CS 540-1: Introduction to Artificial Intelligence

Exam 2: 7:15-9:15pm, April 13, 1998

CLOSED BOOK
(one page of notes allowed)

Write your answers on these pages and show your work. If you feel that a question is not fully specified, state any assumptions you need to make in order to solve the problem. You may use the backs of these sheets for scratch work.

Write your name on this and all other pages of this exam. Make sure your exam contains seven problems on eight pages.

Name ______________________________

Student ID ______________________________

Problem	**Score**	**Max Score**
1	_____	25
2	_____	10
3	_____	15
4	_____	10
5	_____	15
6	_____	15
7	_____	10
Total	_____	100

(over)

PROBLEM 1 - Knowledge Representation (25 points)

Convert the following English sentences to first-order predicate calculus. Be sure to use reasonable predicates and functions.

Squares have three sides.

John is Mary's brother.

Growing flowers makes one content.

Someone owes Susan money.

Alice is younger than all of Bill's children.

Currently, apples cost more per pound than any other fruit.

Getting a speeding ticket increases one's insurance rates.
[You must use *situation calculus* here, where the action is *gotTrafficTicket(?ticketType, ?person)*.]

PROBLEM 2 - Production Systems (10 points)

Assume that working memory contains the following facts:

```
sensor(Mineral, Dir1, 5)  sensor(Wall,    Dir2, 9)  sensor(Food,    Dir3, 7)
sensor(Nothing, Dir4, 8)  sensor(Mineral, Dir5, 3)  sensor(Mineral, Dir6, 5)
sensor(Mineral, Dir7, 7)  sensor(Mineral, Dir8, 2)  sensor(Food,    Dir9, 8)
```

And that you have the following production rules:

```
findSomeObject
{
  NOT (foundSomething())
  sensor(?object, ?direction, ?distance)
     ⇒
  assert(foundSomething())
  assert(closestObject(?object, ?direction, ?distance))
}

findClosestObject
{
  closestObject(?object1, ?direction1, ?distance1)
  sensor(?object2, ?direction2, ?distance2)
  lessThan(?distance2, ?distance1)
     ⇒
  retract(closestObject(?object1, ?direction1, ?distance1))
  assert( closestObject(?object2, ?direction2, ?distance2))
}
```

The *conflict resolution* strategy is to execute the matching rule that has the most preconditions. Also assume that a rule will never be executed more than once *with the same variable bindings*. Negation-by-failure is used, and `lessThan` is a procedurally defined predicate.

List below, in order, the changes to working memory that this production system will make. (When there are multiple ways to match `sensor()`, break ties by choosing the lowest numbered direction.)

PROBLEM 3 - Prolog (15 points)

Consider the Prolog program below.

```
a(1, 3).
a(2, 2).
a(3, 1).
b(2, 4).
b(3, 6).
b(4, 8).
r(X, Y) :- a(X, Z), b(Z, Y).
r(X, Y) :- a(X, X).
```

What would Prolog return if given the following queries? (Report *all* the answers returned, in the order Prolog would return them.)

```
?- r(2, 2).
```

```
?- r(V, W).
```

Show below the search tree that Prolog explores when given the `r(2, 2)` query. Number the nodes to indicate the order they were visited.

PROBLEM 4 - Semantic Networks (10 points)

Draw a semantic network that captures the following (hypothetical) world knowledge.

There are three kinds of computers: mainframe, mini, and personal (PCs).

All computers run Unix.

Windows95 only runs on personal computers.

The price of mainframes is high, of minicomputers is moderate, and of PCs is low.

The XYZ brand of personal computers has a very low price, but does not run Windows95.

PROBLEM 5 - Miscellaneous Questions (15 points)

If an FOPC sentence is truth for all interpretations, then it is said to be ______________.

If a logical reasoning system never produces anything that does not logically following from its axioms ("givens"), then we say that system is ________________.

Why do some logic-based systems use *negation by failure*?

Explain what *procedurally defined predicates* are.

Can the following expressions be unified? Justify your answer.

P(?x, F(?x, G(?y)), ?y) *P(A, ?z, G(C, C))*

PROBLEM 6 - Formal Proofs (15 points)

(A) Starting with the following givens, formally prove (for simplicity, the predicate `state()` and some additional frame axioms are not used here):

$$\exists s \;\; color(Box1, Red, s)$$

WFF		Justification
1	box(Box1) ∧ box(Box2) ∧ (Box1 != Box2) ∧ paint(Red) ∧ location(Loc1) ∧ location(Loc2) ∧ (Loc1 != Loc2)	given
2	at(Box1, Loc1, S0) ∧ at(Box2, Loc2, S0) ∧ color(Box1, Blue, S0) ∧ color(Box2, Red, S0)	given
3	∀ b,p,s box(b) ∧ paint(p) ∧ at(b, Loc2, s) ⇒ color(b, p, result(Paint(b, p), s))	given
4	∀ b1,b2,p1,p2,s box(b1) ∧ (b1 != b2) ∧ color(b1, p1, s) ⇒ color(b1, p1, result(Paint(b2, p2), s))	given
5	∀ b,x,y,s location(y) ∧ at(b, x, s) ∧ (x != y) ⇒ at(b, y, result(Move(b, y), s))	given
6	∀ b1,b2,x,y,s at(b1, x, s) ∧ (b1 != b2) ⇒ at(b1, x, result(Move(b2, y), s))	given
7	∀ x,y (x != y) ⇒ (y != x)	given

(B) Circle one (1) *frame axiom* in the above (just circle its identifying number).

PROBLEM 7 - Interpretations (10 points)

Devise an *interpretation* that shows that the following predicate calculus does not capture the accompanying English sentence. Justify your answer by calculating the truth value of the logical sentence in the interpretation you devised.

Every person can see someone.

$\forall\, x \,\{\, \exists\, y \,[\, person(x) \wedge person(y) \Rightarrow sees(x, y) \,]\, \}$