Fall 2002 exam was a 60 minute exam.

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

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}

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

(25)**II**. <u>Resolution Refutation</u>

    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

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

    Solve by drawing a <u>Refutation Graph</u> resulting from a **<u>complete</u>** 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

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

(25)

IV. <u>Computation Deduction</u>.

    Using **<u>Resolution Refutation</u>** deduce the following computation to <u>obtain a value for the goal (3 pts)</u> by drawing the <u>Consistent Solution Graph (17 pts)</u> for the goal and *<u>prove (or provide a good argument)</u> 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: $\{length(T,N) \land \lambda(add(N,1,M))\} \rightarrow length(cons(H,T),M)$

       Where $\lambda(y)$ means "Evaluate the argument *y*"

  Goal: $(\exists z)length(cons(boo, cons(on,cons(you,nil))),z)$

{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.

Fall 2001 exam was a 90 minute exam.

(25) Conversion to Clause Form

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

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

(25)

II. Resolution Refutation

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

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

[Required: Please note the assigned point values. Each part MUST be answered with something. If left blank, then no credit will be assigned]
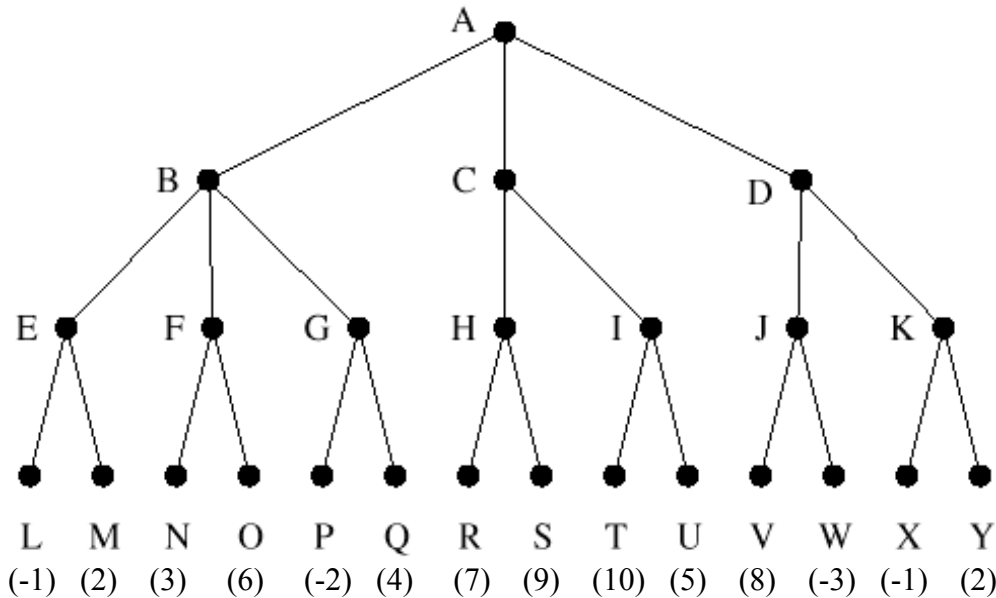
(5)   **a**. Represent the axioms/goal in the Predicate Calculus.
(2)   **b**. Represent any commonsense knowledge needed to solve the problem using Predicate Calculus,
(5)   **c.** Convert your axioms, goal and commonsense knowledge (if any) to clause form,
(10)   **d**. Draw your Refutation Graph,
(3)   **e**. Define your strategy, and describe how your graph meets the strategy

(25)

III. Adversarial Search

Consider the following game tree in which the static scores (in parentheses at the tip nodes) are all from the first player's point of view.
(a) Assuming that the first player is the maximizing player, what move should the first player choose?
(b) Assuming that the first player is the minimizing player, what move should the first player choose?
(c) What nodes would not need to be examined in part (a) using the alpha-beta algorithm—assuming that the nodes are examined in left-to-right order?
(d) What nodes would not need to be examined in part (b) using the alpha-beta algorithm—assuming that the nodes are examined in right-to-left order?
(e) Is the first player's move in parts (a) and (c) or in parts (b) and (d) different? Explain.

(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) $\rightarrow$ depth(S,0)
  R2: depth(H,A_1)$\land$depth(T,A_2)$\land$max(1+A_1,A_2,A_3) $\rightarrow$ depth(cons(H,T),A_3)

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

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

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

Fall 1999 exam was a 90 minute exam.
(25) Conversion to Clause Form
I. Transform the <wff> below into **clause** form. For each of the steps required give a brief description of the step and perform the step (if applicable) on the space provided. Failure to follow this format may result in zero credit.
<wff>:   ($\forall x$)[($\forall y$)[$P(x,y)$] $\rightarrow$ ~{($\forall y$)[$Q(x,y)$ $\rightarrow$ $R(x,y)$]}]

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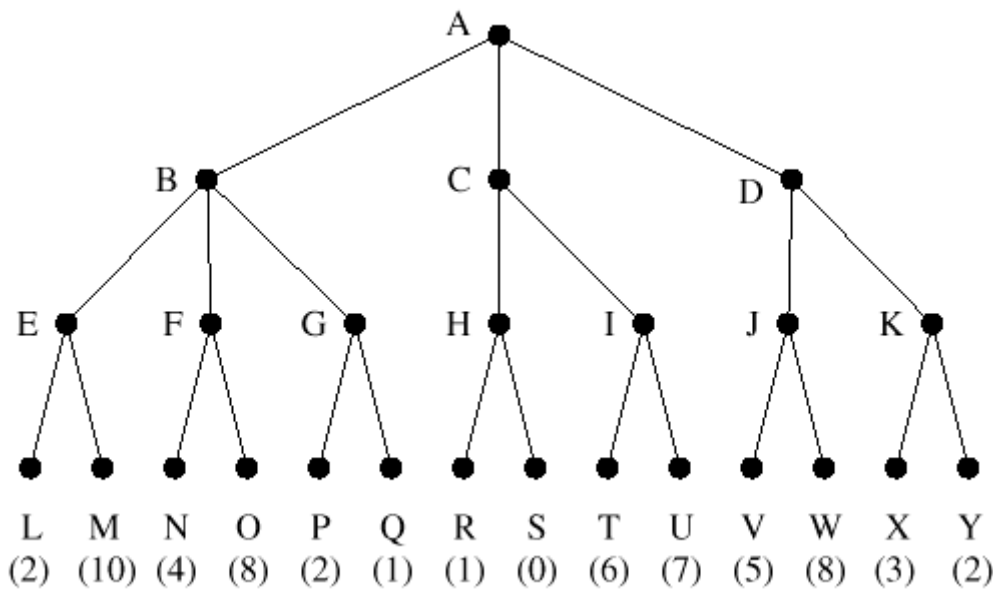
  Axioms:
    1. Block-1 is on the Table.
    2. Block-2 is on the Table.
    3. The Color of Block-1 or the Color of Block-2 is Green.

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.


```
L    M    N    O    P    Q    R    S    T    U    V    W    X    Y
(2) (10) (4)  (8)  (2)  (1)  (1)  (0)  (6)  (7)  (5)  (8)  (3)  (2)
```

(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.

(35)

V. <u>Resolution Applications</u>.

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.
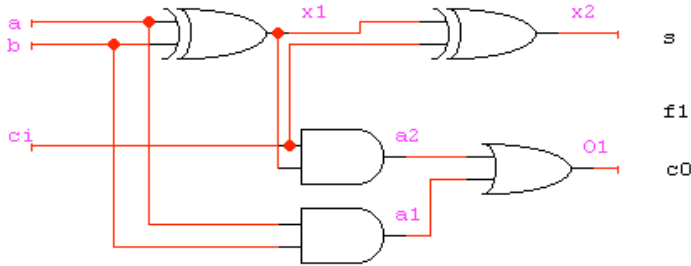
- Let {*f1, x1, x2, a1, a2, o1*} designate the six components.
- Adder(x) means that x ia an adder.
- Xorg(x) means that x is an *xor* gate.
- Andg(x) means that x is an *and* gate.
- Org(x) means that x is an *or* gate.
- I(i,x) designates the ith input port of device *x*.
- O(i,x) designates the ith 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)

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

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

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

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

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

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

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

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

(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 <u>Refutation Graph</u> resulting from a **complete** strategy. (Make sure you mark clearly the required substitutions).

[Required: Please note the assigned point values

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

(25)

III. Heuristic Search

You are to place 6 Queens on a 6x6 board so no two Queens can attack each other. Use a 6-tuple to represent the global database, such that each x_i in the tuple stands for the column number of the queen in row$_i$. Give a heuristic function $h(n)$ that takes into account such things as: (1) two queens cannot occupy the same row or column, (2) queens cannot be in adjacent rows and columns, and (3) a position (i,j) is preferred over position (n,m) if $diag(i,j)<diag(n,m)$ 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 <u>obtain a value for the goal (3 pts)</u> by drawing the <u>Consistent Solution Graph (17 pts)</u> for the goal and *prove* <u>its consistency (5 pts}</u>. Make sure your graph is clearly marked and it follows a complete strategy.

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

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

  Goal: $(\exists z)$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).}

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.

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

(2)   Step 0: _____

(2)   Step 1: _____

(2)   Step 2: _____

(2)   Step 3: _____

(2)   Step 4: _____

(2)   Step 5: _____

(2)   Step 6: _____

(2)   Step 7: _____

(2)   Step 8: _____

I. Conversion to Clause Form (continued)

(2)   Step 9: _____

(2)   Step 10: _____

(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**:
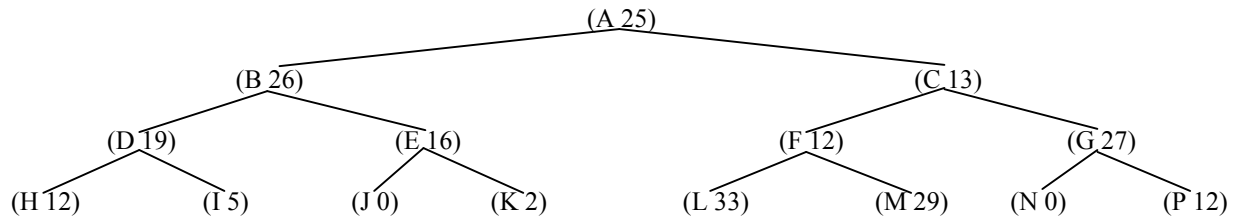

(2)   Answers Part **b**:

(5)   Answers Part **c**:

II. Resolution Refutation(continued)

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

(3)   Answer Part **e**: My strategy is _____

(30)
III. Heuristic Search

The following figure shows a search tree with the state indicated by the tuple inside parentheses. A letter indicates the state name and the integer indicates the estimated cost for finding a solution from that state (a cost of 0 indicates a goal state). Using the Graph-Search algorithm discussed in class, give the solution tree or steps using depth-first search. How many nodes did depth-first expand? Repeat using breadth-first search. How many nodes did breadth-first expand? Repeat using heuristic search. How many nodes did heuristic search expand? Repeat using A^* search. How many nodes did A^* expand? You must <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

```
                                      (A 25)
                 (B 26)                                         (C 13)
          (D 19)         (E 16)                    (F 12)                  (G 27)
       (H 12)   (I 5)  (J 0)   (K 2)          (L 33)   (M 29)        (N 0)      (P 12)
```

III. Heuristic Search. (continued)

(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) $\rightarrow$ herd(cons(sheep,T),cons(sheep,S),G)
R_2: herd(T,S,G) $\rightarrow$ herd(cons(goat,T),S,cons(goat,G))

Goal: $(\exists z)(\exists w)$ 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.