# Master Outline for Machine Learning Topics

## 1. Introduction to Machine Learning

* What is Machine Learning?
* History and Trends in ML
* Relationship with Other Fields (Statistics, AI, Optimization)
* ML Use Cases in Research and Production

## 2. Mathematics for Machine Learning

* Linear Algebra
* - Scalars, Vectors, Matrices, and Tensors
* - Matrix Decompositions (Eigenvalues, SVD, Cholesky)
* - Basis, Rank, and Orthogonality
* Probability and Information Theory
* - Probability Distributions
* - Bayes’ Theorem
* - Entropy, Mutual Information, and KL Divergence
* Vector Calculus and Optimization
* - Gradients and Differentiation
* - Convex Optimization
* - Lagrange Multipliers
* Decision Theory and Statistical Learning
* - Bias-Variance Tradeoff
* - Generalization and Overfitting
* - No Free Lunch Theorem

## 3. Core Machine Learning Concepts

* Supervised Learning
* - Regression (Linear, Logistic, Probit)
* - Classification (SVMs, Decision Trees, Neural Networks)
* Unsupervised Learning
* - Clustering (K-means, Hierarchical)
* - Dimensionality Reduction (PCA, Autoencoders)
* Reinforcement Learning
* - Markov Decision Processes
* - Policy Gradients and Q-Learning

## 4. Model Development and Evaluation

* Training Data Preparation
* - Sampling Techniques
* - Handling Missing Data
* - Data Augmentation
* Feature Engineering
* - Encoding Categorical Features
* - Feature Selection and Extraction
* Model Training
* - Optimization Techniques (SGD, Adam, Momentum)
* - Hyperparameter Tuning
* Model Evaluation
* - Cross-Validation and Generalization
* - Performance Metrics (ROC, Precision-Recall)

## 5. Deep Learning

* Neural Network Foundations
* - Feedforward Networks
* - Activation Functions
* Convolutional Networks
* - CNN Architectures
* - Image Recognition
* Sequence Modeling
* - RNNs, LSTMs, Transformers
* - Sequence-to-Sequence Models
* Generative Models
* - GANs, Variational Autoencoders

## 6. Probabilistic and Bayesian Methods

* Bayesian Inference
* Gaussian Processes
* Monte Carlo Methods
* Graphical Models (Bayesian Networks, Markov Fields)

## 7. Machine Learning Deployment

* Model Deployment Strategies
* Monitoring and Maintenance
* Data Distribution Shifts
* MLOps and Infrastructure

## 8. Advanced Topics

* Self-Supervised Learning
* Continual Learning and Meta Learning
* Ethical AI and Bias Mitigation
* Interpretability and Explainability