Fall 2002 exam was a 60 minute exam.

(25) **Conversion to Clause Form**

I. (a) Transform the wff $A$ below into CNF (clause) matrix form. For each step required give a brief description of the step and perform the step (if applicable) on the space provided. Failure to follow this format may result in no credit.

(b) Rewrite your answer in part (a) as a single (1 line) $\langle wff \rangle$ simplifying if necessary.

(c) Which form is better (matrix form or the 1-line form) and why? {No explanation, No credit}

\[
\{\text{wff}\} \ A: (\forall x)\{ P(x) \rightarrow [\neg(\forall y)\{Q(x,y) \rightarrow P(f(z))\}] \land (\forall y)\{Q(x,y) \rightarrow P(x)\} \}
\]

(25) **II. Resolution Refutation**

Sam, Clyde and Oscar are elephants. We know the following facts about them:

1. Sam is pink.
2. Clyde is gray and likes Oscar.
3. Oscar is either pink, or gray (but not both) and likes Sam.

Use resolution refutation to prove that a gray elephant likes a pink elephant; that is prove

\[
(\exists x)(\exists y)[\text{Gray}(x) \land \text{Pink}(y) \land \text{Likes}(x,y)]
\]

Solve by drawing a **Refutation Graph** resulting from a **complete** strategy. (Make sure you mark clearly the required substitutions).

[Required: Please note the assigned point values. Each part MUST be answered with something. If left blank, then no credit will be assigned]

(a) Represent the axioms/goal in the Predicate Calculus.

(b) Represent any commonsense knowledge needed to solve the problem using Predicate Calculus,

(c) Convert your axioms, goal and commonsense knowledge (if any) to clause form,

(d) Draw your Refutation Graph, show substitutions are consistent.

(e) Define your strategy, and describe how your graph meets the strategy

{Question 3 was on Neural Networks which was tested in test 1 in Fall 2003}

(25) **IV. Computation Deduction**

Using **Resolution Refutation** deduce the following computation to obtain a value for the goal (3 pts) by drawing the **Consistent Solution Graph** (17 pts) for the goal and prove (or provide a good argument) its consistency (5 pts). Make sure your graph is clearly marked and it follows a complete strategy. You may assume that the system "knows" how to handle function $\text{add}(E_1, E_2, E_3)$ such that if $E_1$ and $E_2$ are known, then $E_3$ is set to the sum of $E_1$ and $E_2$ automatically thereby removing $\text{add}(\ldots,\ldots)$ from the resolution stack.

**Facts:**

1. F1: length(nil,0).

**Rules:**

\[ \text{R1: } \{\text{length}(T,N)\land \lambda(\text{add}(N,1,M))\} \rightarrow \text{length}(\text{cons}(H,T),M) \]

Where $\lambda(y)$ means “Evaluate the argument $y$”

**Goal:** $(\exists z)\text{length}(\text{cons}(\text{boo, cons(on,cons(you,nil))}),z)$

{Note: If you prefer, you may use the notation $\text{length}([\text{boo, on, you}],z)$ or $\text{length}((\text{boo on you}),z).}$

**Required:** Draw the graph, show the substitutions are consistent, and obtain the value of the goal.
Fall 2001 exam was a 90 minute exam.

(25) **Conversion to Clause Form**

I. Transform the wff below into clause form. For each step required give a brief description of the step and perform the step (if applicable) on the space provided. Failure to follow this format may result in no credit.

\(<\text{wff}>:\quad A: \forall x \forall y [\{P(x,y) \vee Q(x,y)\} \rightarrow R(x,y)]\)

(25)

II. **Resolution Refutation**

If a course is easy, some students are happy. If a course has a final, no students are happy. Use Resolution to show that, if a course has a final, the course is not easy.

Solve by drawing a Refutation Graph resulting from a complete strategy. (Make sure you mark clearly the required substitutions).

[Required: Please note the assigned point values. Each part MUST be answered with something. If left blank, then no credit will be assigned]

(5) a. Represent the axioms/goal in the Predicate Calculus.

(2) b. Represent any commonsense knowledge needed to solve the problem using Predicate Calculus,

(5) c. Convert your axioms, goal and commonsense knowledge (if any) to clause form,

(10) d. Draw your Refutation Graph,

(3) e. Define your strategy, and describe how your graph meets the strategy

(25)

III. **Adversarial Search**

Consider the following game tree in which the static scores (in parentheses at the tip nodes) are all from the first player’s point of view.

(a) Assuming that the first player is the maximizing player, what move should the first player choose?

(b) Assuming that the first player is the minimizing player, what move should the first player choose?

(c) What nodes would not need to be examined in part (a) using the alpha-beta algorithm—assuming that the nodes are examined in left-to-right order?

(d) What nodes would not need to be examined in part (b) using the alpha-beta algorithm—assuming that the nodes are examined in right-to-left order?

(e) Is the first player’s move in parts (a) and (c) or in parts (b) and (d) different? Explain.

Using Resolution Refutation deduce the following computation to obtain a value for the goal (3 pts) by drawing the Consistent Solution Graph (17 pts) for the goal and prove (or provide a good argument) its consistency (5 pts). Make sure your graph is clearly marked and it follows a complete strategy. You may assume that the system "knows" how to handle function max(E₁, E₂, E₃) such that if E₁ and E₂ are known, then E₃ is set to the maximum of E₁ and E₂ automatically thereby removing max(_, _, _) from the resolution stack. Alternatively, your answers can consist of unevaluated calls to the built-in function max(_, _, _).

Facts:
   F₁: depth(nil,1).

Rules:
   R₁: atomic(S) → depth(S,0)
   R₂: depth(H,A₁)∧depth(T,A₂)∧max(1+A₁,A₂,A₃) → depth(cons(H,T),A₃)

Goal: (∃z)depth(cons(cons(a,nil),cons(b,nil)),z)

{Note: If you prefer, you may use the notation depth([a],b,z) or depth((a b),z).}

Required: Draw the graph, show the substitutions are consistent, and obtain the value of the goal.

Fall 1999 exam was a 90 minute exam.

(25) Conversion to Clause Form

I. Transform the <wff> below into clause form. For each of the steps required give a brief description of the step and perform the step (if applicable) on the space provided. Failure to follow this format may result in zero credit.

<wff>:
   (∀x)[(∀y)[P(x,y)] → ~{(∀y)[Q(x,y) → R(x,y)]}]

II. Resolution Refutation

Given the following axioms, "Show there is something Green on the table" by drawing a Refutation Graph resulting from a Set-of-Support strategy. (Make sure you mark clearly the required substitutions).

Axioms:
   1. Block-1 is on the Table.
   2. Block-2 is on the Table.
   3. The Color of Block-1 or the Color of Block-2 is Green.

Solve by drawing a Refutation Graph resulting from a complete strategy. (Make sure you mark clearly the required substitutions).

[Required: Please note the assigned point values

(7) a. Represent the axioms/goal in the Predicate Calculus.
(3) b. Represent any commonsense knowledge needed to solve the problem using Predicate Calculus,
(7) c. Convert your axioms, goal and commonsense knowledge (if any) to clause form,
(10) d. Draw your Refutation Graph,
(3) e. Describe how your graph meets the strategy]
(30)

III. Adversarial Search

Consider the following game tree in which the static scores (in parentheses at the tip nodes) are all from the first player’s point of view.

(a) Assuming that the first player is the maximizing player, what move should the first player choose?
(b) Assuming that the first player is the minimizing player, what move should the first player choose?
(c) What nodes would not need to be examined in part (a) using the alpha-beta algorithm—assuming that the nodes are examined in left-to-right order?
(d) What nodes would not need to be examined in part (b) using the alpha-beta algorithm—assuming that the nodes are examined in right-to-left order?
(e) Is the first player’s move in parts (a) and (c) or in parts (b) and (d) different? Explain.

IV. Computation Deduction

Using Resolution Refutation deduce the following computation to obtain a value for the goal (3 pts) by drawing the Consistent Solution Graph (21 pts) for the goal and prove its consistency (6 pts). Make sure your graph is clearly marked and it follows a complete strategy.

Facts:

F1. member(X,cons(X,Y)).
F2: subset(nil,Z).

Rules:

R1: member(X2,Y2) → member(X2,cons(U,Y2)).
R2: member(X3,Y3) ∧ subset(Z3,Y3) → subset(cons(X3,Z3),Y3).

Goal: subset(cons(3,cons(2,nil)),cons(1,cons(2,cons(3,cons(4,nil))))).

(Note: If you prefer, you may use the notation subset([3,2],[1,2,3,4]) or subset((3 2),(1 2 3 4)).)

Required: Draw the graph, show the substitutions are consistent, and obtain the value of the goal.
Resolution Applications.

The following full adder in an EEL-3701 lab with asserted inputs \{1,0,1\} for \{a,b,c1\} has asserted outputs \{0,1\} for \{s,c0\}, respectively. This means that if you assert A1, A2 and A3 you will deduce A4 and A5 using plain Resolution [not Resolution Refutation]. However, Jason Gates obtains outputs \{1,1\} and requests your (TA) help in figuring out what is wrong. Using resolution refutation find out what is wrong with the circuit. (Bonus: 5 additional points if you tell me which IC is defective. 5 more points if you give me the IC number, e.g., 74LSXX]. Indicate any commonsense knowledge needed to solve the problem using Predicate Calculus.

- Let \{f1, x1, x2, a1, a2, o1\} designate the six components.
- Adder(x) means that x is an adder.
- Xorg(x) means that x is an xor gate.
- Andg(x) means that x is an and gate.
- Org(x) means that x is an or gate.
- \(I(i,x)\) designates the \(i^{th}\) input port of device \(x\).
- \(O(i,x)\) designates the \(i^{th}\) output port of device \(x\).
- Conn(x,y) means that port \(x\) is connected to port \(y\).
- \(V(x,z)\) means that the value on port \(x\) is \(z\).
- 1 and 0 designate high and low voltages, respectively.

Now:

1. Adder(f1)
2. Xorg(x1)
3. Xorg(x2)
4. Andg(a1)
5. Andg(a2)
6. Org(o1)
7. Conn(I(1,f1),I(1,x1))
8. Conn(I(2,f1),I(2,x1))
9. Conn(I(3,f1),I(2,x2))
10. Conn(I(3,f1),I(1,x2))
11. Conn(I(3,f1),I(1,a1))
12. Conn(I(1,x1),I(1,x1))
13. Conn(I(1,x1),I(2,a2))
14. Conn(I(1,a2),I(1,o1))
15. Conn(I(1,a1),I(2,o1))
16. Conn(I(1,x2),O(1,f1))
17. Conn(I(1,o1),O(2,f1))
18. \(\forall x(Andg(x) \land V(I(1,x),1) \land V(I(2,x),1) \rightarrow V(O(1,x),1))\)
19. \(\forall x \forall n(Andg(x) \land V(I(n,x),0) \rightarrow V(O(1,x),0))\)
20. \(\forall x \forall n(Org(x) \land V(I(n,x),1) \rightarrow V(O(1,x),1))\)
21. \(\forall x(Org(x) \land V(I(1,x),0) \land V(I(2,x),0) \rightarrow V(O(1,x),0))\)
22. \(\forall x \forall z(Xorg(x) \land V(I(1,x),z) \land V(I(2,x),z) \rightarrow V(O(1,x),0))\)
23. \(\forall x \forall y \forall z(Xorg(x) \land V(I(1,x),y) \land V(I(2,x),z) \land y \neq z \rightarrow V(O(1,x),1))\)
24. \(\forall x \forall y \forall z(Conn(x,y) \land V(x,z) \rightarrow V(y,z))\)
Fall 2000 exam was a 60 minute exam.

(25) Conversion to Clause Form
I. Transform the wff below into clause form. For each step required give a brief description of the step and perform the step (if applicable) on the space provided. Failure to follow this format may result in no credit.

\[
A: \forall x \{ P(x) \rightarrow \exists z \left[ \neg \forall y \left[ Q(x,y) \rightarrow P(f(z)) \right] \right] \}
\]

(25)
II. Resolution Refutation
Bill has been murdered, and AL, Ralph, and George are suspects. AL says he did not do it. He says that Ralph was the victim’s friend but that George hated the victim. Ralph says that he was out of town on the day of the murder, and besides he didn’t even know the guy. George says he is innocent and that he saw AL and Ralph with the victim just before the murder. Assuming that everyone—except possibly for the murderer—is telling the truth, using Resolution Refutation, solve the crime.

Solve by drawing a Refutation Graph resulting from a complete strategy. (Make sure you mark clearly the required substitutions).

[Required: Please note the assigned point values
(5) a. Represent the axioms/goal in the Predicate Calculus.
(3) b. Represent any commonsense knowledge needed to solve the problem using Predicate Calculus,
(5) c. Convert your axioms, goal and commonsense knowledge (if any) to clause form,
(10) d. Draw your Refutation Graph,
(2) e. Define your strategy, and describe how your graph meets the strategy]

(25)
III. Heuristic Search
You are to place 6 Queens on a 6x6 board so no two Queens can attack each other. Use a 6-tuple to represent the global database, such that each \( x_i \) in the tuple stands for the column number of the queen in row \( i \). Give a heuristic function \( h(n) \) that takes into account such things as: (1) two queens cannot occupy the same row or column, (2) queens cannot be in adjacent rows and columns, and (3) a position \((i,j)\) is preferred over position \((n,m)\) if \( \text{diag}(i,j) < \text{diag}(n,m) \) where \( \text{diag}(i,j) \) is defined to be the length of the longest diagonal passing through position \((i,j)\). Give the \( A^* \) tree for at least the first 4 levels. Is your \( h(n) \) a lower bound of \( h^*(n) \)? NO JUSTIFICATION \iff \ NO CREDIT

(25)
IV. Computation Deduction
Using Resolution Refutation deduce the following computation to obtain a value for the goal (3 pts) by drawing the Consistent Solution Graph (17 pts) for the goal and prove its consistency (5 pts). Make sure your graph is clearly marked and it follows a complete strategy.

Facts:
F1: appended(nil,A,A).
F2: appended(B,nil,B).
F3: squash(nil,nil)

Rules:
R1: Appended(X_2,Y_2,Z_2) \rightarrow Appended(cons(U_2,X_2),Y_2,cons(U_2,Z_2)).
R2: atomic(S) \rightarrow squash(S,cons(S,nil))
R3: squash(H,A_1)\& squash(T,A_2)\& appended(A_1,A_2,A_3) \rightarrow squash(cons(H,T),A_3)

Goal: \( \exists \)squash(cons(cons(a,nil),cons(b,nil)),z)

(Note: If you prefer, you may use the notation squash([a],b,z) or squash(((a) b),z).}
(20) **Conversion to Clause Form**

**I.** Transform the wff $A$ below into CNF (clause form) matrix form. For each of the steps required give a brief description of the step and perform the step or write N/A (not applicable) on the space provided. Failure to follow this format will result in no credit. In wff $A$ the set \{x,y,z\} are variables, the set \{A,B,C,D,E\} are functions and I is a constant.

$$\{\text{wff } A\}: (\forall x)[(A(x) \land B(x)) \rightarrow [C(x,I) \land (\exists y)((\exists z)[C(y,z) \rightarrow D(x,y)])]} \lor (\forall x)[E(x)]$$

(2) **Step 0:** ___________________________________________________________

(2) **Step 1:** ___________________________________________________________

(2) **Step 2:** ___________________________________________________________

(2) **Step 3:** ___________________________________________________________

(2) **Step 4:** ___________________________________________________________

(2) **Step 5:** ___________________________________________________________

(2) **Step 6:** ___________________________________________________________

(2) **Step 7:** ___________________________________________________________

(2) **Step 8:** ___________________________________________________________
I. Conversion to Clause Form (continued)

(2) Step 9: ____________________________________________

(2) Step 10: ____________________________________________
II. Resolution Refutation

<table>
<thead>
<tr>
<th>EXCITING LIFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL PEOPLE WHO ARE NOT POOR AND ARE SMART ARE HAPPY. THOSE PEOPLE WHO READ ARE NOT STUPID. JOHN CAN READ AND IS WEALTHY. HAPPY PEOPLE HAVE EXCITING LIVES. CAN ANYONE BE FOUND WITH AN EXCITING LIFE?</td>
</tr>
</tbody>
</table>

Solve by drawing a Refutation Graph resulting from a complete strategy. (Make sure you mark clearly the required substitutions).

[Required: Please note the assigned point values. Each part MUST be answered with something. If left blank, then no credit will be assigned]

(5) a. Represent the axioms/goal in the Predicate Calculus.
(2) b. Represent any commonsense knowledge needed to solve the problem using Predicate Calculus,
(5) c. Convert your axioms, goal and commonsense knowledge (if any) to clause form,
(10) d. Draw your Refutation Graph, show substitutions are consistent.
(3) e. Define your strategy, and describe how your graph meets the strategy

(5) Answers Part a:

(2) Answers Part b:

(5) Answers Part c:
II. Resolution Refutation (continued)

(10) Refutation Graph Part d:

(3) Answer Part e: My strategy is

________________________________________
(30)

III. Heuristic Search

The following figure shows a search tree with the state indicated by the tuple inside parentheses. A letter indicates the state name and the integer indicates the estimated cost for finding a solution from that state (a cost of 0 indicates a goal state). Using the Graph-Search algorithm discussed in class, give the solution tree or steps using depth-first search. How many nodes did depth-first expand? Repeat using breadth-first search. How many nodes did breadth-first expand? Repeat using heuristic search. How many nodes did heuristic search expand? Repeat using A* search. How many nodes did A* expand? You must clearly justify your answer(s). "Feelings" or "intuition" are not good/sound reasons. NO JUSTIFICATION $$\iff$$ NO CREDIT. You must give me the details of the algorithm in order to receive any credit for each case. Can any of these algorithms ever find N as a solution? Explain
III. Heuristic Search. (continued)
IV. Computation Deduction.

We wish to separate the sheep from the goats. We define the predicate herd(L,S,G) which is true if S is a list of all the sheep in L, and G is a list of all the goats in L. Using Resolution Refutation deduce the following computation to obtain a value for the goal (3 pts) by drawing the Consistent Solution Refutation Tree (17 pts) for the goal and prove (or provide a good argument) its consistency (5 pts.) Make sure your resolution refutation tree is clearly marked and it follows a complete strategy.

Facts:
\[ F_1: \text{herd(nil,nil,nil)}. \]

Rules:
\[ R_1: \text{herd}(T,S,G) \rightarrow \text{herd}(\text{cons}(\text{sheep},T),\text{cons}(\text{sheep},S),G) \]
\[ R_2: \text{herd}(T,S,G) \rightarrow \text{herd}(\text{cons}(\text{goat},T),S,\text{cons}(\text{goat},G)) \]

Goal: \((\exists z)(\exists w) \text{herd}(\text{cons}(\text{sheep}, \text{cons}(\text{goat},\text{cons}(\text{goat},\text{nil}))),w,z)\)

{Note: If you prefer, you may use the notation herd([\text{sheep,goat,goat}],w,z) or herd((\text{sheep goat goat}),w,z).}

Required: Draw the graph, show the substitutions are consistent, and obtain the value of the goal.
Fall 2004 Exam was 90 minutes

(25) Conversion to Clause Form

I. Transform the wff \( A \) below into CNF (clause form) matrix form. For each of the steps required give a brief description of the step and perform the step or write N/A (not applicable) on the space provided. Failure to follow this format will result in no credit. In wff \( A \) the set \( \{x,y,z\} \) are variables, the set \( \{P,Q,S\} \) are functions and there are no constants.

\[
\{\text{wff } A\}: (\forall x) \exists y \{[P(x,y) \rightarrow Q(y,z)] \land [Q(y,x) \rightarrow S(x,y)]\} \rightarrow (\exists x) (\forall y) [P(x,y) \rightarrow S(x,y)]
\]

(2) Step 0: ____________________________________________

(2) Step 1: ____________________________________________

(2) Step 2: ____________________________________________

(2) Step 3: ____________________________________________

(2) Step 4: ____________________________________________

(2) Step 5: ____________________________________________

(6) Step 6: ____________________________________________

(2) Step 7: ____________________________________________

(2) Step 8: ____________________________________________
I. Conversion to Clause Form (continued)

(2) Step 9: ____________________________________________________________

(1) Step 10: ___________________________________________________________
II. Resolution Refutation

Consider the following database about zebras:

Zebras are mammals, striped, and medium size. Mammals are animals and warm-blooded. Striped things are non-solid and non-spotted. Things of medium size are neither small nor large. If Zeke is a zebra, is Zeke non-large?

Solve by drawing a Refutation Graph resulting from the Breadth-First strategy. (Make sure you mark clearly the required substitutions).

[Required: Please note the assigned point values. Each part MUST be answered with something. If left blank, then no credit will be assigned]

(5) a. Represent the axioms/goal in the Predicate Calculus.
(2) b. Represent any commonsense knowledge needed to solve the problem using Predicate Calculus,
(5) c. Convert your axioms, goal and commonsense knowledge (if any) to clause form,
(10) d. Draw your Refutation Graph, show substitutions are consistent.
(3) e. Describe how your graph meets the strategy. What other strategy could you have used and why?

(5) Answers Part a:

(2) Answers Part b:

(5) Answers Part c:
II. Resolution Refutation (continued)

(10) Refutation Graph Part d:

(3) Answer Part e: My strategy is ________________________________
III. Adversarial Search

Consider the following game tree in which the static scores (in parentheses at the tip nodes) are all from the first player’s point of view.

(a) Assuming that the first player is the maximizing player, what move should the first player choose?
(b) Assuming that the first player is the minimizing player, what move should the first player choose?
(c) What nodes would not need to be examined in part (a) using the alpha-beta algorithm—assuming that the nodes are examined in left-to-right order?
(d) What nodes would not need to be examined in part (b) using the alpha-beta algorithm—assuming that the nodes are examined in left-to-right order?
(e) Is the first player’s move in parts (a) and (c) or in parts (b) and (d) different? Explain.
III. Adversarial Search, (continued)
IV. Computation Deduction.

We wish to replace Ron Zook with Bob Stoops in a short list of ex-Gator coaches. Using Resolution Refutation deduce the following computation to obtain a value for the goal (3 pts) by performing a consistent Refutation Trace (17 pts) for the goal and prove (or provide a good argument) its consistency (5 pts.) Make sure your resolution refutation trace is clearly marked and it follows a complete strategy.

Facts:
\[ F_1: \text{swap}(X,Y,nil,nil). \]

Rules:
\[ R_1: \text{swap}(S_1,S_2,Y,Z) \rightarrow \text{swap}(S_1,S_2,\text{cons}(S_1,Y),\text{cons}(S_2,Z)) \]
\[ R_2: \{\text{swap}(S_1,S_2,Y,Z) \land X \neq S_1\} \rightarrow \text{swap}(S_1,S_2,\text{cons}(X,Y),\text{cons}(X,Z)) \]

Goal: \((\exists z) \text{swap}(\text{ron}, \text{bob}, \text{cons}(\text{steve}, \text{cons}(\text{ron}, \text{cons}(\text{galen},\text{nil}))), z)\)

{Note: If you prefer, you may use the notation \text{swap}(\text{ron}, \text{bob}, (\text{steve ron galen}), z).}

Required: Give the resolution trace, show the substitutions are consistent, and obtain the value of the goal.
Fall 2005 Exam 2 Periods

(20) Conversion to Clause Form

I. Transform the wff \( A \) below into CNF (clause form) matrix form. For each of the 10 “official steps” required give a brief description of the step and perform the step or write N/A (not applicable) on the space provided. Failure to follow this format will result in no credit. In wff \( A \) the set \( \{ w,x,y,t \} \) are variables, the set \( \{ P,Q,R,A,B \} \) are functions and there are no constants.

\[
\{\text{wff } A\}: (\forall x)\{P(x) \rightarrow (A(x) \land B(x) \lor \neg C(x, w))\} \lor (\forall y) (\exists u) [Q(y, t) \lor ((\forall x) R(x) \rightarrow \neg B(y))] 
\]

(2) Step 0: 

(2) Step 1: 

(2) Step 2: 

(1) Step 3: 

(2) Step 4: 

(1) Step 5: 

(4) Step 6: 
I. Conversion to Clause Form (continued)

(1) Step 7: 

(1) Step 8: 

(2) Step 9: 

(2) Step 10: 
II. Resolution Refutation

The members of the Elm St. Bridge Club are Joe, Sally, Bill, and Ellen. Joe is married to Sally. Bill is Ellen’s brother. The spouse of every married person in the club is also in the club. The last meeting of the club was at Joe’s house. Prove that (1) the last meeting of the club was at Sally’s house & (2) Ellen is not married.

Solve by drawing a Refutation Graph resulting from your choice of strategy. (Make sure you mark clearly the required substitutions).

[Required: Please note the assigned point values. Each part MUST be answered with something. If left blank, then no credit will be assigned]

a. Represent the axioms/goal in the Predicate Calculus.
(5)

b. Represent any commonsense knowledge needed to solve the problem using Predicate Calculus,
(2)

c. Convert your axioms, goal and commonsense knowledge (if any) to clause form,
(5)

d. Draw your Refutation Graph, show substitutions are consistent.
(10)

e. Describe how your graph meets the strategy. What other strategy could you have used and why?
(3)

Answers Part a:

Answers Part b:

Answers Part c:
II. Resolution Refutation (continued)

(10) Refutation Graph Part d:

(3) Answer Part e: My strategy is ________________________________________________
II. Heuristic Search

The following figure shows a search tree with the state indicated by the tuple inside parentheses. A letter indicates the state name and the integer indicates the estimated cost for finding a solution from that state (a cost of 0 indicates a goal state). Using the Graph-Search algorithm discussed in class, give the algorithm steps using (1) breadth-first search. How many nodes did breadth-first expand? Repeat using (2) depth-first search. How many nodes did depth-first expand? Repeat using (3) heuristic search (you MUST specify a rule to break ties). How many nodes did heuristic search expand? Repeat using (4) $A^*$ search. How many nodes did $A^*$ expand? You must clearly justify your answer(s). "Feelings" or "intuition" are not good/sound reasons. NO JUSTIFICATION $\iff$ NO CREDIT. You must give me the details of each step of the algorithm in order to receive any credit for each case. Can any of these algorithms ever find N as a solution? Explain

BREADTH FIRST:

```
(A 22)  
/   \  
(20)  (A 22)  
\     /   \  
(H 11) (I 4) (J 2) (K 0) (L 27) (M 22) (N 0) (P 9)
```
III. Heuristic Search. (continued)

DEPTH-FIRST:

HEURISTIC-SEARCH:

A* SEARCH:
(25)

IV. Computation Deduction.

We wish to find the last coach in a short list of UF coaches. Using Resolution Refutation deduce the following computation to obtain a value for the goal (3 pts) by performing a consistent Refutation Trace (17 pts) for the goal and prove (or provide a good argument) its consistency (5 pts.) Make sure your resolution refutation trace is clearly marked and it follows a complete strategy.

Facts:

\begin{align*}
F_1: \text{last(cons(U,nil),U)}. \\
\end{align*}

Rules:

\begin{align*}
R_1: \text{last(X,Y)} &\rightarrow \text{last(cons(W,X),Y)} \\
\end{align*}

Goal: (\exists z) last(cons(steve, cons(ron, cons(urban,nil))), z)

{Note: If you prefer, you may use the notation last( (steve ron urban), z).}

Required: Give the resolution trace (17 pts), show the substitutions are consistent (5pts), and obtain the value of the goal (3 pts).
Fall 2006 was a Two-Period Exam

(20) Conversion to Clause Form

I. Transform the wff $A$ below into CNF (clause form) matrix form. For each of the 10 “official steps” required give a brief description of the step and perform the step or write N/A (not applicable) on the space provided. Failure to follow this format will result in no credit. In wff $A$ the set $\{w,x,y\}$ are variables, the set $\{E\}$ are functions and there are no constants.

\[
\{wff A\} : (\forall x)\{ \sim E(x,y) \rightarrow [ (\exists y) (\exists w) ( E(y,w) \land (\forall x) \{ E(x,w) \rightarrow E(y,x) \} ) ] \} 
\]

(2) Step 0: ____________________________

(2) Step 1: ____________________________

(2) Step 2: ____________________________

(1) Step 3: ____________________________

(2) Step 4: ____________________________

(1) Step 5: ____________________________

(4) Step 6: ____________________________
I. Conversion to Clause Form (continued)

(1) Step 7: 

(1) Step 8: 

(2) Step 9: 

(2) Step 10: 
II. Resolution Refutation

The CUSTOM OFFICIALSsearched EVERYONE WHO ENTERED THIS COUNTRY WHO WAS NOT A VIP. SOME OF THE DRUG PUSHERS ENTERED THIS COUNTRY AND THEY WERE ONLY SEARCHED BY DRUG PUSHERS. NO DRUG PUSHER WAS A VIP. PROVE THAT SOME OF THE CUSTOM OFFICIALS WERE DRUG PUSHERS.

Solve by drawing a Refutation Graph resulting from your choice of strategy. (Make sure you mark clearly the required substitutions).

[Required: Please note the assigned point values. Each part MUST be answered with something. If left blank, then no credit will be assigned]

(5) a. Represent the axioms/goal in the Predicate Calculus. Let E(x) mean “x entered this country,” V(x) mean “x was a VIP,” S(x,y) mean “y searched x,” C(x) mean “x was a custom official” and P(x) mean “x was a drug pusher.”

(2) b. Represent any commonsense knowledge needed to solve the problem using Predicate Calculus,

(5) c. Convert your axioms, goal and commonsense knowledge (if any) to clause form,

(10) d. Draw your Refutation Graph, show substitutions are consistent.

(3) e. Describe how your graph meets the strategy. What other strategy could you have used and why?

(5) Answers Part a:

(2) Answers Part b:

(5) Answers Part c:
II. Resolution Refutation (continued)

(10) Refutation Graph Part d:

(3) Answer Part e: My strategy is ______________________________
III. Heuristic Search

A map is to be colored with a set of n distinct colors, such that no two adjacent countries have the same color. If you can use colors {yellow, red, white and green}, what is a legal coloring for the following map? Colorings are represented as lists of pairs:

( (country color) (country color) ...)

a. Suppose Sol1 represents the use of the A* algorithm with heuristic function h1(n)=number of uncolored countries.
b. Suppose Sol2 represents the use of the A* algorithm with heuristic function h2(n)=Of two states with the same number of uncolored countries, the one with more options open is better. The number of options of a partial coloring might be measured by finding the uncolored country with the fewest possible colors, and returning the number of possible colors for that country.
c. Give the A* results for Sol1 and for Sol2 if the countries are always picked in {H C P K B M} order and the colors are picked in {Y R W G} order. How much better is Sol2 over Sol1?

### Diagrams

- **Map Diagram**: A map with countries labeled Hackiland, Brakot, Mungoia, Oversana, Prodieo, Kalkuli, which are connected in various configurations.
- **Graph Diagram**: A graph with nodes labeled H, C, B, M, P, K, connected by edges in a triangular configuration.
III. Heuristic Search (continued)

Suppose \( S_{\text{sol2}} \) represents the use of the \( A^* \) algorithm with heuristic function \( h_2(n) \). Of two states with the same number of uncolored countries, the one with more options open is better. The number of options of a partial coloring might be measured by finding the uncolored country with the fewest possible colors, and returning the number of possible colors for that country.
Fall 2006
(25)

IV. Computation Deduction.
We wish to make a set of UF basketball centers from a list of tall players. Using Resolution Refutation deduce the following computation to obtain a value for the goal (2 pts) by performing a consistent Refutation Trace (19 pts) for the goal and prove (or provide a good argument for) its consistency (4 pts.) Make sure your resolution refutation trace is clearly marked and it follows a complete strategy. Assume that the evaluation of member is built-in, e.g., member(a,(a b)) returns true, and member (c,(a b)) returns nil.

Facts:
F1: makeset(nil,nil).

Rules:
R1: [ member(X1,Y1) ∧ makeset(Y1,Z1) ] → makeset(cons(X1,Y1),Z1).
R2: [¬member(X2,Y2) ∧ makeset(Y2,Z2) ] → makeset(cons(X2,Y2),cons(X2,Z2)).

Goal: (∃z)(makeset(cons(AL, cons(JOAKIM, cons(AL,nil))), z))

{ Note: If you prefer, you may use the notation makeset( (AL JOAKIM AL), z ) }

Required: Give the entire resolution trace (18 pts) using a complete strategy (tell me what strategy (1)), show the substitutions are consistent (4pts), and obtain the value of the goal (2 pts).
IV. Computation Deduction, (continued)
Fall 2007

(20) Conversion to Clause Form

I. Transform the wff $A$ below into clause form. For each of the 10 “official steps” {the order is important!} required give a brief description of the step and perform the step or write N/A {not applicable} on the space provided. Failure to follow this format will result in no credit. In wff $A$ the set \{v, x, y, z\} are variables, the set \{P,Q,R\} are functions and there are no constants.

$$\{wff\ A\}: (\forall x)(P(x) \to \neg \forall y[\neg Q(x,y) \to P(v)]) \land \forall y \exists z [R(x,y) \to P(x)]$$

(2) Step 0: ____________________________________________________________

(2) Step 1: ____________________________________________________________

(2) Step 2: ____________________________________________________________

(1) Step 3: ____________________________________________________________

(2) Step 4: ____________________________________________________________

(1) Step 5: ____________________________________________________________

(4) Step 6: ____________________________________________________________
I. Conversion to Clause Form (continued)

(1) Step 7: ____________________________________________________________________

(1) Step 8: ____________________________________________________________________

(2) Step 9: ____________________________________________________________________

(2) Step 10: ____________________________________________________________________
II. Resolution Refutation

The mathematical definition of the factorial function is:  
(i) Fact(0)=1,  
(ii) Fact(k)=k*Fact(k-1)  

Some suitable axioms for factorial are:  
(i) Fact(0)=1  
(ii) [k-1=j ∧ Fact(j)=m ∧ k*m=n] → [Fact(k)=n]  
(iii) (∀x)(∀y)[x=y] with side effect {eval(x)/y}

Using the axioms find the value of 2! by using Resolution Refutation and answer extraction. Solve by drawing a Refutation Graph resulting from your choice of strategy. (Make sure you indicate clearly the required substitutions). Note: the function x=y evaluates the left argument and unifies it (equates it) with the right argument, e.g., 4-2=q evaluates 4-2 to 2 and sets q=2 (i.e., it stores the substitution {4-2/x, eval(4-2)/y, q/y, 2/q} or {2/q} in the system.)

[Required: Please note the assigned point values. Each subpart MUST be answered with something. If left blank, then zero credit]

(4) a. Represent the axioms/goal in clause form.
(2) b. Is any commonsense knowledge needed to solve the problem using Predicate Calculus? Explain.
(14) c. Give the Resolvents with the required substitutions.
(5) d. Draw your Refutation Graph.
(3) e. Prove formally that your substitutions are consistent.
(2) f. Describe how your graph meets the strategy. What other strategy could you have used and why?

(4) Answers Part a:

(2) Answer Part b:

(14) Answers (Resolvents & required substitutions) Part c:
II. Resolution Refutation (continued)

(5) Refutation Graph Part d:

(3) Consistency Check Part e:

(2) Answer Part f: My strategy is

What other strategy could you have used and why? Explain:
Fall 2007
(25)

III. Adversarial Search

Consider the following game tree in which the static scores (in parentheses at the tip nodes) are all from the first player’s point of view.

(5) a. Assuming that the first player is the maximizing player, what move should the first player choose?
(5) b. Assuming that the first player is the minimizing player, what move should the first player choose?
(5) c. What nodes would not need to be examined in part (a) using the alpha-beta algorithm—assuming that the nodes are examined in left-to-right order?
(5) d. What nodes would not need to be examined in part (b) using the alpha-beta algorithm—assuming that the nodes are examined in left-to-right order?
(5) e. Is the first player’s move in parts (a) and (c) or in parts (b) and (d) different? Explain.

(5) Part (a):

(5) Part (b):

(5) Part (c):
III. **Adversarial Search.** (continued)

(5) Part (d):

(5) Part (e):
IV. Computation Deduction.

The following facts and rules accomplish the evaluation of the inner product of two vectors. Note that \{A, As, B, Bs, N, Z\} are variables

Fact:
- \( F_1: \text{inner}(\text{nil}, \text{nil}, 0) \).
- \( F_2: \text{is}(X, Y) \) with side effect \{eval(X)/Y\}.

Rule:
- \( R_1: [\text{inner}(As, Bs, Ns) \land \text{is}(Ns + A \times B, N) ] \rightarrow \text{inner}(\text{cons}(A, As), \text{cons}(B, Bs), N) \).

Goal: \( \exists Z (\text{inner}(\text{cons}(1, \text{cons}(2, \text{nil})), \text{cons}(3, \text{cons}(4, \text{nil})), Z)) \)

\{ Note: If you prefer, you may use the notation inner( (1 2), (3 4), Z) \}

Required: Tell me what your strategy is (1 pt). Give the clause form (4 pts) of the axiom set & the negation of the goal. Give me the Resolution resolvents (15 pts) using a complete strategy. Prove the substitutions are consistent (4 pts). Obtain the value of the goal (1 pt). Note: the function \text{is}(X, Y) \) evaluates the left argument and unifies it (equates it) with the right argument, e.g., \text{is}(4+2, Q) \) evaluates 4+2 to 6 and sets \( Q=6 \) (i.e., it stores the substitution \{4+2/X, eval(4+2)/Y, Q/Y, 6/Q\} or \{6/Q\} in the system.)

(1) Tell me your strategy __________________________

(4) Give me your axioms & negation of the goal in clause form

(15) Give me the resolution resolvents
(4) Prove the substitutions are consistent.

(1) Give me the solved goal, i.e., the answer:
Fall 2008

(20) Conversion to Clause Form

1. Transform the wff $A$ below into clause form. For each of the 10 “official steps” {the order is important!} required give a brief description of the step and perform the step or write N/A {not applicable} on the space provided. Failure to follow this format will result in no credit. In $wff A$ the set {w, x, y, z} are variables, the set {Animal, Loves} are functions and there are no constants.

$$wff A: (\forall x)(\exists w)((\forall y)\{\text{Animal}(y) \rightarrow \text{Loves}(x,y)\} \rightarrow ((\forall z)(\exists y)\text{Loves}(y,x)))$$

(2) Step 0:

(2) Step 1:

(2) Step 2:

(1) Step 3:

(2) Step 4:

(1) Step 5:

(4) Step 6:
I. Conversion to Clause Form (continued)

<table>
<thead>
<tr>
<th>(1)</th>
<th>Step 7:</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>Step 8:</td>
</tr>
<tr>
<td>(2)</td>
<td>Step 9:</td>
</tr>
<tr>
<td>(2)</td>
<td>Step 10:</td>
</tr>
</tbody>
</table>
II. Resolution Refutation (30)

The law says that it is a crime for an American to sell weapons to hostile nations. The country Nono, an enemy of America, has some missiles, and all of its missiles were sold to it by Colonel West, who is an American. Is Colonel West a criminal?

Prove that West is a criminal by using **Resolution Refutation**. Draw a **Refutation Graph** resulting from your choice of strategy. (Indicate clearly the required substitutions).

[Required: Please note the assigned point values. Each subpart MUST be answered with something. If left blank, then zero credit]

(5) a. Represent the axioms/goal in the Predicate Calculus. {If you cannot do this, I will give it to you for the 5 points}

(4) b. Represent the axioms/goal in clause form.

(2) c. Is any commonsense knowledge needed to solve the problem? Explain. {If you can’t do it, I will give it to you for 2 pts}

(10) d. Give the Resolvents with the required substitutions.

(5) e. Draw your Refutation Graph.

(2) f. Prove formally that your substitutions are consistent.

(2) g. Describe how your graph meets the strategy. What other strategy could you have used and why?

(5) Answers Part a:

(4) Answer(s) Part b:

(2) Answer(s) Part c:

(10) Answers (Resolvents & required substitutions) Part d:
II. Resolution Refutation (continued)

(5) Refutation Graph Part d:

(2) Consistency Check Part e:

(2) Answer Part f: My strategy is: ____________________________
What other strategy could you have used and why? Explain:
III. Adversarial Search

Consider the following game tree in which the static scores (in parentheses at the tip nodes) are all from the first player’s point of view.

(a) Assuming that the first player is the maximizing player, what move should the first player choose?

(b) Assuming that the first player is the minimizing player, what move should the first player choose?

(c) What nodes would not need to be examined in part (a) using the alpha-beta algorithm—assuming that the nodes are examined in left-to-right order?

(d) What nodes would not need to be examined in part (b) using the alpha-beta algorithm—assuming that the nodes are examined in left-to-right order?

(e) Is the first player’s move in parts (a) and (c) or in parts (b) and (d) different? Explain.
III. Adversarial Search, (continued)

(5) Part (d):

(5) Part (e):

In EEL-5840 Exam 1 we have a **TAIL RECURSIVE** LISP function `COUNT-TOP-ATOMS` (CTA for short) to count the number of top level atoms in a given list expression. Here are fact(s) and rule(s) to define the equivalent predicate `IS_CTA(LIS,N)`. `IS_CTA(LIS,N)` is true when N equals the count of the number of top level atoms in LIS.

\[
\begin{align*}
F_1: & \text{IS}_{-}\text{CTA}(\text{NIL}, 0). \\
R_1: & [\text{ATOM}(U) \land \text{IS}_{-}\text{CTA}(T,N) \land \text{IS}(N+1,\text{ANS})] \rightarrow \text{IS}_{-}\text{CTA}(\text{CONS}(U,T),\text{ANS}) \\
R_2: & [\text{LISTP}(U) \land \text{IS}_{-}\text{CTA}(T,\text{ANS})] \rightarrow \text{IS}_{-}\text{CTA}(\text{CONS}(U,T),\text{ANS})
\end{align*}
\]

Evaluate \((\exists Z)\text{IS}_{-}\text{CTA}(\text{CONS}(\text{CONS}(A,\text{NIL}),\text{CONS}(B,\text{CONS}(\text{CONS}(C,\text{NIL}),\text{NIL}))),Z)\) using computation deduction.

{ Note: If you prefer, you may use the notation \(\text{IS}_{-}\text{CTA}(((A)\ B\ C)),Z\), and \text{ATOM} and \text{LISTP} are the built-in LISP functions we already know }

Required: Tell me what your strategy is (1 pt). Give the clause form (4 pts) of the axiom set & the negation of the goal. Give me the Resolution resolvents (16 pts) using a complete strategy. Prove the substitutions are consistent (3 pts). Obtain the value of the goal (1 pt). Note: the function \(\text{IS}(X,Y)\) evaluates the left argument and unifies it (equates it) with the right argument, e.g., \(\text{IS}(4+2,Q)\) evaluates 4+2 to 6 and sets Q=6 (i.e., it stores the substitution \(\{4+2/X,\ \text{eval}(4+2)/Y,\ Q/Y,\ 6/Q\}\) or \(\{6/Q\}\) in the system.)

(1) Tell me your strategy_____________________

(4) Give me your axioms & negation of the goal in clause form

(16) Give me the resolution resolvents
IV. Computation Deduction. (continued)

(3) Prove the substitutions are consistent.

(1) Give me the solved goal, i.e., the answer: