CS 540-1: Introduction to Artificial Intelligence

Exam 2: 7:15-9:15pm, November 20, 1995

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 (7) problems on eight (8) pages.

Name ______________________________

Student ID ______________________________

Problem	**Score**	**Max Score**
1	_____	18
2	_____	15
3	_____	10
4	_____	15
5	_____	14
6	_____	14
7	_____	14
Total	_____	100

PROBLEM 1 - First-Order Predicate Calculus (18 points)

Give *one* (1) predicate calculus representation for each of these English sentences. If you feel a sentence is ambiguous, provide a more detailed sentence that better captures the version represented by your FOPC. Choose reasonable constants, predicates. and functions - the predicate *John's-car-is-red* is *not* an acceptable answer to the first question.

---

i) *John's car is red.*

---

ii) *All of Wendt's books are cataloged.*

---

iii) *Every player on* [the sports teams] *the Packers and the Brewers is rich.*

---

iv) *Every living thing likes Thanksgiving, except for the turkeys.*

---

v) *Unless it is a blizzard, Mary has some mode of transportation for getting to school.*
[note: use situation calculus to represent this sentence]

PROBLEM 2 - FOPC Interpretations (15 points)

For the English-FOPC pairs below, provide a *formal interpretation* that shows that the FOPC on the right does *not* represent the English on the left. Justify your answers by computing the truth value of the wff, given your interpretation, and compare to the 'obvious' meaning of the English.

---

i) *Some horses do not like hay.* $\exists\, x\, [\, horse(x) \;\Rightarrow\; \neg likes(x, Hay)\,]$

---

ii) *Bridge players who know all the rules are successful.* $\forall\, x,r\, [\, \{\, plays(x, Bridge) \wedge ruleOfBridge(r) \wedge knows(x, r)\, \} \;\Rightarrow\; successful(x)\,]$

PROBLEM 3 - Clausal Form (10 points)

Convert (separately) the following FOPC wff's to clausal form.

$\neg [\forall x,y \{ P(x,y) \wedge \neg Q(F(x), G(x, y)) \}]$

$\exists x \forall y \exists z [P(x,y,z) \Leftrightarrow P(z,y,x)]$

PROBLEM 4 - Pattern Matching (15 points)

i) What is the most general unifier of the following pairs of wff's? (If none exists, report ''fail.'') Assume that capital letters are constants and lowercase letters are variables.

$P(x, y, x, z)$ $P(F(w), A, F(B), w)$

$Q(x, F(x), G(F(x)))$ $Q(1, y, G(F(y)))$

---

ii) Given the following Working Memory (WM), what are the valid *variable-binding sets* for the production rule listed below?

WM: $\{ P(0,0), P(1,2), P(2,1), Q(0,0), Q(0,1), Q(1,2), R(0,0,0), R(0,0,1), R(0,1,2), R(1,2,2) \}$

Rule: $\forall\, x,y,z \;\; [\, P(x,y) \wedge Q(x,z) \wedge R(x, y, z)\,] \;\Rightarrow\; Action(x, y, z)$

If *negation by failure* were used, would the above rule match the above WM more, fewer, or the same number of times? Explain your answer.

PROBLEM 5 - 'Natural Deduction' Theorem Proving (14 points)

Using the inference rules for logic, complete the natural deduction proof below, *whose task is to show that* $\exists$ x Z(x) *follows from the givens.* Be sure to justify your steps by stating the inference rule used, along with the previous line(s) to which it was applied.

#	WFF	Justification
1	$P(1)$	*given*
2	$W(1) \wedge W(2) \wedge W(3)$	*given*
3	$\forall x\ [P(x) \Rightarrow \neg R(x)]$	*given*
4	$\forall x\ [Q(x) \vee R(x)]$	*given*
5	$\forall x\ [\ \{Q(x) \wedge W(x)\} \Rightarrow Z(x)]$	*given*
6		

PROBLEM 6 - Resolution Theorem Proving (14 points)

Consider the following formalization of a recent news story.

(1) Student 1 said that the University should construct more on-campus parking.

$$Student(S1) \wedge [\ BuildsParkingLots(Univ) \Rightarrow ListenedTo(Univ, S1)\ ]$$

(2) Student 2 said that the University should not build more parking lots.

$$Student(S2) \wedge [\ \neg BuildsParkingLots(Univ) \Rightarrow ListenedTo(Univ, S2)\ ]$$

(3) Student 3 said the University never listens to students.

$$\forall x\ [\ Student(x) \Rightarrow \neg ListenedTo(Univ, x)\ ]$$

Use *resolution theorem proving* to show that Student 3's statement is *false*.

First, prepare and number your clauses.

Next, repeatedly apply the resolution inference rule.

PROBLEM 7 - Production Systems (14 points)

Consider the following set of production rules. Assume that the conflict resolution strategy is to pick the rule with the most preconditions that (a) matches working memory (WM) and (b) has not already been used. Break ties by choosing the lowest numbered rule. Also assume that the production system terminates when either (a) no unused rules match WM or (b) the system executes a PRINT action.

ASSERT'ing X means that $\neg X$ is removed from WM and X is added, while RETRACT'ing X means that X is removed from WM and $\neg X$ is added.

(1)	$Q \wedge \neg S$	$\Rightarrow$	*ASSERT(R)*
(2)	$P \wedge Q \wedge \neg R$	$\Rightarrow$	*RETRACT(Q), ASSERT(S)*
(3)	R	$\Rightarrow$	*PRINT("Eureka!")*
(4)	S	$\Rightarrow$	*PRINT("Eureka!")*
(5)	$P \wedge S$	$\Rightarrow$	*RETRACT(P), RETRACT(S), ASSERT(Q)*
(6)	$\neg P \wedge \neg Q \wedge \neg R \wedge \neg S$	$\Rightarrow$	*PRINT("I'm Stuck!")*

Illustrate the operation of this production system by filling out the table below.

Time Step	**Working Memory**	**Matching Unused Rules**	**Chosen Rule**
0	$\{P, Q, \neg R, \neg S\}$		

(The End!)