**UNIVERSITY OF SARGODHA**
**OFFICE OF THE REGISTRAR**
**(ACAD BRANCH)**

# NOTIFICATION

On the recommendations of Academic Council made in its 24th (1/2025) meeting held on 26.08.2025, the Syndicate in its 72nd (4/2025) meeting held on 12.09.2025 has approved the curriculum of MS in Data Science for implementation w.e.f. **Fall 2026** (Annex-**'A'**).

**(WAQAR AHMAD)**
Additional Registrar (General)

No. SU/Acad/26/299

Dated: 01.04.2026

Distribution:

1. Incharge, Department of Information Technology
2. Controller of Examinations
3. Director Academics

C.C:

4. Dean Faculty of Computing & Information Technology
5. Director, QEC
6. Additional Registrar (A & R)
7. Secretary to the Vice-Chancellor
8. PA to Registrar
9. Notification File

# Curriculum of
# MS Data Science
# for
# Main Campus


## Department of Information Technology

## University of Sargodha

(Applicable from Fall 2026)

Vetted
Naeem

03/03/26
Incharge
Department of Information Technology
University of Sargodha

# Table of Contents



Kh. M. A
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## Program's Rationale

The MS Data Science program prepares the scholars to meet the growing demand for professionals who can analyze, manage, and secure data across diverse domains which can help them in intelligent decision making in every field. The program integrates core data science techniques—such as machine learning, statistical and mathematical modeling, and data visualization—with IT concepts, enabling students to develop scalable and secure data-driven solutions. The program will enable the scholars to accomplish three main components of data science: Descriptive Analytics, Predictive Analytics and Prescriptive Analytics for all different data forms including Numerical data, spatial and Image/Videos, time-series, signal/audio data, natural content

A key focus is placed on the application of cryptographic techniques to ensure data security and privacy, data integrity, and secure communication in analytics environments. Students also gain practical experience with cloud computing for large-scale data processing and storage, as well as fog computing to enable low-latency, distributed data analysis close to the source—essential for real-time applications like Internet of Things (IoT) and smart systems. Through a combination of theoretical foundations and research assignments, the program cultivates critical thinking, ethical responsibility, and technical expertise for application of IT in data analytics in various domains including healthcare, business, agriculture, and engineering applications such as sensor data analytics, process optimization, predictive analytics. Graduates will be equipped to design and implement innovative, secure, and efficient data science solutions in both national and global IT landscapes.

## Program Structure

The MS Data Science program is intended for full-time enrollment and requires the successful completion of 30 credit hours. The curriculum is composed of four core courses, four electives, and a research thesis carrying 6 credit hours. This program is designed to offer students both foundational knowledge and specialized expertise in data science. It begins with a set of core courses each carrying 3 credit hours covering fundamental areas such as Data and Information Visualization for smart and intelligent decision making, multimodal data processing and analysis, methods for quantitative analysis of data and data protection and security using advanced cryptography techniques.

The scholars are then allowed to choose from a range of elective courses, totaling 12 credit hours, which enable them to focus on areas most relevant to their career paths or research interests. Possible electives may delve into advanced topics such as Big Data Technologies and Applications, Distributed Data Processing using Cloud computing, Edge and Fog computing techniques. Blockchain technologies, social network analysis. A key component of the program is the research thesis, in which students apply their learning to significant research areas under academic supervision. This not only deepens their understanding of research domain within data science but also apply in various domain for problem solving by proposing novel data-driven research solutions. In addition, it also enhances their ability to conduct independent research and contribute new insights to the field. By combining rigorous coursework with hands-on research, the program aims to produce graduates who are well-equipped to tackle real-world data challenges in both the IT sector and interdisciplinary environments.

## Program Aim & Objectives

The aim of the program is to produce well-rounded professionals who are capable, ethical, and responsible members of the data science and IT community. The graduates will possess both,

theoretical and practical understanding of current and emerging technologies, preparing them for impactful roles in problem solving through data science and analytics and enabling them to provide solutions to real-work problems based on research and innovation.

**Main Objectives of the Program:**

- To develop the ability to analyze real-world problems taking multi-model data and design computational solutions with research-based application of data science techniques in ever-evolving domain of IT
- To provide hands-on experience with data-centric tools for statistical analysis, data visualization, big data applications, and scalable analytics consistent with modern data science workflows.
- To instill strong foundations in information security, enabling students to manage data privacy, secure systems, and uphold ethical standards in digital environments.
- To prepare students to apply cloud computing platforms and services for distributed data processing, storage, and scalable computing environments.
- To enable graduates to understand and apply blockchain technologies for secure, transparent, and decentralized data management across diverse domains.

## Duration

The minimum duration to complete this degree is 2 years and not more than 4 years or 8 semesters.

## Eligibility:

An undergraduate degree/16 years education degree as defined in NCEAC based Computing discipline (as defined in No. 5-4/HEC/CURR/COMP/2023/4394 dated 16-02-2023) which include BS in Information Technology, BS in Computer Science, BS in Software Engineering, BS in Artificial Intelligence, BS in Data Science, BS in Cyber Security, BS in Bioinformatics, BS in Information Systems, BS in Multimedia and Gaming and BS in Computer Engineering.

**OR**

An undergraduate degree (or 16 years' education) in Engineering / Engineering Technology, Mathematics, Statistics, Physics, Economics from an HEC recognized university*

- As per the new HEC policy, the candidate having second division on annual system or CGPA >= 2.00 out or 4.00 in 16-years education.
- The applicant has passed the GRE-subject/equivalent test with at least 50% marks or any other recognized testing body including university admission test.
- Deficiency courses may be imposed to candidates having previous degree in other than computing disciplines.

03/03/26
Department of Information Technology
University of Sargodha

**Equivalence, if required, to be decided by the Chairman concerned and members of Departmental Admission Committee*

## Degree Requirements

For the award of MS degree, a student must have:

- Passed courses totaling at least 32 credit hours, including three core courses.
- Obtained a CGPA of 2.50 or more.

## Distribution of Courses:

The following are the distribution of total credit hours:

| Category or Area | Credit Hours |
|---|---|
| Core | 12 |
| Elective | 12 |
| Thesis/Project/Course work | 6 |
| Understanding of Holy Quran / Ethics | 2 |
| Total Credit Hours | 32 |

## List of Core Courses

| Sr. No | Course Code | Pre-Req | Course Title | Credit Hours |
|---|---|---|---|---|
| 1 | IDDC-701 | None | Data and Information Visualization | 3(3+0) |
| 2 | IDDC-702 | None | Multimodal Data Analytics | 3(3+0) |
| 3 | IDDC-703 | None | Quantitative Methods for Data Science | 3(3+0) |
| 4 | IDDC-704 | None | Data Security and Cryptography | 3(3+0) |

## List of Elective Courses

The following is a non-exhaustive list of elective courses. New elective courses may be added to this list. Students may be recommended to make their choice of electives, in the light of a soft specialization within the field of MS.

| # | Code | Pre-req | Course Title | Credit Hours |
|---|---|---|---|---|
| 1 | IDDE-701 | None | Research Methodology in IT | 3(3+0) |
| 2 | IDDE-702 | None | Big Data Analysis Techniques and Applications | 3(3+0) |
| 3 | IDDE-703 | None | Cloud Computing for Data Science | 3(3+0) |
| 4 | IDDE-704 | None | Point Estimation | 3(3+0) |
| 5 | IDDE-705 | None | Linguistic Data Processing and Computation | 3(3+0) |
| 6 | IDDE-706 | None | Speech and Audio Data Processing | 3(3+0) |
| 7 | IDDE-707 | None | Optimization Methods | 3(3+0) |
| 8 | IDDE-708 | None | Learning Representation and Decision Inference | 3(3+0) |
| 9 | IDDE-709 | None | Probabilistic Graphical Models | 3(3+0) |
| 10 | IDDE-710 | None | Time series Analysis and Prediction | 3(3+0) |
| 11 | IDDE-711 | None | Estimation Theory | 3(3+0) |
| 12 | IDDE-712 | None | Social Network Analysis | 3(3+0) |
| 13 | IDDE-713 | None | Edge and Fog – Driven Data Processing | 3(3+0) |
| 14 | IDDE-714 | None | Blockchain and Data Technologies | 3(3+0) |
| 15 | IDDE-715 | None | Spatial and Visual Data Analytics | 3(3+0) |
| 16 | IDDE-716 | None | Advanced Deep Learning | 3(3+0) |
| 17 | IDDE-717 | None | Advanced Data Mining | 3(3+0) |
| 18 | IDDE-718 | None | Advanced Machine Learning | 3(3+0) |

**Note: MS students may take course(s) from MS(IT) and PhD IT elective courses pool.**

03/03/26
Department of Information Technology
University of Sargodha

## Semester-wise Study Plan

| Sr. No | Course Code | Course Title | Credit Hours |
|---|---|---|---|
| | | **1st Semester** | |
| 1 | IDDC-701 | Data and Information Visualization | 3(3+0) |
| 2 | IDDC-702 | Multimodal Data Analytics | 3(3+0) |
| 3 | | Elective-I | 3(3+0) |
| 4 | | Elective-II | 3(3+0) |
| 5 | URCG-5129 or URCG-5131 | Understanding of Holy Quran I or Ethics I | 1(0-1) |
| | | **2nd Semester** | |
| 1 | IDDC-703 | Quantitative Methods for Data Science | 3(3+0) |
| 2 | IDDC-704 | Data Security and Cryptography | 3(3+0) |
| 3 | | Elective-III | 3(3+0) |
| 4 | | Elective-IV | 3(3+0) |
| 5 | URCG-5130 or URCG-5132 | Understanding of Holy Quran II or Ethics II | 1(0-1) |
| | | **3rd Semester** | |
| 31 | IDDC-700 | MS Thesis | 3(3+0) |
| | | **4th Semester** | |
| 1 | IDDC-700 | MS Thesis | 3(3+0) |

**Research Thesis**

According to the current rules of HEC, a thesis would enable students to have their degree vetted equivalent to an M.Phil. degree. This degree will be awarded based on Research Thesis work only.

09/03/26

Incharge
Department of Information Technology
University of Sargodha

# Contents of MS Data Science
# Course Title: Data and Information Visualization

**Course Code: IDDC-701**
**Course Structure: Lectures: 3/Labs: 0**
**Credit Hours: 3**
**Prerequisites: None**

**Course Objectives**

This course aims to equip students with the principles, methods, and tools essential for effectively transforming raw data into meaningful visual representations. Students will learn how to interpret and present complex data using visual and interactive techniques, improving comprehension, decision-making, and communication. The course focuses on both the theoretical underpinnings of data visualization such as human perception and cognitive psychology and practical skills using modern visualization libraries and frameworks. Emphasis is placed on storytelling through data, ethical visualization practices, and the creation of dashboards and exploration visual tools across various data domains, including time-series, geospatial, hierarchical, and network data.

**Course Syllabus**

The syllabus covers the fundamental concepts of data and information visualization, starting with an introduction to visual encoding and perceptual principles. Students explore a wide range of chart types and visualization paradigms, including categorical, temporal, spatial, hierarchical, and network data. The course includes modules on color theory, visual aesthetics, interactivity, and storytelling through dashboards. Students are introduced to tools such as D3.js, Tableau, Plotly, and Python's visualization stack (Matplotlib, Seaborn, Altair). The latter part of the course focuses on advanced topics like real-time data visualization, 3D visualization, visual analytics, and designing for accessibility and mobile. Case studies from journalism, business intelligence, and scientific domains are incorporated throughout the course.

**Course Outline**

1. Data visualization principles, visual encoding, human perception, interactivity in communication, basic chart types (bar charts, scatter plots, line charts, heatmaps), best practices for data type representation
2. Categorical and temporal visualizations, comparison across time and categories, hierarchical visualizations (treemaps, sunburst charts), geospatial visualizations (choropleth maps, interactive maps)
3. Network and graph visualization, analysis of complex relationships, social and biological networks, multivariate visualizations (parallel coordinates, radar plots), multi-dimensional data representation
4. Color theory and layout design, aesthetic and UX principles, accessibility in visualization, avoiding misleading visuals, truthful representation, storytelling, dashboard design, interactive narratives
5. Advanced visualization topics, dynamic and real-time systems, streaming data dashboards, immersive visualizations (3D, VR), ethics in visualization, final project (interactive visual analysis tool development and presentation).

**Reference Material**

1. Jeffrey D. Camm, James J. Cochran, Michael J. Fry, Jeffrey W. Ohlmann; Data Visualization: Exploring and Explaining with Data; 2024; ISBN 9780357929766; 2nd Edition

12h MA 23/03/26

Department of Information Technology
University of Sargodha

2. Jeffrey Heer, Ben Shneiderman, Catherine Plaisant; Interactive Data Visualization: Foundations, Techniques, and Applications; 2023; ISBN: 978-0367332255; 2nd Edition
3. Scott Murray; Interactive Data Visualization for the Web; 2023; ISBN: 978-1491921289; 2nd Edition
4. Jack Dougherty & Ilya Ilyankou; Hands-On Data Visualization: Interactive Storytelling from Spreadsheets to Code; 2021 (widely used core book); ISBN-13 9781492083403; 1st Edition
5. Nathan Yau; Data Points: Visualization That Means Something; 2021; ISBN: 978-1118651461; 1st Edition
6. Colin Ware; Information Visualization: Perception for Design; 2020; ISBN 9780128128756; 4th Edition

# Course Title: Multimodal Data Analytics

**Course Code: IDDC-702**
**Course Structure: Lectures: 3/Labs: 0**
**Credit Hours: 3**
**Prerequisites: None**

**Course Objectives**

This course aims to equip students with the knowledge and skills required to analyze and interpret multimodal data including text, images, audio, video, and sensor streams using advanced data science and machine learning techniques. The objective is to enable learners to preprocess, fuse, and model multiple data modalities to derive meaningful insights. Students will gain practical experience with state-of-the-art deep learning architectures, data fusion strategies, and real-world applications such as healthcare, social media analytics, and human-computer interaction. Emphasis will be placed on building interpretable and efficient models that handle heterogeneous inputs and deliver robust predictions.

**Course Syllabus**

The syllabus begins with an introduction to multimodal data types and their applications across domains. It covers data collection, cleaning, and feature extraction methods for individual modalities including text, image, audio, video, and sensor data. Students will explore data alignment techniques, early and late fusion strategies, and design deep learning models using architectures like CNNs, LSTMs, and Transformers. Specialized topics such as multimodal sentiment analysis, healthcare applications, and social media analysis will be included. The course concludes with model evaluation, ethical concerns, and a capstone project involving real-world multimodal datasets.

**Course Outline**

1. Introduction to multimodal data, importance in modern data science applications, real-world examples (e.g., text, image, audio), challenges in representation and integration
2. Types of Data Modalities, understanding structure of text, image, audio, video, sensor data, characteristics and encoding styles, real-world applications
3. Data Collection and Preprocessing, methods to collect multimodal data, handling heterogeneous sources, preprocessing challenges (noise, missing data, normalization)
4. Feature Extraction Techniques, modality-specific feature extraction, text (TF-IDF, BERT), image (CNNs), audio (MFCC), sensor (time-frequency analysis)
5. Data Synchronization and Alignment, aligning multimodal streams, temporal and spatial alignment, dynamic time warping, synchronization issues
6. Fusion Strategies in Multimodal Systems, early fusion, late fusion, hybrid models, attention mechanisms, decision-level integration

7. Multimodal Deep Learning Architectures, CNNs, RNNs, LSTMs, transformers, architectures like CLIP, VisualBERT for joint learning
8. Cross-modal Embedding and Representation Learning, shared vector space learning, contrastive learning, cross-modal attention, triplet loss
9. Multimodal Sentiment and Emotion Analysis, combining textual, audio, and facial features, datasets like CMU-MOSEI, emotion classification challenges
10. Applications and Case Studies, use cases in healthcare, education, surveillance, e-commerce, domain-specific integration techniques
11. Explainability and Evaluation in Multimodal Systems, SHAP, attention maps, relevance propagation, evaluation metrics (BLEU, ROUGE, mAP)
12. Design and Implementation of a Multimodal System, hands-on project development, system design, integration, ethical and deployment considerations

**Reference Material**


1. Ramya Haridas & C. R. Rene Robin; *Multimodal Data Fusion and Analytics*; 2024; ISBN: 9781119865414
2. Paul Taylor; *Multimodal Machine Learning: Techniques and Applications*; 2023; ISBN: 9781032214136
3. Louis-Philippe Morency et al.; *Multimodal Machine Learning (Foundations and Trends)*; 2022; DOI: 10.1561/2200000073
4. Michail Giannakos et al. (Eds.); *The Multimodal Learning Analytics Handbook*; 2022; ISBN 9783031080753; 1st Edition
5. Li-minn Ang (Ed.); *Multimodal Analytics for Next-Generation Big Data Technologies and Applications*; 2019; ISBN 9783319975979; 1st Edition


## Course Title: Quantitative Methods for Data Science

**Course Code: IDDC-703**
**Credit Hour: 3**
**Course Structure: Lectures:**
**/Labs:0**
**Prerequisites: None**

**Course Objectives**

This course provides students with a strong foundation in the core quantitative techniques used in data science, including probability, statistics, linear algebra, and optimization. The goal is to develop the mathematical and statistical reasoning necessary to understand, implement, and interpret data-driven models and algorithms. Students will gain a practical understanding of how these methods are applied in real-world data science tasks such as data preprocessing, model building, hypothesis testing, dimensionality reduction, and evaluation of predictive performance. Emphasis is placed on applying these methods through programming tools like Python and R in hands-on data analysis scenarios.

**Course Syllabus**

The course begins with a review of linear algebra, matrix operations, and vector spaces, which underpin many machine learning algorithms. It then moves to probability theory, including random variables, distributions, expectations, and Bayes' theorem, forming the basis for probabilistic models. Statistical methods such as sampling, confidence intervals, hypothesis testing, and regression analysis are covered in depth. Students also learn about numerical optimization techniques including gradient descent and convex optimization, essential for training models. Throughout the course, concepts are illustrated through coding assignments and real-world data problems, reinforcing both theoretical understanding and practical application.



03/03/26
Incharge
Department of Information Technology
University of Sargodha

**Course Outline**

1. Linear Algebra Essentials, matrices and vectors, eigenvalues and eigenvectors, PCA and SVD
2. Probability and Random Variables, probability axioms, discrete and continuous distributions, expectation and variance, Bayesian reasoning, conditional probability
3. Descriptive and Inferential Statistics, data summarization, confidence intervals, hypothesis testing (z-test, t-test, ANOVA), correlation analysis, statistical significance
4. Regression and Predictive Modeling, linear and logistic regression, model assumptions, coefficient interpretation, Lasso and Ridge regression
5. Numerical Optimization, gradient descent, Newton's method, stochastic optimization, loss minimization in ML
6. Dimensionality Reduction and Feature Engineering, PCA, LDA, feature transformation, model efficiency
7. Applications in Data Science, A/B testing, feature importance, bootstrapping, cross-validation mining.

**Reference Material:**


1. Tim Roughgarden; Mathematics for Computer Science and Data Science; 2023; ISBN: 978-1737263013; 1st Edition
2. Kevin P. Murphy; Probabilistic Machine Learning: An Introduction; 2022; ISBN: 978-0262046824; 1st Edition
3. Sheldon M. Ross; Introduction to Probability and Statistics for Engineers and Scientists; 2021; ISBN: 978-0128177396; 6th Edition
4. Michael W. Trosset; An Introduction to Statistical Inference and Its Applications with R; 2020; ISBN: 978-0367149143; 2nd Edition
5. Avrim Blum, John Hopcroft, Ravindran Kannan; Foundations of Data Science; 2020; ISBN: 978-1108716208; 1st Edition
6. Mathematics for Machine Learning by Marc Peter Deisenroth, A. Aldo Faisal, and Cheng Soon Ong (2020)


# Course Title: Data Security and Cryptography

**Course Code: IDDC-704**
**Course Structure: Lectures: 3/Labs: 0**
**Credit Hours: 3**
**Prerequisites: None**
**Course Objectives:**

This course aims to equip students with a strong mathematical foundation for understanding and analyzing modern cryptographic systems. It covers essential concepts from number theory, including divisibility, congruences, and finite fields, and demonstrates their applications in classical and public key cryptography. Students will explore key cryptographic algorithms such as RSA, discrete logarithms, and elliptic curve cryptography, along with advanced techniques in primality testing and integer factorization. The course also introduces emerging topics like zero-knowledge proofs and oblivious transfer. By the end, students will develop the ability to apply mathematical tools to analyze and design secure cryptographic protocols and understand the theoretical underpinnings that ensure their strength.

**Course Syllabus:**

This course provides a rigorous mathematical foundation for modern cryptography by integrating key concepts from number theory and algebra with their practical applications in secure communication.

Incharge
Department of Information Technology
University of Sargodha

It begins with the basics of number theory, including time estimates for arithmetic operations, divisibility, the Euclidean algorithm, and modular congruences, with direct applications in factoring. Students will explore finite fields, quadratic residues, and the law of quadratic reciprocity, which are essential in understanding cryptographic primitives. The course then introduces classical cryptosystems and matrix-based enciphering techniques before progressing to public key cryptography, covering RSA, discrete logarithm-based schemes, knapsack problems, and advanced topics like zero-knowledge protocols and oblivious transfer. Primality testing and factoring algorithms such as pseudoprimes, the rho method, Fermat factorization, continued fraction, and quadratic sieve are studied in depth. Introduction to elliptic curves, their algebraic structure, and their application in cryptosystems, primality testing, and factorization. Theoretical tools and algorithmic insights needed to analyze, implement, and evaluate modern cryptographic protocols.

**Course Outline:**

1. Basics of Number Theory: Time estimates for doing arithmetic, Divisibility and the Euclidean algorithm, Congruences, Some applications to factoring.
2. Finite Fields and Quadratic Residues: Finite fields, Quadratic residues and reciprocity.
3. Cryptography: Some simple cryptosystems, Enciphering matrices.
4. Public Key: The idea of public key cryptography, RSA, Discrete log, Knapsack, Zero-knowledge protocols and oblivious transfer.
5. Primality and Factoring: Pseudoprimes, The rho method, Fermat factorization and factor bases, The continued fraction method, The quadratic sieve method.
6. Elliptic Curves: Basics, Elliptic curve cryptosystems, Elliptic curve primality test, Elliptic curve factorization.

**Reference Material:**


1. Understanding Cryptography: From Established Symmetric and Asymmetric Ciphers to Post-Quantum Algorithms Second Edition 2024.
2. Paar & Pelzl – Understanding Cryptography Second Edition 2024.


03/03/26

Incharge
Department of Information Technology
University of Sargodha

# Contents of MS Data Science in IT Elective Courses

## Course Title: Research Methodology in IT

**Course Code: IDDE-701**
**Course Structure: Lectures: 3/Labs: 0**
**Credit Hours: 3**
**Prerequisites: None**

**Course Objectives:**

This course is designed to equip students with a comprehensive understanding of research methodologies applicable to academic and applied research in the field of Information Technology and related disciplines. It introduces the fundamentals of research, including its objectives, types, and significance, and guides students through each phase of the research process—from problem identification and formulation to literature review and hypothesis development. The course emphasizes both quantitative and qualitative research methods, including the design and execution of surveys, case studies, and mixed methods research. Students will gain practical skills in data analysis using statistical tools, with hands-on training in SPSS for conducting regression, correlation, cross-tabulation, and other statistical tests. In addition, the course covers the structure and components of research proposals and theses, preparing students to produce academically sound and methodologically rigorous research documents.

**Course Syllabus:**

Introduction to Research. Objectives of Research. Importance of Research Methodology in Research Study. Types of Research. Steps in Conducting Research. What is Literature Review? Why need for Literature Review. Types of Literature Review. Systematic Literature Review Protocol. Problem Statement and Problem formulation. Criteria for selecting a problem. Identifying Types of variables in Research. Types of hypotheses. Identifying Target Population. Types of Sampling. Sampling Techniques. Quantitative Research Methods. Scientific Methods. Design of Quantitative Surveys. Techniques to Conduct Quantitative Methods. Introduction to Qualitative Research. Qualitative Research Methods. Data Analysis and Theory in Qualitative Research Articles. Introduction to Mixed Methods Research. Design of Mixed Methods Research. Evaluation of Mixed Methods Research. Case Study. How to Conduct a Case Study. Case Study Protocol. Importance and Benefits of Case Study. Types of Statistical Tests to Conduct Data Analysis. Data Analysis Tools. Introduction to SPSS. Hands on Practice of SPSS. How to Define variables in SPSS. How to Record Collected Data in SPSS. Types of Tests via SPSS including Regression. Correlation. Cross tabulation and others. How to write Good Research Proposal. Contents of Thesis. Important Elements of Research Thesis.

**Course Outline:**

1. Introduction to Research: Definition of Research, Objectives of Research, Importance of Research Methodology, Types of Research
2. Steps in Conducting Research, Problem Statement and Problem Formulation, Criteria for Selecting a Problem, Identifying Types of Variables in Research, Types of Hypotheses, Identifying Target Population, Types of Sampling, Sampling Techniques
3. Literature Review: Definition and Purpose of Literature Review, Importance of Literature Review, Types of Literature Review, Systematic Literature Review Protocol
4. Quantitative Research Methods: Introduction to Quantitative Research, Design of Quantitative Surveys, Techniques to Conduct Quantitative Methods, Types of Statistical Tests for Data Analysis
5. Introduction to Qualitative Research: Qualitative Research Methods, Data Analysis and Theory in Qualitative Research Articles

03/03/21
Department of Information Technology
University of Sargodha

6. Mixed Methods Research: Introduction to Mixed Methods Research, Design of Mixed Methods Research, Evaluation of Mixed Methods Research
7. Case Study: What is a Case Study?, How to Conduct a Case Study, Case Study Protocol, Importance and Benefits of Case Study
8. Introduction to SPSS: Overview of SPSS, Handson Practice of SPSS, Defining Variables and Recording Data in SPSS, Types of Tests via SPSS (Regression, Correlation, Cross Tabulation, etc.)
9. Writing Research Proposal and Thesis: How to Write a Good Research Proposal, Contents of a Thesis, Important Elements of Research Thesis

**Reference Material:**


1. Qualitative Research Methods for Everyone: An Essential Toolkit First Edition by Karen O'Reilly, 2025, 978-1447372158
2. Research Design Simplified: A Beginner's Guide to Qualitative, Quantitative, and Mixed Methods Research by Rafiq Muhammad, 2024, 978-9198900880
3. Research Methodology: Techniques and Trends – Umesh Kumar B. Dubey & D. P. Kothari (CRC Press, 2022) – ISBN 9781138053984


## Course Title: Big Data Analysis Techniques and Applications

**Course Code: IDDE-702**
**Course Structure: Lectures: 3 / Labs: 0**
**Credit Hours: 3**
**Prerequisites: None**

**Course Objectives:**

At the end of this course, the student will become familiar with the fundamental concepts of Big Data management and analytics; will become competent in recognizing challenges faced by applications dealing with very large volumes of data as well as in proposing scalable solutions for them; and will be able to understand how Big Data impacts business intelligence, scientific discovery, and our day-to-day life.

**Course Syllabus:**

Introduction to Big Data, Defining Big Data, Delivering Business benefit from Big Data, Storing Big Data, Analyzing your data characteristics, Overview of Big Data stores, Selecting Big Data Stores, Processing Big Data, Integrating disparate data stores, Employing Hadoop MapReduce, The building blocks of Hadoop MapReduce, Handling streaming data, Tools and Techniques to Analyze Big Data, Abstracting Hadoop MapReduce jobs with Pig, Performing ad hoc Big Data querying with Hive, Creating business value from extracted data, Developing a Big Data Strategy, Employing Hadoop MapReduce, Defining a Big Data strategy for your organization, Enabling analytic innovation, Implementing a Big Data solution.

**Reference Material:**


1. Technologies and Applications for Big Data Value – Edward Curry, Sören Auer, Arne J. Berre, Andreas Metzger, Maria S. Perez, & Sonja Zillner (eds., 2022) – ISBN 9783030783068
2. Big Data Analytics: Theory, Techniques, Platforms, and Applications – Ümit Demirbağa, Gagangeet S. Aujla, Anish Jindal, & Oğuzhan Kalyon (2024) – ISBN 9783031556388
3. Big Data Concepts, Technologies, and Applications – Mohammad Shahid Husain, Mohammad Z. Khan, & Tamanna Siddiqui (CRC Press, 2023) – ISBN 9781032579184


## Course Title: Cloud Computing for Data Science

**Course Code: IDDE-703**

03/03/26
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**Course Structure: Lectures: 3 / Labs: 0**
**Credit Hours: 3 Prerequisite: None**

**Course Objectives:**

This course introduces cloud computing and related techniques, issues, ecosystem and case studies. Students will learn and understand about such fundamental distributed computing "concepts" for cloud computing, how these techniques work inside today's most widely used cloud computing systems and various research papers will be studied.

**Course Syllabus:**

Overview of Distributed Computing, Emergence of Cloud Computing, Global Nature of the Cloud, Cloud Based Service Offerings, Grid Computing , Reliability of Cloud Model, Benefits of Cloud Model, Legal Issues, Key Characteristics of Cloud Computing, Challenges for the Cloud. The Evolution of Cloud
Computing. Web Services Delivered from the Cloud: Communication-as-a-Service (CaaS), Infrastructure-as-a-Service, Monitoring-as-a-Service (MaaS), Platform-as-a-Service (PaaS), Software as-a-Service (SaaS), Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS), Storage: HDFS, NAAS, SAN, Distributed Graph Processing, MapReduce , MapReduce Paradigm, MapReduce Examples, Emerging Paradigms, Distributed Graph Processing, Hadoop Scheduling, Dominant-Resource Fair Scheduling, Building Cloud Networks. Virtualization. Federation, Presence, Identity, and Privacy in the Cloud. Security in the Cloud. Common Standards in Cloud Computing. EndUser Access to Cloud Computing. Mobile Internet Devices and the Cloud.

**Reference Material:**


1. Convergence of Cloud with AI for Big Data Analytics: Foundations and Innovation – Danda B. Rawat, Lalit K. Awasthi, & Valentina E. Balas (eds., 2022) – ISBN 9781119904885
2. Computing for Data Analysis: Theory and Practices – Sanjay Chakraborty & Lopamudra Dey (Springer, 2023) – ISBN 9789811980039
3. Big Data, Cloud Computing and IoT: Tools and Applications – Sita Rani, Pankaj Bhambri, Aman Kataria, Alex Khang, & Arun K. Sivaraman (eds., 2023) – ISBN 9781032287430


## Course Title: Point Estimation

**Course Code: IDDE-704**
**Course Structure: Lectures: 3/ Labs: 0**
**Credit Hours: 3**
**Pre-requisites: None**

Kh. M. A 03/03/26
Incharge
Department of Information Technology
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**Course Objectives:**
This course aims to provide a solid theoretical foundation for statistical inference (estimation and testing). It employs a probabilistic and measure theoretic approach to formulate and solve statistical inference problems. Material to be covered: sufficiency, decision theoretic statistical inference (minimax estimation, Bayes estimation, admissibility, shrinkage & bigdata, etc.), UMVUE, equivariance, information theoretic inference, large sample theory, asymptotic properties of maximum-likelihood methods, and optimal hypothesis tests (UMP, UMPU).

**Course Syllabus:**
This course is concerned with point estimation in Euclidean sample spaces. The first part of the course deals with exact (small-sample) theory, and *Testing Statistical Hypotheses* (TSH). Optimal estimators are derived according to criteria such as unbiasedness, equivariance, and minimaxity. The principal

applications are to exponential and group families, and the systematic discussion of the rich body of (relatively simple) statistical problems.

**Course Outline:**

1. Statistical decision theory involves choosing optimal decisions under uncertainty using frequentist rules or Bayesian probabilities.
2. Exponential families are a group of distributions with common structure that simplify statistical estimation and inference.
3. Hypothesis testing evaluates whether sample data provides sufficient evidence to reject a stated null hypothesis.
4. Resampling methods, such as bootstrapping and permutation, estimate variability and test hypotheses without relying on strong assumptions.
5. Estimating equations and maximum likelihood are techniques to derive parameter estimates by solving equations based on sample data.
6. Empirical Bayes methods estimate prior distributions from the data to improve inference in Bayesian analysis.
7. Large-sample theory examines the properties of estimators and tests as the sample size becomes very large.
8. High-dimensional testing addresses statistical challenges when the number of variables is much greater than the number of observations.
9. Multiple testing and selective inference correct for inflated error rates and biases introduced when many hypotheses are tested or selected post hoc.

**Reference Material:**


1. Theory of Point Estimation (TPE), by Lehmann and Casella, 2nd ed. (1998), Springer.
2. Testing Statistical Hypotheses (TSH), by Lehmann and Romano, 3rd ed. (2005) or 4th ed. (2022), Springer


## Course Title: Linguistic Data Processing and Computation

**Course Code: IDDE-705**
**Course Structure: Lectures: 3/ Lab: 0**
**Credit Hours: 3**
**Prerequisites: None**

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**Course Objective:**

Natural language processing (NLP) is one of the most important technologies of the information age. Understanding complex language utterances is also a crucial part of artificial intelligence. Applications of NLP are everywhere because people communicate most everything in language: web search, advertisement, emails, customer service, language translation, radiology reports, etc. There are a large variety of underlying tasks and machine learning models behind NLP applications. Upon completing, you will be able to recognize NLP tasks in your day-to-day work, propose approaches, and judge what techniques are likely to work well. This course will cover the fundamental concepts in NLP.

**Course Syllabus:**

This course covers a range of topics in computational linguistics/natural language processing, including its introduction to Regular Expressions, Text Normalization, Edit Distance, N- gram Language Models, Naive Bayes and Sentiment Classification, Logistic Regression, Vector Semantics, Neural Networks and Neural Language Models, Part-of-Speech Tagging, Sequence Processing with Recurrent Networks, Formal Grammars of English/Urdu, Syntactic Parsing, etc.

**Course Outline:**

1. Introduction [TB1, Ch. 1]
2. Regular Expressions, Text Normalization, and Edit Distance: Regular Expressions,
3. Words, Corpora, Text Normalization, Minimum Edit Distance, etc. [TB1, Ch. 2]
4. N-gram Language Models: N Grams, Evaluating Language Models, Generalization and Zeros, Smoothing, etc. [TB1, Ch.3]
5. Naive Bayes and Sentiment Classification: Naïve Bayes Classifiers and their training with
6. examples, Its optimization for sentiment analysis and for other text classification, etc. [TB1, Ch.4]
7. Logistic Regression: Classification: The sigmoid; Learning in Logistics Regression; The Cross
8. Entropy loss function; Gradient Descent, Regularization, etc. [TB1, Ch. 5]
9. Vector Semantics: Lexical Semantics, Vector Semantics, Words and Vectors, Cosine for
10. measuring similarity, TF-IDF Weighting terms in the vector, etc. [TB1, Ch. 6]
11. Neural Networks and Neural Language Models: Units, The XOR problem, Feed
12. Forward Neural Network, Training Neural Nets, etc. [TB1, Ch. 7]
13. Part-of-Speech Tagging: Word Classes, Penn POS Tagset, POS Tagging, HMM POS
14. Tagging, etc. [TB1, Ch. 8]
15. Sequence Processing with Recurrent Networks: Simple Recurrent Networks, Applications of
16. RNNs, Deep Networks, Managing Context in RNNs, etc. [TB1, Ch. 9]
17. Formal Grammars of English/Urdu: Constituency, Context Free Grammars, Rules of 18. English/Urdu, Treebanks, etc. [TB1, Ch. 10]
19. Syntactic Parsing: Ambiguity, CKY Parsing, Partial Parsing, etc. [TB1, Ch. 11]

**Reference Material:**


1. Natural Language Processing: A Textbook with Python – Jursic, Musleh, & Roman (eds., 2024) – ISBN 9789819919987
2. Natural Language Processing in the Real World: Text Processing, Analytics, and Classification – Jyotika Singh (CRC Press, 2023) – ISBN 9781032207032
3. Natural Language Processing with Transformers – Lewis Tunstall, Leandro Von Werra, & Thomas Wolf (O'Reilly, 2022) – ISBN 9781098136796


## Course Title: Speech and Audio Data Processing

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**Course Code: IDDE-706**
**Course Structure: Lectures: 3/ Lab: 0**
**Credit Hours: 3**
**Prerequisites: None**

**Course Objective:**

This course offers an in-depth introduction to automatic speech recognition (ASR), the problem of automatically extracting text from human speech. This class will cover many theoretical and practical aspects of machine learning techniques that are employed in large-scale ASR systems. Apart from teaching classical algorithms that form the basis of statistical speech recognition, this class will also cover the latest deep learning techniques that have made important advances in achieving state-of-the-art results for speech recognition.

**Course Syllabus:**

This course is an introduction to automatic speech recognition, speech synthesis, and dialogue systems, from the computer science and linguistics (rather than EE) perspective. Focus on understanding of key algorithms including the noisy channel model, Hidden Markov Models (HMMs), GMM (Gaussian Mixture Model) acoustic models, A* and Viterbi decoding, N. gram language modeling, unit selection

synthesis, dialogue architectures, and the role of linguistic knowledge (esp. phonetics, intonation, pronunciation variation, disfluencies, emotion).

**Course Outline:**

1. Overview of Course, Intro to Probability Theory, and ASR Background: N-gram Language Modeling J+M New Chapter 4: N-grams
2. TTS: Background (part of speech tagging, machine learning, classification, NLP) and Text Normalization J+M New Chapter 7: Phonetics , J+M New Chapter 8 Speech Synthesis, pages 1-10 ,
3. TS: Grapheme-to-phoneme, Prosody (Intonation, Boundaries, and Duration) and the Festival software J+M New Chapter 8, pages 10-25 , Read sections 1, 2, 3, 4, 5, and 6.1 and 6.1.1 from Alan Black's lecture notes on TTS and Festival. , Festival manual (used as Festival's scripting language): Introduction to Scheme for C Programmers, from Cal Tech. Optional Advanced Reading: Chapter 6 "Prosody Prediction from Text" from Taylor, Paul. 2007.
4. TTS: Waveform Synthesis (Diphone and Unit Selection Synthesis) J+M New Chapter 8, pages 25-end Optional Advanced Reading: Chapter 16 "Unit Selection Synthesis" from Taylor, Paul. 2007. Optional
   Advanced Reading: Optional: Section 7 from Alan Black's lecture notes on TTS and Festival. Optional Advanced Reading: The rest of Section 6 of Alan Black's lecture notes
5. ASR: Noisy Channel Model, Bayes, HMMs, Forward, Viterbi J+M New Chapter 6: Hidden Markov Models, pages 1-20 J+M New Chapter 9: Automatic Speech Recognition, pages 1-12
6. ASR: Feature Extraction and Acoustic Modeling, Evaluation J+M New Chapter 9: Automatic Speech Recognition pages 12-31, 31-45 J+M New Chapter 10: Speech Recognition: Advanced Topics pages 11-16
7. ASR: Learning (Baum-Welch) and Disfluencies J+M New Chapter 9: Automatic Speech Recognition 46-52 , J+M New Chapter 10: Speech Recognition: Advanced Topics pages 1-11

**Reference Material:**


1. Speech and Language Processing (3rd Edition draft) – Daniel Jurafsky & James H. Martin 2023
2. Practical Deep Learning for Speech and Language – James Damian (2023) – ISBN 9781484291746
3. Fundamentals of Speech Recognition (Reprint Edition) – Lawrence Rabiner & Biing-Hwang Juang (2022 ) – ISBN 9780131505810


03/03/26
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# Course Title: Optimization Methods

**Course Code: IDDE-707**
**Credit Hour: 3**
**Prerequisite: None**

**Course Objectives:**

This course introduces the principal algorithms for linear, network, discrete, nonlinear, dynamic optimization and optimal control. Emphasis is on methodology and the underlying mathematical structures. Topics include the simplex method, network flow methods, branch and bound and cutting plane methods for discrete optimization, optimality conditions for nonlinear optimization, interior point methods for convex optimization, Newton's method, heuristic methods, and dynamic programming and optimal control methods.

**Course Syllabus:**

The course takes a unified view of optimization and covers the main areas of application and the main optimization algorithms. It covers the following topics: Linear optimization, Robust optimization, Network flows, Discrete optimization, Dynamic optimization, Nonlinear optimization.

**Reference Material:**

1. Introduction to Linear Optimization by Bertsimas, Dimitris, and John Tsitsiklis. Athena Scientific, 1997 or Latest Edition.
2. Numerical Optimization: Theoretical and Practical Aspects, By Joseph-Frédéric Bonnans, Jean Charles Gilbert, Claude Lemarechal, Claudia A. Sagastizábal, Springer Science & Business Media, 2006

## Course Title: Learning Representation and Decision Inference

**Course Code: IDDE-708**
**Course Structure: Lectures: 3/Labs: 0**
**Credit Hours: 3**
**Prerequisites: None**
**Course Objective:**

By the end of the course, students will be equipped to approach new problems or datasets, design suitable models, train them using data, and apply inference to derive answers to their original questions.

**Course Syllabus:**

This course focuses on how to conceptualize and model data effectively. It introduces probabilistic graphical models as powerful tools for representing data, handling uncertainty, and uncovering meaningful insights. Special emphasis is placed on latent variable models, such as latent Dirichlet allocation (used for topic modeling), factor analysis, and Gaussian processes. The course also explores temporal models like hidden Markov models, as well as hierarchical models, deep generative models, and structured prediction techniques.

**Course Outline:**

1. Introduction to probabilistic graphical models with a focus on Bayesian networks and their role in representing complex joint probability distributions.
2. Applications of probabilistic modeling in real-world domains such as neuroscience and political science to model uncertainty and relationships among variables.
3. Overview of undirected graphical models, especially Markov Random Fields (MRFs), used for modeling dependencies without directional assumptions.
4. Study of Conditional Random Fields (CRFs) for sequence labeling and structured prediction, and Gaussian MRFs for modeling continuous variables.
5. Techniques for exact inference in graphical models, including situations where exact solutions are computationally feasible.
6. Algorithms like variable elimination, the concept of treewidth to measure graph complexity, and belief propagation for efficient message passing.
7. Concepts and techniques in unsupervised learning for discovering hidden structures in unlabeled data.
8. Expectation Maximization (EM) algorithm for parameter estimation in models with latent variables using iterative optimization.
9. Gibbs sampling for approximate inference using Markov Chain Monte Carlo (MCMC) to draw samples from high-dimensional distributions.
10. Causal inference techniques and an introduction to Bayesian Additive Regression Trees (BART) for estimating treatment effects and modeling causal relationships.

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University of Sargodha

11. Topic modeling with Latent Dirichlet Allocation (LDA) to discover thematic structures in large collections of documents.
12. Gaussian Processes (GPs) as a non-parametric Bayesian approach for regression and classification with uncertainty quantification.
13. Learning algorithms for Markov Random Fields, including parameter estimation and structure learning techniques.
14. Use of moment matching, the Chow-Liu algorithm for tree-structured models, and pseudo-likelihood for approximate parameter estimation.
15. Variational inference as a deterministic approach to approximate posterior distributions by optimizing a lower bound (ELBO).
16. Mean-field approximation technique assuming independence among latent variables to simplify variational inference.
17. Introduction to deep generative models such as Variational Autoencoders (VAEs) and Generative Adversarial Networks (GANs) for complex data generation.

**Reference Material:**


1. Inference and Representation: A Study in Modeling Science 1st Edition by Mauricio Suárez, 2024, ISBN- 978-0226830049
2. Pathwise Estimation and Inference for Diffusion Market Models 1st Edition, Kindle Edition by Nikolai Dokuchaev, 2019
3. Kevin Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012.


## Course Title: Probabilistic Graphical Models

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**Course Code: IDDE-709**
**Course Structure: Lectures: 3/Labs: 0**
**Credit Hours: 3**
**Prerequisites: None**

Department of Information Technology, University of Sargodha

**Course Objective:**

This course aims to equip students with the knowledge and practical skills needed to design, implement, and apply probabilistic graphical models to real-world problems. Key topics include: (1) Bayesian networks, undirected graphical models, and their temporal variants; (2) methods for both exact and approximate inference; and (3) techniques for learning model parameters and structure

**Course Syllabus:**

Probabilistic graphical models offer a robust framework for representing complex systems through probability distributions, with wide-ranging applications in machine learning, computer vision, natural language processing, and computational biology. By integrating graph theory with probability theory, they enable the modeling of large sets of interdependent random variables in a structured and flexible way. This course presents an in-depth overview of the field, covering essential concepts and techniques for building these models, making predictions, and guiding decisions in uncertain environments.

**Course Outline:**

1. Introduction to probabilistic models, basic probability theory, and Bayesian networks.
2. Overview of undirected graphical models and their representation using Markov Random Fields.
3. Learning parameters and structure of Bayesian networks from data.
4. Exact inference techniques including variable elimination and belief propagation.
5. Sampling-based inference methods like MCMC, Gibbs sampling, and importance sampling.
6. MAP inference and structured prediction tasks such as sequence labeling.
7. Parameter learning using maximum likelihood and expectation-maximization.

8. Bayesian learning with priors and structure learning using scoring methods.
9. Exponential family distributions and variational inference approaches.
10. Advanced topics including deep probabilistic models and recent research trends

**Reference Material:**


1. Machine Learning and Probabilistic Graphical Models for Decision Support Systems – Kim Phuc Tran (ed., 2022) – ISBN 9781032039480
2. Probabilistic Graphical Models: Principles and Techniques – Daphne Koller & Nir Friedman (2022) – ISBN 9780262013192
3. Advances in Global Optimization: Heuristic and Non-Convex Methods – e.g., Developments in Global Optimization (Kluwer, 2023) – ISBN 978144194768
4. Probabilistic Graphical Models: Principles and Techniques by Daphne Koller and Nir Friedman. MIT Press.


# Course Title: Time Series Analysis and Prediction

**Course Code: IDDE-710**
**Course Structure: Lectures: 3/Labs: 0**
**Credit Hours: 3**
**Prerequisites: None**

**Course Objective:**

To develop students' ability to conduct empirical research using time series data by equipping them with techniques for estimating and evaluating economic models, understanding the limitations and potential pitfalls of various methods along with their solutions, and gaining insight into recent advancements and ongoing research in time series analysis.

**Course Syllabus:**

This course offers an overview of the theory and practical applications of time series methods in econometrics. Topics include univariate models for both stationary and non-stationary data, vector autoregressions, frequency domain techniques, approaches for estimation and inference in persistent time series, and the analysis of structural breaks

**Course Outline:**

1. Stationarity concepts, the lag operator, ARMA models, and their covariance structures in time series analysis.
2. Limit theorems essential for asymptotic inference, with applications in OLS and HAC variance estimation.
3. Further discussion on HAC estimators and an introduction to spectral analysis in the frequency domain.
4. Detailed study of the spectral density function for understanding cyclical behavior in time series.
5. Methods for estimating the spectrum and choosing models using criteria like AIC and BIC.
6. Introduction to Generalized Method of Moments (GMM) for efficient estimation using moment conditions.
7. Discussion on the weak instrument problem in IV estimation and its effects on statistical inference.
8. Bootstrap techniques for estimating sampling distributions, confidence intervals, and test statistics.
9. Overview of Vector Autoregressive (VAR) models and their use in modeling multivariate time series.

Kh. M. A
03/03/26
Department of Information Technology
University of Sargodha

10. Estimation and interpretation of VAR models, including forecasting and impulse response functions.
11. Structural VARs and identification strategies for uncovering economically meaningful shocks.
12. Introduction to factor models for reducing dimensionality in large economic datasets.
13. Extended discussion on dynamic factor models and estimation methods.
14. Basic ideas of empirical processes and their application in econometric theory.
15. Tests for unit roots to assess stationarity and integration order in time series.
16. Advanced topics in non-stationarity, including stochastic trends and structural dynamics.
17. Analysis of structural breaks and the basics of cointegration in economic time series.
18. Cointegration theory with focus on long-term equilibrium relationships and ECMs.
19. Introduction to filtering techniques, state-space models, and Kalman filtering for time series.
20. Maximum likelihood estimation in state-space frameworks and the basics of DSGE modeling.
21. Foundational reasons to adopt a Bayesian approach and key concepts of Bayesian analysis.
22. MCMC methods with emphasis on the Metropolis-Hastings algorithm for posterior simulation.
23. Continuation of MCMC techniques using Gibbs sampling for efficient Bayesian computation.

**Reference Material:**


1. Data Science and Predictive Analytics: Biomedical and Health Applications using R Second Edition 2023 by Ivo D. Dinov
2. Introduction to Time Series Analysis and Forecasting 3rd Edition, 2024 by Douglas C. Montgomery, Cheryl L. Jennings, Murat Kulahci
3. Hamilton, James D. Time Series Analysis. Princeton University Press, 1994. ISBN: 9780691042893.


## Course Title: Estimation Theory

**Course Code: IDDE-711**
**Course Structure: Lectures: 3/Labs: 0**
**Credit Hours: 3**
**Prerequisites: None**

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**Course Objective:**

Uncertainty is inherent in many engineering domains, including communications, radar, medical imaging, and more. These applications often require the estimation of parameters and detection of data amidst high levels of noise and uncertainty. For instance, in communications, it is common to estimate characteristics such as frequency, amplitude, and phase—each of which can carry critical information. With a wide range of methods available for parameter estimation, this course explores how to determine the most effective approach under noisy and uncertain conditions. It addresses fundamental questions such as how to define the "best" method and how to reliably identify whether the observed data conforms to a specific model, such as a sinusoid.

**Course Syllabus:**

This course offers an overview of the theory and practical applications of time series methods in econometrics. Topics include univariate models for both stationary and non-stationary data, vector autoregressions, frequency domain techniques, approaches for estimation and inference in persistent time series, and the analysis of structural breaks

**Course Outline:**

1. Introduction to the course, grading policies, and a brief review of key probability concepts including distributions and expectations.
2. Foundations of linear algebra and its applications in statistical modeling, including vector spaces and projections.

3. Further exploration of linear algebra concepts relevant to estimation, focusing on matrix operations and eigende composition.
4. Application of linear algebra in deriving Minimum Mean Square Error (MMSE) estimators for random variables.
5. Introduction to Minimum Variance Unbiased Estimators (MVUE) and the concept of sufficient statistics for estimation.
6. Deeper look at sufficient statistics and introduction to complete statistics for improving estimation accuracy.
7. Formulation and interpretation of the Cramer-Rao Lower Bound (CRLB) for single-parameter estimators.
8. Extension of the CRLB to multi-parameter cases and its implications for estimator performance.
9. Definition and derivation of the Best Linear Unbiased Estimator (BLUE) under Gauss-Markov assumptions.
10. Principles of Maximum Likelihood Estimation (MLE), consistency, efficiency, and asymptotic normality.
11. Introduction to Bayesian estimation using Minimum Mean Square Error (MMSE) under prior distributions (Part 1).
12. Continuation of Bayesian MMSE estimation, including conditional expectations and practical examples (Part 2).
13. Comparison between Bayesian Maximum A Posteriori (MAP) estimation and Linear MMSE (LMMSE) estimation.
14. Application of LMMSE estimation techniques leading into the fundamentals of the Kalman Filter.
15. Kalman Filter theory for recursive estimation in dynamic systems with linear Gaussian assumptions.
16. Introduction to statistical detection theory, including hypothesis testing, likelihood ratio tests, and performance metrics.

**Reference Material:**


1. Fundamentals of Statistical Signal Processing, Volume I: Estimation Theory 1st Edition by Steven Kay
2. Optimal Estimation and Information Fusion: Theory and Algorithms: Theory and Algorithms by Ming Lei, 2025 ISBN-978-9819631728
3. Set-Valued Approaches to Control and Estimation of Uncertain Systems: Theory and Applications by Thach Ngoc Dinh, Andreas Rauh , Sze Zheng Yong, 2025, 978-3031942389


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## Course Title: Social Network Analysis

**Course Code: IDDE-712**
**Course Structure: Lectures: 3/Labs: 0**
**Credit Hours: 3**
**Prerequisites: None**

**Course Objectives**

This course aims to equip students with the theoretical foundations and practical tools needed to analyze, model, and extract meaningful patterns from social networks. It introduces key concepts in network theory and computational techniques for large-scale data analysis, with applications in online platforms such as Twitter, Facebook, LinkedIn, and academic collaboration networks. Students will learn to understand and model user behavior, influence propagation, community structure, and link prediction in real-world networks. By the end of the course, students will be capable of designing data-driven solutions for social network challenges using graph-based algorithms and mining methods.

**Course Syllabus**

The syllabus introduces students to basic concepts in graph theory, types of social networks, and real-world data sources. It continues with foundational topics such as centrality measures, shortest path algorithms, and community detection. Midway through the course, students explore machine learning techniques for social networks, including node classification, influence maximization, link prediction, and clustering. Advanced topics such as signed networks, dynamic networks, and heterogeneous information networks are also covered. The course integrates practical skills by teaching how to mine data from social media platforms using APIs and perform network analysis using Python libraries like NetworkX and Gephi. It concludes with case studies, ethical considerations, and a hands-on capstone project.

**Course Outline**

1. Introduction to Social Networks and Graph Theory, graph terminology (nodes, edges, paths), types of graphs, social vs. technological vs. information networks, real-world datasets (Facebook, Twitter, citation networks)
2. Network Models and Structures, random graphs (Erdős–Rényi), small-world models (Watts-Strogatz), scale-free networks (Barabási-Albert), graph generation, structural patterns, power-law degree distribution
3. Centrality and Influence Measures, degree centrality, closeness centrality, betweenness centrality, eigenvector centrality, identifying influencers, hub detection
4. Community Detection and Clustering, community detection algorithms (Girvan–Newman, Louvain), modularity, strong vs. weak communities, overlapping clusters in social networks
5. Information Diffusion and Influence Propagation, SI, SIR, Independent Cascade models, viral marketing, influence maximization strategies
6. Link Prediction and Graph Embedding, similarity-based link prediction, supervised/unsupervised models, node2vec, DeepWalk, matrix factorization, graph neural networks
7. Mining Social Media Data, data extraction using APIs and scrapers (Twitter, Reddit, LinkedIn), data cleaning, temporal graph creation, NLP on user-generated content
8. Signed, Multiplex, and Dynamic Networks, positive/negative links, trust/distrust networks, multiplex interactions, temporal and dynamic graphs, time-aware modeling
9. Behavioral Modeling and Anomaly Detection, behavioral patterns (homophily, triadic closure, reciprocity), anomaly and spam detection, topological and metadata analysis
10. Ethics, Privacy, and Misuse of Network Data, data privacy, surveillance, misinformation, legal and ethical concerns, responsible mining principles
11. Visualization and Interpretation of Social Networks, visualization tools (Gephi, Cytoscape, NetworkX), visual pattern interpretation, layout algorithms (force-directed, hierarchical)
12. Project in Social Network Analysis, hands-on data analysis, real-world network selection, applying learned methods, visualization and reporting of insights

**Reference Material**


1. Social Network Analysis and Mining Applications in Healthcare and Anomaly Detection – Mehmet Kaya, Sleiman Alhajj, Kashfia Sailunaz, & Min-Yuh Day (eds., 2024) – ISBN 9783031752032
2. Social Network Analysis: Theory and Applications – Mohammad G. Galety, Chiai Al-Atroshi, Buni Balabantaray, & Sachi N. Mohanty (eds., 2022) – ISBN 9781119836230
3. Social Media Mining – Deryck Scrivenor (2022) – ISBN 9781645341291


## Course Title: Edge and Fog – Driven Data Processing

**Course Code: IDDE-713**
**Course Structure: Lectures: 3/Labs: 0**
**Credit Hours: 3**
**Prerequisites: None**

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**Course Objectives**

**Course Objectives**

This course aims to provide an in-depth understanding of edge and fog computing paradigms, emphasizing their role in modern distributed systems for real-time and low-latency data processing. Students will explore architectural differences between cloud, fog, and edge layers, learn to design latency-sensitive applications, and gain hands-on experience with edge/fog frameworks. The course will also focus on energy-efficient processing, security challenges, and integration of AI models at the edge to support intelligent, decentralized decision-making in IoT, healthcare, smart cities, and industrial systems.

**Course Syllabus**

The syllabus covers foundational concepts of edge and fog computing, including architectural layers, system components, and deployment models. It delves into data communication, streaming analytics, and lightweight AI/ML at the edge. Students will analyze trade-offs in latency, power, and bandwidth, and study platforms such as EdgeX Foundry, OpenFog, and AWS Greengrass. Topics include data orchestration, microservices at the edge, containerization, and scalability strategies. Through real-world case studies and lab-based assignments, learners will apply concepts in environments like smart transportation, precision agriculture, and telemedicine.

**Course Outline**

1. Introduction to Edge, Fog, and Cloud Computing; definitions, motivations, comparisons, roles in distributed systems
2. Use Cases and Applications of Edge/Fog Computing; smart cities, autonomous vehicles, industrial IoT, healthcare
3. Architectural Models and Frameworks; hierarchical and flat architectures, fog-to-cloud continuum, OpenFog, ETSI MEC
4. Edge and Fog Nodes: Hardware and Software Stack; Raspberry Pi, Jetson Nano, gateways, firmware, OS constraints
5. Data Acquisition and Preprocessing at the Edge; sensor data collection, cleaning, normalization, compression
6. Real-Time and Streaming Data Processing; stream engines like Apache Kafka and Flink, MQTT-based communication
7. Edge Artificial Intelligence and Machine Learning; lightweight ML models, TensorFlow Lite, PyTorch Mobile, federated learning
8. Containerization and Microservices for Edge Deployment; Docker, K3s, Kubernetes for edge environments
9. Edge-to-Cloud Integration and Communication Protocols; REST APIs, CoAP, MQTT, DDS, 5G, latency and throughput trade-offs
10. Orchestration and Resource Management; resource allocation, dynamic provisioning, task migration, mobility support
11. Power Efficiency and Energy-Aware Computing; energy profiling, dynamic power management, low-power design
12. Security, Privacy, and Trust in Edge/Fog Systems; data protection, access control, TEEs, blockchain integration
13. Simulation and Modeling of Edge/Fog Environments; tools like iFogSim, YAFS, EdgeCloudSim, experiment reproducibility
14. Benchmarking and Performance Evaluation; latency, bandwidth, QoS metrics, edge testbed deployments
15. Ethics, Compliance, and Legal Considerations; GDPR, edge data ownership, regulatory frameworks,

Kh. M. A 03/03/26

Department of Information Technology
University of Sargodha

16. Industry Standards and Future Trends; standardization efforts (ETSI, OpenFog), 6G, edge-AI convergence
17. Case Studies and Industrial Practices; real-world deployments in agriculture, smart energy, logistics Capstone Project/Prototype Design; building and evaluating a functional edge or fog computing application

**Reference Material:**


1. Cloud-Native Architecture: Building Future-Proof, Scalable, and Resilient Applications through Microservices, Containers, and Cloud-Driven Innovation Kindle Edition by Sam Miley, 2025
2. FOG AND EDGE COMPUTING : 2nd Edition by Ajit Singh, 2021,
3. Cloud Security in the Edge and Fog Computing Era by Yogesh Ramaswamy, 2025, ISBN - 978-6206161691


## Course Title: Blockchain and Data Technologies

**Course Code: IDDE-714**
**Course Structure: Lectures: 3/Labs: 0**
**Credit Hours: 3**
**Prerequisites: None**

**Course Objectives**:

aims to equip students with advanced knowledge and skills in understanding, designing, and implementing blockchain technologies. Participants will explore the core principles of decentralized consensus, cryptographic foundations, and smart contract development. The course will delve into real-world applications beyond cryptocurrencies, addressing challenges and opportunities in sectors such as finance, healthcare, and supply chain. By the course's conclusion, students will have the expertise to contribute to innovative blockchain research, develop decentralized solutions, and critically analyze the societal impact of blockchain technology.

**Course Syllabus:**

Cryptocurrency Wallets: Assessment and Security, Cyber-Physical Systems Security: Analysis, Opportunities, Challenges, and Future Prospects, Cybersecurity-Based Blockchain for Cyber-Physical Systems: Challenges and Applications, Trust Management in Cyber-Physical Systems: Issues and Challenges, Blockchain-Based Authentication in IoT Environments: A Survey: Blockchain Technology-Based Smart Cities: A Privacy-Preservation Review, Security in Electronic Health Records System: Blockchain-Based Framework to Protect Data Integrity, A Secure Data-Sharing Framework Based on Blockchain: Teleconsultation Use-Case, Reputation-Based Consensus on a Secure Blockchain Network, AI and Blockchain for Cybersecurity in Cyber-Physical Systems: Challenges and Future Research Agenda, Assessing the Predictability of Bitcoin Using AI and Statistical Models , Proactive AI Enhanced Consensus Algorithm with Fraud Detection in Blockchain

**Reference Material:**


1. Blockchain for Cybersecurity in Cyber-Physical Systems, Yassine Maleh, Mamoun Alazab, Imed Romdhani -Springer (2023)
2. Blockchain for Cybersecurity and Privacy (Internal Audit and IT Audit), Yassine Maleh (editor) - - CRC Press (2020)


## Course Title: Spatial and Visual Data Analytics

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**Course Code: IDDE-715**
**Course Structure: Lectures: 3/Labs: 0**
**Credit Hours: 3**

**Prerequisites: None**

**Course Objectives:**
The course concentrates on the knowledge of Computer Vision and its importance in Computing area having multiple applications.

**Course Syllabus:**
Introduction to Computer Vision, Image formation, Processing, Feature Detection and Matching, Alignment, Image Stitching, Dense Motion Estimation, Structure from Motion, Recognition, Computational Photography, Stereo Correspondence, 3D Reconstruction, Image-based Rendering, Statistical Texture Description, Methods Based on Spatial Frequencies, Laws" Texture Energy Measures, Texture Recognition Method Applications.

**Course Syllabus:**

1. Computer vision fundamentals, key challenges, and major application areas like object detection and 3D modeling.
2. Understanding how images are formed through optics, sensors, and the physical process of image capture.
3. Basic image processing techniques including filtering, enhancement, smoothing, and edge detection.
4. Detection and matching of key features (e.g., corners, blobs) using algorithms like SIFT and Harris detector.
5. Aligning images using matched features for tasks like panoramic stitching and object tracking.
6. Techniques for stitching multiple images into a seamless panorama using geometric transformations.
7. Estimating dense motion fields (optical flow) for tracking movement across video frames.
8. Reconstructing 3D structure from multiple 2D images using camera motion and point correspondences.
9. Introduction to object recognition using classifiers, neural networks, and feature descriptors.
10. Computational photography techniques like HDR imaging, deblurring, and focus manipulation.
11. Finding correspondences between stereo images to estimate depth and generate disparity maps.
12. Recovering 3D models of scenes using multiple views and depth estimation techniques.
13. Rendering new views of scenes from existing images using image-based rendering approaches.
14. Describing textures statistically using spatial frequency, edge frequency, co-occurrence, and run-length features.
15. Advanced texture analysis techniques: texture energy measures, wavelets, syntactic methods, and hybrid approaches with applications in texture classification and segmentation.

**Reference Material:**

1. Introduction to Spatial Data Analysis by Martin Wegmann, Jakob Schwalb-Willmann, Stefan Dech, 2020,
2. Foundations of Computer Vision (Adaptive Computation and Machine Learning series) by Antonio Torralba, Phillip Isola, William T. Freeman, 2020, ISBN - 978-0262048972

## Course Title: Advanced Deep Learning

**Course Code: IDDE-716**
**Course Structure: Lectures: 3/Labs: 0**
**Credit Hours: 3**
**Prerequisites: None**

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University of Sargodha

**Course Objectives:**

This course will introduce advanced understanding and practical skills in deep learning. Students will learn to overcome the limitations of traditional machine learning through the study of neural networks, optimization techniques, and advanced architecture like convolutional and recurrent neural networks. They will explore applications in computer vision, natural language processing, and robotics, while gaining proficiency in large-scale learning and recent advancements in deep learning research. By the end of the course, students will be equipped to tackle complex real-world problems using cutting-edge deep learning techniques.

**Course Syllabus:**

The course syllabus covers a range of advanced topics in deep learning. Beginning with an exploration of machine learning limitations and the necessity for non-linear mappings, the course progresses to delve into foundational neural network concepts such as backpropagation and optimization techniques. Students will then study specialized architecture including convolutional and recurrent neural networks, along with their applications in computer vision, natural language processing, and robotics. Advanced optimization methods and topics like sparse coding, autoencoders, and probabilistic graphical models are also covered. Additionally, recent advancements in deep learning research, large-scale learning, and neural Turing machines are discussed to provide students with a comprehensive understanding of cutting-edge techniques.

**Course Outline:**

1. Introduction: Overview of the limitations of traditional machine learning algorithms (e.g., linear models, decision trees), Challenges with high dimensional data and complex relationships, Need for more powerful models to capture nonlinear patterns and hierarchical representations, Machine Learning, Nonlinear mappings: Introduction to nonlinear mappings in machine learning, Importance of nonlinearity in modeling complex relationships in data, Comparison between linear and nonlinear models, Neural Networks: Basics of neural network architecture (neurons, layers, activation functions), Feedforward neural networks and their applications, Overview of deep neural networks and their advantages over shallow models
2. NonLinear Optimization, Stochastic/MiniBatch Gradient Descent: Introduction to optimization techniques in neural networks, Gradient descent optimization and its variants (stochastic gradient descent, minibatch gradient descent), Importance of stochastic and minibatch gradient descent for largescale learning
3. Back Propagation: Backpropagation algorithm for training neural networks, Calculation of gradients using the chain rule, Role of backpropagation in updating model parameters during training
4. Deep Sparse Coding: Sparse coding as a method for unsupervised feature learning, Introduction to deep sparse coding and its applications in feature extraction, Sparse Autoencoders (SAE): Autoencoders and their role in unsupervised learning, Sparse autoencoders and their ability to learn efficient representations of data, Applications of sparse autoencoders in dimensionality reduction and feature learning
5. Convolutional Neural Networks (CNNs): Architecture of convolutional neural networks, Importance of convolutional layers for capturing spatial hierarchies in data, Applications of CNNs in computer vision tasks such as image classification, object detection, and segmentation, Descriptor Matching techniques in computer vision, Role of CNNs in improving descriptor matching accuracy and efficiency
6. Stereo-based Obstacle Avoidance for Robotics: Overview of stereo vision for depth perception in robotics, CNN-based approaches for obstacle detection and avoidance, Real-world applications of stereo-based obstacle avoidance systems
7. Pooling and Invariance: Pooling layers in CNNs and their role in achieving translation invariance, Importance of invariance in object recognition tasks, Strategies for designing pooling layers in CNN architectures

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8. Visualization/Deconvolutional Networks: Visualization techniques for interpreting deep neural networks, Deconvolutional networks for visualizing feature activations, Applications of visualization techniques in model debugging and understanding
9. Recurrent Neural Networks (RNNs) and their optimization: Architecture of recurrent neural networks, Challenges in training RNNs (e.g., vanishing gradients), Optimization techniques for training RNNs (e.g., gradient clipping, LSTM cells)
10. Applications to NLP: Introduction to natural language processing (NLP) tasks, Applications of RNNs in NLP tasks such as language modeling, text generation, and machine translation, Recent advances in NLP using deep learning techniques
11. Hessian Free Optimization: Overview of Hessian free optimization methods, Advantages of Hessian free optimization over traditional gradient-based methods, Applications of Hessian free optimization in training deep neural networks
12. Language analysis: word/sentence vectors, parsing, sentiment analysis, etc.: learning for text data using word embeddings, Syntax parsing techniques for understanding grammatical structures in sentences, Sentiment analysis using deep learning models
13. Probabilistic Graphical Models: Introduction to probabilistic graphical models (PGMs), Representation of PGMs using Bayesian networks and Markov networks, Inference algorithms for probabilistic graphical models (e.g., belief propagation, Gibbs sampling)
14. Hopfield Nets, Boltzmann machines: Overview of Hopfield networks and their applications in associative memory, Boltzmann machines as stochastic neural networks, Learning algorithms for Boltzmann machines (e.g., contrastive divergence), Deep Belief Nets, Stacked RBMs: Deep belief networks as generative models composed of multiple layers of restricted Boltzmann machines (RBMs), Training algorithms for deep belief networks (e.g., contrastive divergence, wake-sleep algorithm), Applications of deep belief networks in unsupervised learning and feature learning
15. Applications to NLP, Pose and Activity Recognition in Videos: Further applications of deep learning in natural language processing, including question answering and text summarization, Deep learning approaches to pose estimation and activity recognition in videos, Real-world examples of NLP and video analysis applications
16. Recent Advances: Overview of recent advancements in deep learning research: Cutting-edge techniques and architectures (e.g., attention mechanisms, capsule networks, self-supervised learning), Potential future directions and challenges in deep learning
17. Large-Scale Learning: Challenges and techniques for scaling deep learning models to large datasets, Distributed training frameworks (e.g., TensorFlow, Py-Torch distributed), Strategies for efficient model deployment and inference in production systems
18. Neural Turing Machines: Introduction to neural Turing machines (NTMs) as differentiable computers, Architecture of NTMs and their memory-augmented capabilities, Applications of NTMs in algorithmic tasks and sequential decision-making

**Reference Material**


1. Elements of Deep Learning Theory by Golikov , 2025, ISBN - 978-9811271267
2. Deep Learning for Intrusion Detection: Techniques and Applications 1st Edition by Faheem Syeed Masoodi, Alwi Bamhdi, 2025, ISBN - 978-1394285167


## Course Title: Advanced Data Mining

**Course Code: IDDE-717**
**Course Structure: Lectures: 3 / Labs: 0**
**Credit Hour: 3**
**Prerequisites:**
**None**

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**Course Objectives:**

The course "Data Mining: Techniques and Applications" aims to provide students with a comprehensive understanding of data mining concepts and methodologies. Through the exploration of topics such as preprocessing techniques, association rule mining, classification, clustering, and performance evaluation measures, students will gain practical skills in handling and analyzing large datasets. Additionally, they will learn about emerging trends in data mining research, including web and social network mining, big data, and the Internet of Things. By the end of the course, students will be proficient in applying data mining techniques to solve real-world problems and will have practical experience implementing concepts using Python programming language.

**Course Syllabus:**

The course "Data Mining" offers a comprehensive exploration of data mining concepts and methodologies. Beginning with an introduction to data mining, including its applications and significance, the course delves into various techniques such as text data analysis and social network mining. It covers data types and datasets, emphasizing the characteristics of structured data and numeric attribute types. Preprocessing techniques are discussed in detail, including data cleaning, integration, reduction, compression, and transformation, along with the assessment of data quality through summary statistics. The course proceeds to explore association rule mining, focusing on frequent pattern analysis and rule generation using algorithms like Apriori and FP-growth. It also addresses classification methods, including supervised and unsupervised techniques such as decision trees, Naïve Bayes, and K-means clustering. Practical tools like WEKA and RapidMiner are introduced for data exploration and model development. Other topics covered include outlier detection, performance evaluation measures, distance and similarity measures, and emerging trends in data mining research such as web and social network mining, big data, and the Internet of Things. The course also includes hands-on implementation of concepts using Python programming language.

**Course Outline:**

Following is a tentative syllabus for the class:

1. Introduction to data mining, basic concepts, Applications and Significance, Types of Basic DM techniques, Text Data Analysis, Graph Data Analysis, Social Network Mining
2. Data Types and Datasets, Characteristics of Structured Data, Data Objects, Attributes, Types of Attributes, Numeric Attribute types.
3. Pre-Processing Techniques Data Cleaning, Handle missing classes, Data integration, Data reduction, Data Compression, Data transformation, Data Quality, Summary Statistics.
4. Association Rule mining, Table Analysis, Frequent Pattern Analysis, Applications, Document Analysis, Support & Confidence
5. Association Rule mining using Apriori Algorithm and Frequent Pattern Trees, FP-growth, Mining Frequent Itemsets Using the Vertical Data Format, Rule Generation using Confidence.
6. Introduction to Classification Types; Supervised Classification, UnSupervised Classification, Binary classification, multi classification, Clustering, Prediction problems,
7. Supervised Classification (Rule based mining- Decision trees, Naïve Bae Classification, KNearest Neighbors, Support Vector Machines etc.), Model Construction, Train model.
8. Associative Classification, Classifications of algorithm
9. Unsupervised Classification (K Means, K Mediod, Hieratical and Divisive Clustering, Kohonan Self Organizing maps),
10. Types of Clustering (Hierarchical algorithms, Partitional clustering), Cluster Analysis, Inter-Cluster, Cluster Similarity, Cluster Validity, Cohesion and Separation, Agglomerative Clustering
11. Tool WEKA, Exploration (Preprocess data, Classification, Clustering, Association Rules, Attribute Selection, Data Visualization)
12. Tool: Rapid Miner introduction (Preprocess, Loading, Visualizing, apply model, Testing Model , Results, Performance of model)



Kh.M.A 03/03/26
Department of Information Technology
University of Sargodha

13. Outlier & anomaly detection,
14. Performance Evaluation Measures, confusion matrix, Accuracy and Error, precision, recall, f1score, sensitivity, ROC, AUC
15. Distance and Similarity Measures, Euclidean distance, Manhattan distance, Jaccard Coefficient, Dice coefficient, Cosine Similarity, TF □ DF □ IDF, Applications, Algorithms.
16. Web, and Social Network Mining, Data Mining Trends and Research Frontiers, Data Science (BI), Big Data, Speech Recognition , Internet of Things: Connected Home / Internet of Everything, Virtual Personal Assistants, Content Analytics, Hybrid Cloud Computing, Virtual Reality / Augmented Reality
17. Implementing concepts using Python

**Reference Material:**


1. Data Mining: Concepts and Techniques (The Morgan Kaufmann Series in Data Management Systems) 4th Edition by Jiawei Han, Jian Pei , Hanghang Tong, 2022, ISBN - 978-0128117606
2. Data Mining: Practical Machine Learning Tools and Techniques 5th Edition, by Ian H. Witten, Eibe Frank, Mark A. Hall, Christopher J. Pal, 2025, 978-0443158896


# Course Title: Advanced Machine Learning

**Course Code: IDDE-718**
**Credit Hour: 3**
**Prerequisites: None**
**Course Structure: Lectures: 3 / Labs: 0**

**Course Objectives:**

In this course, student will learn about the most effective machine learning techniques, and gain practice implementing them and getting them to work. More importantly, student will learn about not only the theoretical underpinnings of learning, but also gain the practical know-how needed to quickly and powerfully apply these techniques to new problems.

**Course Syllabus:**

This course provides a broad introduction to machine learning, data mining, and statistical pattern recognition. Topics include: (i) Supervised learning (parametric/non-parametric algorithms, support vector machines, kernels, neural networks). (ii) Unsupervised learning (clustering, dimensionality reduction, recommender systems, deep learning). (iii) Best practices in machine learning (bias/variance theory; innovation process in machine learning and AI). The course will also draw from numerous case studies and applications, so that you'll also learn how to apply learning algorithms to building smart robots (perception, control), text understanding (web search, anti-spam), computer vision, medical informatics, audio, database mining, and other areas.

**Course Outline:**

1. Introduction to machine learning concepts, types (supervised, unsupervised), and real-world applications.
2. Understanding linear regression for predicting continuous outcomes and evaluating model fit.
3. Gradient Descent as a general optimization method for parameter learning in various ML models.
4. Classification using logistic regression, handling multi-class problems with One-vs-All, and controlling overfitting with regularization.
5. Introduction to neural networks, their structure, activation functions, and forward/backward propagation.

6. Best practices for applying ML algorithms including debugging, feature engineering, and experimental design.
7. Basics of probability theory and Bayesian inference, foundational for probabilistic models.
8. Naive Bayes classifier and its assumption of feature independence for fast, interpretable predictions.
9. Support Vector Machines (SVMs), their geometric intuition, and use of kernels for non-linear classification.
10. Unsupervised learning techniques such as K-means for clustering and PCA for dimensionality reduction.
11. Anomaly detection methods for identifying unusual patterns or outliers in data.
12. Bayesian Belief Networks as directed probabilistic models for representing uncertainty and dependencies.
13. Learning structure and parameters of probabilistic graphical models from data.
14. Expectation-Maximization (EM) algorithm for parameter estimation in models with hidden variables.
15. Hidden Markov Models (HMMs) for modeling sequential data with hidden state dynamics.
16. Hidden Markov Models

**Reference Material:**


1. Designing Machine Learning Systems: An Iterative Process for Production-Ready Applications 1st Edition by Chip Huyen, 2022, ISBN - 978-1098107963
2. Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems 3rd Edition by Aurélien Géron, 2022, ISBN - 978-1098125974


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# Course Title: Understanding of Holy Quran I

**Course Code: URCG-5129**

## Model Course Outline
## for the Course Understanding of Quran – I

Course Title: Understanding of Quran – I
Course Book: Muallim ul Quran (Volume 1, 2 & 3) by Dr Ubaid ur Rahman
Credit Hours: 1 (0-1)
Contact Hours: 3 per week
Weeks: 15-16 (45-48 hours)

### Course Learning Outcomes:

*By the end of this course, students will be able to:*

1. Develop the ability to understand basic words of the Quran, phrases and sentences that do not contain verbs (unit 1 to 5 of Muallim ul Quran Book) and then sentences having present tense (first half of unit 6 of Muallim ul Quran Book).
2. Acquire a strong foundation for understanding long verses of the Quran with clarity.
3. Comprehend Quranic vocabulary, particles (operative & non operative particles) , compounds (Adjective & Possessive compound), pronouns (singular & plural) and types of plural through hundreds of Quranic sentences.
4. Recognize and understand different styles of Quranic sentences, including nominal sentence, emphatic sentence, double emphatic sentence, negative sentence, interrogative sentence, oath –based sentences.
5. Strengthen understanding of fundamental Quranic linguistic styles, expressions and idioms.
6. Understand at least 30 to 40 % of each page of the holy Quran.

### Provision of material, content and books:

- **Paper book:** All volumes are available in printed book form.
- **Tutorial videos:** Teaching video of each lesson available on YouTube.
- **Confirmation Videos:** A complete series of confirmation videos of all lessons is available in which the student can confirm his answers.
- **A flipbook:** A flipbook edition is also accessible.
- **Helping material:** Helping material for the teachers like quizzes, question papers and images is available on website.

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## Course Outline:

| Weeks | Lectures (1.5 hrs) | Units | Lessons | Assignments/Home Task | Linguistic Rules |
|---|---|---|---|---|---|
| 1. | 1. | 1 | 1-6 | Writing the meaning of Quranic words Lesson 1-8 | Proper Noun Masculine & Feminine |
| | 2. | 1 | 9-14 | Writing the meaning of Quranic words 9-14 | Two kinds of plural Concept of (و) "And" Common Noun |
| 2. | 1. | 1 | 15-17 | Writing the meaning of Quranic words, phrases & translation of Sentences 15-17 | Demonstrative Noun (This & That for Masculine (هذا- هذه) Demonstrative Noun (This & That for Feminine) (ذلك- تلك) |
| | 2. | 1 | 18-19 & Revision (Unit 1) | Writing the meaning of Quranic words , phrases & translation of Sentences 17-19 Quiz | Laam for emphasis (لام التاكيد) Superlative Degree like اكبر Revision of all Quranic Sentences |
| 3. | 1. | Unit 2 | 1-3 | Writing the meaning of Quranic words, phrases & translation of Sentences 1-3 | Emphatic Particle إن Preposition "For" ( اللام) Preposition (في) |
| | 2. | 2 | 4-6 | Writing the meaning of Quranic words, phrases & translation of Sentences 4-6 | Preposition (على- من- إلى) |
| 4. | 1. | 2 | 7- 9 | Writing the meaning of Quranic words & translation of Sentences 7-9 | Preposition (الباء) Absolute Negation Particle Exceptive Particle ( لا النافية للجنس)( ما النافية) (إلا) |
| | 2. | 2 | 10-13 & Revision (Unit 2) | Writing the meaning of Quranic words, phrases & translation of Sentences 10-13 Quiz | Subordinating Conjunction(أن), Was (كان), Vocative Particle(حرف النداء) |

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03/03/26

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| 5. | 1. | Unit 3 | 1-2 | Writing the meaning of Quranic phrases 1-2 | Quranic Adjective Compounds (صفة وموصوف) |
| | 2. | 3 | 3-5 | Writing the meaning of Quranic phrases & translation of sentences 3-5 | Quranic Possessive Construction (مضاف ومضاف إليه) |
| 6. | 1. | 3 | 6 -7 | Writing the meaning of Quranic phrase translation of sentences 6-7 | Quranic Possessive Construction (مضاف ومضاف إليه) |
| | 2. | 3 | 8-10 & Revision (Unit 3) | Writing the meaning of Quranic phrase & translation of sentences 8-10 Quiz | Active Participle (اسم الفاعل), Passive Participle (اسم المفعول), Dual (مثنى) |
| 7. | 1. | Unit 4 | 1-2 | Writing the meaning of Quranic phrase.& translation of sentences 1-2 | Personal Pronoun He( هو المنفصل) Possessive Pronoun His ـه المتصل) |
| | 2. | 4 | 3-4 | Writing the meaning of Quranic phrase & translation of sentences 3 -4 | Possessive Pronoun with prepositions like في بيته Pronoun "His" with prepositions like له، منه، فيه |
| 8. | 1. | 4 | 5-8 | Writing the meaning of Quranic sentences 5-8 | Personal Pronoun You( أنت المنفصل) Possessive Pronoun Your ك المتصل) Possessive Pronoun with prepositions like في بيتك Pronoun "your" with prepositions like لك، منك، فيك |
| | 2. | Mid Term | | | |

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| 9. | 1. | 4 | 9-12 | Writing the meaning of Quranic phrases & sentences 9-12 | Personal Pronoun She( هي المنفصل) Possessive Pronoun Her ها المتصل) Possessive Pronoun with prepositions like في بيتها Pronoun "Her" with prepositions like لها |
| | 2. | 4 | 13-16 | Writing the meaning of Quranic phrases & sentences 13-16 | Personal Pronoun I ( أنا المنفصل) Possessive Pronoun Her ي المتصل) Possessive Pronoun with prepositions like في بيتي Pronoun "My" with prepositions like لي |
| 10. | 1 | 4 | 17 & Revision Unit 4 | Revision of all Quranic sentences of Unit 4 Quiz | Adverb (حال) |
| | 2. | Unit 5 | 1-2 | Writing the meaning of Quranic phrases & sentences 1-2 | Masculine Plural جمع المذكر السالم و جمع المذكر السالم المسبوق بحرف الجر |
| 11. | 1. | 5 | 3-4 | Writing the meaning of Quranic phrases & sentences 3-4 | Possessive Construction with Plurals جمع المذكر السالم المسبوق بالإضافة |
| | 2. | 5 | 5-6 | Writing the meaning of Quranic phrases, sentences & verses 5-6 | Personal Pronoun They ( هم المنفصل) Possessive Pronoun Their هم المتصل) |
| 12. | 1. | 5 | 7-8 | Writing the meaning of Quranic phrases, sentences & verses 7-8 | Possessive Pronoun with prepositions like في بيتهم Pronoun "Their" with prepositions like لهم |
| | 2. | 5 | 9-11 | Writing the meaning of Quranic phrases, sentences & verses 9-11 | Personal Pronoun You ( أنتم المنفصل) Possessive Pronoun Your كم المتصل) Possessive Pronoun with prepositions |

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| | | | | | like في بيتكم |
| 13. | 1. | 5 | 12-14 | Writing the meaning of Quranic phrases & sentences & verses 12-14 | Pronoun "Your" with prepositions like لكم<br>Personal Pronoun We ( نحن المنفصل)<br>Possessive Pronoun Our نا المتصل) |
| | 2. | 5 | 15-16 | Writing the meaning of Quranic sentences & verses 15-16 | Possessive Pronoun with prepositions like في بيتنا<br>Pronoun "Our" with prepositions like لنا |
| 14. | 1. | 5 | 17-18 | Writing the meaning of Quranic sentences & Verses 17-18 | Demonstrative Pronoun These, Those ( هؤلاء- أولئك) |
| | 2. | 5 | 19-23 | Writing the meaning of Quranic sentences & Verses 19-23 | ما / إلا، إن / إلا، إنما، ليس، ما ، ( أم/أم، أن، بل، كأن)<br>( الا، أليس، اليوم، يومئذ، سبحان، مابينهما، قل، إذن، بئس، نعم، كلا، ما أدراك، حسب، أعلم ب، مصير، مرجع، دينا(تمييز) |
| 15. | 1. | 5 | Revision Unit 5 | Quiz | |
| | 2. | 5 | 1-3 (till Page 16) | Writing the meaning of Quranic Verbs &Translation of Quranic Sentences & Verses (1-3) | Introduction of Present Tense(فعل مضارع) & Verbal Sentence ( جملة فعلية)<br>Present Tense<br>الفعل المضارع صيغة المفرد يعلم |
| 16. | 1. | 6 | 3 (From Page 17) & 4 -5 | Translation of Quranic Sentences & Verses 3-5 | Present Tense<br>الفعل المضارع صيغة المفرد يعلم |
| | 2. | 6 | 6 | Translation of Quranic Sentences & Verses | Present Tense<br>الفعل المضارع صيغة الجمع يعلمون |

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# Course Title: Understanding of Holy Quran II

**Course Code: URCG-5130**

## Model Course Outline
## for the Course Understanding of Quran – II

Course Title: Understanding of Quran – II
Course Book: Muallim ul Quran (Volume 3, 4 & 5) by Dr Ubaid ur Rahman
Credit Hours: 1 (0-1)
Contact Hours: 3 per week
Weeks: 15-16 (45-48 hours)

### Course Learning Outcomes:

*By the end of this course, students will be able to:*

1. Directly comprehend hundreds of Quranic sentences & verses.
2. Understand at least 80 to 85 % of each page of the holy Quran.
3. Understand common verses across different Quranic topics.
4. Achieve proficiency in the basic and advance linguistic aspects of the Arabic language.
5. Understand the difference between Quranic verbs in various forms, such as present, past and imperative.
6. Develop the ability to understand long verses of the holy Quran independently and then comprehend their interpretation.

### Provision of material, content and books:

- **Paper book:** All volumes are available in printed book form.
- **Tutorial videos:** Teaching video of each lesson available on YouTube.
- **Confirmation Videos:** A complete series of confirmation videos of all lessons is available in which the student can confirm his answers.
- **A flipbook:** A flipbook edition is also accessible.
- **Helping material:** Helping material for the teachers like quizzes, question papers and images is available on website.

### Course Outline:

| Weeks | Lectures | Units | Lessons | Assignments/Home Task | |
|---|---|---|---|---|---|
| 1. | 1. | 6 | 6 | Understanding & Translation of Verses | Present Tense صیغۃ جمع مذکر غائب مثل یعبدون |
| | 2. | 6 | 7-8 | Understanding & Translation of Verses | Present Tense صیغۃ جمع مذکر غائب مثل یعبدون |
| 2. | 1. | 6 | 9-10 | Understanding & Translation of Verses | Present Tense صیغۃ مفرد مذکر مخاطب (تعبد) وجمع مذکر مخاطب ( تعبدون) |
| | 2. | 6 | 11-12 | Understanding & Translation of Verses | Present Tense صیغۃ جمع مذکر مخاطب ( تعبدون) |

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| | | | | | صیغہ المتکلم (واحد) |
| 3. | 1. | 6 | 13 | Understanding & Translation of Verses | Present Tense<br>صیغہ جمع المتکلم (نحن) |
| | 2. | 6 | 14-15 | Understanding & Translation of Verses | Negative imperative<br>صیغۃ المفرد و صیغۃ الجمع لا تعبد، لا تعبدا |
| 4. | 1. | 6 | 16-17 | Understanding & Translation of Verses | Conditional Sentences & masdar moawal<br>(مصدر مؤول) |
| | 2. | 6 | 18-19 | Understanding & Translation of Verses | Laam uttaleel<br>(لام التعلیل) &<br>Laam ul jhood(لام الجحود) |
| 5. | 1. | 6 | 20-21 | Understanding & Translation of Verses | Present with object pronouns & Passive Voice |
| | 2. | 6 | Revision (Unit 6) | Quiz | |
| 6. | 1. | Unit 7 | 1 (sec 1-3) | Understanding & Translation of Verses | Past Tense<br>صیغۃ المفرد الغائب |
| | 2. | 6 | 1 (Sec 4-5) | Understanding & Translation of Verses | Past Tense<br>صیغۃ المفرد الغائب |
| 7. | 1. | 6 | 1 (Sec 5-6) | Understanding & Translation of Verses | Past Tense<br>صیغۃ المفرد الغائب |
| | 2. | 6 | 1 (Sec 7-9) | Understanding & Translation of Verses | Past Tense<br>صیغۃ المفرد الغائب |
| 8. | 1. | 7 | Revision | Understanding & Translation of Verses<br>QUIZ | Past Tense<br>صیغۃ المفرد الغائب |
| | 2. | MID TERM | | | |
| 9. | 1. | 7 | 2 (sec 1-2) | Understanding & Translation of Verses | Past Tense<br>صیغۃ الجمع للغائب عبدوا |
| | 2. | 7 | 2 (sec 3) | Understanding & Translation of Verses | Past Tense<br>صیغۃ الجمع للغائب عبدوا |
| 10. | 1. | 7 | 2 (sec 4-5) | Understanding & Translation of Verses | Past Tense<br>صیغۃ الجمع للغائب عبدوا |
| | 2. | 7 | 2 (sec 6-7) | Understanding & Translation of Verses | Past Tense<br>صیغۃ الجمع للغائب عبدوا |
| 11. | 1. | 7 | 3 (sec 1-2) | Understanding & Translation of Verses | Past Tense<br>صیغۃ الجمع للمتکلم عبدنا |

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| | 2. | 7 | 3 (sec 2-3) | Understanding & Translation of Verses | Past Tense صيغة الجمع للمتكلم عبدنا |
| 12. | 1. | 7 | 3 (sec 3-4) | Understanding & Translation of Verses | Past Tense صيغة الجمع للمتكلم عبدنا |
| | 2. | 7 | 3 (sec 4-5) | Understanding & Translation of Verses | Past Tense صيغة الجمع للمتكلم عبدنا |
| 13. | 1. | 7 | 4 (sec 1-2-3) | Understanding & Translation of Verses | Past Tense صيغة الجمع للمخاطب عبدتم |
| | 2. | 7 | 4 (sec 4-5) | Understanding & Translation of Verses | Past Tense صيغة الجمع للمخاطب عبدتم |
| 14. | 1. | 7 | 5-6 | Understanding & Translation of Verses Quiz | Past Tense صيغة المتكلم والمخاطب عبدتُ، عبدتَ |
| | 2. | 7 | 7 | Understanding & Translation of Verses | Past Tense صيغة المؤنث للغائب عبدتْ |
| 15. | 1. | 7 | 8 | Understanding & Translation of Verses | Passive Voice (Past Tense) فعل مجهول للمفرد |
| | 2. | 7 | 9 | Understanding & Translation of Verses | Passive Voice (Past Tense) فعل مجهول الجمع |
| 16. | 1. | 8 | 1-4 | Understanding & Translation of Verses | Imperative Verb for singular فعل الأمر للمفرد |
| | 2. | 7 | 5-8 | Understanding & Translation of Verses | Imperative Verb for plural فعل الأمر للجمع |

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# Course Title: Ethics I

## Course Code: URCG-5131

**Ethics-I** **URCG-5131** **1 (0-1)**

**1-Course Description**

The Ethics-I course is designed to provide students with a comprehensive understanding of ethical principles, practices, and theories in various societal contexts. Throughout this degree program, students will explore the complexities of ethical theories of semitic and non-semitic religions along with decision-making and develop critical thinking skills to navigate moral dilemmas. This course will also enable the students to interact with others religious identities with humanistic, inclusive and holistic approach

**2- Learning Objectives**

This course aims to:

1. Introduce students to the fundamental concepts, scope, and importance of ethics.
2. Explore the relationship between law, morality, and social values.
3. Develop a clear understanding of virtuous and immoral ethics and their impact on individual and collective life.
4. Study the role of major religious figures in the moral development of human society and enable students to apply ethical principles for personal development, conflict resolution, and social harmony.

**3- Learning Outcomes**

By the end of the course, students will be able to:

1. Students will be able to identify and analyze major ethical theories, values, and their scope in social and individual life.
2. Differentiate between law and ethics, and analyze their interrelationship.
3. Identify types of virtuous and immoral ethics and assess their social impacts.
4. Examine the ethical teachings of major religions and their relevance in contemporary society.
5. Apply ethical principles to address modern challenges in personal and professional life.

**4-Course Structure**

1. Interactive lectures, Group discussions and debates
2. Reflection papers and presentations
3. Assignments and Quiz

**Course Contents**

**Unit 1: Introduction and Fundamentals of Ethics**

1. Literal and terminological definition of ethics
2. Literal and terminological definition of values
3. Relationship between law and ethics
4. Need, importance, and scope of ethics

**Unit 2: Types of Ethics and Their Impact on Society**

- Virtuous ethics: concept, types, benefits, and outcomes
- Immoral ethics: concept, types, and harms
- Role of ethics in social refinement and establishment of peace

**Unit 3: Virtuous Ethics (Akhlaq-e-Hasanah)**

- Concept, need, and importance of virtuous ethics
- Scope of virtuous ethics in the light of religions
- Major virtues in revealed and non-revealed religions
- Impact of virtuous ethics on individual and collective life

**Unit 4: Immoral Ethics (Akhlaq-e-Razilah)**

- Concept of immoral ethics
- Social problems caused by immoral ethics
- Practical consequences of immoral ethics
- Major vices in revealed and non-revealed religions

**Unit 5: Role of World Religious Figures in Moral Development**

- Prophet Moses (AS): introduction, miracles, and role in moral refinement
- Prophet Jesus (AS): introduction, miracles, and role in moral refinement
- Prophet Muhammad (ﷺ): introduction, miracles, and role in moral refinement

**Textbook**

1. Izutsu, T. (2002). *Ethico-Religious Concepts in the Qur'an*. McGill-Queen's University Press.

**Suggested Readings**

1. Gert, B. (2005). *Morality: Its Nature and Justification*. Oxford University Press.
2. MacIntyre, A. (2007). *After Virtue: A Study in Moral Theory*. University of Notre Dame Press.
3. Al-Ghazali, Abu Hamid (2001). *The Alchemy of Happiness*. Islamic Texts Society.
4. Nasr, S. H. (1994). *The Heart of Islam: Enduring Values for Humanity*. Harper One.
5. Beauchamp, T. L., & Childress, J. F. (2019). *Principles of Biomedical Ethics*. Oxford University Press.
6. Hasan, Z. (2010). *Ethics in Islam: Key Concepts and Contemporary Challenges*. Islamic Research Institute.

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# Course Title: Ethics II

## Course Code: URCG-5132

Ethics-II URCG-5132 1 (0-1)

**1-Course Description**

The course *Ethics-II* is designed to provide students with a deeper understanding of ethical principles and practices from both Semitic and non-Semitic religions, as well as their application in professional and social contexts. Students will engage with Jewish, Christian, Islamic, Hindu, Buddhist, Sikh, Confucian, and Jain ethical traditions. The course emphasizes moral reasoning, decision-making, tolerance, and peacebuilding. It aims to cultivate an inclusive, humanistic, and holistic approach towards ethical living and interfaith engagement.

**2- Learning Objectives**

The course objectives are to:

1. Understand the fundamental principles and theories of ethics.
2. Introduce the ethical and moral teachings of Judaism, Christianity, Islam, and Hinduism.
3. Explore the ethical teachings of non-Semitic religions such as Buddhism, Sikhism, Confucianism, and Jainism.
4. Develop critical thinking skills to evaluate ethical arguments and theories.
5. Promote ethical leadership and interfaith harmony.

**3- Learning Outcomes**

By the end of this course, students will be able to:

1. Identify and analyze major ethical theories and teachings from world religions.
2. Understand the role of religions in improving moral values and social behavior.
3. Demonstrate ethical decision-making in various personal and professional contexts.
4. Recognize the impact of ethical decisions on individuals, communities, and society.
5. Apply skills of ethical leadership, including communication, conflict resolution, and inclusive engagement.

**4-Course Structure**

1. Interactive lectures, Group discussions and debates
2. Reflection papers and presentations
3. Assignments and Quiz

~~Course Title: Ethics-II (For Non-Muslim Students) Course Code: URGC-5130~~

### Course Contents

**Unit 1: Ethical Teachings of Semitic Religions**

- Judaism and its ethical teachings
- Christianity and its ethical teachings
- Islam and its ethical teachings

**Unit 2: Ethical Teachings of Non-Semitic Religions**

- Hinduism and its ethical teachings
- Sikhism and Buddhism: ethical values and practices
- Confucian and Jain ethical traditions

**Unit 3: Professional Ethics**

- Ethics for students and teachers
- Ethics in doctor–patient relationships
- Ethics in trader–customer interactions

**Unit 4: Concept and Significance of Tolerance**

- Definition, need, and importance of tolerance
- Teachings of Semitic religions on tolerance and their contemporary relevance
- Teachings of non-Semitic religions on tolerance and their contemporary relevance

**Unit 5: Foundational Values and Ethics for Peacebuilding in Society**

- Respect for sacred scriptures, personalities, places of worship, and religious symbols
- Promotion of tolerance and broadmindedness
- Encouragement of dialogue and harmony
- Benevolence towards humanity
- Establishment of justice and fairness
- Patience, forbearance, and forgiveness

**Textbook**

- Kidder, R. M. (2009). *How Good People Make Tough Choices: Resolving the Dilemmas of Ethical Living*. Harper.

**Suggested Readings**


1. Barash, D. P., & Webel, C. P. (2014). *Peace and Conflict Studies*. Sage.
2. Smart, N. (1998). *The World's Religions*. Cambridge University Press.
3. Nasr, S. H. (2003). *The Heart of Islam: Enduring Values for Humanity*. HarperOne.
4. Sharma, A. (2006). *Hindu Ethics: Purity, Abortion, and Euthanasia*. SUNY Press.
5. Harvey, P. (2000). *An Introduction to Buddhist Ethics: Foundations, Values and Issues*. Cambridge University Press.
6. Coward, H., & Perkinson, J. (2013). *A Cross-Cultural Dialogue on Ethical Leadership*. Wilfrid Laurier University Press.
7. Confucius. (1998). *The Analects*. Oxford University Press.


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