# Tribhuvan University

## Institute of Science and Technology

## SCHOOL OF MATHEMATICAL SCIENCES

# Syllabus

## Master's in Data Sciences (MDS)- FIRST SEMESTER

**Compulsory Courses**

| Course Code | Course Titles | Credits | Nature |
|---|---|---|---|
| MDS 501 | Fundamentals of Data Science | 3 | Th. |
| MDS 502 | Data Structure and Algorithms | 3 | Th.+ Pr. |
| MDS 503 | Statistical Computing with R | 3 | Th.+ Pr. |
| MDS 504 | Mathematics for Data Science | 3 | Th. |

**Elective Courses (Any One Available on School)**

| Course Code | Course Titles | Credits | Nature |
|---|---|---|---|
| MDS 505 | Data Base Management Systems | 3 | Th.+ Pr. |
| MDS 506 | Programming Concepts and Techniques | 3 | Th.+ Pr. |
| MDS 507 | Linear and Integer Programming | 3 | Th.+ Pr. |

Code No.: MDS 501

Course Title: **Fundamentals of Data Science** Full Marks: 75

Nature: Theory(Compulsory) Credit: 3

***Course Description*:**

This is an introductory course to teach the basics of data science, it's applications and commonly used tools and techniques. The course is designed to introduce key ideas and methodologies used in the domain of data science. The goal of this course is to help understand the fundamental building blocks of data science.

***Learning Objectives:***

Upon the conclusion of the course, students should be able to:

- Describe Data Science, skill sets needed to be a data scientist and be familiar with common tools used for data science. Understand the importance of data quality and familiarize with common data munging techniques.
- Understand and apply commonly used data analysis and machine learning techniques in data science
- Identify the challenges in handling big data, and gain a general understanding of tools to handle big data
- Reason around ethical and privacy issues in data science and understand the common biases affecting data science.

***Course Contents*:**

**Unit 1: Introduction to Data Science [10 Hrs.]**

Introduction to data science, Applications of data science; Limitations of data science

Commonly used tools in data science, their strengths and common use-cases: R/RStudio, Python/Pandas/Jupyter Notebooks, Excel/Tableau/PowerBI;

Data Science life-cycle/Common methodologies for data science: CRISP-DM, OSEMN Framework, TDSP lifecycle;

Review of statistics and probability: Probability distributions, compound events and independence. Statistics: Centrality measures, variability measures, interpreting variance. Correlation analysis: Correlation coefficients, autocorrelation

**Unit 2: Data Munging [8 Hrs.]**

Data quality, common issues with real world data: Duplicates, Missing Data, Non-standard data, Unit mismatch;

Ways to clean up and standardize data; Data enrichment: Need for data enrichment; Common ways to enrich data: correction, extrapolation, augmentation;

Data Validation: Common methods of data validation: type check, range & constraint check, consistency check;

Data format conversion: Commonly used formats: JSON, XML, Tabular, Relational - their strengths and weaknesses,

Motivation behind format conversion.General methods of conversion between data formats. Tabular data: Row based vs column based (Parquet, ORC, CSV). Wide vsnarrow(long) table format. Converting between wide vs narrow formats

**Unit 3: Data Analysis Technique** **[10 Hrs.]**

Feature generation and feature selection algorithms: filters, wrappers, decision trees, random forests;

Common techniques: Linear regression, logistic regression, k-NN, k-means ;

Predictive data analysis: Introduction to predictive data analysis and its common applications.;

Regression based models: linear regression, logistic regression.;

Time series data analytics

**Unit 4: Machine Learning** **[8 Hrs.]**

Introduction to machine learning, type of machine learning methods.;

Supervised vsUnsupervised learning;

Naive Bayes, Decision Trees, SVMs;

Introduction to deep learning, backpropagation.

**Unit 5: Introduction to Big Data** **[8 Hrs.]**

Introduction to big data and the challenges of handling big data;

Commonly used tools for big data: The map-reduce programming paradigm.Hadoop, HDFS, (py)Spark, Hive.

Data warehousing and data lake architecture.

Real-time analytics with Apache Kafka

**Unit 6: Ethical Issues in Data Science** **[4Hrs.]**

Issues with fairness and bias in data science:

Common biases: In group favoritism and out-group negativity, Fundamental attribution error, Negativity bias, Stereotyping, Bandwagon effect, Bias blind spot.

Addressing biases: Group unaware selection, Adjusted group thresholds, Demographic parity, Equal opportunity, Precision parity;

Common issues with privacy and data ethics.

**References:**


1. O'Neil, Cathy and Schutt, Rachel(2013), *Doing Data Science***,** *Straight Talk From TheFrontline*, O'Reilly Media
2. Provost, Foster and Fawcett, Tom (2013). *Data Science for Business***:** *What You Need to Know about Data Mining and Data-analytic Thinking*, O'Reilly Media.


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Code No.: MDS 502

Course Title:**Data Structures and Algorithms** Full Marks: 75

Nature: Theory +Practical (Compulsory) Credit: 3

***Course Description*:**

This course includes the basic foundations in of data structures and algorithms and various data structures like stack, queue, list, tree and graph. Additionally, the course includes idea of sorting and searching.

***Learning Objectives*:**

After successful completion of this course, the student will be able to

- Introduce basic concepts data structures and algorithms, abstract data types, asymptotic notations
- Design and use of data structures such as stack, queue, linked list, tree and graph.

***Course Contents*:**

**Unit 1: Introduction to Data Structures & Algorithms [3 Hrs.]**

Data types, Data structure and Abstract date type
Dynamic memory allocation
Introduction to Algorithms
Asymptotic notations and common functions

**Unit 2: Stack [6 Hrs.]**

Basic Concept of Stack, Stack as an ADT, Stack Operations, Stack Applications
Conversion from Infix to Postfix Expressions and Evaluation of Postfix Expressions using Stack

**Unit 3: Queue [4 Hrs.]**

Basic Concept of Queue, Queue as an ADT, Primitive Operations in Queue
Linear Queue, Circular Queue, Priority Queue, Queue Applications

**Unit 4: Recursion [4 Hrs.]**

Principle of Recursion, Comparison between Recursion and Iteration, Tail Recursion

Factorial, Fibonacci Sequence, GCD, Tower of Hanoi(TOH)

Applications and Efficiency of Recursion

**Unit 5: Lists [8 Hrs.]**

Basic Concept, List and ADT, Array Implementation of Lists, Linked List
Types of Linked List: Singly Linked List, Doubly Linked List, Circular Linked List.
Basic operations in Linked List: Node Creation , Insertion and Deletion from Linked List
Stack and Queue as Linked List

**Unit 6: Sorting [8Hrs.]**

Introduction and Types of sorting: Internal and External sort
Comparison Sorting Algorithms: Bubble, Selection and Insertion Sort, Shell Sort
Divide and Conquer Sorting: Merge, Quick and Heap Sort
Efficiency of Sorting Algorithms.

**Unit 7: Searching and Hashing** **[7Hrs.]**

Introduction to Searching, Search Algorithms: Sequential Search, Binary Search
Efficiency of Search Algorithms
Hashing : Hash Function and Hash Tables, Collision Resolution Techniques

**Unit 8: Trees and Graphs** **[8Hrs.]**

Concept and Definitions, Basic Operations in Binary Tree, Tree Height, Level and Depth
Binary Search Tree, Insertion, Deletion, Traversals, Search in BST
AVL tree and Balancing algorithm, Applications of Trees
Definition and Representation of Graphs, Graph Traversal, Minimum Spanning Trees: Kruskal and Prims Algorithm
Shortest Path Algorithms: Dijksrtra Algorithm.

**Laboratory Works:**

The laboratory work consists of implementing different algorithms and data structures studied in the course using C programming.

**References:**


1. Langsam, Y. ,Augenstein, M.J. &Tanenbaum, A.M. (2015).*Data Structures using C&C*++. , 2nd Edition, Pearson, India.
2. LeenAmmeral.*Programmes and Data Structures in C,* Wiley Professional Computing.
3. Rowe, G.W. (2016).*Introduction to Data Structure and Algroithms with C and C*++ , prentice Hall India.
4. Kruse, R.L., Leung, B.P. &Tondo, C.L.(2013).*Data Structure and Program Design in C,* 2nd Edition, Pearson Education , New Delhi, India.


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Code No.: **MDS 503**
Course Title:**Statistical Computing with R** Full Marks: 75
Nature: Theory +Practical (Compulsory) Credit: 3

***Course Description:***
This is an outcome based course to introduce basic programming in R software followed by use of R software for Statistical Computing. It focuses on the use of R software for data manipulation, data summary/data visualization, supervised and unsupervised learning sand communicate the findings.

***Learning Objectives:***
After completion of the course, students will be able to:
- Understand, use and apply R software for basic programming (program)
- Understand, use and apply R software for data manipulation (wrangle)
- Understand, use and apply R software for data summary and visualization (explore)
- Understand, use and apply R software for supervised learning (model)
- Understand, use and apply R software for unsupervised learning (model)
- Understand, use and apply R software to communicate findings (communicate).

***Course Contents:***

**Unit 1: R Software for Basic Programming [8Hrs.]**

R software, Statistics, Big Data and Data Science. Downloading and installing R software in Windows, Linux and Unix systems. Variables, Data types, Vectors, Lists and Matrix in R. Factors, Data Frames and Dealing with missing values in R. Logical statements, Loops, Functions and Pipes in R. Coding and naming conventions in R. Reproducible Analysis: Markdown Language, YAML Language; R Markdown/knitr document in R IDE (RStudio). Profiling and optimizing codes/scripts in R.

**Unit 2: R Software for Data Manipulation [6 Hrs.]**

Using R packages in R. Reading and Reviewing data in R. Manipulating and Tyding data in R. Data Wrangling in R. Data Transformation in R. Data/Text Mining in R. Big Data in R: Subsampling, Hex and 2D Density Plots.

**Unit 3: R Software for Data Summary and Visualization [10Hrs.]**

Basic graphics/plots in R: Bar chart and histogram, Line chart and Pie chart, Scatterplot and Boxplot, Scatterplot matrix, Social Network Analysis. The Grammar of Graphics: Data, Aesthetic mapping, Geometric objects, Statistical transformation, Scales, Coordinate system, Position adjustment and Faceting using ggplot2 package in R/RStudio. Computing measures of central tendency, dispersion, moments and relative positions in R using packages and functions/scripts.

**Unit 4: R Software for Supervised Learning** **[10 Hrs.]**

Probability Distribution Functions: Use of apply(), lapply() and sapply() fuctions in R for Breakdown Analysis. Random Sampling, Covariance and Correlation; Hypothesis Testing using common parametric and non-parametric statistical tests in R. Machine Learning and Supervised Learning. Specifying supervised models: Linear regression, Logistic Regression, Model matrices and formula. Validating models: Evaluating regression models, evaluating classification models, cross-validation, training, testing and holdouts. Supervised learning packages and its use: Decision Trees, Random Forests, Neural Networks, Support Vector Machines and Naïve Bayes.

**Unit 5: R Software for Unsupervised Learning** **[8 Hrs.]**

Dimensionality Reduction: Principle component analysis, Principle Axis Factoring, Multidimensional scaling; Clustering: k-Means clustering, Hierarchical clustering; Association rules and Monte-Carlo simulations.

**Unit 6: R Software for Communication** **[6Hrs.]**

Markdown Language, R Markdown/knitr document to produce publishable/industry level documents in HTML, PDF and Word formats. Use R Markdown to create reports, websites and dashboards. Use R Markdown to create Shiny apps for effective communication.

**Practical Works:**
The practical works include of class/computer lab using R/RStudiowith individual project work.

**References:**


1. Mailund Thomas (2017).*Beginning Data Sciences in R: Data Analysis, Visualization, and Modelling for the Data Scientists*.Apress: Aarhus, Denmark.

2. Goh Eric &Hui Ming (2019).*Learn R for Applied Statistics*. Apress: Singapore.

3. Wichham Hadley &GloremundGarrette (2017).*R for Data Science*. O'Reilly Media Inc: Sebastopol, Canada.


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*Code No.*: **MDS 504**

Course Title:**Mathematics for Data Science** Full Mark: 75

*Nature*: **Theory** (Compulsory) Credit: 3

***Course Description*:**

The course will cover basic topics in linear algebra to understand high-dimensional vector spaces, matrices and graphs as popular mathematical structures with which to model data (e.g., as models for term-document corpora, high-dimensional regression problems, ranking/classification of web data, adjacency properties of social network data, etc.); and geometric approaches to eigendecompositions, least-squares, principal components analysis, etc. The course requires to solve problems using programming R.

***Learning Objectives*:**

After successful completion of this course the student will be able to

- Understand basic linear algebra techniques which are useful in data science.
- Explain \why different methods do and don't work.
- Understand tools that are used to diagnose problems, to develop new methods, etc.
- Understand how some discrete probability and optimization are used with matrices and graphs, two very common ways to model data.
- Understand the connections between the discrete probability ideas and very related linear algebra ideas.
- Acquire a basic understanding and intuition of why various methods work, so that the student can use them in practical applications data science.
- Use programming R to solve problems of this course.

***Course Contents*:**

**Unit 1: Introduction, Motivation, and Overview** **[9 Hrs.]**

Linear algebra and machine learning,
Representing data as flat tables versus matrices and graphs;
Different ways probability/randomness/noise interacts with data;
Probability and matrices/graphs in data science versus other areas;
Quantification of the inference step.

**Unit 2: Introduction to Matrices and Vectors** **[15Hrs.]**

Vectors, Basic properties of $R^n$;
Norms and balls;
Vector addition and scalar multiplication.
Vector spaces and subspaces;
Matrices,
Operations on matrices, including matrix multiplication;
Functions, linear functions, and linear transformations; Matrices as transformations.
Dot products, angles, and perpendicularity;
Linear combinations, span, and linear independence; Bases, orthonormal bases, and projections.
Applications in the theory of probabilityand data science

**Unit 3: Spectral Theorems** **[14Hrs.]**

Eigenvectors and Eigenvalues:
Quadratic forms and matrices
Symmetric bi-linear functions;
Connections with conic sections;
Definiteness, indefiniteness, and quadratic forms as a sum/difference of squares;
EigenValue Decomposition (EVD)
Singular Value Decomposition (SVD)
Properties of the SVD
Orthogonal subspaces;
Uses of the spectral decomposition
Applications in data science

**Unit 4: System of Linear Equations** **[10 Hrs.]**

Solving system of linear equations:
Geometry of linear equations;
Gaussian elimination;
Row exchanges;
Networks and incidence matrices;
The four fundamental subspaces.
Basis transformations;
Orthogonal bases;
Gram-Schmidt Orthogonalization;
Numerical issues.
Applications in data science

**References:**


1. Nick Fieller (2015).*Basics of Matrix Algebra for Statistics with R*, Chapman and Hall/CRC.
2. Shayle R. Searle& André I. Khuri (2017).*Matrix Algebra Useful for Statistics*, John Wiley & Sons, Inc..
3. Michael W. Mahoney (2018).*Linear Algebra for Data*, University of California Berkeley.
4. Deisenroth, M. P. ,Faisal, A. A. and Ong, C. S. (2019). *Mathematics for Machine Learning*, Cambridge University Press.
5. Jason Brownlee (2018).*Basics of Linear Algebra for Machine Learning*, https://www.mobt3ath.com/uplode/book/book-33342.pdf .


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Code No.: **MDS 505**

Course Title:**Data Base Management Systems** Full Marks: 75

Nature: Theory +Practical (Elective) Credit: 3

***Course Description:***

The course covers on the fundamentals of knowledgebase and relational database management systems, and the current developments in database theory and their practice.

***Course Objectives:***

After the completion of this course, the students should be able to

- Familiarize the students to the fundamentals of Database Management Systems.
- Understand the relational model, ER diagrams and SQL.
- Understand the fundamentals of Transaction Processing and Query Processing.
- Familiarize the different types of database.
- Understand the Security Issues in Databases.

***Course Content:***

**Unit 1: Fundamental Concept of DBMS [6 Hrs.]**

Database and database management system, Data Abstraction and Data Independence,Schema and Instances, Concepts of DDL, DML and DCL, Purpose of Database System, Database System Terminologies, Database characteristics, Data models , Types of data models , Components of DBMS, Relational Algebra. Relational DBMS – Codd's Rule – Entity- Relationship model,

**Unit 2: Relational Languages and Relational Model [7Hrs.]**

Introduction to SQL, Features of SQL, Queries and Sub-Queries,Set Operations, Relations (Joined, Derived), Queries under DDL and DML Commands, Embedded SQL,Views, Relational Algebra, Database Modification, QBE and domain relational calculus

**Unit 3: Database Constraints and Normalization [6 Hrs.]**

Integrity Constraints and Domain Constraints, Assertions and Triggering, Functional Dependencies, Different Normal Forms (1st, 2nd, 3rd, BCNF, DKNF)

**Unit 4: SQL & Query Optimization [6 Hrs.]**

SQL Standards ,Data types , Database Objects- DDL-DML-DCL-TCL, Embedded SQL, Static Vs Dynamic SQL, QUERY OPTIMIZATION: Query Processing and Optimization , Heuristics and Cost Estimates in Query Optimization.

**Unit 5: Transaction Processing and Concurrency Control [6 Hrs.]**

Properties of Transaction, Serializability, Concurrency Control, Locking Mechanisms, Two Phase Commit Protocol, Deadlock handling and Prevention

**Unit 6: Trends in Database Technology [9Hrs.]**

Overview of Physical Storage Media ,RAID , Tertiary storage , File Organization, Organization of Records in Files ,Indexing and Hashing ,Ordered Indices , B+ tree Index Files , B tree Index Files , Static Hashing ,Dynamic Hashing , Introduction to Distributed Databases, Client server technology, Multidimensional and Parallel databases, Spatial and multimedia databases, Mobile and web databases, Data Warehouse, data Mining, Data marts.

**Unit 7: Advanced Topic** **[8Hrs.]**

Concept of Object-Oriented and Distributed Database Model, Properties of Parallel and Distributed Databases, Threats and risks ,Database access Control, Types of Privileges ,Cryptography, Statistical Databases, Distributed Databases Architecture, Transaction Processing, Data Warehousing and Mining, Classification, Association rules-Clustering, Information Retrieval, Relevance ranking, Crawling and Indexing the Web, Object Oriented Databases,XML Databases.

**Practical Works:**

- Fundamental concept of MS-Access or MySQL or any suitable DBMS
- Database Server Installation and Configuration (MS-SQLServer, Oracle)
- DB Client Installation and Connection to DB Server
- Practice with DDL Commands. (Create Database and Tables)
- Practice of Procedure/Trigger and DB Administration & other DBs (MySQL, PG-SQL, DB2.)
- Group Project Development

**References:**

1. RamezElmasri&Shamkant B. Navathe (2015).*Fundamentals of Database Systems*, Seventh Edition, Pearson Education.
2. Korth, H. F. &Silberschatz, A. (2010).*Database system concepts*, McGraw Hill.
3. Majumdar, K.&Bhattacharaya, P. (2004).*Database Management Systems,* Tata McGraw Hill, India.
4. Abraham Silberschatz, Henry F. Korth& S. Sudharshan (2011).*Database System Concepts*, Sixth Edition, Tata McGraw Hill.
5. Date, C.J., Kannan, A.&Swamynathan, S. (2006).*An Introduction to Database Systems*, Eighth Edition, Pearson Education.
6. AtulKahate (2006) .*Introduction to Database Management Systems*, Pearson Education, New Delhi.
7. Alexis Leon & Mathews Leon(2003).*Database Management Systems,* Vikas Publishing House Private Limited, New Delhi.
8. Raghu Ramakrishnan (2010).*Database Management Systems*, Fourth Edition, Tata McGraw Hill.
9. Gupta, G.K.(2011).*Database Management Systems*, Tata McGraw Hill.

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Code No.: MDS 506

Course Title: **Programming Concepts and Techniques** Full Marks: 75

Nature: Theory +Practical (Elective) Credit: 3

***Course Description*:**

This course covers concepts of program and programming language, different program design tools, and different concepts of programming using C programming language.

***Learning Objectives:***

After the completion of this course, the students should be able to

- Understand concepts of program and programming languages
- Know different program design tools
- Write programs using different concepts of C programming.

***Course Contents:***

**Unit 1: Basic Concepts** **[4 Hrs.]**

Program and Programming Languages; Program Design Tools: Algorithm, Flowchart, and Pseudocode; Coding, Compilation and Execution, History of C, Structure of C program, Debugging, Testing and Documentation.

**Unit 2: Elements of C** **[4 Hrs.]**

C Standards( ANSI C and C99), C Character Set, C Tokens, Escape sequence, Delimiters, Variables, Data types (Basic, Derived, and User Defined), Compiling and Executing a C program, Constants and Literals, Expressions, Writing Comments.

**Unit 3: Input and Output** **[2 Hrs.]**

Conversion specification, Reading a character, Writing a character, I/O operations, Formatted I/O.

**Unit 4: Operators and Expression** **[4 Hrs.]**

Arithmetic operator, Relational operator, Logical or Boolean operator, Assignment Operator, Ternary operator, Bitwise operator, Increment or Decrement operator, Conditional operator, Special Operators(sizeof and comma), Evaluation of Expression, Operator Precedence and Associativity.

**Unit 5: Control Statement** **[6Hrs.]**

Conditional Statements, Decision Making and Branching, Decision Making and Looping, Exit function, Break and Continue.

**Unit 6: Arrays** **[6 Hrs.]**

Introduction to Array, Types of Array (Single Dimensional and Multidimensional), Declaration and Memory Representation of Array, Initialization of array, Character Array and Strings, Reading and Writing Strings, Null Character, String Library Functions.

**Unit 7: Functions** **[6Hrs.]**

Library Functions, User defined functions, Function prototype, Function call, and Function Definition, Nested and Recursive Function, Function Arguments and Return Types, Passing Arrays to Function, Passing Strings to Function, Passing Arguments to Functions, Scope visibility and lifetime of a variable, Local and Global Variable.

**Unit 8: Structure and Union** **[6Hrs.]**

Defining and Accessing Structures, Array of structure, Passing structure to function, Passing array of structure to function, Nested Structure, Union, Comparing Structures with Unions.

**Unit 9: Pointers** **[6 Hrs.]**

Introduction, The & and * operator, Declaration of pointer, Pointer Arithmetic, Pointers and Arrays, Pointers and Character Strings, Array of Pointers, Pointers as Function Arguments, Function Returning pointers, Pointers and Structures, Dynamic Memory Allocation.

**Unit 10: File Handling in C** **[4 Hrs.]**

Concept of File, Opening and closing of File, Input Output Operations in File, Random access in File, Error Handling in Files.

**Laboratory Works:**

The laboratory work includes writing computer programs that covers all the concepts of C programming language including data types, variables, operators, all control statements, arrays, functions, structures and unions, pointers, and file handling.

**References:**


1. Byron Gottfried. *Programming with C,* Fourth Edition, McGraw Hill.
2. Herbert Schildt(2000). C *The Complete Reference*, Fourth Edition, Osborne/McGraw-Hill Publication.
3. Paul Deitel, Harvey Deitel, C.(2016).*How to Program,* Eighth Edition, Pearson Publication.
4. Al Kelley, Ira Pohl(2000) .*A Book on C*, Fourth Edition, Pearson Education.
5. Brian W. Keringhan, Dennis M. Ritchiem (1988).*The C programming Language*, Second Edition, Prentice Hall India .
6. Ajay Mittal (2010).*Programming in C.A Practical Approach*, Pearson Publication.
7. Stephen G. Kochan (2001) .*Programming in C*, CBS publishers & distributors.
8. E. Balagurusamy(2008).*Programming in ANSI C*, Third Edition, Tata McGraw- Hill publishing, New Delhi.


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Code No.: MDS 507

Course Title:**Linear and Integer Programming** Full Marks: 75

Nature: Theory+Practical (Elective) Credit: 3

***Course Description:***

The course covers basic introduction of linear and integer based optimization problems, their few solution techniques and implementation of the solution techniques to solve real world problems formulated as linear programming problem and integer programming problem.

***Course Objectives:***

After the completion of this course, the students should be able to

- Know the concept and importance of convexity in optimization.
- Formulate real world problems in the form of linear programming problem(LPP) and integer programming problem (IPP).
- Solve LPP and IPP manually and using software as well.
- Solve the LPP and IPP using graphical and simplex methods.
- Know the total unimodularity, understand and implement cutting plane algorithm and branch and bound technique.

***Course Contents:***

**Unit 1: Convexity and Optimization** **[6Hrs.]**

Affine and Convex Sets, Convex Function, Convex Optimization Problem.

**Unit 2: Problem Formulation** **[10 Hrs.]**

Real world problems, Linear programming problem (LPP) formulation, Integer programming problem(IPP) formulation, Non-linear programming problem (NLP) formulation, Matlab and Python tutorial.

**Unit 3: Linear Programming Problem** **[12Hrs.]**

Three forms of LPP, Graphical Method, The Simplex Method, The General Problem, Linear Equations and Basic Feasible Solutions, Introduction to the Simplex Method, Theory of the Simplex Method, The Simplex Tableau and Examples, Articial Variables, Redundant Systems, A Convergence Proof, Linear Programming and Convexity, Spreadsheet Solution of a Linear Programming Problem.

**Unit 4: Duality and Sensitivity Analysis** **[10 Hrs.]**

Introduction to Duality, Definition of the Dual Problem, Examples and Interpretations, The Duality Theorem, The Complementary Slackness Theorem Examples in Sensitivity Analysis, Matrix Representation of the Simplex Algorithm, Changes in the Objective Function, Addition of a New Variable, Changes in the Constant-Term Column Vector, The Dual Simplex Algorithm, Addition of a Constraint.

**Unit 5: Integer Programming Problem** **[10 Hrs.]**

Introduction to Integer Programming, Total Unimodularity, Gomory's Cutting Plane Algorithm, A Branch and Bound Algorithm.

**Practical Works:**

The practical works includes Python and Matlabsoftwares.

**References:**


1. Stephen Boyd &LievenVandenberghe (2009) .*Convex Optimization*, Cambridge University Press.
2. Alexander Schrijver (1999).*Theory of Linear and Integer Programming*, John Wiley.
3. Paul R. Thie and G. E. Keough (2008).*An Introduction to Linear Programming and Game Theory*, John Wiley.
4. Laurence A Wolsey (1998).*Integer Programming*, John Wiley.


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