CS3491 Artificial Intelligence and Machine Learning — Quick Notes (Anna University, R2021)

Below are concise, exam-focused notes organized unit-wise per the Anna University CS3491 syllabus (Regulation 2021). These align with standard unit topics, learning objectives, and typical question themes for the course.[1] [2] [3] [4] [5] [6]

Unit I: Problem Solving and Search

- What is AI: Study of intelligent agents that perceive and act to maximize goal achievement.[2] [3] [1]
- Agents and Environments: PEAS (Performance, Environment, Actuators, Sensors), agent types: simple reflex, model-based, goal-based, utility-based.[1] [2]
- Problem Formulation: Initial state, actions, transition model, goal test, path cost; state space as a graph.[2] [1]
- Uninformed Search:
  - BFS: Complete, optimal for uniform step cost; time/space O(b^d).[1] [2]
  - DFS: Low memory; may be incomplete, not optimal; time O(b^m).[2] [1]
  - UCS: Complete and optimal for positive costs; uses priority on path cost.[1] [2]
  - IDS: DFS depth-limited iteration; complete, optimal for uniform costs.[2] [1]
- Informed (Heuristic) Search:
  - Greedy Best-First: Expands node with lowest h(n); fast but not optimal.[1] [2]
  - A∗: f(n)=g(n)+h(n); optimal if h is admissible/consistent.[2] [1]
- Local Search/Optimization:
  - Hill Climbing, Simulated Annealing, Genetic Algorithms; suitable for large spaces, CSPs, VMs.[1] [2]
- Adversarial Search (Games):
  - Minimax with depth-limited search; Alpha-Beta pruning reduces explored nodes without altering result.[2] [1]
- Constraint Satisfaction Problems (CSP):
  - Variables, domains, constraints; Backtracking search with MRV, Degree, LCV heuristics; Inference: Forward Checking, Arc Consistency (AC-3).[1] [2]

Unit II: Probabilistic Reasoning

- Uncertainty: Probability as degree of belief; conditional probability, independence, Bayes' rule $P(A|B)=P(B|A)P(A)/P(B)$.[1] [2] [3]
- Naive Bayes: Generative model with conditional independence of features given class; fast baseline classifier.[3] [2] [1]
- Bayesian Networks (BNs):
  - DAG encoding conditional independencies; joint = product of local conditionals.[2] [1]
  - Exact inference: Variable Elimination, Belief Propagation (polytrees).[1] [2]
  - Approximate inference: Sampling (Likelihood weighting, Gibbs), Loopy BP for general graphs.[2] [1]
- Causal Networks: Edges represent causal relations; interventions (do-operator) vs observation; useful for reasoning and decision-making.[1] [2]

Unit III: Supervised Learning

- Basics: Training set, loss functions, overfitting/underfitting, train/val/test split, cross-validation, regularization (L1/L2).[5] [3] [2] [1]
- Linear Regression:
  - Least squares; Gradient Descent/SGD; Multiple regression; Bayesian linear regression (posterior over weights).[3] [2] [1]
- Linear Classification:
  - Logistic Regression: Sigmoid, cross-entropy loss, probabilistic discriminative model.[2] [1]
  - Naive Bayes: Probabilistic generative; Gaussian/Multinomial variants.[1] [2]
  - SVM: Maximum-margin hyperplane; kernels (RBF, polynomial); C and gamma tuning.[2] [1]
- Trees and Ensembles (preview):
  - Decision Trees (ID3/C4.5/CART): Splits by information gain/Gini; pruning to reduce overfitting.[3] [1] [2]
  - Random Forests: Bagging of trees + feature randomness; robust baseline.[3] [1] [2]

Unit IV: Ensemble Techniques and Unsupervised Learning

- Combining Learners:
  - Model combination schemes: Averaging, Voting (hard/soft), Weighted voting.[3] [1] [2]
  - Bagging: Reduces variance by bootstrap aggregation (e.g., Random Forests).[3] [1] [2]
  - Boosting: Sequentially reweights errors (e.g., AdaBoost, Gradient Boosting); can reduce bias; watch for overfitting and noise sensitivity.[3] [1] [2]
  - Stacking: Meta-learner on base model outputs; careful CV needed.[3] [1] [2]
- Unsupervised Learning:

- K-means: Partition into k clusters via centroid updates; sensitive to init; use k-means++. [3] [1] [2]
- KNN (instance-based): Non-parametric; k and distance metric critical; no training cost, high query cost. [3] [1] [2]
- Gaussian Mixture Models (GMM): Soft clustering; EM algorithm alternates E-step (posteriors) and M-step (parameters). [1] [2] [3]

Unit V: Neural Networks and Deep Learning

- Perceptron: Linear binary classifier; learns with perceptron rule if data linearly separable. [5] [2] [3] [1]
- MLP: Layers of neurons with nonlinear activations (sigmoid/tanh/ReLU); universal approximator; trained via backpropagation and (S)GD. [2] [3] [1]
- Activations: Sigmoid/tanh (saturation), ReLU (sparse, mitigates vanishing), Leaky ReLU; choose based on depth and task. [3] [1] [2]
- Optimization: SGD, Momentum, Nesterov, Adam; learning rate schedules; batch vs mini-batch trade-offs. [1] [2] [3]
- Regularization: L2, dropout, early stopping, data augmentation; Batch Normalization for stable training. [2] [3] [1]
- Vanishing/Exploding Gradients: Use ReLU/variants, careful init (He/Xavier), normalization, residual connections (advanced). [3] [1] [2]

Typical Exam Themes and Tips

- Unit I: PEAS, agent types, A* optimality conditions, compare BFS/DFS/UCS/IDS, alpha-beta example, CSP with MRV/AC-3. [7] [8] [1]
- Unit II: Derive Bayes' rule scenarios, construct small BN and perform variable elimination, explain Naive Bayes assumptions and failure cases. [9] [1] [2]
- Unit III: Derive gradient for linear/logistic regression, compare discriminative (LogReg) vs generative (NB), SVM margin intuition and kernel role. [1] [2]
- Unit IV: Differences between bagging/boosting/stacking; AdaBoost steps; run 1–2 EM iterations on a tiny GMM; k-means with given initial clusters. [10] [2] [1]
- Unit V: Perceptron convergence idea, write backprop steps, effects of activation choices, explain vanishing gradients and remedies, regularization methods. [5] [2] [1]

Quick Formulas and Concepts

- Bayes' rule: $P(A|B)=P(B|A)P(A)/P(B)$. [1] [2]
- Logistic regression: $p(y=1|x)=\sigma(w\cdot x+b)$; loss = $-\sum y_i \log p + (1-y_i)\log(1-p)$. [1] [2]
- SVM primal (soft-margin): minimize $\frac{1}{2}||w||^2 + C\sum\xi_i$ subject to $y_i(w\cdot x_i+b)\geq 1-\xi_i$, $\xi_i\geq 0$. [1] [2]
- K-means objective: minimize $\sum_i||x_i-\mu_{c(i)}||^2$; update μ_k as mean of assigned points. [1] [2]
- EM for GMM:

- E-step: $\gamma_{ik} = \pi_k N(x_i|\mu_k,\Sigma_k) / \sum_j \pi_j N(x_i|\mu_j,\Sigma_j)$
- M-step: update π_k, μ_k, Σ_k using γ_{ik}.[2] [1]

- Backprop: chain rule through layers; weight update $w \leftarrow w - \eta \partial L/\partial w$; use BN/Dropout as needed.[3] [1] [2]

Suggested Study Resources

- Syllabus/unit breakdowns and notes aligned to R2021 help plan preparation and map outcomes to topics.[6] [5] [1] [3]
- Question banks and previous papers illustrate typical prompts (Part A short answers, Part B/Part C long answers and numericals).[11] [8] [12] [13]

Use these notes alongside class materials and solve past questions for each unit to strengthen recall and application.

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1. https://padeepz.net/cs3491-artificial-intelligence-and-machine-learning-pdf/
2. https://www.studocu.com/in/document/anna-university/artificial-intelligence-and-machine-learning/cs3491-ai-and-ml-syllabus/44334201
3. https://www.aplustopper.com/cs3491-artificial-intelligence-and-machine-learning-syllabus/
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5. https://learnengineering.in/cs3491-artificial-intelligence-and-machine-learning/
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8. https://www.studocu.com/in/document/anna-university/artificial-intelligence-and-machine-learning/cs3491-aiml-unit-1-question/122863278
9. https://www.brainkart.com/materials/artificial-intelligence-and-machine-learning---cs3491-2056/important-questions-and-question-bank/
10. https://www.scribd.com/document/872884643/CS3491-Expected-Questions-April-May-2025
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13. https://www.enggtree.com/cs3491-artificial-intelligence-and-machine-learning-question-papers-2021-regulation/