**CMSC 330, Fall 2013, Practice Problems 4**

1. Context Free Grammars
   a. List the 4 components of a context free grammar.
   b. Describe the relationship between terminals, non-terminals, and productions.
   c. Define ambiguity.
   d. Describe the difference between scanning & parsing.
   e. Describe an abstract syntax tree (AST)

2. Describing Grammars
   a. Describe the language accepted by the following grammar:
      $S \rightarrow abS \mid a$
   b. Describe the language accepted by the following grammar:
      $S \rightarrow aSb \mid \varepsilon$
   c. Describe the language accepted by the following grammar:
      $S \rightarrow bSb \mid A \qquad A \rightarrow aA \mid \varepsilon$
   d. Describe the language accepted by the following grammar:
      $S \rightarrow AS \mid B \qquad A \rightarrow aAc \mid Aa \mid \varepsilon \qquad B \rightarrow bBb \mid \varepsilon$
   e. Describe the language accepted by the following grammar:
      $S \rightarrow$ S and S | S or S | (S) | true | false
   f. Which of the previous grammars are left recursive?
   g. Which of the previous grammars are right recursive?
   h. Which of the previous grammars are ambiguous? Provide proof.

3. Creating Grammars
   a. Write a grammar for $a^x b^y$, where $x = y$
   b. Write a grammar for $a^x b^y$, where $x > y$
   c. Write a grammar for $a^x b^y$, where $x = 2y$
   d. Write a grammar for $a^x b^y a^z$, where $z = x+y$
   e. Write a grammar for $a^x b^y a^z$, where $z = x-y$
   f. Write a grammar for all strings of *a* and *b* that are palindromes.
   g. Write a grammar for all strings of *a* and *b* that include the substring *baa*.
   h. Write a grammar for all strings of *a* and *b* with an odd number of *a*'s and an odd number of *b*'s.
   i. Write a grammar for the "if" statement in OCaml
   j. Write a grammar for all lists in OCaml
   k. Which of your grammars are ambiguous? Can you come up with an unambiguous grammar that accepts the same language?

4. Derivations, Parse Trees, Precedence and Associativity
   For the following grammar: $S \rightarrow$ S and S | true
   a. List 4 derivations for the string "true and true and true".
   b. Label each derivation as left-most, right-most, or neither.
   c. List the parse tree for each derivation
   d. What is implied about the associativity of "and" for each parse tree?

For the following grammar: S → S and S | S or S | true

e. List all parse trees for the string "true and true or true"
f. What is implied about the precedence/associativity of "and" and "or" for each parse tree?
g. Rewrite the grammar so that "and" has higher precedence than "or" and is right associative

5. Left factoring

   Rewrite the following grammars so they can be parsed by a predicative parser by applying left factoring where necessary

   a. S → a b c | a c
   b. S → a a | a b | a
   c. S → a b A c | a b B a
   d. S → a a A | a a a B | a c

6. Parsing

   For the problem, assume the term "predictive parser" refers to a top-down, recursive descent, non-backtracking predictive parser.

   a. Consider the following grammar: S → S and S | S or S | (S) | true | false
      i. Compute First sets for each production and nonterminal
      ii. Explain why the grammar cannot be parsed by a predictive parser
   b. Consider the following grammar: S → abS | acS | c
      i. Compute First sets for each production and nonterminal
      ii. Show why the grammar cannot be parsed by a predictive parser.
      iii. Rewrite the grammar so it can be parsed by a predictive parser.
      iv. Write a predictive parser for the rewritten grammar.
   c. Consider the following grammar: S → Sa | Sc | c
      i. Show why the grammar cannot be parsed by a predictive parser.
      ii. Rewrite the grammar so it can be parsed by a predictive parser.
      iii. Write a recursive descent parser for your new grammar