2001 Comprehensive Examination
Artificial Intelligence

1. Search. (20 points) Consider a search tree with uniform branching factor b and depth d, and consider a search problem for which there is a single solution in the tree at depth k. A solution at the root of the tree is depth 0. Give expressions for the worst case cost of finding the solution, in terms of nodes visited, for (a) breadth-first search, (b) depth-first search, and (c) iterative deepening (starting at depth 0 and incrementing by 1 on each iteration. Give closed form expressions, if you can; but sums are okay. If you are unable to do this problem in general, you can still get some points by answering the question for the special case of b=2. And, if that is still too daunting, you may be able to scrape out a point or two by fixing k and d as well.

2. Automated Reasoning. (30 points) Two questions related to resolution.

(a) Consider the following pairs of expressions. u, v, w, x, y, z are variables; all other letters are constants. For each pair, say whether or not they are unifiable; if the answer is yes, give the most general unifier.

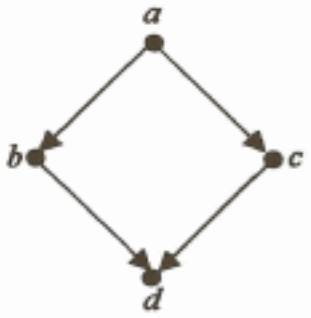
$p(x,b)$ and $p(f(y,y),y)$
$q(x,f(y,a),g(g(x)))$ and $q(z,f(z,u),y)$

(b) Given the following premises, use the resolution method to prove $\neg p(c,a)$.

$\forall y.\ \forall z.(p(y,z) \Rightarrow \neg p(z,y))$
$\forall x.(p(b,x) \Rightarrow p(a,x))$
$p(b,c) \vee p(a,c)$

Note that this is a question about the resolution method. You will get zero points for proving it in any other way.

3. Probability. (30 points) Adapted from Nilsson's *Artificial Intelligence: A New Synthesis*. The admissions committee for a major university wants to know the probability that an applicant is qualified given that the person is admitted. It has the belief network shown below.



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$p(a)$=0.5
$p(b|a)$=1
$p(b|\neg a)$=0.5
$p(c|a)$=1
$p(c|\neg a)$=0.5
$p(d|b,c)$=1
$p(d|b, \neg c)$=0.5
$p(d|\neg b,c)$=0.5
$p(d|\neg b, \neg c)$=0

a - applicant is qualified
b - applicant has a high grade point average
c - applicant has a high graduate record examination score
d - applicant is admitted

What is the probability that an admitted student is qualified? In other words, calculate $p(a|d)$.

4. Natural Language. (20 points) Consider the augmented phrase structure grammar shown below.

$S(r(x, z) \wedge r(y, z)) \rightarrow Q(r(both(x,y), z))$
$Q(w(u, v)) \rightarrow NP(u)\ Verb(w)\ NP(v)$
$NP(x) \rightarrow Noun(x)$
$NP(both(x, y)) \rightarrow NP(x)$ ***and*** $NP(y)$
$Noun(tom) \rightarrow$ ***Tom***
$Noun(dick) \rightarrow$ ***Dick***
$Noun(harry) \rightarrow$ ***Harry***
$Noun(mary) \rightarrow$ ***Mary***
$Verb(hates) \rightarrow$ ***hate***
$Verb(hates) \rightarrow$ ***hates***

(a) Given that s is the top-level non-terminal, is there a semantic interpretation for the expression ***Mary hates Tom and Harry***? If so, what is it?

(b) Given that s is the top-level non-terminal, is there a semantic interpretation for the expression ***Tom and Harry hate Mary***? If so, what is it?

(c) Change the augmentations on the existing rules to eliminate ungrammatical sentences like *Tom and Harry hates Mary* (without eliminating the corresponding grammatical sentences). If you are unable to do this, you can still get partial credit by changing the rules themselves.