Ref No: **Ex/PG/ELE/PE/T/123D/2025**

M. E. ELECTRICAL ENGG. FIRST YEAR 2ND SEMESTER EXAM, 2025
MASTER IN CONTROL SYSTEM ENGG 1ST YEAR 2ND SEMESTER EXAM, 2025

SUBJECT: - SIGNAL PROCESSING FOR MACHINE LEARNING

Time: Three hours — Full Marks 100

No. of Questions		Marks
	Answer any FOUR questions.	
1. (a)	Explain in detail the eigenstructure of principal-components analysis, using the concept of variance probe. In this context, what is *spectral theorem*? Hence draw the relation between the eigenvalues and the variance probes.	15
(b)	Linear discriminant projections are computed for the two-dimensional dataset given below: - Samples for class C_1: $\mathbf{X}_1=(x_1,x_2)=\{(5,3),(1,3),(6,2),(2,4),(4,4)\}$ - Samples for class C_2: $\mathbf{X}_2=(x_1,x_2)=\{(10,11),(5,7),(8,5),(9,7),(6,8)\}$ Determine covariance matrices of both the classes. Then determine the within-class scatter matrix and between-class scatter matrix.	10
2. (a)	In the context of neural networks, describe the conventional model utilized for a generic binary threshold logic neuron (TLN). Describe in detail how one can devise a weight-adjustment procedure for this TLN to solve a two-class classification problem. Differentiate between pattern space and weight space.	13
(b)	State and prove the perceptron convergence algorithm.	12
3. (a)	How are basis functions employed in linear regression? What are the popular choices of basis functions? Explain in detail how can maximum likelihood and least squares be employed to solve a linear regression problem.	13
(b)	Prove that, in Support Vector Machines, maximizing the margin of separation between binary classes is equivalent to minimizing the Euclidean norm of the weight vector $\mathbf{w}$.	12

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4. (a)	Why regularization is employed in solving underdetermined linear systems of the form $\mathbf{b} = \mathbf{Ax}$? How can a minimum-norm solution be obtained in this case? Using Lagrange multipliers show that the closed form pseudo inverse solution is given as: $\hat{\mathbf{x}}_{opt} = \mathbf{A}^T\left(\mathbf{AA}^T\right)^{-1}\mathbf{b}$, where each symbol has its usual meaning.	12
(b)	What are the strengths and weaknesses of dictionary learning (DL) algorithms compared to fixed dictionary algorithms? With a suitable example explain the basic iterative procedure used in DL algorithms. Then explain in detail how is the *sparse coding* stage employed in K-SVD algorithm.	13
5. (a)	Under what circumstances manifold learning performs better than PCA in dimensionality reduction? What is the importance of geodesic distance in manifold learning? Give a detailed, step-by-step description of Locally Linear Embedding (LLE) algorithm employed for manifold learning. What is the main assumption based on which this LLE algorithm is developed?	13
(b)	Describe the basic essence of singular value decomposition. Then find the matrices **U**, **Σ**, and **V** for $\mathbf{A} = \begin{bmatrix} 3 & 0 \\ 4 & 5 \end{bmatrix}$ where each symbol has its usual meaning. The rank is given as $r = 2$.	12
6.	Write short notes on ***any two*** of the following:	12.5×2 =25
(*i*)	Inverse discrete Fourier transform.	
(*ii*)	Logistic regression for binary classification.	
(*iii*)	Linear discriminant analysis for a C-class problem ($C > 2$).	