## Course: Satisfiability Modulo Theories (SMT): ideas and applications

Send your assignment to: leonardo@microsoft.com

- 1. Mark the following formulas as valid, satisfiable or unsatisfiable.
  - a.  $p \lor q \Rightarrow p \land q$
  - b.  $(p \lor q) \land (\neg p \lor q) \land (p \lor \neg q) \land (\neg p \lor \neg q)$
  - c.  $p \land (\neg p \lor q) \land (\neg q \lor r) \land (\neg r \lor \neg p)$
  - $d. \quad p \wedge q \Longrightarrow p$
  - e.  $\neg(p \land q) \lor q$
- 2. Explain the difference between interpreted and uninterpreted symbols. Give examples.
- 3. In a 3CNF formula, every clause has three literals. Show that every CNF formula is equisatisfiable to a 3CNF formula.
- 4. Describe a linear time algorithm for solving 2CNF.
- 5. Show the following formula is unsatisfiable using Resolution.

a. 
$$\neg r \land (r \lor \neg s) \land (p \lor q \lor s) \land (\neg p \lor q \lor s) \land (p \lor \neg q \lor s) \land (\neg p \lor \neg q \lor s)$$

- 6. What is the main disadvantage of Resolution with respect to DPLL?
- 7. What is a theory conflict?
- How many equivalence classes (aka "blue balls) do we have after processing the following set of equations using the union-find & congruence closure algorithm? Show also the contents of each equivalence class.
  - a. { a=b, b=c, f(a) = d, f(b) = e, f(c) = s }
- 9. Pivot variables x and z in the following tableau. What are the sets of basic variables before and after the pivoting step?
  - a. x = r + z y = 2r - z s = 3z
- 10. Give an example of a non-stably infinite theory.
- 11. Show that the bit-vector theory is not convex.
- 12. Show a model for the following satisfiable formula. Assume the symbols +, -, 0, 1, 2 are interpreted by the theory of linear arithmetic.

a.  $x-y \le 2 \land y-z \le -1 \land z-x \le -1$ 

- 13. What is the Bland's rule? What is it used for?
- 14. What kind of atoms is allowed in the difference logic fragment?