Hints for Exercises in **Chapter 2**

1. Difference between propositional logic and first-order logic

Answer:
Propositional logic deals with statements that are either true or false, without internal structure. First-order logic extends this by including quantifiers (∀, ∃), variables, and predicates, allowing more expressive representations.

Hint:
Think about how you'd represent "All humans are mortal" in each logic system.

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2. Syntax and semantics in logic

Answer:
Syntax refers to the formal structure or rules for writing logical expressions. **Semantics** defines the meaning or truth of those expressions in a model.

Hint:
Consider how a grammatically correct sentence might still be meaningless; logic works similarly.

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3. Logical inference

Answer:
Logical inference is the process of deriving new statements from known ones.

- **Valid:** From "All birds fly" and "Penguin is a bird," infer "Penguin flies."
- **Invalid:** From "All birds fly" and "Penguin flies," infer "Penguin is a bird."

Hint:
Try creating your own examples and test their validity.

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4. Soundness and completeness

Answer:
A system is **sound** if all derivable statements are true. It is **complete** if all true statements can be derived. These properties ensure reliability and power in reasoning.

Hint:
Ask: Can I trust the system to never lie and to find all truths?

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5. Limitations of logic in real-world knowledge

Answer:
Logic struggles with uncertainty, ambiguity, and incomplete information. It's rigid and doesn't handle probabilistic reasoning well.

Hint:
Think about how humans deal with vague or contradictory information - can logic do the same?

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6. Resolution principle

Answer:
Resolution is a rule of inference that combines clauses to eliminate contradictions. It's powerful because it's complete for propositional logic and forms the basis of many automated reasoning systems.

Hint:
Try resolving "A OR B" and "NOT A OR C": what do you get?

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7. Translating natural language to logic

Answer:
Example:

- "It is raining or snowing" → $R \lor S$ (Propositional)
- "All cats are mammals" → $\forall x\ (Cat(x) \rightarrow Mammal(x))$ (First-order)

Hint:
Break sentences into subjects, predicates, and logical connectors.

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8. Normal forms in logic

Answer:

- **CNF (Conjunctive Normal Form):** AND of ORs
- **DNF (Disjunctive Normal Form):** OR of ANDs
  They simplify reasoning and are essential for algorithms like resolution.

Hint:
Try converting simple expressions like “(A → B)” into CNF.

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9. Logical connectives and truth tables

Answer:

- **AND (∧):** True if both are true
- **OR (∨):** True if at least one is true
- **NOT (¬):** Inverts truth
- **IMPLIES (→):** False only if premise is true and conclusion false
- **BICONDITIONAL (↔):** True if both sides are equal

Hint:
Build truth tables for each to see how they behave.

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10. Unification in first-order logic

Answer:
Unification is the process of making two logical expressions identical by finding a substitution for variables. It’s crucial for applying resolution in first-order logic.

Hint:
Try matching “Loves(x, y)” with “Loves(John, y)”: what substitution works?

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11. Logic-based AI vs. other approaches

Answer:
Logic-based AI uses formal rules and reasoning. Connectionist (neural networks) and statistical AI rely on data and patterns. Logic is precise; others are flexible and data-driven.

Hint:
Compare how each approach handles language translation or image recognition.

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12. Relevance of logic in AI today

Answer:
Logic is still used in knowledge representation, automated reasoning, planning, and semantic web technologies. It’s essential for explainable AI and rule-based systems.

Hint:
Explore AI applications in law, medicine, or robotics — where rules matter.

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13. Challenges in scaling logic-based systems

Answer:
Complexity grows rapidly with more rules and facts. Handling uncertainty, incomplete data, and real-time reasoning is difficult.

Hint:
Think about how many rules you'd need to model human conversation.

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14. Implementing a theorem prover using resolution

Answer:
A basic theorem prover converts expressions to CNF and applies resolution to check entailment. The example implemented shows how a query like “C” can be proven from a knowledge base.

Hint:
Try modifying the knowledge base and see how the result changes.

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15. Creating a small expert system

Answer:
Use rules like:

- IF animal has feathers THEN it is a bird
- IF bird cannot fly THEN it might be a penguin
  Implement forward chaining to infer conclusions from facts.

Hint:
Pick a narrow domain and list simple rules, then build logic around them.

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16. Knowledge representation and ontologies

Answer:
Ontologies are structured frameworks for organizing knowledge. They define concepts, relationships, and rules, enabling logical reasoning and interoperability.

Hint:
Explore how medical ontologies help diagnose diseases.

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17. Solving a logic puzzle using resolution

Answer:
Choose a puzzle like Sudoku. Represent constraints as logical clauses and apply resolution to eliminate invalid options until a solution emerges.

Hint:
Start with a small grid and write rules for rows, columns, and boxes.

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18. Search algorithms in problem-solving

Answer:
Search algorithms like BFS, DFS, and A* help find solutions in puzzles, games, and planning by exploring possible states and paths.

Hint:
Visualize a maze, how would you find the shortest path?

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19. Challenges in large state spaces

Answer:
Large spaces lead to memory and time issues. It’s hard to explore all possibilities, and heuristics may be needed to guide search.

Hint:
Think about chess, how many moves ahead can you realistically compute?

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20. Local search algorithms

Answer:

- **Hill Climbing:** Moves to better states
- **Simulated Annealing:** Allows occasional worse moves to escape local optima Useful for optimization in large spaces.

Hint:
Try solving a puzzle by tweaking one piece at a time.

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21. Game-playing AI using minimax

Answer:
Implement minimax to evaluate game states and choose optimal moves. Use depth-limited search for simplicity. Let a human play against the AI.

Hint:
Start with Tic-Tac-Toe, can your AI block and win?

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22. Stop word removal function

Answer:
Create a list like ["the", "a", "is", "in"] and filter tokens from a sentence. This helps in text preprocessing for NLP tasks.

Hint:
Try removing stop words from a paragraph, what’s left?

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23. Keyword-based topic detection

Answer:

Define keyword lists for topics. Scan a document for matches and assign the topic with the most hits.

Hint:

Test with news headlines, can you guess the topic?