This is the last assignment before the Midterm and Spring Break.

Notice When you submit this assignment, you are certifying therewith that you understand and accept the following policy, which applies to all assignments.

Collaboration Policy The writeup that you submit must be your own work. You are encouraged to get help from the professor and grutors. You may discuss the problems with classmates, but if you do so, it should be in groups of no more than three. You are not allowed to copy or transcribe solutions from other sources, including the work of other students, the internet, previous solution sets, and images photographed from a whiteboard or blackboard. There is to be no "partnering" where two or more students submit the same writeup. If you get help on a problem, you should say who provided the help on a per-problem basis. Blanket statements such as "worked with John and Mary" are not allowed. Detected infractions may impact your academic career.

Formatting Policy All work must be typeset in electronic media and submitted as a single pdf file, one problem on each page as shown in the following pages. Retain this header page. Handwritten and photographed or scanned work is not allowed. Do not use inverse video (light typography on dark background). Do not rotate images. You will not get credit for difficult-to-read submissions.

For JAPE proofs take a screenshot of your proof and paste it into the document. For written out proofs, just type into a copy of the Google doc master (not the pdf), or use some other method such as LaTeX if you must. You may scrape formulas and symbols directly from the doc master, or from my page full of symbols that I use throughout the course. Once your document is complete, make a pdf and submit to Gradescope.

For tableau proofs, it suggested that you use the spreadsheet method. Please remember to turn off the gridlines from the View menu before taking your screenshot for greater readability.

Once your document is complete, make a pdf and submit to Gradescope.

Please help us grade by placing your solutions in the spaces provided.

Some problems ask to check your solutions using Prover9/Mace4. In these cases, paste in appropriate screen shots of the solution. Download Prover9/Mace4 here: `http://www.cs.unm.edu/~mccune/prover9/download/`. I've created a quickstart guide to help you. Also there are examples in the lecture slides.

When using Mace4, you should use the Reformat menu to reformat to "cooked" mode for ease in reading.

[10 points] 1. Establish the satisfiability or unsatisfiability of the set of clauses below by the resolution method. (Extend the table as needed.) If a set is satisfiable, give an interpretation that satisfies it.

	Clause	Justification	Prover9 version
1	$p \vee \neg q \vee \neg r$	Given	
2	$p \vee q \vee \neg r \vee \neg s$	Given	
3	$p \vee \neg q \vee r \vee s$	Given	
4	$\neg p \vee \neg r \vee \neg s$	Given	
5	$\neg p \vee \neg q \vee s$	Given	
6	$q \vee s$	Given	
7	$r \vee \neg s$	Given	

[2/10 points] Once you have proved the statement by hand, check the result using Prover9/Mace4. (Paste input and output here.)

[10 points] 2. Establish the satisfiability or unsatisfiability of the set of clauses below by the resolution method. (Extend the tables as needed.) If a set is satisfiable, give an interpretation that satisfies it.

	Clause	Justification	Prover9 version
1	$\neg p \vee q \vee r \vee s$	Given	
2	$\neg p \vee \neg q$	Given	
3	$q \vee \neg s$	Given	
4	$\neg q \vee r$	Given	
5	$\neg r \vee s$	Given	

[2/10 points] Once you have proved the statement by hand, check the result using Prover9/Mace4. (Paste input and output here.)

[10 points] 3. Determine whether the pair of atomic formulas below is unifiable by executing the unification algorithm on them. Show the values of the set P and the unifier S as the algorithm iterates. (Using a table as in the lecture slides is a good idea.) If unifiable, give the most general unifier (MGU). (In each case, the variables have already been renamed apart, so the renaming-apart step is not necessary.) If not unifiable, state why unification fails. In unifiable cases, check by direct substitution of the unifier into the formulae.

$$P(g(h(x)), f(h(y)), y, x) \quad \text{vs.}$$
$$P(g(z), \quad f(z), \quad a, b).$$

[10 points] 4. Determine whether the pair of atomic formulae below is unifiable by executing the unification algorithm on them. Show the values of the set P and the unifier S as the algorithm iterates. (Using a table as in the lecture slides is a good idea.) If unifiable, give the most general unifier (MGU). (In each case, the variables have already been renamed apart, so the renaming-apart step is not necessary.) If not unifiable, state why unification fails. In unifiable cases, check by direct substitution of the unifier into the formulae.

$$\begin{array}{llll} P(g(h(x)), & f(h(y)), & y, & x) \quad \text{vs.} \\ P(g(z), & f(z), & h(a), & h(u)). \end{array}$$

[5 points] 5. Try to establish the satisfiability or unsatisfiability of the following set of clauses using resolution. If a set is satisfiable, give an interpretation that satisfies it. [Don't forget that variables do not carry across from one clause to another, but constants do.] (Extend the table as necessary.)

	Clause	Justification
1	$P(a)$	Given
2	$Q(y, x) \vee \neg P(x)$	Given
3	$Q(b, x)$	Given
4	$\neg Q(b, a)$	Given

[2/10 points] Once you have proved the statement by hand, check the result using Prover9/Mace4. (Paste input and output here.)

[10 points] 6. Try to establish the satisfiability or unsatisfiability of the following set of clauses using resolution. If a set is satisfiable, give an interpretation that satisfies it. [Don't forget that variables do not carry across from one clause to another, but constants do.] (Extend the table as necessary.)

	Clause	Justification
1	$P(a)$	Given
2	$Q(y, x) \vee \neg P(x)$	Given
3	$Q(b, x)$	Given
4	$\neg Q(a, b)$	Given

[2/10 points] Once you have proved the statement by hand, check the result using Prover9/Mace4. (Paste input and output here.)

[10 points] 7. Try to establish the satisfiability or unsatisfiability of the following set of clauses using resolution. If a set is satisfiable, give an interpretation that satisfies it. [Don't forget that variables do not carry across from one clause to another, but constants do.] (Extend the table as necessary.)

	Clause	Justification
1	$Q(a)$	Given
2	$P(x) \vee \neg Q(x)$	Given
3	$\neg P(x) \vee Q(f(x))$	Given

[2/10 points] Once you have proved the statement by hand, check the result using Prover9/Mace4. (Paste input and output here.)

[10 points] 8. Prove the following sequent by the resolution method. (Don't forget to negate the conclusion before converting to clausal form.)

$$\forall x\,(P(x) \to Q(x)) \vdash (\exists x\, P(x)) \to (\exists x\, Q(x)).$$

[2/10 points] Once you have proved the statement by hand, check the result using Prover9/Mace4. (Paste input and output here.)

[10 points] 9. Prove the following sequent by the resolution method. (Don't forget to negate the conclusion before converting to clausal form.)

$$(\exists x\, P(x)) \rightarrow (\forall x\, Q(x)) \vdash (\forall x\, (P(x) \rightarrow Q(x))).$$

[2/10 points] Once you have proved the statement by hand, check the result using Prover9/Mace4. (Paste input and output here.)

[10 points] 10. Translate into predicate logic, then prove using resolution.

Premises:

(a) Every child loves candy.

(b) Anyone who loves candy is not a health nut.

(c) Anyone who drinks wheatgrass is a health nut.

(d) Dale drinks wheatgrass.

Conclusion:

(a) Dale is not a child.

[2/10 points] Once you have proved the statement by hand, check the result using Prover9/Mace4. (Paste input and output here.) .