**Phase 0: Prerequisites (1–2 months)**

You need strong foundations in **Math + Programming**.

**A. Mathematics**

1. **Linear Algebra** – Vectors, matrices, dot/cross product, norms, eigenvalues/eigenvectors.
2. **Calculus** – Derivatives, partial derivatives, chain rule, gradients.
3. **Probability & Statistics** – Probability distributions, mean/variance, Bayes theorem, hypothesis testing.
4. **Optimization** – Gradient descent, convex functions.

**B. Programming**

1. **Python** – basics, loops, functions, OOP.
2. **Libraries** – NumPy, Pandas, Matplotlib, Seaborn.
3. **Jupyter Notebook** – for experimentation and visualization.

**Phase 1: Core Machine Learning (2–3 months)**

Learn the basics of ML: supervised, unsupervised, and evaluation metrics.

**A. Supervised Learning**

1. Regression – Linear, Polynomial, Ridge/Lasso.
2. Classification – Logistic Regression, k-NN, Decision Trees, Random Forest, SVM.
3. Model Evaluation – Confusion matrix, Precision, Recall, F1-score, ROC-AUC.

**B. Unsupervised Learning**

1. Clustering – K-Means, Hierarchical, DBSCAN.
2. Dimensionality Reduction – PCA, t-SNE.

**C. Essentials**

1. Train/Test Split, Cross-validation.
2. Overfitting/Underfitting, Bias-Variance tradeoff.
3. Feature Scaling, Feature Engineering.

**Practical:** Build small projects like predicting house prices, customer segmentation, spam detection.

**Phase 2: Advanced Machine Learning (2–3 months)**

Focus on improving performance, understanding advanced algorithms, and ensemble techniques.

1. Ensemble Methods – Bagging, Boosting (Random Forest, XGBoost, LightGBM, CatBoost).
2. Advanced Regression & Classification techniques.
3. Hyperparameter Tuning – Grid Search, Random Search, Bayesian Optimization.
4. Pipelines & Feature Engineering – using sklearn pipelines.
5. Handling Imbalanced Data – SMOTE, class weights.

**Practical:** Participate in Kaggle competitions, try improving models with feature engineering.

**Phase 3: Deep Learning (2–3 months)**

Deep Learning is crucial for advanced ML applications.

1. **Neural Networks** – Perceptron, MLP, activation functions, loss functions.
2. **Frameworks** – TensorFlow, PyTorch.
3. **CNN** – Image classification, object detection basics.
4. **RNN / LSTM / GRU** – Time series, text data.
5. **Transfer Learning** – Using pre-trained models.
6. **Regularization** – Dropout, BatchNorm.

**Practical:** Build projects like digit recognition (MNIST), sentiment analysis, or image classifier.

**Phase 4: Specialized Topics (3–4 months)**

Dive into trending ML topics and real-world applications.

1. **Natural Language Processing (NLP)**
   * Text preprocessing, embeddings, Transformers.
2. **Computer Vision**
   * Image augmentation, segmentation, YOLO, OpenCV basics.
3. **Reinforcement Learning (RL)**
   * Q-Learning, Deep Q-Networks.
4. **Time Series Analysis**
   * ARIMA, Prophet, LSTMs.
5. **ML Ops & Deployment**
   * Model deployment (Flask, FastAPI), Docker, cloud services.

**Practical:** End-to-end projects – deploy ML models as APIs, build chatbots, recommendation systems.

**Phase 5: Expert Level**

1. Research latest papers (arXiv), follow top conferences (NeurIPS, ICML, CVPR).
2. Optimize algorithms for performance and scalability.
3. Learn about interpretability (SHAP, LIME) and fairness in AI.
4. Work on large-scale real-world datasets.
5. Contribute to open-source ML projects.

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