CS 188 Introduction to AI
Fall 2005 Stuart Russell Midterm

You have 80 minutes. The exam is open-book, open-notes. 100 points total. Panic not.

Mark your answers ON THE EXAM ITSELF. Write your name, SID, login, and section number at the top of each page.
For true/false questions, CIRCLE *True* OR *False*.
For multiple-choice questions, CIRCLE **ALL** CORRECT CHOICES (in some cases, there may be more than one).

If you are not sure of your answer in true/false and multiple-choice questions, you may wish to provide a *brief* explanation.

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Q. 1	Q. 2	Q. 3	Q. 4	Q. 5	Q. 6	Total
/12	/16	/16	/16	/18	/22	/100

1. (12 pts.) True/False

(a) (2) *True/False*: There exist task environments E_1 and E_2 and agent A such that A is perfectly rational in both E_1 and E_2, even though E_1 and E_2 are not identical.

(b) (2) *True/False*: Search algorithms cannot be applied in completely unobservable environments.

(c) (2) *True/False*: For any propositional KB for a logical agent that is to operate over T time steps, there is an equivalent circuit-based agent whose circuit is roughly T times smaller.

(d) (2) *True/False*: Every existentially quantified sentence in first-order logic is true in any model that contains exactly one object.

(e) (2) *True/False*: A perfectly rational backgammon agent never loses.

(f) (2) *True/False*: Depth-first search always expands at least as many nodes as A* search with an admissible heuristic.

2. (16 pts.) Problem solving
Consider the problem of solving two 8-puzzles.

(a) (6) Give a complete problem formulation.

(b) (4) How large is the reachable state space? (Give an exact numerical expression; no need to calculate its value.)

(c) (2) Suppose we make the problem adversarial as follows: the two players take turns moving; a coin is flipped to determine the puzzle on which to make a move in that turn; and the winner is the first to solve one puzzle. Which algorithm can be used to choose a move in this setting?

(d) (4) Give an informal proof that someone will eventually win if both play perfectly.

3. (16 pts.) Propositional logic

(a) (5) Briefly explain the following assertion, or find a counterexample: Every pair of propositional clauses has either no resolvents, or all their resolvents are logically equivalent.

(b) (3) *True/False*: $(C \lor (\neg A \land \neg B)) \equiv ((A \Rightarrow C) \land (B \Rightarrow C))$.

(c) (4) *True/False*: For any propositional sentences α, β, γ, if $\alpha \models (\beta \land \gamma)$ then $\alpha \models \beta$ and $\alpha \models \gamma$.

(d) (4) *True/False*: For any propositional sentences α, β, γ, if $\alpha \models (\beta \lor \gamma)$ then $\alpha \models \beta$ or $\alpha \models \gamma$ (or both).

4. (16 pts.) Logical knowledge representation

(a) (8) Which of the following are semantically and syntactically correct translations of "No dog bites a child of its owner"?

i. $\forall x \;\; Dog(x) \;\Rightarrow\; \neg Bites(x, Child(Owner(x)))$

ii. $\neg\exists\, x, y \;\; Dog(x) \land Child(y, Owner(x)) \land Bites(x, y)$

iii. $\forall x \;\; Dog(x) \;\Rightarrow\; (\forall y \;\; Child(y, Owner(x)) \;\Rightarrow\; \neg Bites(x, y))$

iv. $\neg\exists x \;\; Dog(x) \;\Rightarrow\; (\exists y \;\; Child(y, Owner(x)) \land Bites(x, y))$

(b) (8) Translate into first order logic the sentence "Everyone's DNA is unique and is derived from their parents' DNA." You must specify the precise intended meaning of your vocabulary terms. [*Hint*: do not use the predicate $Unique(x)$, since uniqueness is not really a property of an object in itself!]

5. (18 pts.) Logical inference

Suppose a knowledge base contains just the following first-order Horn clauses:

$Ancestor(Mother(x), x)$

$Ancestor(x, y) \land Ancestor(y, z) \Rightarrow Ancestor(x, z)$

Consider a forward chaining algorithm that, on the jth iteration, terminates if the KB contains a sentence that unifies with the query, else adds to the KB every atomic sentence that can be inferred from the sentences already in the KB after iteration $j - 1$.

(a) (12) For each of the following queries, say whether the algorithm will (1) give an answer (if so, write down that answer); or (2) terminate with no answer; or (3) never terminate.

i. (3) $Ancestor(Mother(y), John)$

ii. (3) $Ancestor(Mother(Mother(y)), John)$

iii. (3) $Ancestor(Mother(Mother(Mother(y))), Mother(y))$

iv. (3) $Ancestor(Mother(John), Mother(Mother(John)))$

(b) (3) Can a resolution algorithm prove from the original knowledge base that $\neg Ancestor(John, John)$? Explain briefly.

(c) (3) Suppose the KB is augmented with the assertion that $\neg(Mother(x) = x)$, and that the resolution algorithm includes inference rules for equality. Now what is the answer to (b)?

6. (22 pts.) Game playing

Consider the game of 2×2 tictactoe where each player has the additional option of *passing* (i.e., marking no square). Assume X goes first.

(a) (6) Draw the full game tree down to depth 2. You need not show nodes that are rotations or reflections of siblings already shown. (Your tree should have five leaves.)

(b) (4) Suppose the evaluation function is the number of Xs minus the number of Os. Mark the values of all leaves and internal nodes.

(c) (4) Circle any node that would not be evaluated by alpha–beta during a left-to-right exploration of your tree.

(d) (4) Suppose we wanted to *solve* the game to find the optimal move (i.e., no depth limit). Explain why alpha–beta with an appropriate move ordering would be *much* better than minimax.

(e) (4) Briefly discuss how one might modify minimax so that it can solve the really exciting game of *suicide* 2×2 tictactoe with passing, in which the first player to complete 2-in-a-row loses. Describe optimal play for this game. [*Hint*: which is better—a move that definitely loses or a move whose value is unknown?]