CS 188 Fall 1999	Introduction to AI Stuart Russell	Midterm

You have 1 hour and 20 minutes. The exam is open-book, open-notes.
100 points total.

You will not necessarily finish all questions, so do your best ones first.
Write your answers in blue books. Check you haven't skipped any by accident. Hand them all in. Panic not.

1. **(18 pts.) True/False**
   Decide if each of the following is true or false. If you are not sure you may wish to provide a *brief* explanation to follow your answer.
   (a) (3) A rational agent outperforms all nonrational agents because it knows the actual outcome of its actions.
   (b) (3) A sound logical reasoning procedure is not necessary for passing the Turing test.
   (c) (3) Internal state is of no use to an agent that lives in an accessible environment.
   (d) (3) $R(F(y), y, x)$ and $R(x, F(A), F(v))$ are unifiable.
   (e) (3) Simple hill-climbing is a complete algorithm for solving CSPs.
   (f) (3) $\forall x \;\; x = x$ is a satisfiable sentence.

2. **(20 pts.) Search, constraint satisfaction**
   A domino is made by sticking together two squares along an edge. An n-omino is made by sticking together n squares along edges, any way you please. Thus, there is only one possible domino shape, but there are two distinct 3-ominoes (3-in-a-row and L-shaped).
   (a) (5) Suppose we have to construct an n-omino that is beautiful, for fixed n. Give a complete formulation of the search problem that corresponds to this task, assuming that a beauty detector is available.
   (b) (5) Identify a suitable search algorithm for this task and explain your choice.
   (c) (5) Give an upper bound, in terms of n, on the number of possible n-ominoes. (Hint: think about the branching factor for the construction process.)
   (d) (5) Now consider the problem of *tiling* a given n-omino with dominoes—that is, covering it exactly without overlapping any dominoes. Formulate this problem precisely as a constraint satisfaction problem.

3. **(14 pts.) Propositional Logic**
   Assume we have the following propositions: *BatteryDead*, *RadioWorks*, *OutOfGas*, and *CarStarts*. (You may use the abbreviations B, R, O, C in your answer.)
   (a) (2) What is the total number of possible models?
   (b) (4) How many models are there in which the following sentence is *false*?
   $(\mathit{RadioWorks} \wedge \mathit{CarStarts}) \;\Rightarrow\; (\neg \mathit{OutOfGas} \wedge \neg \mathit{BatteryDead})$
   (c) (4) Is the above sentence equivalent to a set of Horn clauses? Explain.
   (d) (4) Prove that the above sentence is *not* entailed by the sentence $\mathit{RadioWorks} \Rightarrow \neg \mathit{BatteryDead}$.

4. **(12 pts.) First-order logic**
   Let $M(x)$ be true if x is a mail carrier; $B(x)$ be true if x lives in Berkeley; and $K(x, y)$ be true if x knows y. Translate the following sentences into first-order logic:
   (a) (6) There are at least two mail carriers who live in Berkeley.
   (b) (6) All the mail carriers who live in Berkeley know each other.

5. (16 pts.) Resolution

(a) (6) Explain how to prove that two sentences A and B are logically equivalent using resolution.

(b) (10) Consider the two sentences:
A: $\forall x\ [\exists y\ P(x,y)] \Rightarrow Q(x)$
B: $\forall x, y\ P(x,y) \Rightarrow Q(x)$
Prove that A entails B.

6. (20 pts.) Planning

The STRIPS operator $Ride(x, e, f_1, f_2)$ describes the action of a person x riding an elevator e from floor f_1 to floor f_2, and is defined as follows:

$$Op(\text{ACTION}: Ride(x, e, f_1, f_2), \text{PRECOND}: On(x, f_1) \wedge On(e, f_1) \wedge Working(e),$$
$$\text{EFFECT}: \neg On(x, f_1) \wedge \neg On(e, f_1) \wedge On(x, f_2) \wedge On(e, f_2))$$

(a) (3) Write a definition for the STRIPS operator $Call(x, e, f)$ in which person x calls an elevator e from floor f, so that the elevator (eventually) arrives at f.

(b) (4) Write down an effect axiom for the *Ride* action using the information contained in the STRIPS operator definition.

(c) (4) Write down one frame axiom that would be needed for this world, assuming that everything behaves as expected.

(d) (3) Jeb is on floor 2 and wants to go to floor 3, but the one working elevator E is on floor 7. Using the graphical notation for plans from Chapter 11, describe the initial empty plan corresponding to this problem.

(e) (3) Suppose we decide to add a *Ride* step to this plan to get Jeb to floor 3. Show the new plan after the step is added. Be sure to show both preconditions and postconditions for the new step.

(f) (3) Is there more than one way to complete this plan? Explain.