COURSE TITLE	**ADVANCED MACHINE LEARNING**
COURSE CODE	**01AD0506**
COURSE CREDITS	**4**

Objective:

1 Objective of this course is to provide students with fundamental concepts, mathematical intuition, and practical workflow of machine learning for solving real-world problems and to enable students to build, evaluate, interpret, and deploy machine learning models using modern tools and datasets.

Course Outcomes: After completion of this course, student will be able to:

1 Understand the foundations, workflow, and mathematical basis of machine learning techniques

2 Apply preprocessing, feature engineering, regression, and classification methods on real datasets.

3 Analyze and compare machine learning models using suitable performance metrics, validation methods, and tuning strategies

4 Build unsupervised and neural-network-based models for pattern discovery and predictive tasks.

5 Design real-world machine learning solutions considering interpretability, fairness, deployment, and monitoring aspects

Pre-requisite of course: Basic knowledge of probability and statistics, linear algebra, Python programming, data structures, and database fundamentals.

Teaching and Examination Scheme

Theory Hours	Tutorial Hours	Practical Hours	ESE	IA	CSE	Viva	Term Work
3	0	2	50	30	20	25	25

Contents : Unit	Topics	Contact Hours
1	**Introduction to Machine Learning and Data Preparation** Introduction to Artificial Intelligence, Data Science and Machine Learning, Types of learning: supervised, unsupervised, semi-supervised and reinforcement learning, Machine learning workflow; Applications of ML in healthcare, finance, manufacturing, retail, cybersecurity and smart systems, Types of datasets; Training, validation and test sets; Data preprocessing, missing value handling, encoding categorical variables, feature scaling, normalization, standardization, feature selection basics, bias-variance tradeoff, overfitting and underfitting.	7

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Contents : Unit	Topics	Contact Hours
2	**Regression and Classification Fundamentals** Linear regression, multiple linear regression, polynomial regression, Cost function and gradient descent; Regularization concepts, Ridge and Lasso; Classification basics, Logistic regression; k-Nearest Neighbors; Naive Bayes, Model assumptions; Decision boundaries, Case studies for regression and classification problems.	8
3	**Advanced Supervised Learning and Model Evaluation** Decision tree learning, entropy, information gain, Gini index; Random Forest, Ensemble learning; Boosting concepts, Support Vector Machines, margins, kernels;, Performance evaluation metrics for classification and regression, Confusion matrix, precision, recall, F1-score, ROC-AUC, MAE, MSE, RMSE, R^2; Cross-validation, Hyperparameter tuning; Grid search and random search, Model selection strategies.	8
4	**Unsupervised Learning and Dimensionality Reduction** Introduction to unsupervised learning; Clustering concepts; k-means clustering, Hierarchical clustering; Density-based clustering basics, Distance measures; Cluster validation; Association with business segmentation and anomaly identification; Principal Component Analysis, Feature extraction vs feature selection; Visualization of high-dimensional data, Applications in recommendation, customer segmentation and fault detection.	7
5	**Neural Networks and Modern Machine Learning** Perceptron model; Multi-Layer Perceptron (MLP), Activation functions; Forward propagation and backpropagation, Loss functions; Training neural networks; Optimization basics; Regularization in neural networks, Introductory concepts of deep learning; Overview of CNN, RNN and transfer learning, Use cases of neural networks in image, text and time-series problems.	7
6	**Real-World Machine Learning Systems, Explainability and Responsible AI** End-to-end ML pipeline design; Feature engineering in practice, Handling class imbalance; Model interpretability and explainability basics, Feature importance, SHAP/LIME overview; Fairness, bias, ethics, trust, privacy and responsible AI, Model serialization and deployment basics; Batch vs real-time inference, Monitoring, retraining, drift awareness and lifecycle management, Mini case studies based on industry-ready ML solutions.	8
Total Hours		**45**

Suggested List of Experiments:

Contents : Unit	Topics	Contact Hours
1	**Practical 1** Installation and setup of Python machine learning environment; loading datasets; performing exploratory data analysis; identifying data types, missing values, and outliers.	2

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Suggested List of Experiments:

Contents : Unit	Topics	Contact Hours
2	**Practical 2** Data preprocessing using imputation, encoding categorical variables, feature scaling, normalization, and train-test split preparation.	2
3	**Practical 3** Implement simple and multiple linear regression on a real dataset; evaluate using MAE, MSE, RMSE, and R^2.	2
4	**Practical 4** Implement logistic regression and k-Nearest Neighbors for classification; compare model performance using confusion matrix, precision, recall, and F1-score.	2
5	**Practical 5** Implement Naive Bayes and Decision Tree classifiers; compare results and visualize the decision tree.	2
6	**Practical 6** Implement Random Forest and Support Vector Machine models; perform hyperparameter tuning using cross-validation	2
7	**Practical 7** Perform k-means clustering and hierarchical clustering on a dataset; visualize and interpret the clusters	2
8	**Practical 8** Apply Principal Component Analysis (PCA) for dimensionality reduction and compare model performance before and after PCA.	2
9	**Practical 9** Build and train a basic Multi-Layer Perceptron (MLP) for classification or regression using a standard dataset.	2
10	**Practical 10** Develop a mini end-to-end machine learning pipeline including preprocessing, model training, evaluation, model saving/loading, and prediction on new data.	2
11	**Practical 11** Perform model interpretability and evaluation on a trained machine learning model using feature importance and explain the model predictions for selected samples; prepare a short comparative analysis report	4
Total Hours		**24**

Textbook :

1 Machine Learning, Tom M. Mitchell, McGraw-Hill, 1997

References:

1 An Introduction to Statistical Learning: with Applications in Python, An Introduction to Statistical Learning: with Applications in Python, Gareth James, Daniela Witten, Trevor Hastie and Robert Tibshirani, Springer, -

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References:

2 Pattern Recognition and Machine Learning, Pattern Recognition and Machine Learning, Christopher M. Bishop, Springer, -

Suggested Theory Distribution:

The suggested theory distribution as per Bloom's taxonomy is as follows. This distribution serves as guidelines for teachers and students to achieve effective teaching-learning process

Distribution of Theory for course delivery					
Remember / Knowledge	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Higher order Thinking / Creative**
15.00	20.00	25.00	20.00	10.00	10.00

Instructional Method:

1 The course delivery method will depend upon the requirement of content and need of students. The teacher in addition to conventional teaching method by black board, may also use any of tools such as demonstration, role play, Quiz, brainstorming, MOOCs etc.

2 The internal evaluation will be done on the basis of continuous evaluation of students in the laboratory and class-room.

3 Practical examination will be conducted at the end of semester for evaluation of performance of students in laboratory.

4 Students will use supplementary resources such as online videos, NPTEL videos, e-courses, Virtual Laboratory

Supplementary Resources:

1 Stanford CS229: Machine Learning course materials and notes

2 Carnegie Mellon University 10-301/10-601: Introduction to Machine Learning course materials.

3 Google Cloud Machine Learning Engineer learning path and production ML resources

4 https://nptel.ac.in/courses/106/106/106106139/

5 https://www.coursera.org/learn/machine-learning

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