CSC 444 Final Exam

There are 6 questions. Solutions are due by electronic turn-in no later than 11:59pm on Monday, December 20. Upload one or more pdf files with your solutions. The file name should contain your own first and last name, e.g. joe-smith-1.pdf, joe-smith-2.pdf. Do not turn in odt, doc, or any other format files. Your answers may be typed or neatly hand-printed and scanned. If the page is hand-written, it is acceptable to have a few items crossed out, but if the page was extensively revised, make a clean copy before scanning it. You may upload your solutions multiple times. You may refer to your notes and textbooks and other general sources of information. However, you should not discuss the problems or search on the web for solutions to the particular problems. (You may search for general information about a topic, for example, modal logic, resolution, etc.)

1. The assertions:

- Anyone who loves all people is enlightened.
- The Buddha loves all living things.
- People are living things.

can be translated into FOL as follows:

$\forall x\ ((\forall y\ (person(y) \supset loves(x,y))) \supset enlightened(x))$

$\forall x\ (living(x) \supset loves(Buddha, x))$

$\forall x\ (person(x) \supset living(x))$

Create a resolution refutation proof that the Buddha is enlightened:

$enlightened(Buddha)$

Be careful to handle conversion to CNF, skolemization, and renaming of variables during resolution properly. Show all details. Make sure it is clear which pairs of literals are being resolved upon. In particular, be very careful in translating the first FOL statement into CNF: this is the kind of nested quantification that many people got wrong on the midterm exam.

2. Consider the following Markov Logic theory:

Hard formula: $\forall x\ (\neg penguin(x)\ \vee\ bird(x))$

Soft formula, weight 10: $\forall x\ (\neg bird(x)\ \vee\ fly(x))$

Soft formula, weight 20: $\forall x\ (\neg penguin(x)\ \vee\ \neg fly(x))$

Hard formula: $penguin(Tweety)$

Calculate

$P(fly(Tweety))$

Show all steps of your calculation. Begin by listing all of the models of the hard formulas, and computing the sum of the weighted <u>ground</u> clauses true in each model.

Next, suppose the following clauses are added to the theory:

Soft formula, weight 15: $\forall x, y\ (\neg friend(x,y)\ \vee\ fly(x) \vee\ \neg fly(y))$

Hard formula: $penguin(Fred)$

Hard formula: $friend(Tweety, Fred)$

Hard formula: $friend(Fred, Tweety)$

Note that the soft formula above is equivalent to

$\forall x, y\ (friend(x, y)\ \vee\ \neg fly(x)) \supset \neg fly(y)$

Calculate $P(fly(Tweety))$ and $P\big(fly(Tweety) \wedge fly(Fred)\big)$. Show all steps.

3. Consider the follow propositional theory:

$\neg healthy \supset (bacterialInfection\ \vee viralInfection)$

$takingAntibiotics\ \supset \neg BacterialInfection$

$fever \supset \neg healthy$

Compute the Horn LUB and all of the Horn GLBs. Show all of your work. Simplify the bounds as much as possible.

Next, use the bounds to try to determine the answers to the following two queries. For each, show how using the bounds would return Yes, No, or Unknown.

$bacterialInfection\ \vee takingAntibiotics$?

$(takingAntibiotics\ \wedge fever) \supset viralInfection$?

4. Write a Kripke structure with 2 agents, John and Alice, 3 states, w0, w1, and w2, and the single proposition S, which means "it is snowing", such that the following statements are true in w0:

- John believes it is snowing.
- Alice believes it is snowing.
- John believes that Alice believes it is not snowing.
- Johns believes that Alice believes that John believes it is snowing.

Your structure should respect the property of belief that if an agent believes something, then he believes that he believes that thing. For example, since John believes it is snowing, then John believes that John believes it is snowing.

5. Consider the following diagnosis problem. The background theory is:

$(turnKey \wedge \neg Ab(battery) \wedge \neg Ab(gas)) \supset engineStarts$

$Ab(gas) \supset \neg engineRuns$

$\neg engineRuns \supset \neg engineStarts$

$turnKey$

The observation is $\neg engineStarts$. The abducibles are the Ab predicates. Compute all of the abductive diagnoses and all of the consistency-based diagnoses. Show all steps of your work.

6. Consider a SAT-modulo theory that contains a proposition p that is supposed to mean "x = y + 1" for some integer valued variables x and y. Suppose we are doing an eager circuit based encoding, and will represent x and y as 2-bit numbers, using the Boolean propositions X1, X0, Y1, Y0, where X1 is the high-order bit of x, X0 is the low-order bit of x, etc.

Write a formula in proposition logic that asserts "p if and only if x = y+1".
Next, convert this formula to CNF.