EEL-5840 Class Exam 2 ______________________________

Fall 2009 Sample Questions (Name)

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) <wff> simplifying if necessary.

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

{wff} *A*: $(\forall x)\{ P(x) \rightarrow [\sim(\forall y)\{Q(x,y) \rightarrow P(f(z))\} \wedge (\forall y)\{Q(x,y) \rightarrow P(x)\}] \}$

(1) Step 0: ________________

Eliminate redundant quantifiers and take the existential closure

$A{:}(\exists z)(\forall x)\{ P(x) \rightarrow [\sim(\forall y)\{Q(x,y) \rightarrow P(f(z))\} \wedge (\forall y)\{Q(x,y) \rightarrow P(x)\}] \}$

(1) Step 1: ________________

Remove implications

$A{:}(\exists z)(\forall x)\{\sim P(x) \vee [\sim(\forall y)\{\sim Q(x,y) \vee P(f(z))\} \wedge (\forall y)\{\sim Q(x,y) \vee P(x)\}] \}$

(1) Step 2: ________________

Move the Negations down to the *Atf*s

$A{:}(\exists z)(\forall x)\{\sim P(x) \vee [(\exists y)\{Q(x,y) \wedge \sim P(f(z))\} \wedge (\forall y)\{\sim Q(x,y) \vee P(x)\}] \}$

(1) Step 3: ________________

Standardize Variables Apart

$A{:}(\exists z)(\forall x)\{\sim P(x) \vee [(\exists y)\{Q(x,y) \wedge \sim P(f(z))\} \wedge (\forall w)\{\sim Q(x,w) \vee P(x)\}] \}$

(1) Step 4: ________________

Skolemize: Let $z = h(.) = B$; $y = g(x)$

$A{:}(\forall x)\{\sim P(x) \vee [\{Q(x, g(x)) \wedge \sim P(f(B))\} \wedge (\forall w)\{\sim Q(x,w) \vee P(x)\}] \}$

(1) Step 5: ________________

Move universal quantifiers to the left.

$A{:}(\forall x)(\forall w)\{\sim P(x) \vee [\{Q(x, g(x)) \wedge \sim P(f(B))\} \wedge \{\sim Q(x,w) \vee P(x)\}] \}$

(1) Step 6: ________________

Distribute $\vee$ over $\wedge$ using $E_1 \vee (E_2 \wedge E_3) = (E_1 \vee E_2) \wedge (E_1 \vee E_3)$

$A{:}(\forall x)(\forall w)\{\sim P(x) \vee [Q(x, g(x)) \wedge \sim P(f(B))] \wedge [\sim P(x) \vee \sim Q(x,w) \vee P(x)]\}$

$A{:}(\forall x)(\forall w)\{[\sim P(x) \vee Q(x, g(x))] \wedge [\sim P(x) \vee \sim P(f(B))] \wedge [\sim P(x) \vee \sim Q(x,w) \vee P(x)] \}$

(1) Step 7: ________________

Write in Matrix Form

$A{:}\ \forall x \forall w[\sim P(x) \vee Q(x, g(x))]$

$\wedge\ \forall x \forall w[\sim P(x) \vee \sim P(f(B))]$

$\wedge\ \forall x \forall w[\sim P(x) \vee \sim Q(x,w) \vee P(x)]$

(1) Step 8: ________________

Remove Universal Quantifiers

$A{:}\ [\sim P(x) \vee Q(x, g(x))]$

$\wedge\ [\sim P(x) \vee \sim P(f(B))]$

$\wedge\ [\sim P(x) \vee \sim Q(x,w) \vee P(x)]$

I. Conversion to Clause Form (continued)

(1) Step 9: ____________________

Rename Variables

A: $[\sim P(x_1) \vee Q(x_1, g(x_1))]$

$[\sim P(x_2) \vee \sim P(f(B))]$

$[\sim P(x_3) \vee \sim Q(x_3, w_1) \vee P(x_3)]$

(1) Step 10: ____________________

Step 10 Remove Tautologies & Simplify

A: $[\sim P(x_1) \vee Q(x_1, g(x_1))]$

$\wedge\ [\sim P(x_2) \vee \sim P(f(B))]$

(5) Part (a) Answer:

$[\sim P(x_1) \vee Q(x_1, g(x_1))]$

$[\sim P(x_2) \vee \sim P(f(B))]$

(5) Part (b) Answer:

A: $(\forall x)\{\sim P(x) \vee [Q(x, g(x)) \wedge \sim P(f(B))]\}$ or

A: $(\forall x)\{P(x) \rightarrow [Q(x, g(x)) \wedge \sim P(f(B))]\}$

(5) Part (c) Answer:

Part (a) answer is more general than part (b) because if you substitute for x, say x=Obj in part (b)
You obtain $\{\sim P(Obj) \vee [Q(Obj, g(Obj)) \wedge \sim P(f(B))]\}$ which is $[\sim P(Obj) \vee Q(Obj, g(Obj))] \wedge [\sim P(Obj) \vee \sim P(f(B))]$
But substituting in part (a) yields $[\sim P(Obj) \vee Q(Obj\ g(Obj))] \wedge [\sim P(x_2) \vee \sim P(f(B))]$ which is more general.

(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

$(\exists x)(\exists y)[Gray(x) \wedge Pink(y) \wedge Likes(x,y)]$

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]

(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**:

Sam, Clyde and Oscar are elephants. Sam is pink. Clyde is gray and likes Oscar. Oscar is either pink, or gray (but not both) and likes Sam. Prove that a gray elephant likes a pink elephant.

[1] Pink(Sam)
[2] Gray(Clyde)
[3] Likes(Clyde,Oscar)
[4] Pink(Oscar) ∨ Gray(Oscar)
[5] Likes(Oscar,Sam)
[6] $(\exists x)(\exists y)[Gray(x) \wedge Pink(y) \wedge Likes(x,y)]$ {given}

(2) Answers Part **b**:

None needed

(5) Answers Part **c**:

[1] Pink(Sam)
[2] Gray(Clyde)
[3] Likes(Clyde,Oscar)
[4] Pink(Oscar) ∨ Gray(Oscar)
[5] Likes(Oscar,Sam)
[6'] ~Gray(x) ∨ ~Pink(y) ∨ ~Likes(x,y)

II. Resolution Refutation(continued)

(10) Refutation Graph Part **d**:

[7] ~Gray(Clyde) ∨ ~Pink(Oscar)
[8] ~Pink(Oscar)
[9] ~Gray(Oscar) ∨ ~Pink(Sam)
[10] ~Gray(Oscar)
[11] Pink(Oscar)
[12] Nil

[6] [3] [2] [6] [5] [1] [4]
$\Re_1$ $\Re_3$
$\Re_2$ $\Re_4$
$\Re_5$
nil

$\Re_1$=[6] with [3] ~Gray(x) ∨ ~Pink(y){Clyde/x;Oscar/y} or ~Gray(Clyde) ∨ ~Pink(Oscar)
$\Re_2$=$\Re_1$ with [2] ~Pink(Oscar)
$\Re_3$=[6] with [5] ~Gray(x’) ∨ ~Pink(y’){Oscar/x’;Sam/y’} or ~Gray(Oscar) ∨ ~Pink(Sam)
$\Re_4$=$\Re_3$ with [1] ~Gray(Oscar)
$\Re_5$=$\Re_4$ with [4] Pink(Oscar)
$\Re_6$=Nil with $\Re_5$ and $\Re_2$
Consistency Check

U_1=[Clyde,Oscar,Oscar,Sam] U_2=[x,y,x’,y’]
U_1=U_2[Clyde/x;Oscar/y;Oscar/x’;Sam/y/]]
Since U_1 & U_2 unify, then the substitutions are consistent

(3) Answer Part **e**: My strategy is _______ Set of Support ________________________________
Since every resolvent comes from the negation of the goal wff with the base set or one of its descendants

(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 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 add(_,_,_) from the resolution stack.

Facts:

F1: length(nil,0).

Rules:

R1: {length(T,N)∧λ(add(N,1,M))} → length(cons(H,T),M)

Where λ(*y*) means "Evaluate the argument *y*"

Goal: (∃*z*)length(cons(boo, cons(on,cons(you,nil))),*z*)

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

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

F1: length(nil,0).

R1:~length(T,N) ∨ ~λ(add(N,1,M)) ∨ length(cons(H,T),M)

~Goal: ~length(cons(boo,cons(on,cons(you,nil))),*z*)

$\Re_1$=~Goal-$\Re$-R1: ~depth(T,N) ∨ ~λ(add(N,1,M)){boo/H,cons(on,cons(you,nil))/T,z/M,N+1/M}

$\Re_1$: ~length(cons(on,cons(you,nil)),N)

$\Re_2$=$\Re_1$-$\Re$-R1': ~depth(T',N') ∨ ~λ(add(N',1,M')){on/H',cons(you,nil)/T',N/M';N'+1/M'}

$\Re_2$: ~length(cons(you,nil),N')

$\Re_3$=$\Re_2$-$\Re$-R1": ~depth(T",N") ∨ ~λ(add(N",1,M")){you/H", nil/T";N'/M";N"+1/M"}

$\Re_3$: ~length(nil,N")

$\Re_3$=$\Re_2$-$\Re$-F1: Nil {0/N"}

Therefore N"=0; M"= λ(0+1)=1; N'=1; M'=λ(1+1)=2; N=2; M=λ(2+1)=3; Z=3

Substitutions will be consistent because I changed variables every time I re-used any rules and all the variables were originally standardized apart. To prove consistency we assemble all the numerators in a set, say U_1 and all the denominators in a set, say, U_2 and see if $U_1=U_2\sigma$ and $\sigma\neq$null.

EEL-5840 Class Exam 2 _______________________________
Fall 2009 Sample Questions (Name)

Fall 2001 exam was a 90 minute exam.

(25) <u>Conversion to Clause Form</u>

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.

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

(2) Step 0: ____________________

Eliminate redundant quantifiers and take the existential closure - not needed here

(2) Step 1: ____________________

Remove implications

A: $\forall x \forall y[\sim\{P(x,y) \vee Q(x,y)\} \vee R(x,y)]$

(2) Step 2: ____________________

Move the Negations down to the *Atf*s

A: $\forall x \forall y[\sim P(x,y) \wedge \sim Q(x,y) \vee R(x,y)]$

(2) Step 3: ____________________

Standardize Variables Apart

Not Needed here: A: $\forall x \forall y[\sim P(x,y) \wedge \sim Q(x,y) \vee R(x,y)]$

(2) Step 4: ____________________

Skolemize: Not needed here

A: $\forall x \forall y[\sim P(x,y) \wedge \sim Q(x,y) \vee R(x,y)]$

(2) Step 5: ____________________

Move universal quantifiers to the left: Not needed here

A: $\forall x \forall y[\sim P(x,y) \wedge \sim Q(x,y) \vee R(x,y)]$

(2) Step 6: ____________________

Distribute $\vee$ over $\wedge$ using $(E1 \wedge E2) \vee E3 = (E1 \vee E3) \wedge (E2 \vee E3)$

A: $\forall x \forall y\{[\sim P(x,y) \vee R(x,y)] \wedge [\sim Q(x,y) \vee R(x,y)]\}$

(2) Step 7: ____________________

Write in Matrix Form

A: $\forall x \forall y\{ [\sim P(x,y) \vee R(x,y)] \}$

$\forall x \forall y\{ [\sim Q(x,y) \vee R(x,y)] \}$

(2) Step 8: ____________________

Remove Universal Quantifiers

A: $\{ [\sim P(x,y) \vee R(x,y)] \}$

$\{ [\sim Q(x,y) \vee R(x,y)] \}$

(2) Step 9: ____________________

Rename Variables

A: $\{ [\sim P(x_1,y_1) \vee R(x_1,y_1)] \}$ Step 10

$\{ [\sim Q(x_2,y_2) \vee R(x_2,y_2)] \}$ Remove Tautologies & Simplify

(5) Answer:

$\{ [\sim P(x_1,y_1) \;\; R(x_1,y_1)] \}$

$\{ [\sim Q(x_2,y_2) \;\; R(x_2,y_2)] \}$

(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

(5) Answers Part **a**:

For every course and every student, if the course has a final and the student is taking the course, then the student is not happy. For every course, if the course is easy, then there is a student taking the course who is not happy.

[1] $\forall c \forall s\{\, [F(c) \wedge T(s,c)] \rightarrow \sim H(s)\, \}$
[2] $\forall c E(c) \rightarrow \exists s[T(s,c) \wedge H(s)]$
[3] Goal: $(\forall c)[F(c) \rightarrow \sim E(c)]$

(2) Answers Part **b**:

None needed

(5) Answers Part **c**:

[1] $\sim F(c) \vee \sim T(s,c) \vee \sim H(s)$
[2a] $\sim E(c) \vee T(g(c),c)$
[2b] $\sim E(c) \vee H(g(c))$
[3a] F(Crip_Course)
[3b] E(Crip_Course)

g(c) designates the Skolem happy student in each course and Crip_Course designates the Skolem course with a final that is hypothesized to be easy.

II. Resolution Refutation(continued)

(10) Refutation Graph Part **d**:

[1] $\sim F(c) \vee \sim T(s,c) \vee \sim H(s)$
[2] $\sim E(c) \vee T(g(c),c)$
[3] $\sim E(c) \vee H(g(c))$
[4] F(Crip_Course)
[5] E(Crip_Course)

[4] [1] [5] [2] [5] [3]
$\Re_3$ $\Re_1$ $\Re_2$
$\Re_4$
nil

$\Re_1$=[5] with [2] $T(g(c),c)$ {Crip_Course/c} or T(g(Crip_Course),Crip_Course)
$\Re_2$=[5] with [3] $H(g(c))$ {Crip_Course/c} or H(g(Crip_Course))
$\Re_3$=[4] with [1] $\sim T(s,c) \vee \sim H(s)$ {Crip_Course/c} or ~T(s,Crip_Course) ∨ ~H(s)
$\Re_4$=$\Re_3$ with $\Re_1$ $\sim H(s)$ {g(Crip_Course)/s} or ~H(g(Crip_Course))

$\Re_5 = \Re_4$ with $\Re_2$ nil

Consistency Check

U_1=[Crip_course, Crip_course, Crip_course, g(Crip_course)] U_2=[c,c,c,s]

U_1=U_2[Crip_course/c,g(Crip_course)/s]

Since U_1 & U_2 unify, then the substitutions are consistent

(3) Answer Part **e**: My strategy is _______ Set of Support ______________________________________

Since every resolvent comes from the negation of the goal wff with the base set or one of its descendants

(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.

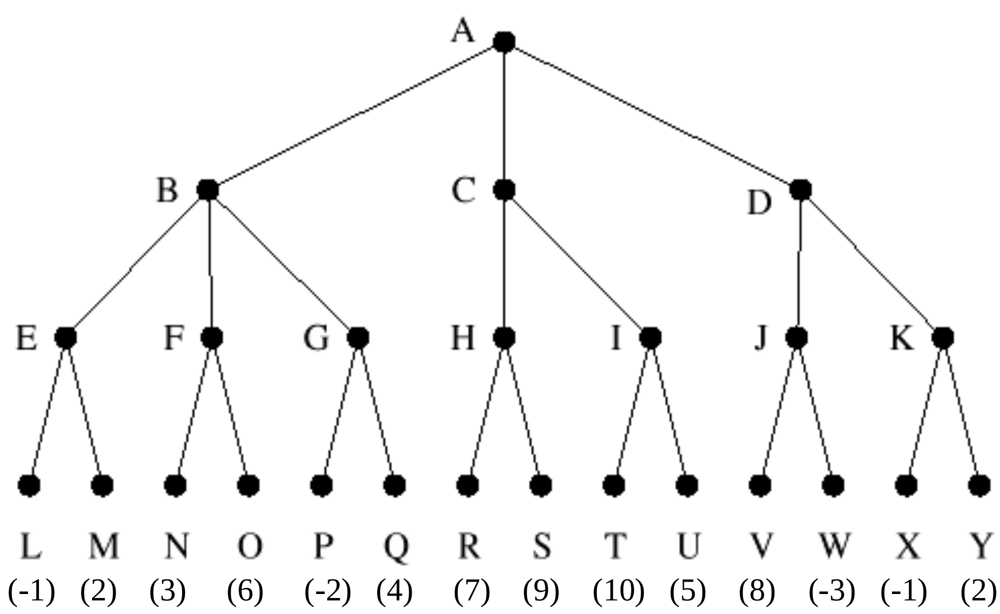
(a) Assuming that the first player is the maximizing player, what move should the first player choose?

(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.



Part (a)

E,F,G,H,I,J,K chooses max or E=M(2); F=O(6); G=Q(4); H=S(9); I=T(10); J=V(8); K=Y(2)

B,C,D chooses min or B=E=M(2); C=H=S(9); D= K=Y(2)

A chooses max or A=C=H=S(9)

A chooses C

Part (b)

E,F,G,H,I,J,K chooses min or E=L(-1); F=N(3); G=P(-2); H=R(7); I=U(5); J=W(-3); K=X(-1)
B,C,D chooses max or B=F=N(2); C=H=R(7); D= K=X(-1)
A chooses min or A=D=K=X(-1)
A chooses D

Part (c)

E chooses max evaluating L & M or α_E=2(M); Now B chooses min so $\beta_B \le$ 2(M)
Evaluate N; now $\alpha_F \ge$3(N) but $\beta_B \le$ 2(M) therefore Beta Cutoff and not evaluate O
Evaluate P; now $\alpha_F \ge$-2(P) but $\beta_B \le$ 2(M) therefore evaluate Q, now α_G=4(Q)
Now B chooses min so β_B = 2(M), therefore $\alpha_A \ge$2(M)
Evaluate R; now $\alpha_H \ge$7(R) and $\beta_C \le$ 7(R) therefore evaluate S, now α_H=9(S) and $\beta_C \le$ 9(S)
Evaluate T; now $\alpha_H \ge$10(T); but $\beta_C \le$ 7(R); stop and do not evaluate U and now β_C = 9(S) and $\alpha_A \ge$ 9(S)
Evaluate V; now $\alpha_J \ge$8(V); and $\beta_D \le$ 8(V) Alpha cutoff at D and do not evaluate W,X,Y or K
A chooses C to H to 9(S)
Do Not Evaluate {O,U,W,X,Y, and K} [students claim you do have to evaluate W}

Part (d)

K chooses min evaluating Y & X or β_K=-1(X); Now D chooses max so $\alpha_D \ge$-1(X)
Evaluate W; now $\beta_J \le$-3(W) but $\alpha_D \ge$-1(X) therefore Alpha Cutoff and not evaluate V
α_D=-1(X); $\beta_A \le$-1(X)
Evaluate U; now $\beta_I \le$5(U) and but $\alpha_C \ge$5(X) therefore Beta Cutoff and do not evaluate T,R,S, or H
Evaluate Q; now $\beta_G \le$4(Q) and $\alpha_B \ge$5(Q) therefore Beta Cutoff and do not evaluate P,O,N,M,L or F,E
A chooses D to K to -1(X)
Do Not Evaluate {V,T,R,S,H, P,O,N,M,L and F,E }

Part (e)

A chooses C to H to 9(S) in both parts (a) and (c) because Alpha-Beta and Minimax produce the same results for the same problem.
Similarly, A chooses D to K to -1(X) in both parts (b) and (d) because Alpha-Beta and Minimax produce the same results for the same problem.
In my analysis that was indeed the case.

EEL-5840 Class Exam 2 ______________________________
Fall 2009 Sample Questions (Name)

(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 max(E_1,E_2,E_3) such that if E_1 and E_2 are known, then E_3 is set to the maximum of E_1 and E_2 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: $depth(H,A_1) \wedge depth(T,A_2) \wedge max(1+A_1,A_2,A_3) \rightarrow depth(cons(H,T),A_3)$

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.

F1: depth(nil,1).

R1: atomic(S) → depth(S,0)

R2: $\sim depth(H,A_1) \vee \sim depth(T,A_2) \vee \sim max(1+A_1,A_2,A_3) \vee depth(cons(H,T),A_3)$

~Goal: ~depth(cons(cons(a,nil),cons(b,nil)),*z*); fact1:atomic(a); fact2:atomic(b)

$\mathfrak{R}_1$=~Goal-$\mathfrak{R}$-R2: $\sim depth(H,A_1) \vee \sim depth(T,A_2) \vee \sim max(1+A_1,A_2,A_3)$ {cons(a,nil)/H,cons(b,nil)/T,*z*/A_3}

$\mathfrak{R}_1$: $\sim depth(cons(a,nil),A_1) \vee \sim depth(cons(b,nil),A_2) \vee \sim max(1+A_1,A_2,z)$

$\mathfrak{R}_2$=$\mathfrak{R}_1$-$\mathfrak{R}$-R2': $\sim depth(H',A_1') \vee \sim depth(T',A_2') \vee \sim max(1+A_1',A_2',A_3') \vee \sim depth(cons(b,nil),A_2)$
$\vee \sim max(1+A_1,A_2,z)$ {a/H',nil/T',A_1/A_3'}

$\mathfrak{R}_2$: $\sim depth(a,A_1') \vee \sim depth(nil,A_2') \vee \sim max(1+A_1',A_2',A_1) \vee \sim depth(cons(b,nil),A_2) \vee \sim max(1+A_1,A_2,z)$

$\mathfrak{R}_3$=$\mathfrak{R}_2$-$\mathfrak{R}$-R1: $\sim atomic(S) \vee \sim depth(nil,A_2') \vee \sim max(1+A_1',A_2',A_1) \vee \sim depth(cons(b,nil),A_2)$
$\vee \sim max(1+A_1,A_2,z)$ {a/S,0/A_1'}

$\mathfrak{R}_3$: $\sim atomic(a) \vee \sim depth(nil,A_2') \vee \sim max(1+0,A_2',A_1) \vee \sim depth(cons(b,nil),A_2) \vee \sim max(1+A_1,A_2,z)$

$\mathfrak{R}_4$: $\mathfrak{R}_3$-$\mathfrak{R}$-fact1: $\sim depth(nil,A_2') \vee \sim max(1+0,A_2',A_1) \vee \sim depth(cons(b,nil),A_2) \vee \sim max(1+A_1,A_2,z)$

$\mathfrak{R}_5$: $\mathfrak{R}_4$-$\mathfrak{R}$-F1: $\sim max(1+0,A_2',A_1) \vee \sim depth(cons(b,nil),A_2) \vee \sim max(1+A_1,A_2,z)$ {1/A_2'}

$\mathfrak{R}_5$: $\sim max(1+0,1,A_1) \vee \sim depth(cons(b,nil),A_2) \vee \sim max(1+A_1,A_2,z)$

Evaluate $\sim max(1+0,1,A_1)$ with {1/A_1}

R2'': $\sim depth(H'',A_1'') \vee \sim depth(T'',A_2'') \vee \sim max(1+A_1'',A_2'',A_3'') \vee depth(cons(H'',T''),A_3'')$

$\mathfrak{R}_6$: $\mathfrak{R}_5$-$\mathfrak{R}$-R2'' $\sim depth(H'',A_1'') \vee \sim depth(T'',A_2'') \vee \sim max(1+A_1'',A_2'',A_3'')$

∨~max(1+1,A_2,*z*) {b/H'',nil/T''A_2/A_3''}
$\Re_6$: ~depth(b,A_1'')∨~depth(nil,A_2'')∨~max(1+A_1'',A_2'',A_2)∨~max(1+1,A_2,*z*)

$\Re_7$: $\Re_6$-$\Re$-R3'': ~atomic(S')∨~depth(nil,A_2'')∨~max(1+A_1'',A_2'',A_2)∨~max(1+1,A_2,*z*) {b/S',0/A_1''}
$\Re_7$: ~atomic(b)∨~depth(nil,A_2'')∨~max(1+0,A_2'',A_2)∨~max(1+1,A_2,*z*)

$\Re_8$: $\Re_7$-$\Re$-fact2: ~depth(nil,A_2'')∨~max(1+0,A_2'',A_2)∨~max(1+1,A_2,*z*)

$\Re_9$: $\Re_8$-$\Re$-F1: ~max(1+0,A_2'',A_2)∨~max(1+1,A_2,*z*) {1/A_2''}
max(1+0,1,A_2)∨~max(1+1,A_2,*z*)

Evaluate ~max(1+0,1,A_2) with {1/A_2}

Evaluate ~max(1+1,1,*z*) with {2/z}

z=2
Goal: depth(cons(cons(a,nil),cons(b,nil)),*2*)

Substitutions will be consistent because I changed variables every time I re-used any rules and all the variables were originally standardized apart. To prove consistency we assemble all the numerators in a set, say U_1 and all the denominators in a set, say, U_2 and see if $U_1=U_2\sigma$ and $\sigma\neq$null.

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>: $(\forall x)[(\forall y)[P(x,y)] \rightarrow \sim\{(\forall y)[Q(x,y) \rightarrow R(x,y)]\}]$

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).

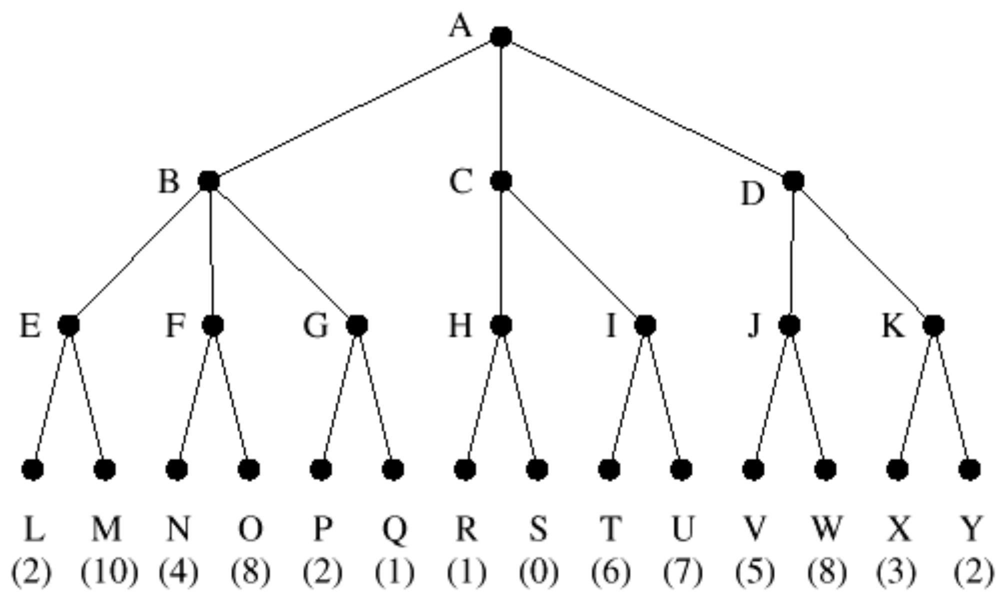
[Required: Please note the assigned point values

(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.



(30)
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.

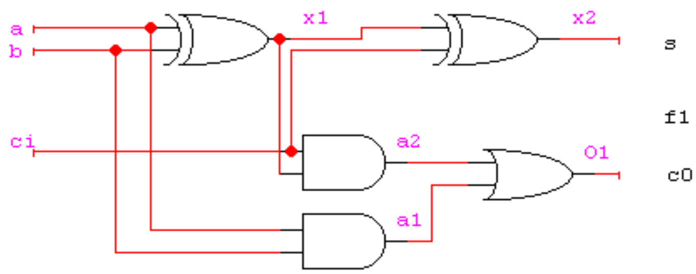
EEL-5840 Class Exam 2 ______________________________

Fall 2009 Sample Questions (Name)

(35)

V. 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 ia 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 ith input port of device *x*.
- O(i,x) designates the ith 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:

Adder(*f1*)
1. Xorg(*x1*)
2. Xorg(*x2*)
3. Andg(*a1*)
4. Andg(*a2*)
5. Org(*o1*)
6. Conn(I(1,f1),I(1,x1))
7. Conn(I(2,f1),I(2,x1))
8. Conn(I(1,f1),I(1,a1))
9. Conn(I(2,f1),I(2,a1))
10. Conn(I(3,f1),I(2,x2))
11. Conn(I(3,f1),I(1,a2))
12. Conn(O(1,x1),I(1,x1))
13. Conn(O(1,x1),I(2,a2))
14. Conn(O(1,a2),I(1,o1))
15. Conn(O(1,a1),I(2,o1))
16. Conn(O(1,x2),O(1,f1))
17. Conn(O(1,o1),O(2,f1))

A1. V(I(1,f1),1)
A2. V(I(2,f1),0)
A3. V(I(3,f1),1)
A4. V(O(1,f1),0)
A5. V(O(2,f1),1)

$$18. \forall x(Andg(x) \wedge V(I(1,x),1) \wedge V(I(2,x),1) \rightarrow V(O(1,x),1))$$

$$19. \forall x \forall n(Andg(x) \wedge V(I(n,x),0) \rightarrow V(O(1,x),0))$$

$$20. \forall x \forall n(Org(x) \wedge V(I(n,x),1) \rightarrow V(O(1,x),1))$$

$$21. \forall x(Org(x) \wedge V(I(1,x),0) \wedge V(I(2,x),0) \rightarrow V(O(1,x),0))$$

$$22. \forall x \forall z(Xorg(x) \wedge V(I(1,x),z) \wedge V(I(2,x),z) \rightarrow V(O(1,x),0))$$

$$23. \forall x \forall y \forall z(Xorg(x) \wedge V(I(1,x),y) \wedge V(I(2,x),z) \wedge y \neq z \rightarrow V(O(1,x),1))$$

$$24. \forall x \forall y \forall z(Conn(x,y) \wedge V(x,z) \rightarrow V(y,z))$$

EEL-5840 Class Exam 2 ____________________________
Fall 2009 Sample Questions (Name)

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.

<wff>: A: $(\forall x)\{P(x)\rightarrow \exists z\{\sim\forall y[Q(x,y)\rightarrow P(f(z))]\wedge\forall y[Q(x,y)\rightarrow P(z)]\}\}$

(2) Step 0: ____________________

Eliminate redundant quantifiers and take the existential closure - not needed here

(2) Step 1: ____________________

Remove implications

A: $(\forall x)\{\sim P(x)\vee\exists z\{\sim\forall y[\sim Q(x,y)\vee P(f(z))]\wedge\forall y[\sim Q(x,y)\vee P(z)]\}\}$

(2) Step 2: ____________________

Move the Negations down to the *Atfs*

A: $(\forall x)\{\sim P(x)\vee\exists z\{\exists y[Q(x,y)\wedge\sim P(f(z))]\wedge\forall y[\sim Q(x,y)\vee P(z)]\}\}$

(2) Step 3: ____________________

Standardize Variables Apart

A: $(\forall x)\{\sim P(x)\vee\exists z\{\exists w[Q(x,w)\wedge\sim P(f(z))]\wedge\forall y[\sim Q(x,y)\vee P(z)]\}\}$

(2) Step 4: ____________________

Skolemize: Let $z=g(x)$ and $w=h(x)$

A: $(\forall x)\{\sim P(x)\vee\{[Q(x,h(x))\wedge\sim P(f(g(x)))]\wedge\forall y[\sim Q(x,y)\vee P(g(x))]\}\}$

(2) Step 5: ____________________

Move universal quantifiers to the left

A: $(\forall x)\ (\forall y)\{\sim P(x)\vee\{[Q(x,h(x))\wedge\sim P(f(g(x)))]\wedge[\sim Q(x,y)\vee P(g(x))]\}\}$

(2) Step 6: ____________________

Distribute $\vee$ over $\wedge$ using $E1 \vee (E2 \wedge E3) = (E1 \vee E2) \wedge (E1 \vee E3)$

A: $(\forall x)\ (\forall y)\{\sim P(x)\vee[Q(x,h(x))\wedge\sim P(f(g(x)))]\}\wedge\{\sim P(x)\vee[\sim Q(x,y)\vee P(g(x))]\}\}$

A: $(\forall x)\ (\forall y)\{\sim P(x)\vee Q(x,h(x))\}\wedge\{\sim P(x)\vee\sim P(f(g(x)))\}\wedge\{\sim P(x)\vee[\sim Q(x,y)\vee P(g(x))]\}\}$

(2) Step 7: ____________________

Write in Matrix Form {already in matrix form}

A: $(\forall x)\ (\forall y)\{\sim P(x)\vee Q(x,h(x))\}\wedge\{\sim P(x)\vee\sim P(f(g(x)))\}\wedge\{\sim P(x)\vee\sim Q(x,y)\vee P(g(x))\}$

(2) Step 8: ____________________

Remove Universal Quantifiers

A: $\{\sim P(x)\vee Q(x,h(x))\}\wedge\{\sim P(x)\vee\sim P(f(g(x)))\}\wedge\{\sim P(x)\vee\sim Q(x,y)\vee P(g(x))\}$

(2) Step 9: ____________________

Rename Variables

A: $\{\sim P(x_1)\vee Q(x_1,h(x_1))\}\wedge\{\sim P(x_2)\vee\sim P(f(g(x_2)))\}\wedge\{\sim P(x_3)\vee\sim Q(x_3,y_3)\vee P(g(x_3))\}$

(5) Answer:

$\{\sim P(x_1)\vee Q(x_1,h(x_1))\}$

$\{\sim P(x_2)\vee\sim P(f(g(x_2)))\}$

$\{\sim P(x_3)\vee\sim Q(x_3,y_3)\vee P(g(x_3))\}$

(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

(5) Answers Part **a**:

Let I(x) mean x is innocent; F(x,y) mean x is a friend of y; Hate(x,y) x hates y; Out(x) x is out of town With(x,y) x is with y; Knows(x,y) x knows y

[1] I(AL) → F(Ralph,Bill) ∧ Hate(George,Bill)

[2] I(Ralph) → Out(Ralph) ∧ ~Knows(Ralph,Bill)

[3] I(George) → With(AL,Bill) ∧ With(Ralph,Bill)

[4] Goal: (∃z)~I(z)

(3) Answers Part **b**:

[5] (∀x)(∀y)Hate(x,y) → ~F(x,y) If x hates y then x is not a friend of y; also (∀x)(∀y)F(x,y) → ~Hate(x,y)

[6] (∀x)(∀y)F(x,y) → Knows(x,y) If x is a friend of y then x knows y.

[7] (∀x) Out(x) → ~With(x,Bill) If x is out of town then x cannot be with Bill

[8] ~Knows(x,y)→~With(x,y)∧~F(x,y) If x does not know y then x is not a friend of y nor can x be with y

[9] ~Knows(x,Bill) → I(x) If x does not know Bill, then x must be innocent.

[10] I(AL)∨I(Ralph) Either AL or Ralph are innocent (i.e., George is not innocent)

[11] I(George)∨I(Ralph) Either George or Ralph are innocent (i.e., AL is not innocent)

[12] I(AL)∨I(George) Either AL or George are innocent (i.e., Ralph is not innocent)

(5) Answers Part **c**:

[1a] ~I(AL) ∨ F(Ralph,Bill)

[1b] ~I(AL) ∨ Hate(George,Bill)

[2a] ~I(Ralph) ∨ Out(Ralph)

[2b] ~I(Ralph) ∨ ~Knows(Ralph,Bill)

[3a] ~I(George) ∨ With(AL,Bill)

[3b] ~I(George) ∨ With(Ralph,Bill)

[4'] I(z) {The negation of the goal in clause form}

[5] ~Hate(x,y) ∨ ~F(x,y)

[6] ~F(x,y) ∨ Knows(x,y)

[7] ~Out(x) ∨ ~With(x,Bill)

[8a] Knows(x,y) ∨ ~With(x,y)

[8b] Knows(x,y) ∨ ~F(x,y)

[9] Knows(x,y) ∨ I(x)

[10] I(AL)∨I(Ralph)

[11] I(George)∨I(Ralph)

[12] I(AL)∨I(George)

II. Resolution Refutation(continued)

(10) Refutation Graph Part **d**:

[1a] ~I(AL) ∨ F(Ralph,Bill)
[1b] ~I(AL) ∨ Hate(George,Bill)
[2a] ~I(Ralph) ∨ Out(Ralph)
[2b] ~I(Ralph) ∨ ~Knows(Ralph,Bill)
[3a] ~I(George) ∨ With(AL,Bill)
[3b] ~I(George) ∨ With(Ralph,Bill)
[4'] I(z) {The negation of the goal in clause form}
[5] ~Hate(x,y) ∨ ~F(x,y)
[6] ~F(x,y) ∨ Knows(x,y)
[7] ~Out(x) ∨ ~With(x,Bill)
[8a] Knows(x,y) ∨ ~With(x,y)
[8b] Knows(x,y) ∨ ~F(x,y)
[9] Knows(x,Bill) ∨ I(x)
[10] I(AL)∨I(Ralph)
[11] I(George)∨I(Ralph)
[12] I(AL)∨I(George)

$\mathfrak{R}_1$=[4'] with [2b] ~Knows(Ralph,Bill) {Ralph/z}
$\mathfrak{R}_2$=$\mathfrak{R}_1$ with [6] ~F(Ralph,Bill)
$\mathfrak{R}_3$=$\mathfrak{R}_2$ with [1a] ~I(AL)
$\mathfrak{R}_4$=$\mathfrak{R}_3$ with [10] I(Ralph)
$\mathfrak{R}_5$=$\mathfrak{R}_4$ with [2a] Out(Ralph)
$\mathfrak{R}_6$=$\mathfrak{R}_5$ with [7] ~With(Ralph,Bill)
$\mathfrak{R}_7$=$\mathfrak{R}_6$ with [10] ~I(George)
$\mathfrak{R}_8$=$\mathfrak{R}_7$ with [12] I(AL)
$\mathfrak{R}_9$=$\mathfrak{R}_8$ with $\mathfrak{R}_3$ nil

Since z= Ralph then ~I(Ralph)

(2) Answer Part **e**: My strategy is _______ Ancestry Filetered ____________________________________
Since every resolvent uses a parent from the base or one that is an ancestor of the other parent

(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 $diag(i,j)<diag(n,m)$ where $diag(i,j)$ 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 <==> 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) → Appended(cons(U_2,X_2),Y_2,cons(U_2,Z_2)).
R2: atomic(S) → squash(S,cons(S,nil))
R3: squash(H,A_1)∧squash(T,A_2)∧appended(A_1,A_2,A_3) → squash(cons(H,T),A_3)

Goal: (∃*z*)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*).}

~Goal: ~squash(cons(cons(a,nil),cons(b,nil)),*z*); fact1:atomic(a); fact2:atomic(b)

$\Re_1$=~Goal-$\Re$-R3: ~squash(H,A_1)∨~squash(T,A_2)∨~append(A_1,A_2,A_3) {cons(a,nil)/H,cons(b,nil)/T,*z*/A_3}
$\Re_1$: ~squash(cons(a,nil),A_1)∨~squash(cons(b,nil),A_2)∨~append(A_1,A_2,*z*)

$\Re_2$=$\Re_1$-$\Re$-R3': ~squash(H',A_1')∨~squash(T',A_2')∨~append(A_1',A_2',A_3')∨~squash(cons(b,nil),A_2)
∨~append(A_1,A_2,*z*) {a,/H',nil/T',A_1/A_3'}
$\Re_2$: ~squash(a,A_1')∨~squash(nil,A_2')∨~append(A_1',A_2',A_1)∨~squash(cons(b,nil),A_2)∨~append(A_1,A_2,*z*)

$\Re_3$=$\Re_2$-$\Re$-R2: ~atomic(S)∨~squash(nil,A_2')∨~append(A_1',A_2',A_1)∨~squash(cons(b,nil),A_2) ∨~append(A_1,A_2,*z*)
{a/S,cons(S,nil)/A_1'}
$\Re_3$: ~atomic(a)∨~squash(nil,A_2')∨~append(cons(a,nil),A_2',A_1)∨~squash(cons(b,nil),A_2)∨~append(A_1,A_2,*z*)

$\Re_4$: $\Re_3$-$\Re$-fact1: ~squash(nil,A_2')∨~append(cons(a,nil),A_2',A_1)∨~squash(cons(b,nil),A_2)∨~append(A_1,A_2,*z*)

$\Re_5$: $\Re_4$-$\Re$-F3: ~append(cons(a,nil),A_2',A_1)∨~squash(cons(b,nil),A_2)∨~append(A_1,A_2,*z*) {nil/A_2'}
$\Re_5$: ~append(cons(a,nil),nil,A_1)∨~squash(cons(b,nil),A_2)∨~append(A_1,A_2,*z*)

$\Re_6$: $\Re_5$-$\Re$-F2: ~squash(cons(b,nil),A_2)∨~append(A_1,A_2,*z*) {cons(a,nil)/A_1}
$\Re_6$: ~squash(cons(b,nil),A_2)∨~append(cons(a,nil),A_2,*z*)

$\Re_7$: $\Re_6$-$\Re$-R3”: ~squash(H”,A_1”)∨~squash(T”,A_2”)∨~append(A_1”,A_2”,A_3”)∨~append(cons(a,nil),A_2,*z*)
{b,/H”,nil/T”,A_2/A_3”}
$\Re_7$: ~squash(b,A_1”)∨~squash(nil,A_2”)∨~append(A_1”,A_2”,A_2)∨~append(cons(a,nil),A_2,*z*)

IV. Computation Deduction. (continued)

$\Re_8$: $\Re_7$-$\Re$-R2': ~atomic(S')∨~squash(nil,A_2")∨~append(A_1",A_2",A_2)∨~append(cons(a,nil),A_2,*z*) {b/S',cons(S',nil)/A_1"}

$\Re_8$: ~atomic(b)∨~squash(nil,A_2")∨~append(cons(b,nil),A_2",A_2)∨~append(cons(a,nil),A_2,*z*)

$\Re_9$: $\Re_8$-$\Re$-fact2: ~squash(nil,A_2")∨~append(cons(b,nil),A_2",A_2)∨~append(cons(a,nil),A_2,*z*)

$\Re_{10}$=$\Re_9$-$\Re$-F3: ~append(cons(b,nil),A_2",A_2)∨~append(cons(a,nil),A_2,*z*) {nil/A_2"}

$\Re_{10}$= ~append(cons(b,nil),nil,A_2)∨~append(cons(a,nil),A_2,*z*)

$\Re_{11}$=$\Re_{10}$-$\Re$-F2: ~append(cons(a,nil),A_2,*z*) {cons(b,nil)/A_2}

$\Re_{11}$: ~append(cons(a,nil),cons(b,nil),*z*)

$\Re_{12}$=$\Re_{11}$-$\Re$-R1: ~append(X_2,Y_2,Z_2) {a/U_2,nil/X_2,cons(b,nil)/Y_2,cons(a,Z_2)/z}

$\Re_{12}$= ~append(nil,cons(b,nil),Z_2)

$\Re_{13}$=$\Re_{12}$-$\Re$-F1: nil {cons(b,nil),Z_2}

z=cons(a,cons(b,nil))

Goal: squash(cons(cons(a,nil),cons(b,nil)),*cons(a,cons(b,nil*))

Substitutions will be consistent because I changed variables every time I re-used any rules and all the variables were originally standardized apart. To prove consistency we assemble all the numerators in a set, say U1 and all the denominators in a set, say, U2 and see if U1σ=U2 and σ≠null.

Fall 2003 Exam 2

(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.

{*wff A*}: (∀*x*){[A(*x*) ∧ B(*x*)]→[C(*x*,I) ∧ (∃*y*)((∃z)[C(*y*,*z*)]→D(*x*,*y*))]} ∨ (∀*x*)[E(*x*)]

(2) Step 0: ______________________

Eliminate redundant quantifiers and take the existential closure (not applicable)

A_0: (∀*x*){[A(*x*) ∧ B(*x*)]→[C(*x*,I) ∧ (∃*y*)((∃z)[C(*y*,*z*)]→D(*x*,*y*))]} ∨ (∀*x*)[E(*x*)]

(2) Step 1: ______________________

Remove implications

A_1: (∀*x*){~[A(*x*) ∧ B(*x*)] ∨ [C(*x*,I) ∧ (∃*y*)((∃z)[~C(*y*,*z*)]∨D(*x*,*y*))]} ∨ (∀*x*)[E(*x*)]

(2) Step 2: ______________________

Move the Negations down to the *Atf*s

A_2: (∀*x*){[~A(*x*) ∨ ~B(*x*)] ∨ [C(*x*,I) ∧ (∃*y*)((∃*z*)[~C(*y*,*z*)]∨D(*x*,*y*))]} ∨ (∀*x*)[E(*x*)]

(2) Step 3: ______________________

Standardize Variables Apart

A_3: (∀*x*){[~A(*x*) ∨ ~B(*x*)] ∨ [C(*x*,I) ∧ (∃*y*)((∃*z*)[~C(*y*,*z*)]∨D(*x*,*y*))]} ∨ (∀*w*)[E(*w*)]

(2) Step 4: ____________________

Skolemize: Let $y = f(x)$; $z=g(x)$

A_4: $(\forall x)\{[\sim A(x) \vee \sim B(x)] \vee [C(x,I) \wedge (\sim C(f(x),g(x)) \vee D(x,f(x)))]\} \vee (\forall w)[E(w)]$

(2) Step 5: ____________________

Move universal quantifiers to the left.

A_5: $(\forall x)(\forall w)\{[\sim A(x) \vee \sim B(x)] \vee [C(x,I) \wedge (\sim C(f(x),g(x)) \vee D(x,f(x)))]\} \vee E(w)$

(2) Step 6: ____________________

Distribute $\vee$ over $\wedge$ using $E_1 \vee (E_2 \wedge E_3) = (E_1 \vee E_2) \wedge (E_1 \vee E_3)$

A_{6a}: $(\forall x)(\forall w)\{\sim A(x) \vee \sim B(x) \vee C(x,I) \vee E(w)\} \wedge$

A_{6b}: $(\forall x)(\forall w)\{\sim A(x) \vee \sim B(x) \vee \sim C(f(x),g(x)) \vee D(x,f(x)) \vee E(w)\}$

(2) Step 7: ____________________

Write in Matrix Form

A_7: $(\forall x)(\forall w)[\sim A(x) \vee \sim B(x) \vee C(x,I) \vee E(w)]$

$(\forall x)(\forall w)[\sim A(x) \vee \sim B(x) \vee \sim C(f(x),g(x)) \vee D(x,f(x)) \vee E(w)]$

(2) Step 8: ____________________

Remove Universal Quantifiers

A_8: $[\sim A(x) \vee \sim B(x) \vee C(x,I) \vee E(w)]$

$[\sim A(x) \vee \sim B(x) \vee \sim C(f(x),g(x)) \vee D(x,f(x)) \vee E(w)]$

I. Conversion to Clause Form (continued)

(2) Step 9: ____________________

Rename Variables

A_9: [~A(x_1) ∨ ~B(x_1) ∨ C(x_1,I) ∨ E(w_1)]

[~A(x_2) ∨ ~B(x_2) ∨ ~C(f(x_2),g(x_2)) ∨ D(x_2,f(x_2)) ∨ E(w_2)]

(2) Step 10: ____________________

Step 10 Remove Tautologies & Simplify (not applicable)

A_{10}: [~A(x_1) ∨ ~B(x_1) ∨ C(x_1,I) ∨ E(w_1)]

[~A(x_2) ∨ ~B(x_2) ∨ ~C(f(x_2),g(x_2)) ∨ D(x_2,f(x_2)) ∨ E(w_2)]

(25)

II. Resolution Refutation

EXCITING LIFE

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?

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**:

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?

[1] $(\forall x)[\{\sim \text{poor}(x) \wedge \text{smart}(x)\} \rightarrow \text{happy}(x)]$

[2] $(\forall y)[\text{read}(y) \rightarrow \text{smart}(y)]$

[3] $\text{read}(John) \wedge \sim \text{poor}(John)$

[4] $(\forall z)[\text{happy}(z) \rightarrow \text{exciting}(z)]$

[5] $(\exists w)[\text{exciting}(w)]$ {goal}

(2) Answers Part **b**:

None needed

(5) Answers Part **c**:

[1] $\text{poor}(x) \vee \sim \text{smart}(x) \vee \text{happy}(x)$

[2] $\sim \text{read}(y) \vee \text{smart}(y)$

[3a] $\text{read}(John)$

[3b] $\sim \text{poor}(John)$

[4] $\sim \text{happy}(z) \vee \text{exciting}(z)$

[5’] $\sim \text{exciting}(w)$

II. Resolution Refutation(continued)

(10) Refutation Graph Part **d**:

[5’] ~exciting(*w*)
[6] ~happy(*z*)
[7] poor(*x*) ∨ ~smart(*x*)
[8] poor(*y*) ∨ ~read(*y*)
[9] poor(*John*)
[10] nil

[5’] [4] [1] [2] [3a] [3b]
$\mathfrak{R}_1$
$\mathfrak{R}_2$
$\mathfrak{R}_3$
$\mathfrak{R}_4$
nil

$\mathfrak{R}_1$=[5’] with [4] ~happy(z) {z/*w*}
$\mathfrak{R}_2$=$\mathfrak{R}_1$ with [1] poor(x) ∨ ~smart(*x*) {*x*/*z*}
$\mathfrak{R}_3$=$\mathfrak{R}_2$ with [2] poor(*y*) ∨ ~read(*y*) {*y*/*x*}
$\mathfrak{R}_4$=$\mathfrak{R}_3$ with [3a] poor(*John*) {*John*/*y*}
$\mathfrak{R}_5$=Nil with $\mathfrak{R}_4$ and [3b]
Consistency Check
U_1=[*z,x,y,John*] U_2=[*w,z,x,y*]
U_1=U_2[z/*w*, *x*/*z*, *y*/*x*, *John*/*y*]
Since U_1 & U_2 unify, then the substitutions are consistent

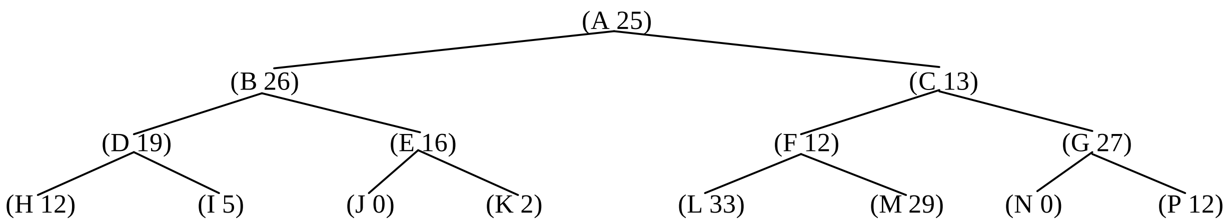
(3) Answer Part **e**: My strategy is _______ Set of Support ____
Since every resolvent $\mathfrak{R}_1$-$\mathfrak{R}_5$ comes from the negation of the goal wff with the base set or one of its descendants

EEL-5840 Class Exam 2 ______________________________
Fall 2009 Sample Questions (Name)

(30)

III. <u>Heuristic Search</u>

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 <u>clearly justify</u> your answer(s). "Feelings" or "intuition" are not good/sound reasons. NO JUSTIFICATION <==> 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



ALGORITHM DETAILS: YOU CAN USE ALGORITHM GRAPHSEARCH FOR EVERYTHING

START: OPEN={*A*} CLOSED={} G={} M={} $f(n)=g(n)+h(n)$ where $g(n)=depth(n)$ & $h(n)$=heuristic fcn

BREADTH FIRST: USE THE FUNCTION $f(n)$=CAR(OPEN) AND APPEND M AT THE END OF THE OPEN LIST.

1. The algorithm selects *A* and expands *A* (applies Γ) in order to obtain M={*B*,*C*}
   n_1=B; n_2=C; Open={B,C}, Closed={A}, G={A}, $f(n_1)=1$; $f(n_2)=1$
2. The algorithm expands *B* in order to obtain M={*D*,*E*}
   n_3=D; n_4=E; Open={C,D,E}, Closed={A,B}, G={A,B}, $f(n_3)=1$; $f(n_4)=1$
3. The algorithm expands *C* in order to obtain M={*F*,*G*}
   n_5=F; n_6=G; Open={D,E,F,G}, Closed={A,B,C}, G={A,B,C}, $f(n_5)=1$; $f(n_6)=1$
4. The algorithm expands *D* in order to obtain M={*H*,*I*}
   n_7=H; n_8=I; Open={E,F,G,H,I}, Closed={A,B,C,D}, G={A,B,C,D}, $f(n_7)=1$; $f(n_8)=1$
5. The algorithm expands *E* in order to obtain M={*J*,*K*}
   n_9=J; n_{10}=K; Open={F,G,H,I,J,K}, Closed={A,B,C,D,E}, G={A,B,C,D,E}, $f(n_9)=1$; $f(n_{10})=1$
6. The algorithm expands *F* in order to obtain M={*L*,*M*}
   n_{11}=L; n_{12}=M; Open={G,H,I,J,K,L,M}, G=Closed={A,B,C,D,E,F}, $f(n_{11})=1$; $f(n_{12})=1$
7. The algorithm expands *G* in order to obtain M={*N*,*P*}
   n_{13}=N; n_{14}=P; Open={H,I,J,K,L,M,N,P}, G=Closed={A,B,C,D,E,F,G}, $f(n_{13})=1$; $f(n_{14})=1$
8. The algorithm expands *H* in order to obtain M={}
   Open={I,J,K,L,M,N,P}, G=Closed={A,B,C,D,E,F,G,H}
9. The algorithm expands *I* in order to obtain M={}
   Open={J,K,L,M,N,P}, G=Closed={A,B,C,D,E,F,G,H,I}
10. The algorithm expands *J* in order to obtain M={}
    J is a solution and the algorithm terminates. BFS expands {A,B,C,D,E,F,G,H,I,J} 10 nodes

III. Heuristic Search. (continued)

DEPTH-FIRST: USE THE FUNCTION $f(n)$=DEPTH(N) AND APPEND M AT THE FRONT OF THE OPEN LIST.

1. The algorithm selects *A* and expands *A* (applies Γ) in order to obtain M={*B*,*C*}
n_1=B; n_2=C; Open={B,C}, Closed={A}, G={A}, $f(n_1)=1$; $f(n_2)=1$
2. The algorithm expands *B* in order to obtain M={*D*,*E*}
n_3=D; n_4=E; Open={D,E,C}, Closed={A,B}, G={A,B}, $f(n_3)=2$; $f(n_4)=2$
3. The algorithm expands *D* in order to obtain M={*H*,*I*}
n_4=H; n_5=I; Open={H,I,E,C}, Closed={A,B,D}, G={A,B,D}, $f(n_5)=3$; $f(n_6)=3$
4. The algorithm expands *H* in order to obtain M={}
Open={I,E,C}, G=Closed={A,B,D,H}
5. The algorithm expands *I* in order to obtain M={}
Open={E,C}, G=Closed={A,B,D,H,I}
6. The algorithm expands *E* in order to obtain M={*J*,*K*}
n_6=J; n_7=K; Open={J,K,C}, Closed={A,B,D,H,I,E}, G={A,B,D,H,I,E}, $f(n_9)=3$; $f(n_{10})=3$
7. The algorithm expands *J* in order to obtain M={}
J is a solution and the algorithm terminates. DFS expands {A,B,D,H,I,E,J} 7 nodes

HEURISTIC-SEARCH: USE THE FUNCTION $f(n)= h(n)$ AND SORT THE OPEN LIST USING f VALUES.

1. The algorithm selects *A* and expands *A* (applies Γ) in order to obtain M={*B*,*C*}
n_1=B; n_2=C; Open={B,C}, Closed={A}, G={A}, $f(n_1)=26$; $f(n_2)=13$
2. The algorithm expands *C* in order to obtain M={*F*,*G*}
n_3=F; n_4=G; Open={F,B,G}, Closed={A,C}, G={A,C}, $f(n_3)=12$; $f(n_4)=27$
3. The algorithm expands *F* in order to obtain M={*L*,*M*}
n_5=L; n_6=M; Open={B,G,M,L}, G=Closed={A,C,F}, $f(n_5)=33$; $f(n_6)=29$
4. The algorithm expands *B* in order to obtain M={*D*,*E*}
n_7=D; n_8=E; Open={E,D,G,M,L}, G=Closed={A,C,F.B}, $f(n_7)=19$; $f(n_8)=16$
5. The algorithm expands *E* in order to obtain M={*J*,*K*}
n_9=J; n_{10}=K; Open={J,K,D,G,M,L }, G=Closed={A,C,F,B,E}, $f(n_9)=0$; $f(n_{10})=2$
6. The algorithm expands *J* in order to obtain M={}
J is a solution and the algorithm terminates. Heuristic search expands {A,C,F,B,E,J} 6 nodes

A* SEARCH: USES $f(n)=g(n)+h(n)$ where $g(n)=depth(n)$ & $h(n)$=cost AND SORT THE OPEN LIST USING f

1. The algorithm selects *A* and expands *A* (applies Γ) in order to obtain M={*B*,*C*}
n_1=B; n_2=C; Open={B,C}, Closed={A}, G={A}, $f(n_1)=1+26$; $f(n_2)=1+13$
2. The algorithm expands *C* in order to obtain M={*F*,*G*}
n_3=F; n_4=G; Open={F,B,G}, Closed={A,C}, G={A,C}, $f(n_3)=2+12$; $f(n_4)=2+27$
3. The algorithm expands *F* in order to obtain M={*L*,*M*}
n_5=L; n_6=M; Open={B,G,M,L}, G=Closed={A,C,F}, $f(n_5)=3+33$; $f(n_6)=3+29$
4. The algorithm expands *B* in order to obtain M={*D*,*E*}
n_7=D; n_8=E; Open={E,D,G,M,L}, G=Closed={A,C,F.B}, $f(n_7)=2+19$; $f(n_8)=2+16$
5. The algorithm expands *E* in order to obtain M={*J*,*K*}
n_9=J; n_{10}=K; Open={J,K,D,G,M,L }, G=Closed={A,C,F,B,E}, $f(n_9)=3+0$; $f(n_{10})=3+2$
6. The algorithm expands *J* in order to obtain M={}
J is a solution and the algorithm terminates. Heuristic search expands {A,C,F,B,E,J} 6 nodes

N WILL NOT BE FOUND BY ANY OF THE ALGORITHMS BECAUSE PATH {A,B,E,J} IS CONSIDERED BEFORE {A,C,G,N} due to the fact that h(E)=16 and h(G)=27 and $h(E)<h(G)$.

(25)

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: herd(nil,nil,nil).

Rules:

R_1: herd(T,S,G) → herd(cons(sheep,T),cons(sheep,S),G)

R_2: herd(T,S,G) → herd(cons(goat,T),S,cons(goat,G))

Goal: (∃*z*)(∃*w*) herd(cons(sheep, cons(goat,cons(goat,nil))),*w*,*z*)

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

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

(1 pts) I am using Set-of-Support which is a complete strategy

F_1: herd(nil,nil,nil).

R_1:~ herd(T,S,G) ∨ herd(cons(sheep,T),cons(sheep,S),G)

R_2:~ herd(T',S',G') ∨ herd(cons(goat,T'),S',cons(goat,G'))

~Goal: ~herd(cons(sheep,cons(goat,cons(goat,nil))),*w*,*z*)

(3 pts) $\Re_1=\Re$\{~Goal,R_1\}: ~herd(T,S,G) { cons(goat,cons(goat,nil))/T,cons(sheep,S)/*w*,G/*z*}

$\Re_1$: ~herd(cons(goat,cons(goat,nil)),S,G)

(3 pts) $\Re_2=\Re$\{$\Re_1$,R_2\}: ~herd(T',S',G'){ cons(goat,nil)/T',S'/S;cons(goat,G')/G}

$\Re_2$: ~herd(cons(goat,nil),S',G')

(3 pts) $\Re_3=\Re_2$-$\Re$-R2": ~herd(nil,T",G") {nil/T";S"/S',cons(goat,G")/G'}

$\Re_3$: ~herd(nil,S",G")

(3 pts) $\Re_4=\Re_3$-$\Re$-F1: nil {nil/S",nil/G"}

(4 pts) Therefore G"=nil; G'=cons(goat,G")=cons(goat,nil); G=cons(goat,G')=cons(goat,(cons(goat,nil)); *z*=G= cons(goat,(cons(goat,nil)); S"=nil; S'=S"=nil; S=S'=nil; *w*=cons(sheep,s)=cons(sheep,nil).

(3) *Anwer:* (∃*z*)(∃*w*)herd(cons(sheep, cons(goat,cons(goat,nil))),*w*,*z*) is true
with *w*=cons(sheep,nil) and. *z*= cons(goat,(cons(goat,nil))

(5) Substitutions will be consistent because I changed variables every time I re-used any rules and all the variables were originally standardized apart. To prove consistency we assemble all the numerators in a set, say, U_1, and all the denominators in a set, say, U_2 and show that $U_1=U_2\sigma$ and $\sigma\neq$null.

EEL-5840 | Class Exam 2 | ______________________________
Fall 2009 | Sample Questions | (Name)

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.

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

(2) Step 0: Eliminate redundant quantifiers and take the existential closure

A_0: $\exists z(\forall x \exists y)\{[P(x,y) \rightarrow Q(y,z)] \wedge [Q(y,x) \rightarrow S(x,y)]\} \rightarrow (\exists x \forall y)[P(x,y) \rightarrow S(x,y)]$

(2) Step 1: Remove implications

A_1: $\exists z \sim(\forall x \exists y)\{[\sim P(x,y) \vee Q(y,z)] \wedge [\sim Q(y,x) \vee S(x,y)]\} \vee (\exists x \forall y)[\sim P(x,y) \vee S(x,y)]$

(2) Step 2: Move the Negations down to the *Atf*s

A_2: $\exists z\ (\exists x \forall y)\{[\ P(x,y) \wedge \sim Q(y,z)] \vee [Q(y,x) \wedge \sim S(x,y)]\} \vee (\exists x \forall y)[\sim P(x,y) \vee S(x,y)]$

(2) Step 3: Standardize Variables Apart

A_3: $\exists z\ (\exists x_1 \forall y_1)\{[\ P(x_1,y_1) \wedge \sim Q(y_1,z)] \vee [Q(y_1,x_1) \wedge \sim S(x_1,y_1)]\} \vee (\exists x_2 \forall y_2)[\sim P(x_2,y_2) \vee S(x_2,y_2)]$

(2) Step 4: Skolemize: Let z=C_1, $x_1 = C_2$; x_2=C_3

A_4: $(\forall y_1)\{[\ P(C_2,y_1) \wedge \sim Q(y_1,C_1)] \vee [Q(y_1,C_2) \wedge \sim S(C_2,y_1)]\} \vee (\forall y_2)[\sim P(C_3,y_2) \vee S(C_3,y_2)]$

(2) Step 5: Move universal quantifiers to the left

A_5: $(\forall x)(\forall y)\{[\ P(C_2,x) \wedge \sim Q(x,C_1)] \vee [Q(x,C_2) \wedge \sim S(C_2,x)]\} \vee [\sim P(C_3,y) \vee S(C_3,y)]$

(6) Step 6: Multiply out & distribute $\vee$ over $\wedge$ using $E_1 \vee (E_2 \wedge E_3) = (E_1 \vee E_2) \wedge (E_1 \vee E_3)$

A_{6a}: $(\forall x)(\forall y)\{[P(C_2,x) \vee Q(x,C_2)] \wedge [P(C_2,x) \vee \sim S(C_2,x)] \wedge [\sim Q(x,C_1) \vee Q(x,C_2)] \wedge [\sim Q(x,C_1) \vee \sim S(C_2,x)]\}$
$\vee\ [\sim P(C_3,y) \vee S(C_3,y)]$

A_{6b}: $(\forall x)(\forall y)\{[\sim P(C_3,y) \vee S(C_3,y) \vee P(C_2,x) \vee Q(x,C_2)] \wedge [\sim P(C_3,y) \vee S(C_3,y) \vee P(C_2,x) \vee \sim S(C_2,x)]$
$\wedge [\sim P(C_3,y) \vee S(C_3,y) \vee \sim Q(x,C_1) \vee Q(x,C_2)] \wedge [\sim P(C_3,y) \vee S(C_3,y) \vee \sim Q(x,C_1) \vee \sim S(C_2,x)]\}$

(2) Step 7: Write in Matrix Form

A_7: $(\forall x)(\forall y)[\sim P(C_3,y) \vee S(C_3,y) \vee P(C_2,x) \vee Q(x,C_2)]$
$(\forall x)(\forall y)[\sim P(C_3,y) \vee S(C_3,y) \vee P(C_2,x) \vee \sim S(C_2,x)]$
$(\forall x)(\forall y)[\sim P(C_3,y) \vee S(C_3,y) \vee \sim Q(x,C_1) \vee Q(x,C_2)]$
$(\forall x)(\forall y)[\sim P(C_3,y) \vee S(C_3,y) \vee \sim Q(x,C_1) \vee \sim S(C_2,x)]]$

(2) Step 8: Eliminate Universal Quantifiers

A_8: $[\sim P(C_3,y) \vee S(C_3,y) \vee P(C_2,x) \vee Q(x,C_2)]$
$[\sim P(C_3,y) \vee S(C_3,y) \vee P(C_2,x) \vee \sim S(C_2,x)]$
$[\sim P(C_3,y) \vee S(C_3,y) \vee \sim Q(x,C_1) \vee Q(x,C_2)]$
$[\sim P(C_3,y) \vee S(C_3,y) \vee \sim Q(x,C_1) \vee \sim S(C_2,x)]]$

I. Conversion to Clause Form (continued)

(2) Step 9: Rename Variables

A_9: $[\sim P(C_3,y_1) \vee S(C_3,y_1) \vee P(C_2,x_1) \vee Q(x_1,C_2)]$
$[\sim P(C_3,y_2) \vee S(C_3,y_2) \vee P(C_2,x_2) \vee \sim S(C_2,x_2)]$
$[\sim P(C_3,y_3) \vee S(C_3,y_3) \vee \sim Q(x_3,C_1) \vee Q(x_3,C_2)]$
$[\sim P(C_3,y_4) \vee S(C_3,y_4) \vee \sim Q(x_4,C_1) \vee \sim S(C_2,x_4)]]$

(1) Step 10: Remove Tautologies & Simplify (not applicable)

A_{10}: $[\sim P(C_3,y_1) \vee S(C_3,y_1) \vee P(C_2,x_1) \vee Q(x_1,C_2)]$
$[\sim P(C_3,y_2) \vee S(C_3,y_2) \vee P(C_2,x_2) \vee \sim S(C_2,x_2)]$
$[\sim P(C_3,y_3) \vee S(C_3,y_3) \vee \sim Q(x_3,C_1) \vee Q(x_3,C_2)]$
$[\sim P(C_3,y_4) \vee S(C_3,y_4) \vee \sim Q(x_4,C_1) \vee \sim S(C_2,x_4)]]$

EEL-5840 Class Exam 2 ______________________________

Fall 2009 Sample Questions (Name)

(25)

II. Resolution Refutation

CONSIDER THE FOLLOWING DATABASE ABOUT ZEBRAS
ZEBRAS ARE MAMMALS, STRIPPED, 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**:

ZEBRAS ARE MAMMALS, STRIPPED, 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?

[1] $(\forall x)[\text{zebra}(x)\rightarrow\text{mammal}(x)]$

[2] $(\forall x)[\text{zebra}(x)\rightarrow\text{striped}(x)]$

[3] $(\forall x)[\text{zebra}(x)\rightarrow\text{medium}(x)]$

[4] $(\forall x)[\text{mammal}(x)\rightarrow\text{animal}(x)]$

[5] $(\forall x)[\text{mammal}(x)\rightarrow\text{warm}(x)]$

[6] $(\forall x)[\text{striped}(x)\rightarrow\text{nonsolid}(x)]$

[7] $(\forall x)[\text{striped}(x)\rightarrow\text{nonspotted}(x)]$

[8] $(\forall x)[\text{medium}(x)\rightarrow\text{nonsmall}(x)]$

[9] $(\forall x)[\text{medium}(x)\rightarrow\text{nonlarge}(x)]$

[10] $[\text{zebra}(zeke)\rightarrow\text{nonlarge}(zeke)]$

(2) Answers Part **b**:

None needed

(5) Answers Part **c**:

[1] $\sim\text{zebra}(x_1) \vee \text{mammal}(x_1)$

[2] $\sim\text{zebra}(x_2) \vee \text{striped}(x_2)$

[3] $\sim\text{zebra}(x_3) \vee \text{medium}(x_3)$

[4] $\sim\text{mammal}(x_4) \vee \text{animal}(x_4)$

[5] $\sim\text{mammal}(x_5) \vee \text{warm}(x_5)$

[6] $\sim\text{striped}(x_6) \vee \text{nonsolid}(x_6)$

[7] $\sim\text{striped}(x_7) \vee \text{nonspotted}(x_7)$

[8] $\sim\text{medium}(x_8) \vee \text{nonsmall}(x_8)$

[9] $\sim\text{medium}(x_9) \vee \text{nonlarge}(x_9)$

[10a] $\text{zebra}(zeke)$

[10b] $\sim\text{nonlarge}(zeke)]$

II. Resolution Refutation(continued)

(10) Refutation Graph Part **d**:

[10a] [1] [2] [3] [4] [5] [6] [7] [8] [10b] [9]

$\Re_1$ $\Re_2$ $\Re_3$ $\Re_5$ $\Re_6$ $\Re_7$ $\Re_8$ $\Re_9$ $\Re_4$ $\Re_{10}$

nil nil

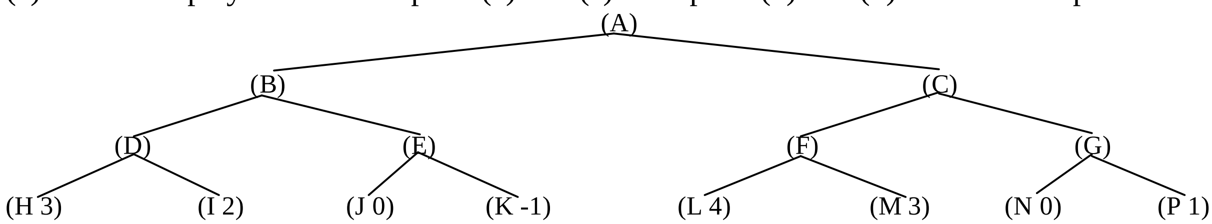
$\Re_1$=[10a'] with [1] mammal(zeke) {zeke/x_1}
$\Re_2$=[10a'] with [2] striped(zeke) {zeke/x_2}
$\Re_3$=[10a'] with [3] medium(zeke) {zeke/x_3}
$\Re_4$=[10b'] with [9] ~medium(zeke) {zeke/x_9}
$\Re_5$=[1] with [4] animal(x_1) {x_1/x_4}
$\Re_6$=[1] with [5] warm(x_1) {x_1/x_4}
$\Re_7$=[2] with [6] nonsolid(x_2) {x_2/x_6}
$\Re_8$=[2] with [7] nospotted(x_2) {x_2/x_7}
$\Re_9$=[3] with [8] nosmall(x_3) {x_3/x_8}
$\Re_{10}$=[3] with [9] nonlarge(x_3) {x_3/x_9}
$\Re_{11}$=Nil with $\Re_3$ and $\Re_4$
$\Re_{12}$=Nil with [10b'] and $\Re_{10}$
Consistency Check
U_1=[zeke, zeke, zeke, zeke] U_2=[x_1,x_2,x_3,x_9]
U_1=U_2[zeke/x_1, zeke/x_2, zeke/x_3, zeke/x_9]
Since U_1 & U_2 unify, then the substitutions are consistent

(3) Answer Part **e**: My strategy is Breadth First______________________________
(1) Since every 1st level resolvent $\Re_1$-$\Re_{10}$ comes from the base set + negation of the wff to be proved.
Nil came from two first level resolvents $\Re_3$ and $\Re_4$ or from a 1st level resolvent $\Re_{10}$ and from a base set [10b']
(2) Since Nil came from a 1st level resolvent $\Re_{10}$ which came from the negation of the wff
and from it and another member of the negation of the wff [10b'], this represents a set of support strategy

(2
5)
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.



Part (a)

D, E, F, G choose max or D=(H 3); E=(J 0); F=(L 4); G=(P 1)
B, C chooses min or B= E=(J 0); C=(P 1)
A chooses max or A=C=G=(P 1)
A chooses C toward solution A→C→G→P

Part (b)

D, E, F, G choose min or D=(I 2); E=(K -1); F=(M 3); G=(N 0)
B, C chooses max or B=D=(I 2); C=F=(M 3)
A chooses min or A=B=D=(I 2)
A chooses B toward solution A→B→D→I

Part (c)

D chooses max evaluating (H 3) & (I 2) or α_D=3 (H 3); Now B chooses min so $\beta_B \leq 3$ (H 3)
Evaluate (J 0); now $\alpha_E \geq 0$ (J 0) and $\beta_B \leq 3$ (H 3) therefore no Beta Cutoff and continue
Evaluate (K –1); now α_E=0 (J 0) now β_B = 0 (J 0)
Now B chooses min so β_B = 0 (J 0), therefore $\alpha_A \geq 0$ (J 0)
Evaluate (L 4); now $\alpha_F \geq 4$ (L 4) and $\beta_C \leq 4$ (L 4) therefore no Alpha cutoff & continue
Evaluate (M 3); now α_F=4 (L 4); and $\beta_C \leq 4$ (L 4)
Evaluate (N 0); now $\alpha_G \geq 0$ (N 0); no cutoff & continue
Evaluate (P 1); now α_G=1 (P 1); β_C =1 (P 1) no cutoff & continue
A chooses C to G to P (P 1)
Alpha-Beta had Pruning resulted in no advantage

III. Adversarial Search. (continued)

Part (d)

D chooses min evaluating (H 3) & (I 2) or β_D=2 (I 2); Now B chooses max so $\alpha_E \geq 2$ (I 2)
Evaluate (J 0); now $\beta_F \leq 0$ (J 0) and $\alpha_E \geq 2$ (I 2) Alpha Cutoff at E and continue α_E=2 (I 2); $\beta_A \leq 2$ (I 2)
Evaluate (L 4); now $\beta_D \leq 4$ (L 4) and $\alpha_C \geq 4$ (L 4) therefore no Alpha cutoff & continue
Evaluate (M 3); now α_F=4 (L 4); and $\beta_C \leq 4$ (L 4) and $\beta_A \leq 2$ (I 2) Beta Cutoff at C and β_A=2 (I 2)
A chooses B to D to I (I 2)
Do Not Evaluate {K, G, N, P}

Part (e)

A chooses C toward solution A→C→G→P in both parts (a) and (c) because Alpha-Beta and Minimax produce the same results for the same problem.
Similarly, A chooses B toward solution A→B→E→J in both parts (b) and (d) because Alpha-Beta and Minimax produce the same results for the same problem.
In my analysis that was indeed the case.

(25)

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: swap(X,Y,nil,nil).

Rules:

R_1: swap(S_1,S_2,Y,Z) → swap(S_1,S_2,cons(S_1,Y),cons(S_2,Z))

R_2: {swap(S_1,S_2,Y,Z) ∧ X≠S_1} → swap(S_1,S_2,cons(X,Y),cons(X,Z))

Goal: (∃*z*) swap(ron, bob, cons(steve, cons(ron, cons(galen,nil))), *z*)

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

Required: Give the resolution trace, show the substitutions are consistent, and obtain the value of the goal.

(1 pts) I am using Set-of-Support which is a complete strategy

F_1: swap(A,B,nil,nil).

R_1:~ swap(S_1,S_2,Y_1, Z_1) ∨ swap (S_1,S_2,cons(S_1,Y_1),cons(S_2,Z_1))

R_2:~ swap(S_1,S_2,Y_2, Z_2) ∨ ~X≠S_1 ∨ swap(S_1,S_2,cons(X,Y_2),cons(X,Z_2))

~Goal: ~swap(ron, bob, (steve ron galen), *z*)

(3 pts) $\Re_1$=$\Re${~Goal,R_2}: ~swap(S_1,S_2,Y_2, Z_2) ∨ ~X≠S_1 {ron/S_1, bob/S_2, steve/X, (ron galen)/Y_2, cons(X,Z_2)/z}

$\Re_1$: ~swap(ron, bob. (ron galen), Z_2) ∨ ~steve≠ron {this evaluates to nil}

(3 pts) $\Re_2$=$\Re${$\Re_1$,R_1}: ~ swap(S_1,S_2,Y_1, Z_1) {ron/S_1, bob/S_2, (galen)/Y_1, cons(S_2,Z_1)/Z_2}

$\Re_2$: ~swap(ron, bob, cons(galen,nil), Z_1)

(3 pts) $\Re_3$=$\Re_2$-$\Re$-R2': ~swap(S_1,S_2,Y_2', Z_2') ∨ ~X'≠S_1 {ron/S_1, bob/S_2, galen/X', nil/Y_2', cons(X',Z_2')/Z_1}

$\Re_3$: ~swap(ron, bob. nil, Z_2') ∨ ~galen≠ron {this evaluates to nil}

(3 pts) $\Re_4$=$\Re_3$-$\Re$-F1: nil {ron/S_1, bob/S_2, nil/ Z_2'}

(4 pts) Therefore Z_2'=nil; Z_1=cons(galen,nil)= (galen); Y_2'=nil; Z_2=cons(bob,(galen))=(bob galen); *z*=cons(steve, cons(bob, cons(galen,nil)))=(steve bob galen)

(3) *Anwer:* (∃z)swap(ron, bob, cons(steve, cons(ron,cons(galen,nil))), *z*) is true
with z = cons (steve, cons(bob, cons(galen,nil))) = (steve bob galen)

(5) Substitutions will be consistent because I changed variables every time I re-used any rules and all the variables were originally standardized apart. To prove consistency we assemble all the numerators in a set, say, U_1, and all the denominators in a set, say, U_2 and show that U_1=$U_2\sigma$ and σ≠null.

EEL-5840 | Class Exam 2 | _______________
Fall 2009 | Sample Questions | (Name)

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.

$$\{wff\ A\}: (\forall x)\{P(x) \rightarrow (A(x) \wedge B(x) \vee \sim C(x, w))\} \vee (\forall y)\ (\exists u)\ [Q(y,t) \vee ((\forall x)\ R(x) \rightarrow \sim B(y))]$$

(2) Step 0: Eliminate redundant quantifiers and take the existential closure

A_0: $(\exists w)\ (\exists t)\ (\forall x)\ \{P(x) \rightarrow (A(x) \wedge B(x) \vee \sim C(x, w))\} \vee (\forall y)\ [Q(y,t) \vee ((\forall x)\ R(x) \rightarrow \sim B(y))]$

(2) Step 1: Remove implications

A_1: $(\exists w)\ (\exists t)\ (\forall x)\ \{\sim P(x) \vee (A(x) \wedge B(x) \vee \sim C(x, w))\} \vee (\forall y)\ [Q(y,t) \vee (\sim(\forall x)\ R(x) \vee \sim B(y))]$

(2) Step 2: Move the Negations down to the *Atf*s

A_2: $(\exists w)\ (\exists t)\ (\forall x)\ \{\sim P(x) \vee (A(x) \wedge B(x) \vee \sim C(x, w))\} \vee (\forall y)\ [Q(y,t) \vee ((\exists x)\sim R(x) \vee \sim B(y))]$

(1) Step 3: Standardize Variables Apart

A_3: $(\exists w)\ (\exists t)\ (\forall x)\ \{\sim P(x) \vee (A(x) \wedge B(x) \vee \sim C(x, w))\} \vee (\forall y)\ [Q(y,t) \vee ((\exists z)\sim R(z) \vee \sim B(y))]$

(2) Step 4: Skolemize: Let $w=W$, $t = T$; $z= f(y)$

A_4: $(\forall x)\{\sim P(x) \vee (A(x) \wedge B(x) \vee \sim C(x, W))\} \vee (\forall y)\ [Q(y,T) \vee \sim R(f(y)) \vee \sim B(y)]$

(1) Step 5: Move universal quantifiers to the left

A_5: $(\forall x)\ (\forall y)\ \{\sim P(x) \vee (A(x) \wedge B(x) \vee \sim C(x, W))\} \vee [Q(y,T) \vee \sim R(f(y)) \vee \sim B(y)]$

(4) Step 6: Multiply out & distribute ∨ over ∧ using $E_1 \vee (E_2 \wedge E_3) = (E_1 \vee E_2) \wedge (E_1 \vee E_3)$

A_{6a}: $(\forall x)(\forall y)\{(\sim P(x) \vee Q(y,T) \vee \sim R(f(y)) \vee \sim B(y)) \vee [(\sim C(x,W) \vee A(x)) \wedge (\sim C(x,W) \vee B(x))]\}$

A_{6b}: $(\forall x)(\forall y)\{[\sim P(x) \vee Q(y,T) \vee \sim R(f(y)) \vee \sim B(y) \vee \sim C(x,W) \vee A(x)] \wedge$
$[\sim P(x) \vee Q(y,T) \vee \sim R(f(y)) \vee \sim B(y) \vee \sim C(x,W) \vee B(x)]\}$

I. Conversion to Clause Form (continued)

(1) Step 7: Write in Matrix Form

A_7: $(\forall x)(\forall y)[\ \sim P(x) \vee Q(y,T) \vee \sim R(f(y)) \vee \sim B(y) \vee \sim C(x,W) \vee A(x)]$

$(\forall x)(\forall y)[\ \sim P(x) \vee Q(y,T) \vee \sim R(f(y)) \vee \sim B(y) \vee \sim C(x,W) \vee B(x)]$

(1) Step 8: Eliminate Universal Quantifiers

A_8: $[\ \sim P(x) \vee Q(y,T) \vee \sim R(f(y)) \vee \sim B(y) \vee \sim C(x,W) \vee A(x)]$

$[\ \sim P(x) \vee Q(y,T) \vee \sim R(f(y)) \vee \sim B(y) \vee \sim C(x,W) \vee B(x)]$

(2) Step 9: Rename Variables

A_9: $[\ \sim P(x_1) \vee Q(y_1,T) \vee \sim R(f(y_1)) \vee \sim B(y_1) \vee \sim C(x_1,W) \vee A(x_1)]$

$[\ \sim P(x_2) \vee Q(y_2,T) \vee \sim R(f(y_2)) \vee \sim B(y_2) \vee \sim C(x_2,W) \vee B(x_2)]$

(2) Step 10: Remove Tautologies & Simplify: 2nd row drops out since $\{\sim B(y_2) \vee B(x_2)\}$ = True

A_{10}: $[\ \sim P(x_1) \vee Q(y_1,T) \vee \sim R(f(y_1)) \vee \sim B(y_1) \vee \sim C(x_1,W) \vee A(x_1)]$

(25)

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 A T 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]

(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**:

[1] is_member(Joe)
[2] is_member(Sally)
[3] is_member(Bill)
[4] is_member(Ellen)
[5] married(Joe,Sally)
[6] sibling(Bill,Ellen)
[7] $(\forall x)(\forall y)\{[\text{married}(x,y) \wedge \text{is\_member}(x)] \rightarrow \text{is\_member}(y)\}$
[8] last_meeting(Joe)
G1:last_meeting(Sally)
G2: $\sim(\exists y)\text{married}(\text{Ellen},y)$

(2) Answers Part **b**:

[9] $(\forall x)(\forall y)\{[\text{married}(x,y)\wedge\text{last\_meeting}(x)]\rightarrow\text{last\_meeting}(y)\}$
[10] $(\forall x)(\forall y)\{\text{married}(x,y)\rightarrow\text{married}(y,x)\}$
[11] $(\forall x)(\forall y)\{\text{married}(x,y)\rightarrow\sim\text{sibling}(x,y)\}$
[12] $(\forall x)(\forall y)(\forall z)\{\text{married}(x,y) \rightarrow \sim\text{married}(x,z)\}$

(5) Answers Part **c**:

[1] is_member(Joe)
[2] is_member(Sally)
[3] is_member(Bill)
[4] is_member(Ellen)
[5] married(Joe,Sally)
[6] sibling(Bill,Ellen)
[7] $\sim\text{married}(x_7,y_7) \vee \sim\text{is\_member}(x_7) \vee \text{is\_member}(y_7)$
[8] last_meeting(Joe)
[9] $\sim\text{married}(x_9,y_9) \vee \sim\text{last\_meeting}(x_9) \vee \text{last\_meeting}(y_9)$
[10] $\sim\text{married}(x_{10},y_{10}) \vee \text{married}(y_{10},x_{10})$
[11] $\sim\text{married}(x_{11},y_{11}) \vee \sim\text{sibling}(x_{11},y_{11})\}$
[12] $\sim\text{married}(x_{12},y_{12}) \vee \sim\text{married}(x_{12},z_{12})\}$
~G1: ~last_meeting(Sally)
~G2: married(Ellen,Joe) ∨ married(Ellen,Bill)

II. <u>Resolution Refutation</u>(continued)

(10) Refutation Graph Part **d**:

[~G1] [9]

$\Re_1$ [8]

$\Re_2$ [5]

nil

[~G2] [10]

$\Re_4$ [11]

$\Re_5$ [6]

$\Re_6$ [10]

$\Re_7$ [12]

$\Re_8$ [5]

nil

$\Re_1$=[~G1] with [9] ~married(x_9,Sally)∨~last_meeting(x_9) {Sally/y_9}
$\Re_2$=$\Re_1$ with [8] ~married(Joe,Sally) {Joe/x_9}
$\Re_3$=$\Re_2$ with 5 nil

$\Re_4$=[~G2] with [10] married(Bill,Ellen) ∨ married(Ellen,Joe) {Ellen/x_{10}, Bill/y_{10}}
$\Re_5$=$\Re_4$ with [11] ~sibling(Bill,Ellen) ∨ married(Ellen,Joe) {Bill/x_{11}, Ellen/y_{11}}
$\Re_6$=$\Re_5$ with [6] married(Ellen,Joe)
$\Re_7$=$\Re_6$ with [10] married(Joe,Ellen) {Ellen/x_{10}', Joe/y_{10}'}
$\Re_8$=$\Re_7$ with [12] ~married(Joe,z_{12}) {Joe/x_{12}, Ellen/y_{12}}
$\Re_9$=$\Re_8$ with [5] nil {Sally/z_{12}}

Consistency Check
U$_1$=[Sally,Joe,Ellen,Bill,Bill,Ellen,Ellen,Joe,Joe,Ellen,Sally] U$_2$=[y_9,x_9,x_{10},y_{10},x_{11},y_{11},x_{10}',y_{10}',x_{12},y_{12},z_{12}]
U$_1$=U$_2$[Sally/y_9,Joe/x_9,Ellen/x_{10},Bill/y_{10},Bill/x_{11},Ellen/y_{11},Ellen/x_{10}',Joe/y_{10}',Joe/x_{12},Ellen/y_{12},Sally/z_{12}]
Since U$_1$ & U$_2$ unify, then the substitutions are consistent

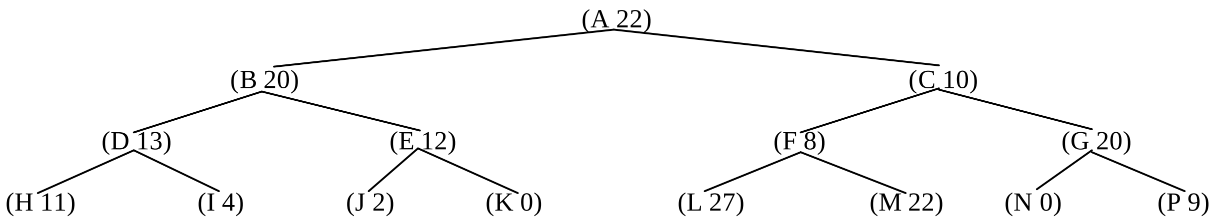
(3) Answer Part **e**: My strategy is Set-of-Support______________________________
Every resolvent $\Re_1$-$\Re_9$ comes from the negation of the wff to be proved. Note ~G2 is not Horne.
I could have used ancestry-filtered or breadth-first because they are complete strategies.

EEL-5840 Class Exam 2 _______________________________
Fall 2009 Sample Questions (Name)

(30)

III. Heritage 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 <==> 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



ALGORITHM DETAILS: YOU CAN USE ALGORITHM GRAPHSEARCH FOR EVERYTHING

START: OPEN={A} CLOSED={} G={} M={} $f(n)=g(n)+h(n)$ where $g(n)=depth(n)$ & $h(n)$=heuristic fcn

BREADTH FIRST: APPEND M AT THE END OF THE OPEN LIST & $f(n)$=null.

1. The algorithm selects A and expands A (applies Γ) in order to obtain M={B,C}
   n_1=B; n_2=C; Open={B,C}, Closed={A}, G={A,B,C}, $f(n_1)=1$; $f(n_2)=1$
2. The algorithm expands B in order to obtain M={D,E}
   n_3=D; n_4=E; Open={C,D,E}, Closed={A,B}, G={A,B,C,D,E}, $f(n_3)=1$; $f(n_4)=1$
3. The algorithm expands C in order to obtain M={F,G}
   n_5=F; n_6=G; Open={D,E,F,G}, Closed={A,B,C}, G={A,B,C,D,E,F,G}, $f(n_5)=1$; $f(n_6)=1$
4. The algorithm expands D in order to obtain M={H,I}
   n_7=H; n_8=I; Open={E,F,G,H,I}, Closed={A,B,C,D}, G={A,B,C,D,E,F,G,H,I}, $f(n_7)=1$; $f(n_8)=1$
5. The algorithm expands E in order to obtain M={J,K}, n_9=J; n_{10}=K
   Open={F,G,H,I,J,K}, Closed={A,B,C,D,E}, G={A,B,C,D,E,F,G,H,I,J,K}, $f(n_9)=1$; $f(n_{10})=1$
6. The algorithm expands F in order to obtain M={L,M}, n_{11}=L; n_{12}=M, }; $f(n_{11})=1$; $f(n_{12})=1$
   Open={G,H,I,J,K,L,M}, Closed={A,B,C,D,E,F}, G={A,B,C,D,E,F,G,H,I,J,K,L,M
7. The algorithm expands G in order to obtain M={N,P}, n_{13}=N; n_{14}=P; $f(n_{13})=1$; $f(n_{14})=1$
   Open={H,I,J,K,L,M,N,P}, Closed={A,B,C,D,E,F,G}, G={A,B,C,D,E,F,G,H,I,J,K,L,M,P}
8. The algorithm expands H in order to obtain M={}
   Open={I,J,K,L,M,N,P}, Closed={A,B,C,D,E,F,G,H}, G={A,B,C,D,E,F,G,H,I,J,K,L,M,P}
9. The algorithm expands I in order to obtain M={}
   Open={J,K,L,M,N,P}, G={A,B,C,D,E,F,G,H,I,J,K,L,M,P}, Closed={A,B,C,D,E,F,G,H,I}
10. The algorithm expands J in order to obtain M={}
    Open={K,L,M,N,P}, G={A,B,C,D,E,F,G,H,I,J,K,L,M,P}, Closed={A,B,C,D,E,F,G,H,I,J}
11. The algorithm expands K in order to obtain M={}, G={A,B,C,D,E,F,G,H,I,J,K,L,M,P}
    K is a solution exit w/ success. BFS expands Closed={A,B,C,D,E,F,G,H,I,J,K} 11 nodes

III. Heuristic Search. (continued)

DEPTH-FIRST: APPEND M AT THE FRONT OF THE OPEN LIST WITH $f(n)$= NULL (ALTERNATIVELY USE $f(n)$=DEPTH(n)).

1. The algorithm selects *A* and expands *A* (applies Γ) in order to obtain M={*B*,*C*}
 n_1=B; n_2=C; Open={B,C}, Closed={A}, G={A,B,C}, $f(n_1)=1$; $f(n_2)=1$
2. The algorithm expands *B* in order to obtain M={*D*,*E*}
 n_3=D; n_4=E; Open={D,E,C}, Closed={A,B}, G={A,B,C,D,E}, $f(n_3)=2$; $f(n_4)=2$
3. The algorithm expands *D* in order to obtain M={*H*,*I*}
 n_5=H; n_6=I; Open={H,I,E,C}, Closed={A,B,D}, G={A,B,C,D,E,H,I}, $f(n_5)=3$; $f(n_6)=3$
4. The algorithm expands *H* in order to obtain M={}, G={A,B,C,D,E,H,I}
 Open={I,E,C}, G=Closed={A,B,D,H}
5. The algorithm expands *I* in order to obtain M={}, G={A,B,C,D,E,H,I}
 Open={E,C}, G=Closed={A,B,D,H,I}
6. The algorithm expands *E* in order to obtain M={*J*,*K*}
 n_7=J; n_8=K; Open={J,K,C}, Closed={A,B,D,H,I,E}, G={A,B,C,D,E,H,I,J,K}, $f(n_7)=3$; $f(n_8)=3$
7. The algorithm expands *J* in order to obtain M={}
 Open={K,C}, Closed={A,B,D,H,I,E,J}, G={A,B,C,D,E,H,I,J,K}
8. The algorithm expands *K* in order to obtain M={}
 K is a solution and the algorithm terminates. DFS expands Closed={A,B,D,H,I,E,J,K} 8 nodes

HEURISTIC-SEARCH: USE THE FUNCTION $f(n)=h(n)$ AND SORT THE OPEN LIST USING *f* VALUES, FIFO.

1. The algorithm selects *A* and expands *A* (applies Γ) in order to obtain M={*B*,*C*}
 n_1=B; n_2=C; Open={B,C}, Closed={A}, G={A,B,C}, $f(n_1)=20$; $f(n_2)=10$, Open={C_{10},B_{20}}
2. The algorithm expands *C* in order to obtain M={*F*,*G*}
 n_3=F; n_4=G; Open={F,G,B}, Closed={A,C}, G={A,B,C,F,G}, $f(n_3)=8$; $f(n_4)=20$, Open={F_8,B_{20},G_{20}}
3. The algorithm expands *F* in order to obtain M={*L*,*M*}, G={A,B,C,F,G,L,M}
 n_5=L; n_6=M; Open={M,L,G,B}, Closed={A,C,F}, $f(n_5)=27$; $f(n_6)=22$, Open={B_{20},G_{20},M_{22},L_{27}}
4. The algorithm expands *B* in order to obtain M={*D*,*E*}, G={A,B,C,F,G,L,M,D,E}
 n_7=D; n_8=E; Open={E,D,G,M,L}, Closed={A,C,F.B}, $f(n_7)=13$; $f(n_8)=12$, Open={E_{12},D_{13},M_{22},L_{27}}
5. The algorithm expands *E* in order to obtain M={*J*,*K*}, G={A,B,C,F,G,L,M,D,E,J,K}
 n_9=J; n_{10}=K; Open={J,K,D,G,M,L}, Closed={A,C,F,B,E}, $f(n_9)=2$; $f(n_{10})=0$
6. The algorithm expands *K* in order to obtain M={}, G={A,B,C,F,G,L,M,D,E,J,K}
 K is a solution and the algorithm terminates. Heuristic search expands Closed={A,C,F,B,E,K} 6 nodes

HEURISTIC-SEARCH: USE THE FUNCTION $f(n)=h(n)$ AND SORT THE OPEN LIST USING *f* VALUES, LIFO.

1. The algorithm selects *A* and expands *A* (applies Γ) in order to obtain M={*B*,*C*}
 n_1=B; n_2=C; Open={B,C}, Closed={A}, G={A,B,C}, $f(n_1)=20$; $f(n_2)=10$, Open={C_{10},B_{20}}
2. The algorithm expands *C* in order to obtain M={*F*,*G*}
 n_3=F; n_4=G; Open={F,G,B}, Closed={A,C}, G={A,B,C,F,G}, $f(n_3)=8$; $f(n_4)=20$, Open={F_8,G_{20},B_{20}}
3. The algorithm expands *F* in order to obtain M={*L*,*M*}, G={A,B,C,F,G,L,M}; n_5=L; n_6=M
 Open={M,L,G,B}, Closed={A,C,F}, $f(n_5)=27$; $f(n_6)=22$, Open={G_{20},B_{20},M_{22},L_{27}}
4. The algorithm expands *G* in order to obtain M={*N*,*P*}; G={A,B,C,F,G,L,M,N,P}; n_7=N; n_8=P
 Open={N,P,B,M,L}, Closed={A,C,F.G}, $f(n_7)=0$; $f(n_8)=9$, Open={N_0,P_9, B_{20},M_{22},L_{27}}
5. The algorithm expands *N* in order to obtain M={}, G={A,B,C,F,G,L,M,N,P}
 N is a solution and the algorithm terminates. Heuristic search expands Closed={A,C,F,G,N} 5 nodes

A* SEARCH: USES $f(n)=g(n)+h(n)$ where $g(n)=depth(n)$ & $h(n)$=cost AND SORT THE OPEN LIST USING *f*

1. The algorithm selects *A* and expands *A* (applies Γ) in order to obtain M={*B*,*C*}
 n_1=B; n_2=C; Open={B,C}, Closed={A}, G={A,B,C}, $f(n_1)=1+20$; $f(n_2)=1+10$, Open={C_{11}, B_{21}}
2. The algorithm expands *C* in order to obtain M={*F*,*G*}
 n_3=F; n_4=G; Open={F,B,G}, Closed={A,C}, G={A,B,C,F,G}, $f(n_3)=2+8$; $f(n_4)=2+20$, Open={F_{10},B_{21},G_{22}}
3. The algorithm expands *F* in order to obtain M={*L*,*M*}; G={A,B,C,F,G,L,M}, n_5=L; n_6=M
 Open={B,G,M,L}, Closed={A,C,F}, $f(n_5)=3+27$; $f(n_6)=3+22$, Open={B_{21},G_{22},M_{25},L_{30}}
4. The algorithm expands *B* in order to obtain M={*D*,*E*}; G={A,B,C,F,G,L,M,D,E}, n_7=D; n_8=E
 Open={E,D,G,M,L}, Closed={A,C,F.B}, $f(n_7)=2+13$; $f(n_8)=2+12$, Open={E_{14},D_{15},G_{22},M_{25},L_{30}}
5. The algorithm expands *E* in order to obtain M={*J*,*K*}; G={A,B,C,F,G,L,M,D,E,J,K}, n_9=J; n_{10}=K
 Open={J,K,D,G,M,L}, Closed={A,C,F,B,E}, $f(n_9)=3+2$; $f(n_{10})=3+0$; Open={K_3,J_5, D_{15},G_{22},M_{25},L_{30}}
6. The algorithm expands *K* in order to obtain M={}, G={A,B,C,F,G,L,M,D,E,J,K}
 K is a solution and the algorithm terminates. Heuristic search expands Closed={A,C,F,B,E,K} 6 nodes

N is found by heuristic search with LIFO: {A,C,F,G} comes before {A,C,F,B} & h(B)= h(G)=20 & *LIFO* orders G before B.

(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:

F_1: last(cons(U,nil),U).

Rules:

R_1: last(X,Y) → last(cons(W,X),Y)

Goal: (∃*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).

(1 pts) I am using Set-of-Support which is a complete strategy
F_1: last(cons(U,nil),U).
R_1:~ last(X,Y) ∨ last(cons(W,X),Y)
~Goal: ~last((steve ron urban), *z*)

(4 pts) $\Re_1=\Re\{\sim Goal,R_1\}$: ~last(X,Y) {steve/W, (ron urban)/X, *z*/Y}
$\Re_1$: ~last((ron urban), *z*)

(4 pts) $\Re_2=\Re\{\Re_1,R_1\}$: ~ last(X',Y') {ron/W', (urban)/X', z/Y'}
$\Re_2$: ~last((urban), *z*)

(4 pts) $\Re_3=\Re\{\Re_2,F_1\}$: nil {urban/U, U/z}

(4 pts) Therefore *z*=U=Y'=Y=urban; X'=(urban); W'=ron; X=(ron urban); W=steve

(3) *Anwer:* (∃z)last(cons(steve, cons(ron,cons(urban,nil))), *z*) is true
with *z* = urban

(5) Substitutions will be consistent because I changed variables every time I re-used any rules and all the variables were originally standardized apart. To prove consistency we assemble all the numerators in a set, say, U_1, and all the denominators in a set, say, U_2 and show that $U_1=U_2\sigma$ and $\sigma\neq$null.
U_1=[steve,(ron,urban),z,ron,(urban),z,urban,U], U_2=[W,X,Y,W',X',Y',U,z]and $U_1=U_2\sigma$
σ={steve/W, (ron urban)/X, z/Y, ron/W', (urban)/X', z/Y', urban/U, U/z} and σ≠null.

EEL-5840 | Class Exam 2 | __________________________
Fall 2009 | Sample Questions | (Name)

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*}: $(\forall x)\{\ \sim E(x,v) \rightarrow [\ (\exists y)\ (\exists w)\ (\ E(y,w) \wedge\ (\forall x)\ \{\ E(x,w) \rightarrow E(y,x)\ \}\ )\ ]\ \}$

(2) Step 0: Eliminate redundant quantifiers and take the existential closure________________

A_0: $(\exists v)\ (\forall x)\{\ \sim E(x,v) \rightarrow [\ (\exists y)\ (\exists w)\ (\ E(y,w) \wedge\ (\forall x)\ \{\ E(x,w) \rightarrow E(y,x)\ \}\ )\ ]\ \}$

(2) Step 1: Remove implications________________

A_1: $(\exists v)\ (\forall x)\{\ \sim\sim E(x,v) \vee [\ (\exists y)\ (\exists w)\ (\ E(y,w) \wedge\ (\forall x)\ \{\ \sim E(x,w) \vee E(y,x)\ \}\ )\ ]\ \}$

(2) Step 2: Move the Negations down to the *Atf*s________________

A_2: $(\exists v)\ (\forall x)\{\ E(x,v) \vee [\ (\exists y)\ (\exists w)\ (\ E(y,w) \wedge\ (\forall x)\ \{\ \sim E(x,w) \vee E(y,x)\ \}\ )\ ]\ \}$

(1) Step 3: Standardize Variables Apart________________

A_3: $(\exists v)\ (\forall x)\{\ E(x,v) \vee [\ (\exists y)\ (\exists w)\ (\ E(y,w) \wedge\ (\forall z)\ \{\ \sim E(z,w) \vee E(y,z)\ \}\ )\ ]\ \}$

(2) Step 4: Skolemize: Let $v=f(.)=V$, $y= f(x)$, $w= g(x)$ ________________

A_4: $(\forall x)\{\ E(x,V) \vee [(E(f(x),g(x)) \wedge\ (\forall z)\ \{\ \sim E(z,g(x)) \vee E(f(x),z)\ \}\ )\ ]\ \}$

(1) Step 5: Move universal quantifiers to the left________________

A_5: $(\forall x)\ (\forall z)\ \{\ E(x,V) \vee [(E(f(x),g(x)) \wedge \{\ \sim E(z,g(x)) \vee E(f(x),z)\ \}\ )\ ]\ \}$

(4) Step 6: Multiply & d^n $\vee$ over $\wedge$ using $P_1 \wedge (P_2 \vee P_3) \equiv (P_1 \wedge P_2) \vee (P_1 \wedge P_3)$ or $P_1 \vee (P_2 \wedge P_3) \equiv (P_1 \vee P_2) \wedge (P_1 \vee P_3)$____

Let $P_1=E(x,V)$ $P_2=E(f(x),g(x))$ $P_3=\sim E(z,g(x))$ $P_4=E(f(x),z))$ $P_5= P_3 \vee P_4$

A_5: $\{\ P_1 \vee [(P_2 \wedge \{P_3 \vee P_4\})]\ \} \equiv \{\ P_1 \vee [(P_2 \wedge P_5)]\ \} \equiv \{[P_1 \vee P_2] \wedge [P_1 \vee P_5]\}$

A_6: $(\forall x)\ (\forall z)\ \{\ [E(x,V) \vee E(f(x),g(x))] \wedge [E(x,V) \vee \sim E(z,g(x)) \vee E(f(x),z))\ ]\ \}$

I. Conversion to Clause Form (continued)

(1) Step 7: Write in Matrix Form

A_7: $(\forall x)$ $[\ E(x,V) \vee E(f(x),g(x))\ ]$

$(\forall x)(\forall z)\ [\ E(x,V) \vee {\sim}E(z,g(x)) \vee E(f(x),z)]$

(1) Step 8: Eliminate Universal Quantifiers

A_8: $[\ E(x,V) \vee E(f(x),g(x))]$

$[\ E(x,V) \vee {\sim}E(z,g(x)) \vee E(f(x),z)]$

(2) Step 9: Rename Variables

A_9: $[\ E(x_1,V) \vee E(f(x_1),g(x_1))]$

$[\ E(x_2,V) \vee {\sim}E(z,g(x_2)) \vee E(f(x_2),z)]$

(2) Step 10: Remove Tautologies & Simplify: None

A_{10}: $[\ E(x_1,V) \vee E(f(x_1),g(x_1))\ ]$

$[\ E(x_2,V) \vee {\sim}E(z,g(x_2)) \vee E(f(x_2),z)\ ]$

Fall 2006
(25)

II. Resolution Refutation

> THE CUSTOM OFFICIALS SEARCHED 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**:

[1] $(\forall x)([E(x) \wedge \sim V(x)] \rightarrow (\exists y)\{S(x,y) \wedge C(y)\})$ THE CUSTOM OFFICIALS SEARCHED EVERYONE WHO ENTERED THIS COUNTRY WHO WAS NOT A VIP

[2] $(\exists x)[P(x) \wedge E(x) \wedge (\forall y)\{S(x,y) \rightarrow P(y)\}]$ SOME OF THE DRUG PUSHERS ENTERED THIS COUNTRY & THEY WERE ONLY SEARCHED BY DRUG PUSHERS

[3] $(\forall x)[P(x) \rightarrow \sim V(x)]$ NO DRUG PUSHER WAS A VIP

Goal: $(\exists x)[P(x) \wedge C(x)]$ SOME OF THE CUSTOM OFFICIALS WERE DRUG PUSHERS

(2) Answers Part **b**:

None

(5) Answers Part **c**:

[1] $\sim E(x_1) \vee V(x_1) \vee S(x_1,f(x_1))$

[2] $\sim E(x_2) \vee V(x_2) \vee C(f(x_2))$

[3] $P(a)$

[4] $E(a)$

[5] $\sim S(a,y) \vee P(y)$

[6] $\sim P(x_3) \vee \sim V(x_3)$

~Goal: $\sim P(z) \vee \sim C(z)$

II. Resolution Refutation(continued)

(10) Refutation Graph Part **d**:

[~Goal] [3]

$\Re_1$ [2]

$\Re_2$ [4]

$\Re_3$ [6]

$\Re_4$ [3]

nil

$\Re_1$=[~Goal] with [3] ~C(a) {a/z}
$\Re_2=\Re_1$ with [2] ~E(x_2) ∨ V(x_2) {$a/f(x_2)$}
$\Re_3=\Re_2$ with [4] V(a) {a/x_2}
$\Re_4=\Re_3$ with [6] ~P(a) {a/x_3}
$\Re_5=\Re_4$ with [3] nil

Consistency Check

$U_1=[a,a,a,a]$ $U_2=[z,f(x_2),x_2,x_3,]$
$U_1=U_2\sigma$ with $\sigma = [a/z,\ a/f(x_2),\ a/x_2,\ a/x_3]$
Since U_1 & U_2 unify with a non-nil substitution σ, then the substitutions are consistent

(3) Answer Part **e**: My strategy is Set-of-Support____
Every resolvent $\Re_1$-$\Re_5$ comes from the negation of the wff to be proved.
In logic, a Horn clause is a clause (a disjunction of literals) with at most one positive literal.
The clauses are not Horne because there is more than 1 positive literal in clauses [1] and [2].
I could have used ancestry-filtered or breadth-first because they are complete strategies.
I cannot use linear-input or unit preference because they are incomplete strategies.

Fall 2006
(30)

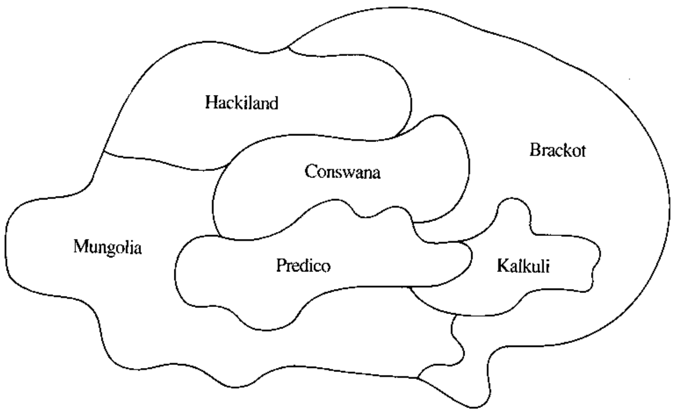
III. Heuristic Search

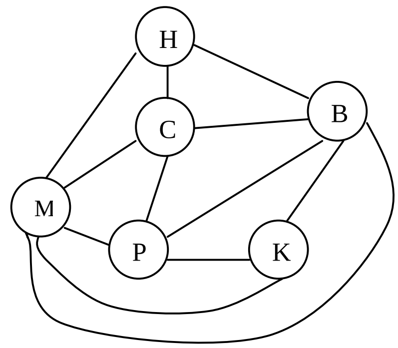
A map is to be colored with a set of n distinct colors, such that no two adjacent countries have the same color. If you can use colors {yellow, red, white and green} what is a legal coloring for the following map? Colorings are represented as lists of pairs:
((country color) (country color)...)

a. Suppose Sol_1 represents the use of the A* algorithm with heuristic function $h_1(n)$=number of uncolored countries.

b. Suppose Sol_2 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.

c. Give the A* results for Sol_1 and for Sol_2 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 Sol_2 over Sol_1?





Hidden Solution {send back}
{Y,R,W,G}
[H,C,P,K,B,M]
17 Nodes
$f(n)=h_1(n)$ = number of uncolored countries

III. Heuristic Search (continued)

Suppose Sol_2 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

Hidden Solution {send back}
{Y,R,W,G}
[H,C,P,K,B,M]
8 Nodes
$f(n)=h_2(n)$=the number of colors for the uncolored country with fewest possible colors
Solution two is about 7/15 or about 50% better

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:

F_1: makeset(nil,nil).

Rules:

R_1: [member(X_1,Y_1) ∧ makeset(Y_1,Z_1)] → makeset(cons(X_1,Y_1),Z_1).
R_2: [~member(X_2,Y_2) ∧ makeset(Y_2,Z_2)] → makeset(cons(X_2,Y_2),cons(X_2,Z_2)).

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).

(1 pts) I am using Set-of-Support which is a complete strategy
F1: makeset(nil,nil).
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: ~makeset(cons(al, cons(joakim, cons(al,nil))), z))

(3 pts) $\Re_1$=$\Re${~Goal,R_1}: ~member(X_1,Y_1) ∨ ~makeset(Y_1,Z_1) {AL/X_1, (JOAKIM AL)/Y_1,z/Z_1}
$\Re_1$: ~member(AL,(JOAKIM AL)) ∨ ~makeset((JOAKIM AL), *z*) with ~member(AL,(JOAKIM AL)) returning nil
$\Re_1$: ~makeset((JOAKIM AL), *z*)

(3 pts) $\Re_2$=$\Re${$\Re_1$,R'$_1$}: ~member(X'$_1$,Y'$_1$) ∨ ~makeset(Y'$_1$,Z'$_1$) {JOAKIM/X'$_1$, (AL)/Y'$_1$, z/Z'$_1$}
$\Re_2$: ~member(JOAKIM,(AL)) ∨ ~makeset((AL), *z*) with ~member(JOAKIM,(AL)) returning true i.e., inconsistent!

(3 pts) $\Re_3$=$\Re${$\Re_1$,R_2}: member(X_2,Y_2) ∨ ~makeset(Y_2,Z_2) {JOAKIM/X_2,(AL)/Y_2, cons(JOAKIM,Z_2)/z}
$\Re_3$: member(JOAKIM,(AL)) ∨ ~makeset((AL), Z_2) with member(JOAKIM,(AL)) returning nil
$\Re_3$: ~makeset((AL), Z_2)

IV. Computation Deduction. (continued)

(3 pts) $\Re_4=\Re\{\Re_3,R''_1\}$: ~member(X''$_1$,Y''$_1$) ∨ ~makeset(Y''$_1$,Z''$_1$) {AL/X''$_1$, nil/Y''$_1$, Z_2/Z''$_1$}
$\Re_4$: ~(member(AL,nil)) ∨ ~makeset(nil,Z_2) with ~member(AL,nil) returning true i.e., inconsistent!

(3 pts) $\Re_5=\Re\{\Re_3,R''_2\}$: member(X''$_2$,Y''$_2$) ∨ ~makeset(Y''$_2$,Z''$_2$) {AL/X''$_2$,nil/Y''$_2$, cons(AL,Z''$_2$)/Z_2}
$\Re_5$: member(AL,nil) ∨ ~makeset(nil, Z''$_2$) with member(AL,nil) returning nil
$\Re_5$: ~makeset(nil, Z''$_2$)

(3 pts) $\Re_6=\Re\{\Re_5,F_1\}$: nil {nil/Z''$_2$}
Therefore, Z_2=cons(AL,nil), and z=cons(JOAKIM,Z_2)=cons(JOAKIM,cons(AL,nil))=(JOAKIM AL)

(4) Substitutions will be consistent because I changed variables every time I re-used any rules and all the variables were originally standardized apart. To prove consistency we assemble all the numerators in a set, say, U_1, and all the denominators in a set, say, U_2 and show that $U_1=U_2\sigma$ and $\sigma\neq$null.
U_1=[AL,(JOAKIM,AL),z,JOAKIM,(AL),z, JOAKIM,(AL),cons(JOAKIM,Z_2),AL,nil,Z_2,AL,nil,cons(AL,Z''$_2$),nil],
U_2=[X_1,Y_1,Z_1,X'$_1$,Y'$_1$,Z'$_1$,X_2,Y_2,z,X''$_1$,Y''$_1$,Z''$_1$,X''$_2$,Y''$_2$,Z_2,Z''$_2$]and $U_1=U_2\sigma$
σ={ AL/X_1, (JOAKIM AL)/Y_1,z/Z_1, JOAKIM/X'$_1$, (AL)/Y'$_1$, z/Z'$_1$, JOAKIM/X_2,(AL)/Y_2, cons(JOAKIM,Z_2)/z,
AL/X''$_1$, nil/Y''$_1$, Z_2/Z''$_1$, AL/X''$_2$,nil/Y''$_2$, cons(AL,Z''$_2$)/Z_2, nil/Z''$_2$ } and $\sigma\neq$null.

(2) *Anwer:* (∃z) (makeset(cons(AL, cons(JOAKIM, cons(AL,nil))), *z*)) is true
with *z* = cons(JOAKIM,cons(AL,nil)) or *z* = (JOAKIM AL)

EEL-5840 Class Exam 2 ______________________________
Fall 2009 Sample Questions (Name)

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.

$\{wff\ A\}: (\forall x)(P(x) \rightarrow \{\sim\forall y[\sim Q(x,y) \rightarrow P(v)] \wedge \forall y \exists z[R(x,y) \rightarrow P(x)]\})$

(2) Step 0: Eliminate redundant quantifiers and take the existential closure.______________

The variable v is free, put a ∃*v* in front of the entire *wff*. Remove ∃z since it is redundant

$A_0: (\exists v)(\forall x)(P(x) \rightarrow \{\sim\forall y[\sim Q(x,y) \rightarrow P(v)] \wedge \forall y[R(x,y) \rightarrow P(x)]\})$

(2) Step 1: Remove implications______________

$A_1: (\exists v)(\forall x)(\sim P(x) \vee \{\sim\forall y[Q(x,y) \vee P(v)] \wedge \forall y[\sim R(x,y) \vee P(x)]\})$

(2) Step 2: Move the Negations down to the *Atfs*______________

$A_2: (\exists v)(\forall x)(\sim P(x) \vee \{\exists y[\sim Q(x,y) \wedge \sim P(v)] \wedge \forall y[\sim R(x,y) \vee P(x)]\})$

(1) Step 3: Standardize Variables Apart______________

$A_3: (\exists v)(\forall x)(\sim P(x) \vee \{\exists y[\sim Q(x,y) \wedge \sim P(v)] \wedge \forall z[\sim R(x,z) \vee P(x)]\})$

(2) Step 4: Skolemize: Let $v=f(.)=V$, $y=f(x)$ ______________

$A_4: (\forall x)(\sim P(x) \vee \{[\sim Q(x,f(x)) \wedge \sim P(V)] \wedge \forall z[\sim R(x,z) \vee P(x)]\})$

(1) Step 5: Move universal quantifiers to the left______________

$A_5: (\forall x)\ (\forall z)\ (\sim P(x) \vee \{[\sim Q(x,f(x)) \wedge \sim P(V)] \wedge [\sim R(x,z) \vee P(x)]\})$

(4) Step 6: Multiply & d^n ∨ over ∧ using $E_1 \vee (E_2 \wedge E_3) \equiv (E_1 \vee E_2) \wedge (E_1 \vee E_3)$______________

Let $E_1 = \sim P(x)$; $E_2 = \sim Q(x,f(x)) \wedge \sim P(V)$; $E_3 = \sim R(x,z) \vee P(x)$; thus A: $E_1 \vee (E_2 \wedge E_3) \equiv (E_1 \vee E_2) \wedge (E_1 \vee E_3)$

$A_6: \{ (E_1 \vee E_2) \wedge (E_1 \vee E_3) \} \equiv \{ [E_1 \vee \sim Q(x,f(x))] \wedge [E_1 \vee \sim P(V)])] \wedge [E_1 \vee E_3] \}$

$A_6': (\forall x)\ (\forall z)\ \{ [\sim P(x) \vee \sim Q(x,f(x))] \wedge [\sim P(x) \vee \sim P(V)] \wedge [\sim P(x) \vee \sim R(x,z) \vee P(x)] \}$

I. Conversion to Clause Form (continued)

(1) Step 7: Write in Matrix Form______________________________

A_7: $(\forall x)$ $[\sim P(x) \vee \sim Q(x, f(x))]$

$(\forall x)$ $[\sim P(x) \vee \sim P(V)]$

$(\forall x)(\forall z)$ $[\sim P(x) \vee \sim R(x,z) \vee P(x)]$

(1) Step 8: Eliminate Universal Quantifiers______________________________

A_8: $[\sim P(x) \vee \sim Q(x, f(x))]$

$[\sim P(x) \vee \sim P(V)]$

$[\sim P(x) \vee \sim R(x,z) \vee P(x)]$

(2) Step 9: Rename Variables______________________________

A_9: $[\sim P(x_1) \vee \sim Q(x_1, f(x_1))]$

$[\sim P(x_2) \vee \sim P(V)]$

$[\sim P(x_3) \vee \sim R(x_3,z) \vee P(x_3)]$

(2) Step 10: Remove Tautologies & Simplify:______________________________

$[\sim P(x_3) \vee \sim R(x_3,z) \vee P(x_3)] = [true \vee \sim R(x_3,z)] = true$. Also $row_1 \wedge row_2 \wedge true = row_1 \wedge row_2$

A_{10}: $[\sim P(x_1) \vee \sim Q(x_1, f(x_1))]$

$[\sim P(x_2) \vee \sim P(V)]$

But since $(\forall x_2)$ $[\sim P(x_2) \vee \sim P(V)] \equiv \sim P(x_2)$, i.e., $\sim P(x_2)$ subsumes $\sim P(V)$

$[\sim P(x_1) \vee \sim Q(x_1, f(x_1))] \wedge \sim P(x_2) \equiv \sim P(x)$

EEL-5840 Class Exam 2 ______________________________
Fall 2009 Sample Questions (Name)

Fall 2007
(30)

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) $[k-1=j \wedge Fact(j)=m \wedge k*m=n] \rightarrow [Fact(k)=n]$
(iii) $(\forall x)(\forall y)[x=y]$ 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**:
[1] Fact(0)=1
[2] $\sim k-1=j \vee \sim Fact(j)=m \vee \sim k*m=n \vee Fact(k)=n$ i.e., $k-1\neq j \vee Fact(j)\neq m \vee k*m\neq n \vee Fact(k)=n$
[3] [x=y] with side effect {eval(x)/y}
Goal: $[(\exists n)n=Fact(2)]$ or [4]~ Goal: $[Fact(2)\neq n \vee Ans(n)]$

(2) Answer Part **b**:
None

(14) Answers (Resolvents & required substitutions) Part **c**:

$\Re_1$=[~Goal] with [2] $k_1-1\neq j_1 \vee Fact(j_1)\neq m_1 \vee k_1*m_1\neq n_1 \vee Ans(n)$ $\{n/n_1, 2/k_1\}$
$\Re_1$: $2-1\neq j_1 \vee Fact(j_1)\neq m_1 \vee 2*m_1\neq n \vee Ans(n)$

$\Re_2$=[$\Re_1$] with [3] $Fact(j_1)\neq m_1 \vee 2*m_1\neq n \vee Ans(n)$ $\{1/j_1\}$
$\Re_2$: $Fact(1)\neq m_1 \vee 2*m_1\neq n \vee Ans(n)$

$\Re_3$=[$\Re_2$] with [2] $k_2-1\neq j_2 \vee Fact(j_2)\neq m_2 \vee k_2*m_2\neq n_2 \vee 2*m_1\neq n \vee Ans(n)$ $\{1/k_2, m_1/n_2\}$
$\Re_3$: $1-1\neq j_2 \vee Fact(j_2)\neq m_2 \vee 1*m_2\neq m_1 \vee 2*m_1\neq n \vee Ans(n)$

$\Re_4$=[$\Re_3$] with [3] $Fact(j_2)\neq m_2 \vee 1*m_2\neq m_1 \vee 2*m_1\neq n \vee Ans(n)$ $\{0/j_2\}$
$\Re_4$: $Fact(0)\neq m_2 \vee 1*m_2\neq m_1 \vee 2*m_1\neq n \vee Ans(n)$

$\Re_5$=[$\Re_4$] with [1] $1*m_2\neq m_1 \vee 2*m_1\neq n \vee Ans(n)$ $\{1/m_2\}$
$\Re_5$: $1*1\neq m_1 \vee 2*m_1\neq n \vee Ans(n)$

$\Re_6$=[$\Re_5$] with [3] $2*m_1\neq n \vee Ans(n)$ $\{1/m_1\}$
$\Re_6$: $2*1\neq n \vee Ans(n)$

$\Re_7$=[$\Re_6$] with [3] nil $\vee$ Ans(n) {2/n}
$\Re_7$: Ans(2)

II. Resolution Refutation(continued)

(5) Refutation Graph Part **d**:

[~Goal] [2]

$\Re_1$ [3]

$\Re_2$ [2]

$\Re_3$ [3]

$\Re_4$ [1]

$\Re_5$ [3]

$\Re_6$ [3]

nil

(3) Consistency Check Part **e**:

Consistency Check $\{n/n_1, 2/k_1, 1/j_1, 1/k_2, m_1/n_2, 0/j_2, 1/m_2, 1/m_1, 2/n\}$

$U_1=[n,2,1,1,m_1,0,1,1,2]$ $U_2=[n_1,k_1,j_1,k_2,n_2,j_2,m_2,m_1,n]$

$U_1=U_2\sigma$ with $\sigma = [n/n_1, 2/k_1, 1/j_1, 1/k_2, m_1/n_2, 0/j_2, 1/m_2, 1/m_1, 2/n]$

Since U_1 & U_2 unify with a non-nil substitution σ, then the substitutions are consistent

(2) Answer Part **f**: My strategy is Set-of-Support_______________________________

What other strategy could you have used and why? Explain:

Every resolvent $\Re_1$-$\Re_7$ comes from the negation of the wff to be proved.

In logic, a Horn clause is a clause (a disjunction of literals) with at most one positive literal.

The clauses are Horne because there is no more than 1 positive literal in all clauses.

I could have used ancestry-filtered or breadth-first because they are complete strategies.

I could use linear-input or unit preference because they are complete strategies for Horne Clauses.

EEL-5840 Class Exam 2 ______________________________
Fall 2009 Sample Questions (Name)

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.

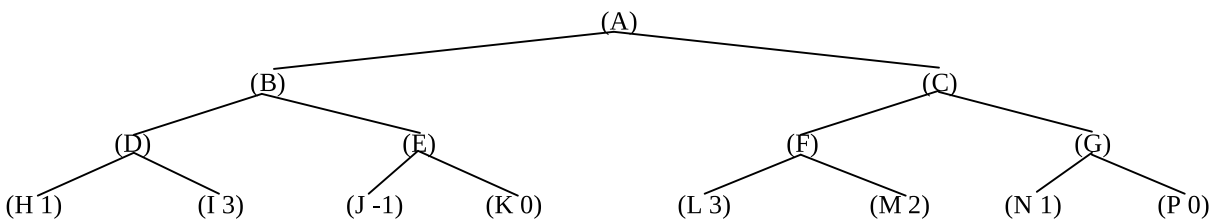
(5) a. Assuming that the first player is the maximizing player, what move should the first player choose?

(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):

D, E, F, G choose max or D→(I 3); E→(K 0); F→(L 3); G→(N 1)
B, C chooses min of B→E→(K 0); C→G→(N 1)
A chooses max or A→C→G→(N 1)
A chooses C toward solution A→C→G→N

(5) Part (b):

D, E, F, G choose min or D→(H 1); E→(J -1); F→(M 2); G→(P 0)
B, C chooses max of B→D→(H 1); C→F→(M 2)
A chooses min or A→B→D→(H 1)
A chooses B toward solution A→B→D→H

(5) Part (c):

Evaluate (H 1) & (I 3) D chooses max or α_D=3 from (I 3); Now B chooses min so $\beta_B \leq 3$ from (I 3)
Evaluate (J -1); now $\alpha_E \geq -1$ from (J -1) and $\beta_B \leq 3$ (H 3) therefore no Beta Cutoff and continue
Evaluate (K 0); now α_E=0 from (K 0) and β_B = 0 from (K 0)
Now B chooses min so β_B = 0 from (K 0), therefore $\alpha_A \geq 0$ from (K 0)
Evaluate (L 3) and
Evaluate (M 2); now α_F=3 from (L 3); and $\beta_C \leq 3$ from (L 3)
Evaluate (N 1); now $\alpha_G \geq 1$ from (N 1); no cutoff & continue
Evaluate (P 0); now α_G=1 from (N 1); β_C =1 from (N 1) no cutoff & continue
A chooses C to G to N (N 1) i.e., A→C→G→N
Alpha-Beta had Pruning resulted in no advantage

III. Adversarial Search. (continued)

(5) Part (d):

Evaluate (H 1) & (I 3) and D chooses min or β_D=1 from (H 1)
Now B chooses max so $\alpha_E \geq 1$ from (H 1)
Evaluate (J -1); now $\beta_F \leq -1$ from (J -1) but $\alpha_E \geq 1$ from (H 1)
Alpha Cutoff at E, do not evaluate (K 0) and continue α_E=1 from (H 1); $\beta_A \leq 1$ from (H 1)
Evaluate (L 3)
Evaluate (M 2) now β_F=2 (M 2) and $\alpha_C \geq 2$ (M 2)
Beta cutoff at C. A→B→D→H
Do Not Evaluate {K, G, N, P}

(5) Part (e):

A chooses C toward solution A→C→G→N in both parts (a) and (c) because Alpha-Beta and Minimax produce the same results for the same problem.
Similarly, A chooses B toward solution A→B→D→H in both parts (b) and (d) because Alpha-Beta and Minimax produce the same results for the same problem.
In my analysis that was indeed the case.

Fall 2007
(25)
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: inner(nil,nil,0).
F_2: is(X,Y) with side effect {eval(X)/Y}.

Rule:
R_1: [inner(As,Bs,Ns) ∧ is(Ns+A*B,N)] → inner(cons(A,As),cons(B,Bs),N).

Goal: (∃Z)(inner(cons(1, cons(2,nil)), cons(3, cons(4,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 is(X,Y) evaluates the left argument and unifies it (equates it) with the right argument, e.g., 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____I am using Set-of-Support which is a complete strategy________________

(4) Give me your axioms & negation of the goal in clause form
F_1: inner(nil,nil,0).
F_2: is(X,Y) with side effect {eval(X)/Y}.
R: ~inner(As,Bs,Ns) ∨ ~is(Ns+A*B,N) ∨ inner(cons(A,As), cons(B,Bs), N).
~Goal: ~inner(cons(1, cons(2,nil)), cons(3, cons(4,nil)), Z))

(15) Give me the resolution resolvents

(3 pts) $\Re_1=\Re$\{~Goal,R\}: ~inner(As,Bs,Ns) ∨ ~is(Ns+A*B,N) {1/A, cons(2,nil)/As, 3/B, cons(4,nil)/Bs, Z/N}
$\Re_1$: ~inner(cons(2,nil),cons(4,nil),Ns) ∨ ~is(Ns+1*3,Z)

(3 pts) $\Re_2=\Re\{\Re_1$,R'}: ~inner(As',Bs',Ns')∨~is(Ns'+A'*B',N')∨~is(Ns+1*3,Z) {2/A', nil/As', 4/B', nil/Bs', Ns/N'}
$\Re_2$: ~inner(nil,nil,Ns')∨~is(Ns'+2*4,N')∨~is(Ns+1*3,Z)

(3 pts) $\Re_3=\Re\{\Re_2,F_1\}$: ~is(Ns'+2*4,N')∨~is(Ns+1*3,N) {0/Ns}
$\Re_3$: ~is(0+2*4,N')∨~is(N'+1*3,Z)

IV. Computation Deduction. (continued)

(3 pts) $\Re_4=\Re\{\Re_3,F_2\}$: ~is(N'+1*3,Z) {0+2*4/X, N'/Y, 8/N'}
$\Re_4$: ~is(8+1*3,Z)

(3 pts) $\Re_5=\Re\{\Re_4,F_2'\}$: nil {8+1*3/X', Z/Y', 11/Z}

Therefore, {11/Z} yields that the inner product of (1 2) and (3 4) is 11 or inner((1 2), (3 4), 11) is true

(4) Prove the substitutions are consistent.

Substitutions will be consistent because I changed variables every time I re-used any rules and all the variables were originally standardiZed apart. To prove consistency we assemble all the numerators in a set, say, U_1, and all the denominators in a set, say, U_2 and show that $U_1=U_2\sigma$ and $\sigma\neq$null.
{1/A, cons(2,nil)/As, 3/B, cons(4,nil)/Bs, Z/N} {0/Ns} {0+2*4/X, N'/Y, 8/N'}
{2/A', nil/As', 4/B', nil/Bs', Ns/N'} {8+1*3/X', Z/Y', 11/Z}
U_1=[1,cons(2,nil),3, cons(4,nil),Z, 0,(0+2*4),N',8,2,nil,4,nil,ns,(8+1*3),Z,11],
U_2=[A,As,B,Bs,N,Ns,X,Y,N',A',As',B',Bs',N',X',Y',Z]and $U_1=U_2\sigma$
σ={ {1/A, cons(2,nil)/As, 3/B, cons(4,nil)/Bs, Z/N, 0/Ns, 0+2*4/X, N'/Y, 8/N',
2/A', nil/As', 4/B', nil/Bs', Ns/N', 8+1*3/X', Z/Y', 11/Z } and $\sigma\neq$null.

(1) Give me the solved goal, i.e., the answer:
Anwer: (∃Z) (inner(cons(1, cons(2,nil)), cons(3, cons(4,nil)), Z)) is true
with Z = 11

EEL-5840 Class Exam 2 ______________________________
Fall 2009 Sample Questions (Name)

Fall 2008

(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 {*w, x, y, z*} are variables, the set {Animal, Loves} are functions and there are no constants.

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

(2) Step 0: Eliminate redundant quantifiers and take the existential closure.________________

Remove $(\exists w)$ & $(\forall z)$ since they are redundant

A_0: $(\forall x)[(\forall y)\{Animal(y) \rightarrow Loves(x,y)\} \rightarrow \{(\exists y)Loves(y,x)\}]$

(2) Step 1: Remove implications________________

A_1: $(\forall x)[\sim (\forall y)\{\sim Animal(y) \vee Loves(x,y)\} \vee \{(\exists y)Loves(y,x)\}]$

(2) Step 2: Move the Negations down to the *Atfs*________________

A_2: $(\forall x)[(\exists y)\{Animal(y) \wedge \sim Loves(x,y)\} \vee \{(\exists y)Loves(y,x)\}]$

(1) Step 3: Standardize Variables Apart________________

A_3: $(\forall x)[(\exists y)\{Animal(y) \wedge \sim Loves(x,y)\} \vee \{(\exists z)Loves(z,x)\}]$

(2) Step 4: Skolemize: Let $y=f(x)$, $z=g(x)$ ________________

A_4: $(\forall x)[\{Animal(f(x)) \wedge \sim Loves(x, f(x))\} \vee \{Loves(g(x),x)\}]$

(1) Step 5: Move universal quantifiers to the left________________

A_5: $(\forall x)[\{Animal(f(x)) \wedge \sim Loves(x, f(x))\} \vee \{Loves(g(x),x)\}]$

(4) Step 6: Multiply & d^n ∨ over ∧ using $(E_2 \wedge E_3) \vee E_1 \equiv E_1 \vee (E_2 \wedge E_3) \equiv (E_1 \vee E_2) \wedge (E_1 \vee E_3)$________________

Let $E_1=Loves(g(x),x)$;$E_2=Animal(f(x))$;$E_3=\sim Loves(x, f(x))$; thus A: $E_1 \vee (E_2 \wedge E_3) \equiv (E_1 \vee E_2) \wedge (E_1 \vee E_3)$

A_6: $\{ (E_1 \vee E_2) \wedge (E_1 \vee E_3) \} \equiv \{ [Loves(g(x),x) \vee Animal(f(x))] \wedge [Loves(g(x),x) \vee \sim Loves(x, f(x))]\}$

or A_6: $\{ (E_1 \vee E_2) \wedge (E_1 \vee E_3) \} \equiv \{ [Animal(f(x)) \vee Loves(g(x),x)] \wedge [\sim Loves(x, f(x)) \vee Loves(g(x),x)]\}$

____
(Name)

I. Conversion to Clause Form (continued)

(1) Step 7: Write in Matrix Form

A_7: $(\forall x)$ [Animal($f(x)$) ∨ Loves($g(x)$,x)]
$(\forall x)$ [~Loves(x, $f(x)$) ∨ Loves($g(x)$,x)]

(1) Step 8: Eliminate Universal Quantifiers

A_8: [Animal($f(x)$) ∨ Loves($g(x)$,x)]
[~Loves(x, $f(x)$) ∨ Loves($g(x)$,x)]

(2) Step 9: Rename Variables

A_9: [Animal($f(x_1)$) ∨ Loves($g(x_1)$,x_1)]
[~Loves(x_2, $f(x_2)$) ∨ Loves($g(x_2)$,x_2)]

(2) Step 10: Remove Tautologies & Simplify:

A_{10}: [Animal($f(x_1)$) ∨ Loves($g(x_1)$,x_1)]
[~Loves(x_2, $f(x_2)$) ∨ Loves($g(x_2)$,x_2)]

A_{10}': [Loves($g(x)$,x) ∨{Animal($f(x)$)∧~Loves(x, $f(x)$)}]

EEL-5840 | Class Exam 2 | ______________________________
Fall 2009 | Sample Questions | (Name)

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 is 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**:

[1] $(\forall x)(\forall y)(\forall z)$ [{American(x) ∧ Weapon(y) ∧ Sells(x,y,z) ∧ Hostile(z)} → Criminal(x)]
[2] $(\exists x)$[Owns(Nono,x) ∧ Missile(x)]
[3] $(\forall x)${[Missile(x) ∧ Owns(Nono,x)] → Sells(West,x,Nono)}
[4] Enemy(Nono,America)
[5] American(West)
Goal: Criminal(West) or [8] ~Goal: ~Criminal(West)

(4) Answer(s) Part **b**:

[1] ~American(x_1) ∨ ~Weapon(y_1) ∨ ~Sells(x_1,y_1,z_1) ∨ ~Hostile(z_1) ∨ Criminal(x_1)
[2a] Owns(Nono,M_1)
[2b] Missile(M_1)
[3] ~Missile(x_2) ∨ ~Owns(Nono,x_2) ∨ Sells(West,x_2,Nono)
[4] Enemy(Nono,America)
[5] American(West)
Goal: Criminal(West) or [8] ~Goal: ~Criminal(West)

(2) Answer(s) Part **c**: All enemies of America are also hostile to America and all missiles are weapons.
[6] $(\forall x)$[Enemy(x,America) → Hostile(x)] ≡ ~Enemy(x_3,America) ∨ Hostile(x_3)
[7] $(\forall x)$[Misile(x) → Weapon(x)] ≡ ~Misile(x_4) ∨ Weapon(x_4)

(10) Answers (Resolvents & required substitutions) Part **d**:

$\Re_1$=[~Goal] with [1] ~American(x_1) ∨ ~Weapon(y_1) ∨ ~Sells(x_1,y_1,z_1) ∨ ~Hostile(z_1) {West/x_1}
$\Re_1$: ~American(West) ∨ ~Weapon(y_1) ∨ ~Sells(West,y_1,z_1) ∨ ~Hostile(z_1)

$\Re_2$=[$\Re_1$] with [5] ~Weapon(y_1) ∨ ~Sells(West,y_1,z_1) ∨ ~Hostile(z_1) {}

$\Re_3$=[$\Re_2$] with [7] ~Misile(x_4) ∨ ~Sells(West,y_1,z_1) ∨ ~Hostile(z_1){y_1/x_4}
$\Re_3$: ~Misile(y_1) ∨ ~Sells(West,y_1,z_1) ∨ ~Hostile(z_1)

$\Re_4$=[$\Re_3$] with [2b] ~Sells(West,M_1,z_1) ∨ ~Hostile(z_1) {M_1/y_1}

$\Re_5$=[$\Re_4$] with [3] ~Missile(x_2) ∨ ~Owns(Nono,x_2) ∨ ~Hostile(z_1) { M_1/x_2,Nono/z_1}
~Missile(M_1) ∨ ~Owns(Nono,M_1) ∨ ~Hostile(Nono)

$\Re_6$=[$\Re_5$] with [2b] ~Owns(Nono,M_1) ∨ ~Hostile(Nono)

$\Re_7$=[$\Re_6$] with [2a] ~Hostile(Nono){}

$\Re_8$=[$\Re_7$] with [6] ~Enemy(Nono,America) {Nono/x_3}

$\Re_9$=[$\Re_8$] with [4] nil

II. Resolution Refutation(continued)

(5) Refutation Graph Part **d**:

[~Goal] [1]

$\Re_1$ [5]

$\Re_2$ [7]

$\Re_3$ [2b]

$\Re_4$ [3]

$\Re_5$ [2b]

$\Re_6$ [2a]

$\Re_7$ [6]

$\Re_8$ [4]

nil

(2) Consistency Check Part **e**:

Consistency Check {West/x_1, y_1/x_4, M_1/y_1,M_1/x_2,Nono/z_1, Nono/x_3 }

U_1=[West,y_1,M_1,M_1,Nono,Nono] U_2=[x_1,x_4,y_1,x_2,z_1,x_3]

$U_1=U_2\sigma$ with σ = [West/x_1, y_1/x_4, M_1/y_1,M_1/x_2,Nono/z_1,Nono/x_3]

Since U_1 & U_2 unify with a non-nil substitution σ, then the substitutions are consistent

Since I changed variable names in all clauses and used clauses once in each resolution, then all substitutions are consistent

(2) Answer Part **f**: My strategy is: Set-of-Support______________________________

What other strategy could you have used and why? Explain:

Every resolvent $\Re_1$-$\Re_8$ comes from the negation of the wff to be proved.

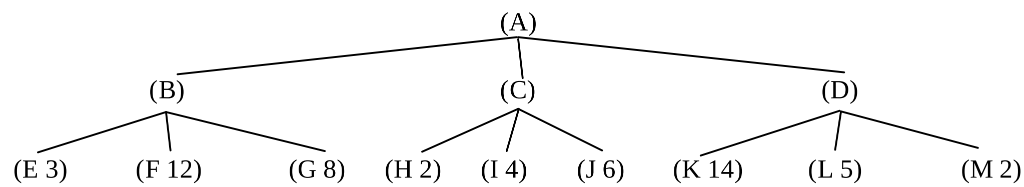
In logic, a Horn clause is a clause (a disjunction of literals) with at most one positive literal.

The clauses are Horne because there is no more than 1 positive literal in all clauses.

I could have used ancestry-filtered or breadth-first because they are complete strategies.

I could use linear-input because it is a complete strategy for Horne Clauses.

(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):

B, C, D choose min or B→(E 3); C→(H 2); D→(M 2)
A chooses max or A→B→(E 3)
A chooses B toward solution A→B→E and all nodes were evaluated

(5) Part (b):

B, C, D choose max or B→(F 12); C→(J 6); D→(K 14)
A chooses min or A→C→(J 6)
A chooses C toward solution A→C→J and all nodes were evaluated

(5) Part (c):

Evaluate (E 3) & (F 12) & (G 8); B chooses min so $\beta_B = 3$ and $\alpha_a \geq 3$ from (E 3)
Evaluate (H 2); now $\beta_c \leq 2$ therefore Alpha Cutoff and do not evaluate I & J
Evaluate (K 14); now $\beta_d \leq 14$; evaluate (L 5) now $\beta_d \leq 5$; evaluate (M 2) and $\beta_d = 2$ from (M 2)
A chooses max or A→B→(E 3)
A chooses B toward solution A→B→E
Alpha-Beta Pruning saved two nodes I and J

III. Adversarial Search. (continued)

(5) Part (d):

Evaluate (E 3) & (F 12) & (G 8); B chooses max so α_b=12 and $\beta_a \leq 12$ from (F 12)
Evaluate (H 2) with $\alpha_c \geq 2$; evaluate (I 4) with $\alpha_c \geq 4$; evauate (J 6) therefore with $\alpha_c = 6$; now $\beta_a \leq 6$
Evaluate (K 14); now $\alpha_d \geq 14$; Beta Cutoff and do not evaluate L and M and $\alpha_d = 14$
A chooses min or A→C→(J 6)
Alpha-Beta Pruning saved two nodes L and M

(5) Part (e):

A chooses B toward solution A→B→E in both parts (a) and (c) because Alpha-Beta and Minimax produce the same results for the same problem.
Similarly, A chooses C toward solution A→C→J in both parts (b) and (d) because Alpha-Beta and Minimax produce the same results for the same problem.
In my analysis that was indeed the case.

EEL-5840 Class Exam 2 ______________________________
Fall 2009 Sample Questions (Name)

(25)
IV. Computation Deduction.

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.

F_1: IS_CTA(NIL, 0).
R_1:[ATOM(U) ∧ IS_CTA(T,N) ∧ IS(N+1,ANS)] → IS_CTA(CONS(U,T),ANS)
R_2:[LISTP(U) ∧ IS_CTA(T,ANS)] → IS_CTA(CONS(U,T),ANS)

Evaluate (∃Z)IS_CTA(CONS(CONS(A,NIL),CONS(B,CONS(CONS(C,NIL),NIL))),Z) using computation deduction.

{ Note: If you prefer, you may use the notation IS_CTA(((A) B (C)),Z), and ATOM and 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 IS(X,Y) evaluates the left argument and unifies it (equates it) with the right argument, e.g., 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____I am using Set-of-Support which is a complete strategy________________

(4) Give me your axioms & negation of the goal in clause form
F_1: IS_CTA(nil,0).
R_1: ~ATOM(V) ∨ ~IS_CTA(R,N) ∨ ~IS(N+1,ANS$_1$) ∨ IS_CTA(CONS(V,R),ANS$_1$).
R_2: ~LISTP(U) ∨ ~IS_CTA(T,ANS$_2$) ∨ IS_CTA(CONS(U,T),ANS$_2$)
~Goal: ~IS_CTA(CONS(CONS(A,NIL),CONS(B,CONS(CONS(C,NIL),NIL))),Z)

(16) Give me the resolution resolvents

(4 pts) $\mathfrak{R}_1=\mathfrak{R}\{\sim Goal,R_2\}$:~LISTP(U)∨~IS_CTA(T,ANS){CONS(A,NIL)/U,CONS(B,CONS(CONS(C,NIL),NIL))/T, Z/ANS$_2$}
$\mathfrak{R}_1$: ~LISTP(CONS(A,NIL))∨~IS_CTA(CONS(B,CONS(CONS(C,NIL),NIL)),Z)
$\mathfrak{R}_1$: ~t ∨~IS_CTA(CONS(B,CONS(CONS(C,NIL),NIL)),Z) {EVALUATE LISTP(CONS(A,NIL)) TO t}
$\mathfrak{R}_1$: ~IS_CTA(CONS(B,CONS(CONS(C,NIL),NIL)),Z)

(4 pts) $\mathfrak{R}_2=\mathfrak{R}\{\mathfrak{R}_1,R_1\}$: ~ATOM(V) ∨ ~IS_CTA(R,N) ∨ ~IS(N+1,ANS$_1$) {B/V, CONS(CONS(C,NIL),NIL)/R, Z/ANS$_1$}
$\mathfrak{R}_2$: ~ATOM(B) ∨ ~IS_CTA(CONS(CONS(C,NIL),NIL),N) ∨ ~IS(N+1,Z) {EVALUATE ATOM(B) TO t}
$\mathfrak{R}_2$: ~t ∨ ~IS_CTA(CONS(CONS(C,NIL),NIL),N) ∨ ~IS(N+1,Z)
$\mathfrak{R}_2$: ~IS_CTA(CONS(CONS(C,NIL),NIL),N) ∨ ~IS(N+1,Z)

IV. Computation Deduction. (continued)

(4 pts) $\mathfrak{R}_3=\mathfrak{R}\{\mathfrak{R}_2,R_2\}$: ~LISTP(U') ∨ ~IS_CTA(T',ANS$_2$') {CONS(C,NIL)/U',NIL/T',N/ANS$_2$'}
$\mathfrak{R}_3$: ~LISTP(CONS(C,NIL)) ∨ ~IS_CTA(NIL,N) ∨ ~IS(N+1,ANS){EVALUATE LISTP(CONS(C,NIL) TO t}
$\mathfrak{R}_3$: ~t ∨ ~IS_CTA(NIL,N) ∨ ~IS(N+1,Z)
$\mathfrak{R}_3$: ~IS_CTA(NIL,N) ∨ ~IS(N+1,Z)

(4 pts) $\mathfrak{R}_4=\mathfrak{R}\{\mathfrak{R}_3,F_1\}$: ~IS(N+1,Z) {0/N}
$\mathfrak{R}_4$= nil {1/Z}

Therefore, {0/N, 1/Z} yields that IS_CTA(CONS(CONS(A,NIL),CONS(B,CONS(CONS(C,NIL),NIL))),1) is true

(3) Prove the substitutions are consistent.

Substitutions will be consistent because I changed variables every time I re-used R_2 and all the variables were originally standardized apart. To prove consistency we assemble all the numerators in a set, say, U_1, and all the denominators in a set, say, U_2 and show that $U_1=U_2\sigma$ and $\sigma\neq$null.
{s}={CONS(A,NIL)/U,CONS(B,CONS(CONS(C,NIL),NIL))/T, Z/ANS$_2$, B/V, CONS(CONS(C,NIL),NIL)/R, Z/ANS$_1$, CONS(C,NIL)/U',NIL/T',N/ANS$_2$'}
U_1=[CONS(A,NIL),CONS(B,CONS(CONS(C,NIL),NIL)), Z, B, CONS(CONS(C,NIL),NIL), Z, CONS(C,NIL),NIL,N],
U_2=[U, T, ANS$_2$, V, R, ANS$_1$, U', T', ANS$_2$']and $U_1=U_2\sigma$
σ={CONS(A,NIL)/U,CONS(B,CONS(CONS(C,NIL),NIL))/T, Z/ANS$_2$, B/V, CONS(CONS(C,NIL),NIL)/R, Z/ANS$_1$, CONS(C,NIL)/U',NIL/T',N/ANS$_2$'} and $\sigma\neq$null.

(1) Give me the solved goal, i.e., the answer:
Anwer: (∃Z)IS_CTA(CONS(CONS(A,NIL),CONS(B,CONS(CONS(C,NIL),NIL))),Z) is true with Z=1