

CONTENTS

| Title | Page No. |
|---|----------|
| MODULE 1: MATHEMATICAL FOUNDATIONS | |
| Sets, functions, relations; Metric spaces; Vector spaces; Graph theory; Combinatorics; Boolean logic; Numerical computation; Stability & conditioning | 01-42 |
| MODULE 2: LINEAR ALGEBRA | 43-87 |
| Matrix operations; Rank & null space; Orthogonality; LU, QR; Eigenvalues; SVD; PCA; Least squares | |
| MODULE 3: CALCULUS & OPTIMIZATION | 88-127 |
| Partial derivatives; Gradient & Hessian; Chain rule; Convex sets; Lagrange multipliers; Gradient descent; SGD; Newton methods | |
| MODULE 4: PROBABILITY THEORY | 128-187 |
| Random variables; Expectation; Variance; Conditional probability; Bayes theorem; Gaussian, Bernoulli, Poisson; CLT | |
| MODULE 5: STATISTICAL INFERENCE | 188-217 |
| MLE; Bayesian inference; Hypothesis testing; Confidence intervals; Bias-variance; VC dimension | |
| MODULE 6: OPTIMIZATION IN ML | 218-237 |
| Convex loss; Regularization L1/L2; Iterative solvers; Coordinate descent; Distributed optimization | |
| MODULE 7: MACHINE LEARNING FOUNDATIONS | 238-266 |
| Linear regression; Logistic regression; SVM; Kernel methods; Clustering; k-means | |
| MODULE 8: NEURAL NETWORKS | 267-294 |
| Perceptron; Activation functions; Backpropagation; Gradient flow; Regularization; Optimization issues | |

| | |
|--|---------|
| MODULE 9: GRAPH THEORY | 295-311 |
| Adjacency matrix; Laplacian; Spectral clustering; Graph embeddings; Network analysis | |
| MODULE 10: ADVANCED TOPICS | 312-324 |
| Topological Data Analysis; Random matrix theory; Information theory; Entropy; KL divergence | |
| MODULE 11: PROBABILISTIC MODELS | 325-335 |
| Bayesian networks; Markov random fields; Variational inference | |
| MODULE 12: NUMERICAL METHODS | 336-350 |
| Conjugate gradient; Power iteration; Sparse methods; Compressed sensing | |
| MODULE 13: ETHICS & INTERPRETABILITY | 351-369 |
| Explainability (SHAP, LIME); Fairness metrics; Bias in AI | |
| MODULE 14: CAPSTONE PROJECT | 370-387 |
| Research project; Model implementation; Theoretical analysis; Case studies | |