

# Fundamentals of Machine Learning (4341603) - Summer 2025 Solution

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## Question 1(a) [3 marks]

Define machine Learning. Give any two applications of machine learning.

### Solution

Machine Learning is a subset of artificial intelligence that enables computers to learn and make decisions from data without being explicitly programmed for every task.

#### Applications:

- **Email spam detection:** Automatically identifies and filters spam emails
- **Recommendation systems:** Suggests products on e-commerce sites like Amazon

**Table 1.** ML vs Traditional Programming

Traditional Programming	Machine Learning
Input data + Program → Output	Input data + Output → Program
Rules are explicitly coded	Rules are learned from data

### Mnemonic

“ML = Make Learning from data”

## Question 1(b) [4 marks]

Define: Under fitting and overfitting.

### Solution

**Underfitting** occurs when a model is too simple to capture underlying patterns in data, resulting in poor performance on both training and test data.

**Overfitting** occurs when a model learns training data too well, including noise, causing poor performance on new unseen data.

**Table 2.** Comparison

Aspect	Underfitting	Overfitting
Training accuracy	Low	High
Test accuracy	Low	Low
Model complexity	Too simple	Too complex
Solution	Increase complexity	Reduce complexity

**Mnemonic**

“Under = Under-performs, Over = Over-learns”

**Question 1(c) [7 marks]**

Describe different types of machine learning with suitable example.

**Solution**

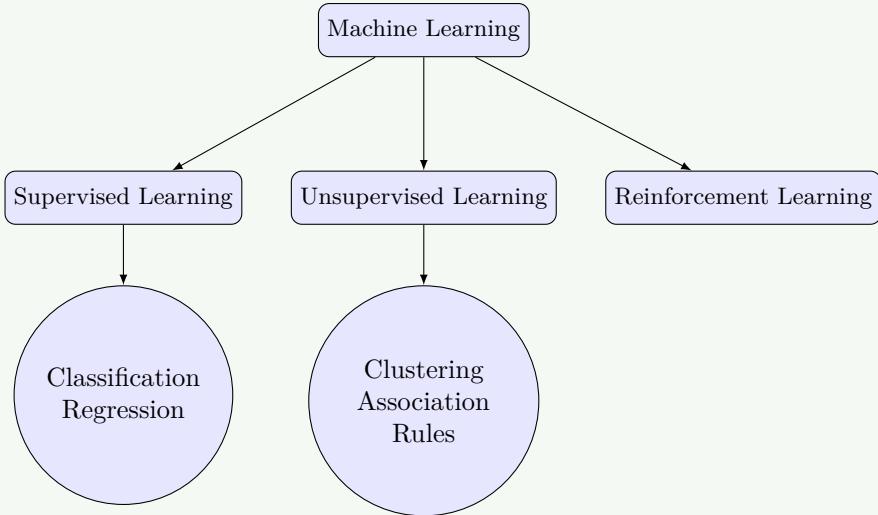
**Table 3.** Types of Machine Learning

Type	Description	Example
Supervised	Uses labeled training data	Email classification
Unsupervised	No labeled data, finds patterns	Customer segmentation
Reinforcement	Learns through rewards/penalties	Game playing AI

**Supervised Learning** uses input-output pairs to train models. The algorithm learns from examples to predict outcomes for new data.

**Unsupervised Learning** discovers hidden patterns in data without target labels. It groups similar data points together.

**Reinforcement Learning** trains agents to make decisions by rewarding good actions and penalizing bad ones.



**Figure 1.** Types of Machine Learning

**Mnemonic**

“Super Un-supervised Reinforces learning”

**Question 1(c) OR [7 marks]**

Describe different tools and technology used in the field machine learning.

**Solution**

**Table 4.** ML Tools and Technologies

Category	Tools	Purpose
<b>Programming</b>	Python, R	Core development
<b>Libraries</b>	Scikit-learn, TensorFlow	Model building
<b>Data Processing</b>	Pandas, NumPy	Data manipulation
<b>Visualization</b>	Matplotlib, Seaborn	Data plotting

**Python** is the most popular language due to its simplicity and extensive libraries.

**Scikit-learn** provides simple tools for data mining and analysis, perfect for beginners.

**TensorFlow** and **PyTorch** are advanced frameworks for deep learning applications.

**Jupyter Notebook** offers interactive development environment for experimentation.



**Figure 2.** ML Tools Workflow

### Mnemonic

“Python Pandas Scikit Tensor Jupyter”

## Question 2(a) [3 marks]

Give the difference between Qualitative data and Quantitative data.

### Solution

**Table 5.** Qualitative vs Quantitative Data

Qualitative Data	Quantitative Data
<b>Non-numerical</b> categories	<b>Numerical</b> values
Colors, names, grades	Height, weight, price
Cannot be measured	Can be measured

**Qualitative data** describes qualities or characteristics that cannot be measured numerically.

**Quantitative data** represents measurable quantities expressed as numbers.

### Mnemonic

“Quality = Categories, Quantity = Numbers”

## Question 2(b) [4 marks]

Find the mean and median for the following data: 3,4,5,5,7,8,9,11,12,14.

### Solution

**Given data:** 3, 4, 5, 5, 7, 8, 9, 11, 12, 14

**Mean calculation:**

- Sum =  $3 + 4 + 5 + 5 + 7 + 8 + 9 + 11 + 12 + 14 = 78$
- Count = 10 numbers
- **Mean** =  $78/10 = 7.8$

**Median calculation:**

- Data is already sorted

- For 10 numbers: Median = (5th + 6th value)/2
- Median** =  $(7+8)/2 = 7.5$

**Table 6.** Results

Measure	Value
Mean	7.8
Median	7.5

**Mnemonic**

“Mean = Average, Median = Middle”

**Question 2(c) [7 marks]**

Describe machine learning activities in detail.

**Solution****Table 7.** Machine Learning Activities

Activity	Description	Example
<b>Data Collection</b>	Gathering relevant data	Survey responses
<b>Data Preprocessing</b>	Cleaning and preparing data	Removing duplicates
<b>Feature Selection</b>	Choosing important variables	Age, income for loans
<b>Model Training</b>	Teaching algorithm patterns	Feeding training data
<b>Model Evaluation</b>	Testing model performance	Accuracy measurement

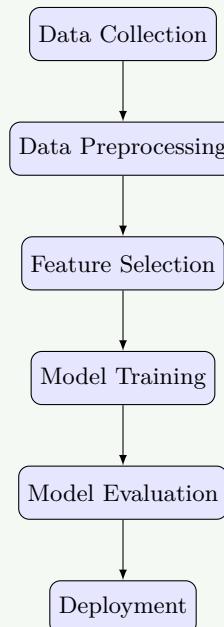
**Data Collection** involves gathering information from various sources like databases, sensors, or surveys.

**Data Preprocessing** includes cleaning, transforming, and organizing raw data for analysis.

**Feature Selection** identifies the most relevant variables that contribute to predictions.

**Model Training** uses algorithms to learn patterns from prepared training data.

**Model Evaluation** tests how well the trained model performs on new, unseen data.



**Figure 3.** Machine Learning Activities Flow**Mnemonic**

“Collect Process Feature Train Evaluate Deploy”

**Question 2(a) OR [3 marks]**

Give the difference between predicative model and descriptive model.

**Solution****Table 8.** Predictive vs Descriptive Models

Predictive Model	Descriptive Model
<b>Forecasts</b> future outcomes	<b>Explains</b> current patterns
Uses supervised learning	Uses unsupervised learning
Stock price prediction	Customer segmentation

**Predictive models** use historical data to make predictions about future events or unknown outcomes.

**Descriptive models** analyze existing data to understand current patterns and relationships.

**Mnemonic**

“Predict = Future, Describe = Present”

**Question 2(b) OR [4 marks]**

Classify the following using appropriate data type: hair color, gender, blood group type, time of day.

**Solution****Table 9.** Data Type Classification

Data	Type	Reason
<b>Hair color</b>	Nominal	Categories with no order
<b>Gender</b>	Nominal	Categories with no order
<b>Blood group</b>	Nominal	Categories with no order
<b>Time of day</b>	Continuous	Measurable quantity

**Nominal data** represents categories without any natural ordering.

**Continuous data** can take any value within a range and is measurable.

**Mnemonic**

“Names = Nominal, Numbers = Numerical”

**Question 2(c) OR [7 marks]**

Explain various methods used in data pre-processing.

## Solution

**Table 10.** Data Preprocessing Methods

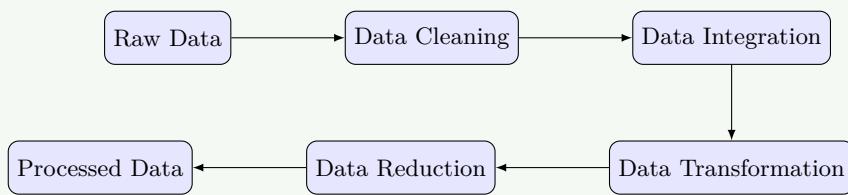
Method	Purpose	Example
<b>Data Cleaning</b>	Remove errors and inconsistencies	Fix typos, remove duplicates
<b>Data Integration</b>	Combine multiple sources	Merge customer databases
<b>Data Transformation</b>	Convert to suitable format	Normalize values 0-1
<b>Data Reduction</b>	Reduce dataset size	Select important features

**Data Cleaning** removes or corrects erroneous, incomplete, or irrelevant data.

**Data Integration** combines data from multiple sources into a unified dataset.

**Data Transformation** converts data into appropriate formats for analysis.

**Data Reduction** decreases dataset size while maintaining information quality.



**Figure 4.** Data Preprocessing Pipeline

## Mnemonic

“Clean Integrate Transform Reduce”

## Question 3(a) [3 marks]

Give difference between classification and regression.

## Solution

**Table 11.** Classification vs Regression

Classification	Regression
<b>Discrete output</b>	<b>Continuous</b> output
Predicts categories	Predicts numerical values
Email: spam/not spam	House price prediction

**Classification** predicts discrete categories or classes from input data.

**Regression** predicts continuous numerical values from input data.

## Mnemonic

“Class = Categories, Regress = Real numbers”

## Question 3(b) [4 marks]

Write confusion matrix using appropriate example. Calculate accuracy and error rate for it.

### Solution

#### Example: Email Classification

**Table 12.** Confusion Matrix

	Predicted Spam	Predicted Not Spam
Actual Spam	85 (TP)	15 (FN)
Actual Not Spam	10 (FP)	90 (TN)

#### Calculations:

- **Accuracy** =  $(TP + TN)/(TP + TN + FP + FN) = (85 + 90)/200 = 87.5\%$
- **Error Rate** =  $(FP + FN)/(TP + TN + FP + FN) = (10 + 15)/200 = 12.5\%$

#### Key Terms:

- **TP**: True Positive - Correctly predicted spam
- **TN**: True Negative - Correctly predicted not spam

### Mnemonic

“True Positive True Negative = Correct predictions”

## Question 3(c) [7 marks]

Explain KNN algorithm in detail.

### Solution

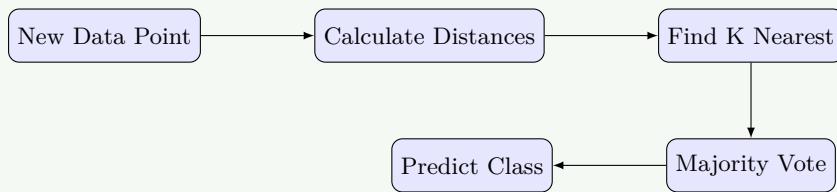
**K-Nearest Neighbors (KNN)** is a simple classification algorithm that classifies data points based on the majority class of their K nearest neighbors.

**Table 13.** KNN Algorithm Steps

Step	Description	Example
<b>Choose K</b>	Select number of neighbors	K=3
<b>Calculate Distance</b>	Find distance to all points	Euclidean distance
<b>Find Neighbors</b>	Identify K closest points	3 nearest points
<b>Vote</b>	Majority class wins	2 cats, 1 dog → cat

#### Working Process:

1. Calculate distances between test point and all training points
2. Sort distances and select K nearest neighbors
3. Count votes from each class among neighbors
4. Assign class with majority votes



**Figure 5.** KNN Process Flow

#### Advantages:

- Simple to implement and understand
- No training required - lazy learning algorithm

**Mnemonic**

“K Nearest Neighbors Vote for classification”

**Question 3(a) OR [3 marks]**

Give any three applications of multiple linear regression.

**Solution****Applications of Multiple Linear Regression:****Table 14.** Applications

Application	Variables	Purpose
<b>House Price Prediction</b>	Size, location, age	Estimate property value
<b>Sales Forecasting</b>	Advertising, season, price	Predict revenue
<b>Medical Diagnosis</b>	Symptoms, age, history	Risk assessment

**Multiple Linear Regression** uses multiple input variables to predict a continuous output variable.

**Mnemonic**

“Multiple inputs, One output”

**Question 3(b) OR [4 marks]**

Explain bagging, boosting and stacking in detail.

**Solution****Table 15.** Ensemble Methods

Method	Approach	Example
<b>Bagging</b>	Parallel training, average results	Random Forest
<b>Boosting</b>	Sequential training, learn from errors	AdaBoost
<b>Stacking</b>	Meta-learner combines models	Neural network combiner

**Bagging** trains multiple models on different data subsets and averages predictions.

**Boosting** trains models sequentially, each learning from previous model's mistakes.

**Stacking** uses a meta-model to learn how to combine predictions from base models.

**Mnemonic**

“Bag parallel, Boost sequential, Stack meta”

**Question 3(c) OR [7 marks]**

Explain single linear regression with its application.

### Solution

**Single Linear Regression** finds the best straight line relationship between one input variable (X) and one output variable (Y).

**Formula:**  $Y = a + bX$

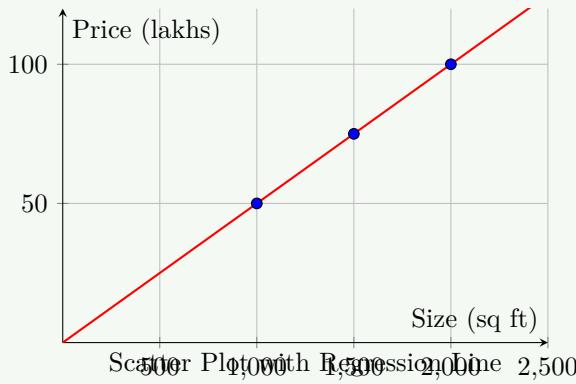
- a: Y-intercept
- b: Slope of line

**Table 16.** Application Example - House Price vs Size

House Size (sq ft)	Price (lakhs)
1000	50
1500	75
2000	100

#### Working Process:

1. Collect data with input-output pairs
2. Plot points on scatter graph
3. Find best line that minimizes error
4. Make predictions using line equation



**Figure 6.** Linear Regression Visualization

#### Applications:

- Sales vs Advertising: More ads → More sales
- Temperature vs Ice cream sales: Hot weather → More sales

### Mnemonic

“One X predicts One Y with a line”

## Question 4(a) [3 marks]

Define the following: (1)support (2) confidence.

### Solution

**Support** measures how frequently an itemset appears in the dataset.

**Confidence** measures how often items in consequent appear when antecedent is present.

**Table 17.** Definitions

Measure	Formula	Example
Support	Count(itemset)/Total transactions	Bread appears in 60% transactions
Confidence	Support(A $\cup$ B)/Support(A)	80% who buy bread also buy butter

**Support = Frequency of occurrence**

**Confidence = Reliability of rule**

#### Mnemonic

“Support = How often, Confidence = How reliable”

## Question 4(b) [4 marks]

Explain applications of unsupervised learning.

#### Solution

**Table 18.** Unsupervised Learning Applications

Application	Purpose	Example
<b>Customer Segmentation</b>	Group similar customers	Marketing campaigns
<b>Data Compression</b>	Reduce data size	Image compression
<b>Anomaly Detection</b>	Find unusual patterns	Fraud detection
<b>Recommendation Systems</b>	Suggest similar items	Music recommendations

**Customer Segmentation** groups customers with similar buying behavior for targeted marketing.

**Data Compression** reduces storage space by finding patterns and removing redundancy.

**Anomaly Detection** identifies unusual patterns that may indicate fraud or errors.

#### Mnemonic

“Segment Compress Detect Recommend”

## Question 4(c) [7 marks]

Write and explain apriori algorithm with suitable example.

#### Solution

**Apriori Algorithm** finds frequent itemsets and generates association rules for market basket analysis.

**Table 19.** Algorithm Steps

Step	Description	Example
<b>Find frequent 1-itemsets</b>	Count individual items	{Bread}:4, {Milk}:3
<b>Generate 2-itemsets</b>	Combine frequent items	{Bread,Milk}:2
<b>Apply minimum support</b>	Filter infrequent sets	Keep if support $\geq$ 50%
<b>Generate rules</b>	Create if-then rules	Bread $\rightarrow$ Milk

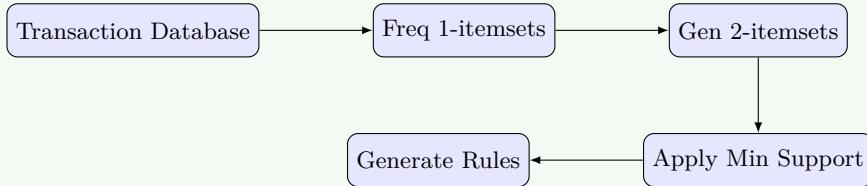
#### Example Dataset:

- Transaction 1: {Bread, Milk, Eggs}
- Transaction 2: {Bread, Milk}

- Transaction 3: {Bread, Eggs}
- Transaction 4: {Milk, Eggs}

**Working Process:**

1. Scan database to count item frequencies
2. Generate candidate itemsets of increasing size
3. Prune infrequent itemsets below minimum support
4. Generate association rules from frequent itemsets

**Figure 7.** Apriori Algorithm Steps**Mnemonic**

“A-priori knowledge helps find frequent patterns”

**Question 4(a) OR [3 marks]**

List out the difference between clustering and classification.

**Solution****Table 20.** Clustering vs Classification

Clustering	Classification
Unsupervised learning	Supervised learning
No labeled data	Uses labeled training data
Groups similar data	Assigns predefined labels

**Clustering** discovers hidden groups in unlabeled data.

**Classification** assigns new data to known categories using trained models.

**Mnemonic**

“Cluster = Groups unknown, Classify = Labels known”

**Question 4(b) OR [4 marks]**

Explain the clustering process in detail.

**Solution****Table 21.** Clustering Process Steps

Step	Description	Purpose
<b>Data Preparation</b>	Clean and normalize data	Ensure quality input
<b>Distance Metric</b>	Choose similarity measure	Euclidean, Manhattan
<b>Algorithm Selection</b>	Pick clustering method	K-means, Hierarchical
<b>Cluster Validation</b>	Evaluate cluster quality	Silhouette score

**Clustering Process** groups similar data points together based on their characteristics.

**Key decisions include choosing the number of clusters and appropriate distance metrics.**  
**Validation ensures clusters are meaningful and well-separated.**

### Mnemonic

“Prepare Distance Algorithm Validate”

## Question 4(c) OR [7 marks]

Write and explain K-means clustering algorithm with suitable example.

### Solution

**K-means** partitions data into K clusters by minimizing within-cluster sum of squares.

Table 22. Algorithm Steps

Step	Description	Example
<b>Initialize centroids</b>	Random K center points	C1(2,3), C2(8,7)
<b>Assign points</b>	Each point to nearest centroid	Point(1,2) → C1
<b>Update centroids</b>	Mean of assigned points	New C1(1.5, 2.5)
<b>Repeat</b>	Until centroids stop moving	Convergence

#### Example: Customer Income vs Age

- Customer 1: (Income=30k, Age=25)
- Customer 2: (Income=35k, Age=30)
- Customer 3: (Income=70k, Age=45)
- Customer 4: (Income=75k, Age=50)

#### Working Process:

- Choose K=2 clusters for young/old customers
- Initialize centroids randomly
- Calculate distances from each customer to centroids
- Assign customers to nearest centroid
- Update centroid positions to center of assigned customers
- Repeat until stable

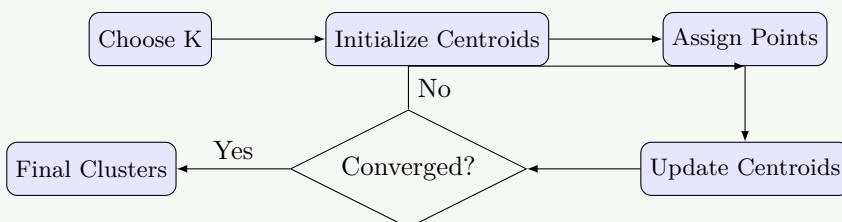


Figure 8. K-Means Logic

**Mnemonic**

“K centroids Mean their assigned points”

**Question 5(a) [3 marks]**

List the applications of matplotlib.

**Solution**

**Table 23.** Matplotlib Applications

Application	Purpose	Example
<b>Data Visualization</b>	Create charts and graphs	Bar charts, histograms
<b>Scientific Plotting</b>	Research presentations	Mathematical functions
<b>Dashboard Creation</b>	Interactive displays	Business metrics

Matplotlib is Python's primary plotting library for creating static, animated, and interactive visualizations.

**Mnemonic**

“Mat-plot-lib = Math Plotting Library”

**Question 5(b) [4 marks]**

Write down code to plot a vertical line and horizontal line using matplotlib.

**Solution**

```

1 import matplotlib.pyplot as plt
2
3 # Create figure
4 plt.figure(figsize=(8, 6))
5
6 # Plot vertical line at x=3
7 plt.axvline(x=3, color='red', linestyle='--', label='Vertical Line')
8
9 # Plot horizontal line at y=2
10 plt.axhline(y=2, color='blue', linestyle='--', label='Horizontal Line')
11
12 # Add labels and title
13 plt.xlabel('X-axis')
14 plt.ylabel('Y-axis')
15 plt.title('Vertical and Horizontal Lines')
16 plt.legend()
17 plt.grid(True)
18 plt.show()
```

**Key Functions:**

- **axvline():** Creates vertical line
- **axhline():** Creates horizontal line

**Mnemonic**

“axvline = Vertical, axhline = Horizontal”

## Question 5(c) [7 marks]

Explain features and applications of Scikit-Learn.

### Solution

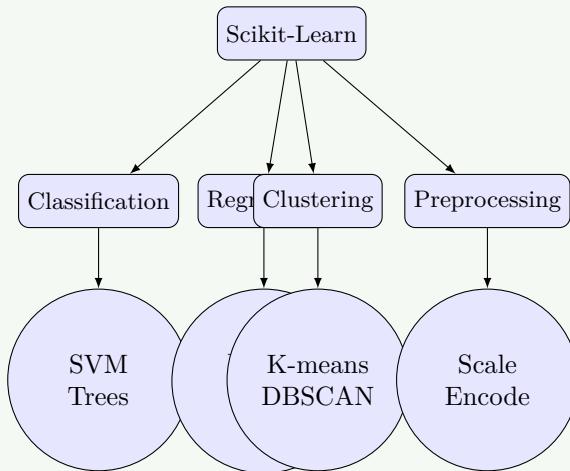
**Table 24.** Scikit-Learn Features

Feature	Description	Example
<b>Simple API</b>	Easy to use interface	fit(), predict()
<b>Multiple Algorithms</b>	Various ML methods	SVM, Random Forest
<b>Data Preprocessing</b>	Built-in data tools	StandardScaler
<b>Model Evaluation</b>	Performance metrics	accuracy_score

**Scikit-Learn** is Python's most popular machine learning library providing simple tools for data analysis.

#### Applications:

- **Classification:** Email spam detection
- **Regression:** House price prediction
- **Clustering:** Customer segmentation
- **Dimensionality Reduction:** Data visualization



**Figure 9.** Scikit-Learn Components

### Mnemonic

“Scikit = Science Kit for machine learning”

## Question 5(a) OR [3 marks]

Give the purpose of NumPy in machine learning.

### Solution

**Table 25.** NumPy Purpose in ML

Purpose	Description	Benefit
<b>Numerical Computing</b>	Fast array operations	Efficient calculations
<b>Foundation Library</b>	Base for other libraries	Pandas, Scikit-learn use it
<b>Mathematical Functions</b>	Built-in math operations	Statistics, linear algebra

NumPy provides the foundation for numerical computing in Python machine learning applications.  
**Essential for handling large datasets and performing mathematical operations efficiently.**

### Mnemonic

“Num-Py = Numerical Python”

## Question 5(b) OR [4 marks]

Write down steps to import csv file in pandas.

### Solution

```

1 import pandas as pd
2
3 # Step 1: Import pandas library
4 # Step 2: Use read_csv() function
5 data = pd.read_csv('filename.csv')
6
7 # Step 3: Display first few rows
8 print(data.head())
9
10 # Optional: Specify parameters
11 data = pd.read_csv('file.csv',
12                     delimiter=',',
13                     header=0,
14                     index_col=0)

```

### Steps:

1. Import pandas library
2. Use read\_csv() function with filename
3. Verify data with head() method

### Mnemonic

“Import Read Verify”

## Question 5(c) OR [7 marks]

Explain features and applications of Pandas.

### Solution

**Table 26.** Pandas Features

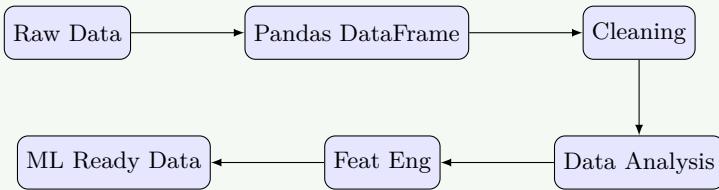
Feature	Description	Example
<b>Data Structures</b>	DataFrame and Series	Tabular data handling
<b>Data I/O</b>	Read/write multiple formats	CSV, Excel, JSON
<b>Data Cleaning</b>	Handle missing values	dropna(), fillna()
<b>Data Analysis</b>	Statistical operations	groupby(), describe()

Pandas is the primary data manipulation library in Python for machine learning projects.

### Key Capabilities:

- Data Loading from various file formats

- **Data Cleaning** and preprocessing operations
- **Data Transformation** and reshaping
- **Statistical Analysis** and aggregation



**Figure 10.** Pandas Workflow

### Mnemonic

“Pandas = Panel Data for analysis”