series of even and odd functions
- Lecture 50 - Fourier half-range series
- Lecture 51 - Parseval's Identity
- Lecture 52 - Complex form of Fourier series
- Lecture 53 - Fourier integrals
- Lecture 54 - Fourier sine and cosine integrals
- Lecture 55 - Fourier transforms
- Lecture 56 - Fourier sine and cosine transforms
- Lecture 57 - Convolution theorem for Fourier transforms
- Lecture 58 - Applications of Fourier transforms to BVP - I
- Lecture 59 - Applications of Fourier transforms to BVP - II
- Lecture 60 - Applications of Fourier transforms to BVP - III

Lecture 1 - Definition and classification of linear integral equations

Lecture 2 - Conversion of IVP into integral equations

Lecture 3 - Conversion of BVP into an integral equations

Lecture 4 - Conversion of integral equations into differential equations

Lecture 5 - Integro-differential equations

Lecture 6 - Fredholm integral equation with separable kernel: Theory

Lecture 7 - Fredholm integral equation with separable kernel: Examples

Lecture 8 - Solution of integral equations by successive substitutions

Lecture 9 - Solution of integral equations by successive approximations

Lecture 10 - Solution of integral equations by successive approximations: Resolvent kernel

Lecture 11 - Fredholm integral equations with symmetric kernels: Properties of eigenvalues and eigenfunctions

Lecture 12 - Fredholm integral equations with symmetric kernels: Hilbert Schmidt theory

Lecture 13 - Fredholm integral equations with symmetric kernels: Examples

Lecture 14 - Construction of Green function - I

Lecture 15 - Construction of Green function - II

Lecture 16 - Green function for self adjoint linear differential equations

Lecture 17 - Green function for non-homogeneous boundary value problem

Lecture 18 - Fredholm alternative theorem - I

Lecture 19 - Fredholm alternative theorem - II

Lecture 20 - Fredholm method of solutions

Lecture 21 - Classical Fredholm theory: Fredholm first theorem - I

Lecture 22 - Classical Fredholm theory: Fredholm first theorem - II

Lecture 23 - Classical Fredholm theory: Fredholm second theorem and third theorem

Lecture 24 - Method of successive approximations

Lecture 25 - Neumann series and resolvent kernels - I

Lecture 26 - Neumann series and resolvent kernels - II

Lecture 27 - Equations with convolution type kernels - I

Lecture 28 - Equations with convolution type kernels - II

Lecture 29 - Singular integral equations - I

Lecture 30 - Singular integral equations - II

Lecture 31 - Cauchy type integral equations - I

- Lecture 32 - Cauchy type integral equations - II
- Lecture 33 - Cauchy type integral equations - III
- Lecture 34 - Cauchy type integral equations - IV
- Lecture 35 - Cauchy type integral equations - V
- Lecture 36 - Solution of integral equations using Fourier transform
- Lecture 37 - Solution of integral equations using Hilbert transform - I
- Lecture 38 - Solution of integral equations using Hilbert transform - II
- Lecture 39 - Calculus of variations: Introduction
- Lecture 40 - Calculus of variations: Basic concepts - I
- Lecture 41 - Calculus of variations: Basic concepts - II
- Lecture 42 - Calculus of variations: Basic concepts and Euler equation
- Lecture 43 - Euler equation: Some particular cases
- Lecture 44 - Euler equation : A particular case and Geodesics
- Lecture 45 - Brachistochrone problem and Euler equation - I
- Lecture 46 - Euler's equation - II
- Lecture 47 - Functions of several independent variables
- Lecture 48 - Variational problems in parametric form
- Lecture 49 - Variational problems of general type
- 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
- Lecture 59 - Variational problem with a movable boundary for a functional dependent on two functions
- Lecture 60 - Hamilton's principle: Variational principle of least action

NPTEL : NOC:Nonlinear Programming (Mathematics)

Co-ordinators : S. K. Gupta

Lecture 1 - Convex Sets and Functions

Lecture 2 - Properties of Convex Functions - I

Lecture 3 - Properties of Convex Functions - II

Lecture 4 - Properties of Convex Functions- III

Lecture 5 - Convex Programming Problems

Lecture 6 - KKT optimality conditions

Lecture 7 - Quadratic Programming Problems - I

Lecture 8 - Quadratic Programming Problems - II

Lecture 9 - Separable Programming - I

Lecture 10 - Separable Programming - II

Lecture 11 - Geometric Programming - I

Lecture 12 - Geometric Programming - II

Lecture 13 - Geometric Programming - III

Lecture 14 - Dynamic Programming - I

Lecture 15 - Dynamic Programming - II

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

Lecture 17 - Dynamic Programming - IV

Lecture 18 - Search Techniques - I

Lecture 19 - Search Techniques - II

Lecture 20 - Search Techniques - III

Lecture 1 - Introduction to error analysis and linear systems

Lecture 2 - Gaussian elimination with Partial pivoting

Lecture 3 - LU decomposition

Lecture 4 - Jacobi and Gauss Seidel methods

Lecture 5 - Iterative methods-II

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

Lecture 7 - Regula Falsi and Secant methods

Lecture 8 - Newton-Raphson method

Lecture 9 - Fixed point iteration method

Lecture 10 - System of Nonlinear equations

Lecture 11 - Introduction to Eigenvalues and Eigenvectors

Lecture 12 - Similarity Transformations and Gershgorin Theorem

Lecture 13 - Jacobi's Method for Computing Eigenvalues

Lecture 14 - Power Method

Lecture 15 - Inverse Power Method

Lecture 16 - Interpolation - Part I (Introduction to Interpolation)

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 31 - Numerical Integration - Part I (Methodology of Numerical Integration and Rectangular rule)

Lecture 32 - Numerical Integration - Part II (Quadrature formula and Trapezoidal rule with associated errors) Numerical 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)

Lecture 36 - Introduction to Ordinary Differential equations

Lecture 37 - Numerical methods for ODE-1

Lecture 38 - Numerical Methods - II

Lecture 39 - R-K Methods for solving ODEs

Lecture 40 - Multi-step Method for solving ODEs

Lecture 1 - Matrix Operations and Types of Matrices

Lecture 2 - Determinant of a Matrix

Lecture 3 - Rank of a Matrix

Lecture 4 - Vector Space - I

Lecture 5 - Vector Space - II

Lecture 6 - Linear dependence and independence

Lecture 7 - Bases and Dimension - I

Lecture 8 - Bases and Dimension - II

Lecture 9 - Linear Transformation - I

Lecture 10 - Linear Transformation - II

Lecture 11 - Orthogonal Subspaces

Lecture 12 - Row Space, Column Space and Null Space

Lecture 13 - Eigen Values and Eigen Vectors - I

Lecture 14 - Eigen Values and Eigen Vectors - II

Lecture 15 - Diagonalizable Matrices

Lecture 16 - Orthogonal Sets

Lecture 17 - Gram Schmidt orthogonalization and orthogonal bases

Lecture 18 - Introduction to Matlab

Lecture 19 - Sign Integer Representation

Lecture 20 - Computer Representation of Numbers

Lecture 21 - Floating Point Representation

Lecture 22 - Round-off Error

Lecture 23 - Error Propagation in Computer Arithmetic

Lecture 24 - Addition and Multiplication of Floating Point Numbers

Lecture 25 - Conditioning and Condition Numbers - I

Lecture 26 - Conditioning and Condition Numbers - II

Lecture 27 - Stability of Numerical Algorithms - I

Lecture 28 - Stability of Numerical Algorithms - II

Lecture 29 - Vector Norms - I

Lecture 30 - Vector Norms - II

Lecture 31 - Matrix Norms - I

- Lecture 32 - Matrix Norms - II
- Lecture 33 - Convergent Matrices - I
- Lecture 34 - Convergent Matrices - II
- Lecture 35 - Stability of non linear system
- Lecture 36 - Condition number of a matrix: Elementary Properties
- Lecture 37 - Sensitivity Analysis - I
- Lecture 38 - Sensitivity Analysis - II
- Lecture 39 - Residual Theorem
- Lecture 40 - Nearness to Singularity
- Lecture 41 - Estimation of the Condition Number
- Lecture 42 - Singular value decomposition of a matrix - I
- Lecture 43 - Singular value decomposition of a matrix - II
- Lecture 44 - Orthonormal Projections
- Lecture 45 - Algebraic and geometric properties of SVD
- Lecture 46 - SVD and their applications
- Lecture 47 - Perturbation theorem for singular values
- Lecture 48 - Outer product expansion of a matrix
- Lecture 49 - Least square solutions - I
- 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

Lecture 1 - Introduction to Numerical solutions

Lecture 2 - Numerical Solution of ODE

Lecture 3 - Numerical solution of PDE

Lecture 4 - Finite difference approximation

Lecture 5 - Polynomial fitting and one-sided approximation

Lecture 6 - Solution of parabolic equation

Lecture 7 - Implicit and C-N scheme for solving 1D parabolic equation

Lecture 8 - Stability analysis of Explicit scheme for solving parabolic equation

Lecture 9 - Stability of Crank-Nicolson's scheme

Lecture 10 - Approximation of derivative boundary conditions

Lecture 11 - Solution of two-dimensional parabolic equation

Lecture 12 - Solution of 2D parabolic equation using ADI scheme

Lecture 13 - Solution of Elliptic Equation

Lecture 14 - Solution of Elliptic equation using SOR method

Lecture 15 - Solution of Elliptic equation using ADI scheme

Lecture 16 - Solution of Hyperbolic equation

Lecture 17 - Stability analysis for Hyperbolic equations

Lecture 18 - Characteristics of PDE

Lecture 19 - Lax-Wendroff's method

Lecture 20 - Wendroff's method

Lecture 1 - Functions of several variables

Lecture 2 - Limits for multivariable functions - I

Lecture 3 - Limits for multivariable functions - II

Lecture 4 - Continuity of multivariable functions

Lecture 5 - Partial Derivatives - I

Lecture 6 - Partial Derivatives - II

Lecture 7 - Differentiability - I

Lecture 8 - Differentiability - II

Lecture 9 - Chain rule - I

Lecture 10 - Chain rule - II

Lecture 11 - Change of variables

Lecture 12 - Euler's theorem for homogeneous functions

Lecture 13 - Tangent planes and Normal lines

Lecture 14 - Extreme values - I

Lecture 15 - Extreme values - II

Lecture 16 - Lagrange multipliers

Lecture 17 - Taylor's theorem

Lecture 18 - Error approximation

Lecture 19 - Polar-curves

Lecture 20 - Multiple Integrals

Lecture 21 - Change Of Order Of Integration

Lecture 22 - Change of Variables in Multiple Integral

Lecture 23 - Introduction to Gamma Function

Lecture 24 - Introduction to Beta Function

Lecture 25 - Properties of Beta and Gamma Functions - I

Lecture 26 - Properties of Beta and Gamma Functions - II

Lecture 27 - Dirichlet's Integral

Lecture 28 - Applications of Multiple Integrals

Lecture 29 - Vector Differentiation

Lecture 30 - Gradient of a Scalar Field and Directional Derivative

Lecture 31 - Normal Vector and Potential field

[Lecture 32 - Gradient \(Identities\), Divergence and Curl \(Identities\)](#)

[Lecture 33 - Some Identities on Divergence and Curl](#)

[Lecture 34 - Line Integral \(I\)](#)

[Lecture 35 - Applications of Line Integrals](#)

[Lecture 36 - Green's Theorem](#)

[Lecture 37 - Surface Area](#)

[Lecture 38 - Surface Integral](#)

[Lecture 39 - Divergence Theorem of Gauss](#)

[Lecture 40 - Stoke's Theorem](#)

- Lecture 1 - Introduction to differential equations - I
- Lecture 2 - Introduction to differential equations - II
- Lecture 3 - Existence and uniqueness of solutions of differential equations - I
- Lecture 4 - Existence and uniqueness of solutions of differential equations - II
- Lecture 5 - Existence and uniqueness of solutions of differential equations - III
- Lecture 6 - Existence and uniqueness of solutions of a system of differential equations
- Lecture 7 - Linear System
- Lecture 8 - Properties of Homogeneous Systems
- Lecture 9 - Solution of Homogeneous Linear System with Constant Coefficients - I
- Lecture 10 - Solution of Homogeneous Linear System with Constant Coefficients - II
- Lecture 11 - Solution of Homogeneous Linear System with Constant Coefficients - III
- Lecture 12 - Solution of Non-Homogeneous Linear System with Constant Coefficients
- Lecture 13 - Power Series
- Lecture 14 - Uniform Convergence of Power Series
- Lecture 15 - Power Series Solution of Second Order Homogeneous Equations
- Lecture 16 - Regular singular points - I
- Lecture 17 - Regular singular points - II
- Lecture 18 - Regular singular points - III
- Lecture 19 - Regular singular points - IV
- Lecture 20 - Regular singular points - V
- Lecture 21 - Critical points
- Lecture 22 - Stability of Linear Systems - I
- Lecture 23 - Stability of Linear Systems - II
- Lecture 24 - Stability of Linear Systems - III
- Lecture 25 - Critical Points and Paths of Non-linear Systems
- Lecture 26 - Boundary value problems for second order differential equations
- Lecture 27 - Self - adjoint Forms
- Lecture 28 - Sturm - Liouville problem and its properties
- Lecture 29 - Sturm - Liouville problem and its applications
- Lecture 30 - Green's function and its applications - I
- Lecture 31 - Green's function and its applications - II

- Lecture 32 - Origins and Classification of First Order PDE
- Lecture 33 - Initial Value Problem for Quasi-linear First Order Equations
- Lecture 34 - Existence and Uniqueness of Solutions
- Lecture 35 - Surfaces orthogonal to a given system of surfaces
- Lecture 36 - Nonlinear PDE of first order
- Lecture 37 - Cauchy method of characteristics - I
- Lecture 38 - Cauchy method of characteristics - II
- Lecture 39 - Compatible systems of first order equations
- Lecture 40 - Charpitâ€™s method - I
- Lecture 41 - Charpitâ€™s method - II
- Lecture 42 - Second Order PDE with Variable Coefficients
- Lecture 43 - Classification and Canonical Form of Second Order PDE - I
- Lecture 44 - Classification and Canonical Form of Second Order PDE - II
- Lecture 45 - Classification and Characteristic Curves of Second Order PDEs
- Lecture 46 - Review of Integral Transforms - I
- Lecture 47 - Review of Integral Transforms - II
- Lecture 48 - Review of Integral Transforms - II
- Lecture 49 - Review of Integral Transforms - III
- Lecture 50 - Laplace Equation - I
- Lecture 51 - Laplace Equation - II
- Lecture 52 - Laplace and Poisson Equations
- Lecture 53 - One dimensional wave equation and its solution - I
- Lecture 54 - One dimensional wave equation and its solution - II
- Lecture 55 - One dimensional wave equation and its solution - III
- Lecture 56 - Two dimensional wave equation and its solution - I
- Lecture 57 - Solution of non-homogeneous wave equation
- Lecture 58 - Solution of homogeneous diffusion equation - I
- Lecture 59 - Solution of homogeneous diffusion equation - II
- Lecture 60 - Duhamelâ€™s principle

Lecture 1 - Elementary row operations

Lecture 2 - Echelon form of a matrix

Lecture 3 - Rank of a matrix

Lecture 4 - System of Linear Equations - I

Lecture 5 - System of Linear Equations - II

Lecture 6 - Introduction to Vector Spaces

Lecture 7 - Subspaces

Lecture 8 - Basis and Dimension

Lecture 9 - Linear Transformations

Lecture 10 - Rank and Nullity

Lecture 11 - Inverse of a Linear Transformation

Lecture 12 - Matrix Associated with a LT

Lecture 13 - Eigenvalues and Eigenvectors

Lecture 14 - Cayley-Hamilton Theorem and Minimal Polynomial

Lecture 15 - Diagonalization

Lecture 16 - Special Matrices

Lecture 17 - More on Special Matrices and Gerschgorin Theorem

Lecture 18 - Inner Product Spaces

Lecture 19 - Vector and Matrix Norms

Lecture 20 - Gram Schmidt Process

Lecture 21 - Normal Matrices

Lecture 22 - Positive Definite Matrices

Lecture 23 - Positive Definite and Quadratic Forms

Lecture 24 - Gram Matrix and Minimization of Quadratic Forms

Lecture 25 - Generalized Eigenvectors and Jordan Canonical Form

Lecture 26 - Evaluation of Matrix Functions

Lecture 27 - Least Square Approximation

Lecture 28 - Singular Value Decomposition

Lecture 29 - Pseudo-Inverse and SVD

Lecture 30 - Introduction to Ill-Conditioned Systems

Lecture 31 - Regularization of Ill-Conditioned Systems

[Lecture 32 - Linear Systems: Iterative Methods - I](#)

[Lecture 33 - Linear Systems: Iterative Methods - II](#)

[Lecture 34 - Non-Stationary Iterative Methods: Steepest Descent - I](#)

[Lecture 35 - Non-Stationary Iterative Methods: Steepest Descent - II](#)

[Lecture 36 - Krylov Subspace Iterative Methods \(Conjugate Gradient Method\)](#)

[Lecture 37 - Krylov Subspace Iterative Methods \(CG and Pre-Conditioning\)](#)

[Lecture 38 - Introduction to Positive Matrices](#)

[Lecture 39 - Positive Matrices, Positive Eigenpair, Perron Root and vector, Example](#)

[Lecture 40 - Polar Decomposition](#)

- Lecture 1 - Introduction to Mathematical Modeling
- Lecture 2 - Discrete Time Linear Models in Population Dynamics - I
- Lecture 3 - Discrete Time Linear Models in Population Dynamics - II
- Lecture 4 - Discrete Time Linear Age Structured Models
- Lecture 5 - Numerical Methods to Compute Eigen Values
- Lecture 6 - Discrete Time Non-Linear Models in Population Dynamics - II
- Lecture 7 - Analysis on Logistic Difference Equation
- Lecture 8 - Classifications of Bifurcation
- Lecture 9 - Discrete Time Non - Linear Models in Population Dynamics - II
- Lecture 10 - Discrete Time Prey - Predator Model
- Lecture 11 - Introduction to Continuous Time Models
- Lecture 12 - Solution of First Order First Degree Differential Equations
- Lecture 13 - Continuous Time Models in Population Dynamics - I
- Lecture 14 - Continuous Time Models in Population Dynamics - II
- Lecture 15 - Stability and Linearization of System of Ordinary Differential Equations
- Lecture 16 - Continuous Time Single Species Models
- Lecture 17 - Qualitative Solution of Differential Equations - Phase Diagrams - I
- Lecture 18 - Qualitative Solution of Differential Equations - Phase Diagrams - II
- Lecture 19 - Continuous Time Lotka - Volterra Competition Model
- Lecture 20 - Continuous Time Prey - Predator Model

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- Lecture 2 - Formulation of Dynamical Systems - II
- Lecture 3 - Existence and Uniqueness Theorem - I
- Lecture 4 - Existence and Uniqueness Theorem - II
- Lecture 5 - Linear Systems - I
- Lecture 6 - Linear Systems - II
- Lecture 7 - Solutions of Linear Systems - I
- Lecture 8 - Solutions of Linear Systems - II
- Lecture 9 - Solutions of Linear Systems - III
- Lecture 10 - Fundamental Matrix - I
- Lecture 11 - Fundamental Matrix - II
- Lecture 12 - Fundamental Matrix for Non-Autonomous systems
- Lecture 13 - Solutions of Non-Homogeneous Systems
- Lecture 14 - Stability of Systems: Equilibrium Points
- Lecture 15 - Stability of Linear Autonomous Systems - I
- Lecture 16 - Stability of Linear Autonomous Systems - II
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- Lecture 18 - Stability of Weakly Non-Linear Systems - I
- Lecture 19 - Stability of Weakly Non-Linear Systems - II
- Lecture 20 - Stability of Non-Linear Systems using Linearization
- Lecture 21 - Properties of Phase Portrait
- Lecture 22 - Properties of Orbits
- Lecture 23 - Phase Portrait: Types of Critical Points
- Lecture 24 - Phase Portrait of Linear Differential Equations - I
- Lecture 25 - Phase Portrait of Linear Differential Equations - II
- Lecture 26 - Phase Portrait of Linear Differential Equations - III
- Lecture 27 - Poincare Bendixson Theorem
- Lecture 28 - Limit Cycle
- Lecture 29 - Lyapunov Stability - I
- Lecture 30 - Lyapunov Stability - II
- Lecture 31 - Introduction to Control Systems - I

Lecture 32 - Introduction to Control Systems - II

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Lecture 34 - Controllability of Non-autonomous Systems

Lecture 35 - Observability - I

Lecture 36 - Observability - II

Lecture 37 - Results on Controllability and Observability

Lecture 38 - Companion Form

Lecture 39 - Feedback Control - I

Lecture 40 - Feedback Control - II

Lecture 41 - Feedback Control - III

Lecture 42 - Feedback Control - IV

Lecture 43 - State Observer

Lecture 44 - Stabilizability

Lecture 45 - Introduction to Discrete Systems - I

Lecture 46 - Introduction to Discrete Systems - II

Lecture 47 - Lyapunov Stability Theory - I

Lecture 48 - Lyapunov Stability Theory - II

Lecture 49 - Lyapunov Stability Theory - III

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Lecture 51 - Optimal Control - II

Lecture 52 - Optimal Control - III

Lecture 53 - Optimal Control - IV

Lecture 54 - Optimal Control for Discrete Systems - I

Lecture 55 - Optimal Control for Discrete Systems - II

Lecture 56 - Controllability of Discrete Systems

Lecture 57 - Observability of Discrete Systems

Lecture 58 - Stability for Discrete Systems

Lecture 59 - Relation between Continuous and Discrete Systems - I

Lecture 60 - Relation between Continuous and Discrete Systems - II

Lecture 1 - Analytic Function

Lecture 2 - Cauchy-Riemann Equations

Lecture 3 - Harmonic Functions, Harmonic Conjugates and Milne's Method

Lecture 4 - Applications to the Problems of Potential Flow - I

Lecture 5 - Applications to the Problems of Potential Flow - II

Lecture 6 - Complex Integration

Lecture 7 - Cauchy's Theorem - I

Lecture 8 - Cauchy's Theorem - II

Lecture 9 - Cauchy's Integral Formula for the Derivatives of Analytic Function

Lecture 10 - Morera's Theorem, Liouville's Theorem and Fundamental Theorem of Algebra

Lecture 11 - Winding Number and Maximum Modulus Principle

Lecture 12 - Sequences and Series

Lecture 13 - Uniform Convergence of Series

Lecture 14 - Power Series

Lecture 15 - Taylor Series

Lecture 16 - Laurent Series

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