Phitron AI/ML Course Tentative Outline

Updated automatically every 5 minutes

Tentative Outline

Month 1 — Python, Math, and Statistics for AI-ML

Week 1 — Python Foundations and Workflow

- **Module 1 — Python Core Foundations**

1. Course setup (Python 3.9–3.11, venv, VS Code, notebooks versus scripts)
2. Python basics refresh (types, slicing, truthiness, f-strings)
3. Control flow and comprehensions
4. Functions that scale (args and kwargs, type hints)
5. Working with files and paths (pathlib, CSV read and write, images)
6. Errors and exceptions (try, except, else, finally)
7. Mini-project: clean-CSV pipeline skeleton

- **Module 2 — Data Stack and Production Python**

1. NumPy quickstart (arrays, broadcasting)
2. Pandas Essentials I (Series and DataFrame, indexing)
3. Pandas essentials II (joins and merge, groupby)
4. Data cleaning and preprocessing
5. Quick EDA with Matplotlib and Seaborn
6. Packaging your code (layout, modules)
7. Logging and one unit test (pytest intro)

- **Module 2.5 — Practise Module**
- Build a Python CSV cleaning pipeline and test with pytest.
- **Module 3 — Colab and Kaggle Workflow and GPU Usage**

1. Google Colab basics and GPU runtime
2. Colab runtime management and checkpoints
3. Kaggle notebooks and dataset handling
4. Data persistence with Google Drive or Kaggle
5. Packaging and shipping Week-1 project
6. Performance and troubleshooting on GPUs
7. Exporting results to Drive or Kaggle

- **Week-01 Assignment**

- One Python notebook that loads, cleans, and plots a dataset.

Week 2 — NumPy, Pandas, Visualization

- **Module 1 — NumPy Essentials (8 videos)**

1. Arrays, dtypes, shapes
2. Indexing and slicing, boolean masks
3. Broadcasting and vectorization patterns
4. Ufuncs, reductions, axis semantics
5. Random module and reproducibility
6. Linear algebra quick tour (matmul, einsum)
7. Memory layout and performance tips
8. Mini-lab: vectorize a slow Python loop

- **Module 2 — Pandas Essentials (8 videos)**

1. DataFrame creation, inspect, dtypes
2. Index, loc and iloc, filtering and chaining
3. GroupBy and aggregate, transform, apply
4. Merges and joins (one-to-one, one-to-many, many-to-many)
5. Reshape: melt and pivot, wide to long
6. Dates and times, categoricals, string ops
7. Missing values: detect, impute, document
8. Mini-lab: tidy a messy table and join two sources

- **Module 2.5 — Practise Module**
- Clean a messy dataset using Pandas and join multiple tables.
- **Module 3 — Plotting with Matplotlib and Seaborn (7 videos)**

1. Matplotlib basics, subplots, savefig
2. Distributions: histogram or KDE; box or violin
3. Relationships: scatter or line with faceting
4. Categorical plots; error bars and confidence intervals
5. Styling, annotations, legends, tick formatting
6. Multi-panel figure for a report
7. Mini-lab: recreate a publication-style chart

- **Week Assignment**
- Submit one notebook that cleans, joins, and plots data.

Week 3 — Data Preprocessing and EDA

- **Module 1 — Data Cleaning (8 videos)**

1. Data quality checklist and audit log
2. Missing data patterns; MCAR, MAR, MNAR intuition
3. Imputation (simple and by-group); when to drop
4. Outliers: IQR and z-score; winsorize versus cap
5. Type fixing, parsing dates, strings and categories
6. Duplicates, de-skewing, de-dup strategies
7. Scaling and normalization (when and why)
8. Mini-lab: clean a “dirty” CSV end-to-end

- **Module 2 — Feature Prep and Splits (7 videos)**

1. Train, validation, test splits and leakage pitfalls
2. Encoding categoricals (one-hot and ordinal), rare levels
3. Numeric transforms: log or bins, interaction terms
4. Text basics: token counts and TF-IDF (preview)
5. Reproducible preprocessing pipelines
6. Tracking versions: data card and changelog
7. Mini-lab: build a reusable preprocess script

- **Module 2.5 — Practise Module**
- Build a preprocessing script for encoding and scaling.
- **Module 3 — EDA Techniques (7 videos)**

1. Question-driven EDA strategy
2. Univariate profiles and normality checks
3. Bivariate or segment EDA; Simpson’s paradox demo
4. Correlation heatmaps (with caveats)
5. Target-aware summaries
6. EDA report templates
7. Mini-lab: ten-figure EDA storyboard for stakeholders

- **Week Assignment**
- Cleaning and EDA repository with reproducible report.

Week 4 — Math Foundations

- **Module 1 — Linear Algebra for ML (8 videos)**

1. Vectors, matrices, tensors; shapes and intuition
2. Matrix operations, norms, distances, cosine similarity

3. Projections and least squares geometry
4. Rank, null space, conditioning
5. Eigen and SVD intuition (dimensionality and PCA preview)
6. Batch linear algebra with NumPy
7. From algebra to models: linear regression as least squares
8. Mini-lab: PCA-style transform with NumPy

- **Module 2 — Probability and Statistics Basics (7 videos)**

1. Random variables, PMF or PDF or CDF
2. Common distributions
3. Conditional probability and Bayes' rule
4. Sampling, CLT intuition
5. Estimation: confidence interval versus prediction interval; effect sizes
6. Hypothesis tests: t-test and chi-square
7. Correlation versus causation; confounders

- **Module 2.5 — Practise Module**
- Bootstrap a confidence interval using NumPy.
- **Module 3 — Practical Math in Code (7 videos)**

1. Loss functions: MSE and cross-entropy
2. Gradient descent from scratch
3. Logistic regression math to vectorized NumPy training
4. Numerical stability (log-sum-exp, clipping)
5. Regularization (L1 and L2) and bias-variance
6. Feature scaling and optimization dynamics
7. Mini-lab: train a tiny logistic regression from scratch

- **Week Assignment**
- PCA demo and logistic regression in NumPy.

Month 2 — AI and ML Core Foundations

Week 1 — Supervised Learning Basics

- **Module 1 — Regression and Classification (7 videos)**

1. Evaluation metrics: Accuracy, Precision, Recall, F1, ROC AUC
2. Logistic regression theory and intuition
3. Linear regression mathematics and applications
4. Decision trees (CART) concepts

5. Random forests (bagging)
6. Practical: Titanic dataset with logistic regression and decision tree
7. Mini-lab: visualize decision boundaries

- **Module 2 — Stronger Supervised Algorithms (6 videos)**

1. k-Nearest Neighbors basics
2. Support Vector Machines and kernel tricks
3. Gradient Boosting with XGBoost or LightGBM
4. Ensemble learning concepts
5. Practical: house price prediction
6. Practical: classification with Gradient Boosting

- **Module 2.5 — Practise Module**
- Implement Random Forest and XGBoost on the same dataset and compare.
- **Module 3 — Unsupervised Learning Introduction (6 videos)**

1. What is unsupervised learning
2. k-Means clustering demo
3. Hierarchical clustering
4. Gaussian Mixture Models concepts
5. DBSCAN clustering demo
6. Mini-lab: compare clustering outputs visually

- **Week Assignment**
- Run logistic regression and random forest; run k-Means and PCA. Submit one notebook and a short reflection.

Week 2 — Advanced Supervised and Clustering

- **Module 1 — Advanced Supervised Algorithms (7 videos)**

1. SVM with kernels
2. Regularization methods (L1 and L2)
3. Gradient Boosting deeper dive
4. CatBoost and handling categorical features
5. Practical: spam classification with SVM
6. Practical: tabular dataset with CatBoost
7. Mini-lab: boosting versus SVM comparison

- **Module 2 — Clustering Algorithms (6 videos)**

1. k-Means intuition with different k
2. Mini-Batch k-Means

3. Agglomerative clustering
4. Gaussian Mixture Models applied
5. DBSCAN with noise handling
6. Mini-lab: visual comparison of clustering methods

- **Module 2.5 — Practise Module**
- Apply k-Means and DBSCAN on the same dataset with a short comparison.
- **Module 3 — Dimensionality Reduction (6 videos)**

1. PCA detailed concepts
2. t-SNE basics and visualization
3. UMAP for manifold learning
4. PCA practical demo
5. t-SNE demo
6. Mini-lab: compare PCA and t-SNE

- **Week Assignment**
- Run clustering with PCA preprocessing. Deliver one notebook and one summary report.

Week 3 — Semi-Supervised and Self-Supervised Learning

- **Module 1 — Semi-Supervised Learning (6 videos)**

1. Why semi-supervised learning matters
2. Pseudo-labeling explained
3. Practical pseudo-labeling
4. Consistency regularization
5. Practical consistency regularization
6. Mini-lab: compare semi-supervised outputs

- **Module 2 — Self-Supervised Learning (7 videos)**

1. What is self-supervised learning
2. Autoencoders explained
3. Autoencoder demo on MNIST
4. Contrastive learning overview
5. Contrastive learning demo
6. Applications of self-supervised learning
7. Mini-lab: autoencoder reconstructions

- **Module 2.5 — Practise Module**
- Train an autoencoder and compare with a simple contrastive method.

- **Module 3 — Applications of SSL (5 videos)**

1. Semi-supervised learning for tabular data
2. Semi-supervised learning for image tasks
3. Self-supervised learning in Transformers
4. Self-supervised learning in vision models
5. Mini-lab: run a pre-trained HuggingFace model

- **Week Assignment**
- Run one semi-supervised and one self-supervised method and compare with a supervised baseline.

Week 4 — Interpretability and Transition to Deep Learning

- **Module 1 — Interpretability Basics (4 videos)**

1. Review of classification methods
2. Regularization explained
3. Explainable AI: SHAP and LIME intro
4. SHAP or LIME practical demo

- **Module 1.5 — Practise Module**
- Run a supervised model with SHAP or LIME and reflect on key insights.
- **Module 2 — Clustering Review and Evaluation (6 videos)**

1. Review of clustering methods
2. Review of PCA and t-SNE
3. Clustering metrics: Silhouette and Davies–Bouldin
4. Hybrid approach: clustering for semi-supervised tasks
5. Practical: evaluate k-Means or DBSCAN
6. Mini-lab: compare cluster quality

- **Module 2.5 — Practise Module**
- Implement PCA then clustering; evaluate with Silhouette Score.
- **Module 3 — Foundation Models (6 videos)**

1. Pseudo-labeling and consistency review
2. Autoencoders and contrastive learning review
3. Foundation models overview: BERT, GPT, ViT
4. Pretraining and fine-tuning
5. Autoencoder reconstruction demo
6. Mini-lab: inference with a pre-trained Transformer

- **Week Assignment**

- One supervised model with interpretability, one unsupervised method with evaluation, and one self-supervised or pre-trained model run.

Month 3 — Deep Learning and Transformers Intro

Week 1 — Neural Network Foundations and Optimization

- **Module 1 — MLP and Backpropagation Basics (5 videos)**

1. Perceptron and MLP intuition; notation and shapes
2. Forward pass math with tensors and shape safety
3. Losses: cross-entropy versus MSE; logits and softmax; label smoothing
4. 14m — Backpropagation with chain rule and layer-wise gradients
5. Gradient checks with finite differences

- **Module 2 — Optimization Fundamentals (5 videos)**

1. SGD and Momentum
2. Nesterov Momentum versus Momentum
3. Adam and AdamW with decoupled weight decay
4. Learning rate schedules: step, cosine, warmup
5. Batch size versus generalization and throughput

- **Module 2.5 — Practise Module**
- Implement an MLP in NumPy, verify gradients, and compare SGD versus Adam on a toy dataset.
- **Module 3 — Activations, Initialization, and Normalization (5 videos)**

1. ReLU, GELU, Tanh, Sigmoid: saturation and dead neurons
2. Initialization: Xavier and He; why it matters
3. Batch Normalization and Layer Normalization: where and why
4. Residual connections and stability
5. Practical tuning checklist and common fixes

- **Week Assignment**
- Train an MLP on MNIST. Compare two optimizers and one learning rate schedule; submit curves and a stability note.

Week 2 — Regularization and Training Stability

- **Module 1 — Regularization and Generalization (5 videos)**

1. Bias-variance trade-off and diagnostics
2. L2 weight decay versus L1 and sparsity
3. Dropout and stochastic depth with caveats
4. Early stopping patterns and checkpoints

5. Label smoothing and confidence calibration

- **Module 2 — Data Augmentation as Regularizer (5 videos)**

1. Flips, rotations, random crops
2. Color jitter and Random Erasing
3. MixUp and CutMix explained
4. RandAugment overview and policy tuning
5. When augmentation hurts and how to detect it

- **Module 2.5 — Practise Module**
- Ablate two regularizers on the same dataset and summarize effects on curves and F1 or ROC AUC.
- **Module 3 — Practical Stability in Training (5 videos)**

1. Exploding and vanishing gradients; gradient clipping
2. Gradient noise scale and batch size choice
3. Warmup and restarts with cosine annealing
4. Mixed precision training and speed-ups
5. Best practices for very small datasets

- **Week Assignment**
- Train two MLP variants with different regularizers; submit curves, metrics, and an ablation table.

Week 3 — Transfer Learning with Pretrained CNNs

- **Module 1 — Pretrained CNN Families (5 videos)**

1. VGG, ResNet, EfficientNet design trade-offs
2. Parameters, FLOPs, and latency basics
3. Pooling heads and classifier design
4. Choosing a backbone for your data size
5. Common pitfalls including domain shift

- **Module 2 — Transfer Learning Workflows (5 videos)**

1. Feature extraction versus fine-tuning
2. Freezing and gradual unfreezing
3. Discriminative learning rates
4. Augmentation strategies for transfer learning
5. Key hyperparameters: learning rate and weight decay

- **Module 2.5 — Practise Module**

- Fine-tune ResNet-18 and EfficientNet-B0 on the same dataset; compare accuracy and speed.
- **Module 3 — Hands-on Transfer Learning (5 videos)**

1. Data module and transforms
2. Model setup and freezing policy
3. Training loop and scheduler
4. Validation and early stopping
5. Checkpoints and an inference script

- **Week Assignment**
- Deliver a transfer learning notebook and a two-model comparison with curves and confusion matrices.

Week 4 — Transformers for Vision

- **Module 1 — Self-Attention Basics (5 videos)**

1. Attention mechanism intuition
2. Query, Key, Value explained
3. Encoder-decoder concept
4. Scaled dot-product attention math
5. Limitations and compute trade-offs

- **Module 2 — Vision Transformers (5 videos)**

1. Patch embeddings and positional encodings
2. Multi-head self-attention block
3. Variants: DeiT Tiny, Base, Large
4. Throughput versus accuracy trade-offs
5. Training challenges for ViT

- **Module 2.5 — Practise Module**
- Train a tiny Vision Transformer on CIFAR-10 and compare with a CNN baseline.
- **Module 3 — CNN versus Transformer Comparison (5 videos)**

1. Fair training protocol design
2. Matching augmentation and learning rate
3. Metrics and plots
4. Error analysis contrasts
5. Practical takeaways

- **Week Assignment**

- Compare ResNet-18 and ViT-Tiny under identical training; submit curves and a results table.

Month 4 — Image Processing and Object Detection with Hybrid Vision

Week 1 — Image Processing with OpenCV

- **Module 1 — Image Operations and Histograms (5 videos)**

1. Resizing and aspect ratios
2. Interpolation choices
3. Normalization schemes
4. Histograms and histogram equalization
5. Color spaces: RGB, HSV, LAB

- **Module 2 — Filters and Edges (5 videos)**

1. Blur filters: Gaussian, median, bilateral
2. Sharpening kernels
3. Sobel and Canny edges
4. Morphology: erode, dilate, open, close
5. Practical preprocessing pipelines

- **Module 2.5 — Practise Module**
- Build a preprocessing pipeline and export before and after panels on ten images.
- **Module 3 — Augmentation for Classification (5 videos)**

1. Flips, rotations, random crops
2. Color jitter and Random Erasing
3. MixUp and CutMix basics
4. RandAugment overview
5. When to disable augmentation

- **Week Assignment**
- Notebook with pipeline and three visuals: histograms, edges, augmented examples.

Week 2 — CNN Foundations for Vision

- **Module 1 — CNN Math and Intuition (5 videos)**

1. Convolutions, stride, padding
2. Receptive fields and dilation
3. Pooling versus strided convolution
4. Nonlinearities in CNNs
5. Parameter counting and capacity

- **Module 2 — Classic to Modern CNNs (5 videos)**

1. LeNet, AlexNet, VGG motifs
2. ResNet and skip connections
3. EfficientNet scaling
4. Depthwise separable convolution
5. Choosing an architecture for your problem

- **Module 2.5 — Practise Module**
- Train a tiny CNN and compare to an MLP on the same dataset; include confusion matrices.
- **Module 3 — Training and Evaluating a Solid CNN (5 videos)**

1. Loss and optimizer choices
2. Learning rate scheduling
3. Regularization: weight decay and dropout
4. Augmentation combinations that work
5. Early stopping and checkpoints

- **Week Assignment**
- Run baseline versus improved CNN with plots and an ablation table.

Week 3 — Object Detection

- **Module 1 — Detection Fundamentals (5 videos)**

1. Sliding windows and proposals
2. R-CNN family overview
3. Anchors and feature pyramids
4. Non-maximum suppression mechanics
5. Datasets and annotations

- **Module 2 — YOLO and SSD Concepts (5 videos)**

1. One-shot detection idea
2. YOLO heads and grid design
3. SSD multi-scale predictions
4. Training tricks and pitfalls
5. Where detectors fail

- **Module 2.5 — Practise Module**
- Run a pretrained YOLO or SSD on twenty-five to fifty images and collect results.
- **Module 3 — Evaluating Detectors (5 videos)**

1. Intersection over Union and mean Average Precision
2. Tuning confidence threshold and NMS

3. Error analysis by class and size
4. Qualitative visualization techniques
5. Quick robustness checks

- **Week Assignment**
- Short report with detector results including mean Average Precision and Intersection over Union; discuss three error cases.

Week 4 — Hybrid Vision Models

- **Module 1 — Hybrid Architectures (5 videos)**

1. Convolutional stem with attention blocks
2. Windowed attention in Swin Transformer
3. Convolutional vision transformers such as CvT
4. Multi-scale feature routing
5. Latency versus accuracy trade-offs

- **Module 2 — Fusion Patterns (5 videos)**

1. Early fusion and late fusion
2. Cross-attention bridges
3. Feature concatenation versus summation
4. Knowledge distillation to hybrids
5. Memory and compute budgeting

- **Module 2.5 — Practise Module**
- Build a simple Swin and EfficientNet fusion; profile throughput and accuracy.
- **Module 3 — Benchmarking CNN, ViT, and Hybrid (5 videos)**

1. Fair experimental setup
2. Metric suite and latency measurement
3. Results tables and plots
4. Error cases per model
5. Choosing the winner and why

- **Week Assignment**
- Train CNN, ViT, and Hybrid on one dataset; submit accuracy and latency table with a short analysis.

Month 5 — NLP Foundations and Applications

Week 1 — NLP Basics and Embeddings

- **Module 1 — Text Preprocessing and Tokenization (6 videos)**

1. Text normalization and cleaning

2. Tokenization fundamentals
3. Subword tokenization: BPE and WordPiece
4. Handling OOV and rare words
5. Building a simple tokenizer pipeline
6. Mini-lab: compare tokenizers on a sample corpus

- **Module 2 — Word and Contextual Embeddings (6 videos)**

1. Word2Vec and GloVe concepts
2. Training or loading word embeddings
3. Evaluating embeddings with analogies
4. Contextual embeddings overview (ELMo to BERT)
5. Using pre-trained embeddings in a model
6. Mini-lab: visualize embeddings with t-SNE

- **Module 2.5 — Practise Module**
- Build a small text pipeline that tokenizes and embeds, then classify with logistic regression.
- **Module 3 — Classic NLP Tasks (5 videos)**

1. Sentiment analysis pipeline
2. Topic modeling overview (LDA)
3. N-gram language models
4. Text classification metrics and pitfalls
5. Packaging a simple sentiment model

- **Week Assignment**
- Prepare a notebook that trains a classic text classifier and reports metrics and error cases.

Week 2 — Sequence Models

- **Module 1 — RNNs and GRUs (5 videos)**

1. Recurrent neural network fundamentals
2. Vanishing and exploding gradients in RNNs
3. GRU internals and intuition
4. Training a small GRU for sentiment
5. Tips for batching and padding

- **Module 2 — LSTMs and Attention (5 videos)**

1. LSTM internals and intuition
2. Sequence to sequence basics

3. Additive versus multiplicative attention
4. Implement attention in a seq2seq model
5. Evaluate with BLEU or ROUGE

- **Module 2.5 — Practise Module**
- Build a small seq2seq model with attention for toy translation.
- **Module 3 — Practical Seq2Seq (5 videos)**

1. Data preparation and tokenization for seq2seq
2. Teacher forcing and scheduled sampling
3. Inference with greedy and beam search
4. Handling long sequences and truncation
5. Error analysis for sequence tasks

- **Week Assignment**
- Train a GRU or LSTM model on a small dataset and submit metrics with a short error analysis.

Week 3 — Transformers for NLP

- **Module 1 — Transformer Architecture (5 videos)**

1. Encoder and decoder stacks
2. Multi-head attention and feed-forward layers
3. Positional encodings
4. Layer normalization and residual connections
5. Training dynamics and scaling laws

- **Module 2 — BERT and GPT Families (5 videos)**

1. Masked language modeling versus causal modeling
2. Fine-tuning BERT for classification
3. Prompting and zero-shot with GPT-style models
4. Parameter efficient fine-tuning (adapters and LoRA)
5. Evaluation and safety considerations

- **Module 2.5 — Practise Module**
- Fine-tune a small BERT for sentiment or NER using HuggingFace.
- **Module 3 — HuggingFace Practical (5 videos)**

1. Datasets and tokenizers
2. Trainer API and custom loops
3. Checkpoints and early stopping
4. Exporting and inference

5. Packaging a CLI for predictions

- **Week Assignment**
- Submit a fine-tuned BERT notebook with metrics and an inference script.

Week 4 — NLP Applications and Responsible AI

- **Module 1 — Applications (5 videos)**

1. Summarization
2. Translation
3. Question answering
4. Named entity recognition
5. Retrieval augmented generation overview

- **Module 2 — Evaluation, Bias, and Safety (5 videos)**

1. Metrics for classification and generation
2. Bias and fairness checks
3. Toxicity and safety guardrails
4. Data drift monitoring
5. Model cards and documentation

- **Module 2.5 — Practise Module**
- Create a small evaluation and bias checklist for your best NLP model.
- **Module 3 — Deployment for NLP (5 videos)**

1. Serving models with a simple API
2. Batch versus online inference
3. Latency and cost considerations
4. Logging and feedback loops
5. Building a minimal demo page

- **Week Assignment**
- Final NLP mini-project: pick one task, fine-tune or build a model, and deliver metrics and a small demo.