

**INTRODUCTION TO MACHINE LEARNING
(ECE3122)**

Time Allotted : 2½ hrs

Full Marks : 60

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve:

12 × 1 = 12

Choose the correct alternative for the following

- (i) Which of the following is a data normalization method?
 - (a) Min-Max
 - (b) Scaling
 - (c) Dropout
 - (d) Cross-validation
- (ii) The bias-variance trade-off suggests that:
 - (a) Increasing model complexity always reduces error
 - (b) High bias leads to underfitting, high variance leads to overfitting
 - (c) Low bias and high variance always lead to better accuracy
 - (d) Variance does not affect generalization
- (iii) In PCA, the first principal component is:
 - (a) The eigenvector with the smallest eigenvalue
 - (b) The eigenvector with the largest eigenvalue
 - (c) A random direction in feature space
 - (d) Always aligned with the first feature
- (iv) A model achieves 95% training accuracy but only 70% test accuracy. This indicates:
 - (a) Underfitting
 - (b) Overfitting
 - (c) Proper generalization
 - (d) Data normalization issue only
- (v) In k-NN classification, the choice of k controls:
 - (a) The number of training samples
 - (b) The bias-variance trade-off
 - (c) The number of features
 - (d) The learning rate
- (vi) The kernel trick in SVM is used to:
 - (a) Reduce dataset size
 - (b) Map data into higher-dimensional space
 - (c) Compute covariance matrix
 - (d) Normalize data
- (vii) Which algorithm is best suited for clusters of arbitrary shape and handling noise?
 - (a) K-means
 - (b) DBSCAN
 - (c) EM algorithm
 - (d) Hierarchical clustering

- (viii) Self-Organizing Map (SOM) is mainly based on:
 - (a) Competitive learning
 - (b) Supervised learning
 - (c) Random forest
 - (d) Regression analysis
- (ix) In majority voting ensemble, the final class label is chosen by:
 - (a) Weighted average
 - (b) Class with highest votes
 - (c) Random selection
 - (d) Maximum likelihood estimation
- (x) In a Markov Decision Process (MDP), the next state depends only on:
 - (a) Past states
 - (b) Current state and action
 - (c) All previous states
 - (d) Random noise

Fill in the blanks with the correct word

- (xi) In Candidate Elimination Algorithm, the _____ boundary contains the most specific hypotheses, while the _____ boundary contains the most general hypotheses.
- (xii) Min-Max normalization rescales data to a range of _____, whereas Z-score normalization transforms data to have _____ mean and _____ standard deviation.
- (xiii) Version Space is defined as the set of all hypotheses in the hypothesis space that are _____ with the training data.
- (xiv) Backpropagation in neural networks is based on the principle of _____ descent.
- (xv) The hyperplane in a Support Vector Machine is defined as _____.

Group - B

- 2. (a) Why is normalization required in ML? Compare Min-Max normalization and Z-score normalization. [[CO1/CO2](Analyse/IOCQ)]
- (b) Normalize the dataset [20, 100, 180] using Min-Max scaling to range [0,1]. [[CO1/CO2](Apply/IOCQ)]
5 + 7 = 12
- 3. (a) Given covariance matrix

$$\sum \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}$$
 Find eigenvalues and eigenvectors, and identify the principal components. [[CO2](Analyse/IOCQ)]
- (b) Explain bias and variance in ML with examples. [[CO2](Remember/LOCQ)]
- (c) Analyze how PCA reduces dimensionality while retaining maximum variance. Justify why it is preferred over simple feature selection methods, with examples. [[CO2](Justify/HOCQ)]
4 + 4 + 4 = 12

Group - C

- 4. (a) Explain the difference between classification and regression. Provide examples for each. [CO3][Understand/LOCQ]

- (b) Apply logistic regression to classify whether customers will make a purchase based on features such as age, income, and previous purchases. Evaluate the model using accuracy and precision. *[CO3][Analyse/IOCQ]*

Customer_ID	Age	Income (k\$)	Previous_Purchases	Will_Purchase (0/1)
1	25	40	2	0
2	35	55	5	1
3	45	70	3	1
4	22	30	1	0
5	50	90	6	1

6 + 6 = 12

5. (a) Describe the concept of the bias-variance trade-off and its impact on model performance. *[CO3][Remember/LOCQ]*
- (b) Create a decision tree classifier using a health dataset (e.g., patient age, BMI, blood pressure) to predict whether a patient has diabetes. Evaluate the model's accuracy and generalization performance. *[CO3][Evaluate/HOCQ]*

Patient_ID	Age	BMI	Blood_Pressure	Cholesterol	Diabetes (0/1)
1	45	28.5	120	180	1
2	50	32.0	140	200	0
3	35	25.0	110	170	0
4	60	30.5	130	220	1
5	40	27.0	115	190	0

6 + 6 = 12

Group - D

6. (a) Explain how a self-organizing map (SOM) works for clustering and visualizing high-dimensional data. Discuss its applications. *[CO6][Analyse/LOCQ]*
- (b) Using the provided customer data, create a self-organizing map (SOM) to visualize the clusters of customers. Compare the clustering results with those obtained from K-means and discuss the differences. *[CO6][Create/HOCQ]*

Customer_ID	Age	Income (k\$)	Spending_Score (1-100)	Previous_Purchases	Region
1	25	40	60	2	A
2	35	55	90	5	B
3	45	70	30	3	A
4	22	30	70	1	B
5	50	90	50	6	A

6 + 6 = 12

7. (a) Why are Gaussian Mixture Models considered more flexible than K-means? *[CO4][Remember/LOCQ]*

- (b) A dataset follows a mixture of 2 Gaussians:
- Cluster 1: $\mu=0, \sigma=1, P=0.5$
 - Cluster 2: $\mu=3, \sigma=1, P=0.5$
- For $x=2$, compute probability density under each Gaussian and final mixture density.
- [CO4][Analyze/IOCQ]*
4 + 8 = 12

Group - E

8. (a) Explain how bagging reduces variance. Give one real-life application. *[CO5][Analyze/IOCQ]*
- (b) Train a simple Random Forest of 3 trees using bootstrap sampling from dataset {1,2,3,4,5}. Show how samples can vary in each tree. *[CO6][Evaluate/HOCQ]*
5 + 7 = 12
9. (a) What is boosting? How does it differ from bagging? *[CO5][Understand/LOCQ]*
- (b) Define reinforcement learning and explain the concept of reward signal. *[CO5][Analyze/IOCQ]*
- (c) A robot navigates a grid world of 3×3 cells. It gets +10 reward at goal state (bottom-right), and -1 reward per step. Evaluate possible state transitions and rewards for one episode. *[CO6][Evaluate/HOCQ]*
4 + 4 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	31.25	40.62	28.13