University of Nevada, Las Vegas Computer Science 456/656 Spring 2026

Assignment 2: Due Saturday September 12, 2026, midnight

Name:_____

You are permitted to work in groups, get help from others, read books, and use the internet. Turn in the assignment as instruced by the Graduate Assistant, Sabrina Wellace, `wallace4@unlv.nevada.edu`

Officially, the Dyck language is over the alphabet $\{(,)\}$, the left and right parentheses, and consists of all "balanced" strings of parentheses, such as "()" "(())()" However, when written without sufficient caution, such as by rushed students taking an exam, the two symbols look so similar that the grader (me, or whoever) is easily confused. Thus, this semester, I will use the alphabet $\{a, b\}$ instead, so that the Dyck language contains, for example, the strings "ab" and "$aabbab$."

1. True **T**/False **F**/Open **O**, meaning that the answer is not known to science at this time.

   (i) _____ $\mathcal{P} = \mathcal{NP}$.

   (ii) _____ $\mathcal{P} = \mathcal{NC}$.

   (iii) _____ co-$\mathcal{P} = \mathcal{P}$.

   (iv) _____ co-$\mathcal{NP} = \mathcal{NP}$.

   (v) _____ A language is recursive (decidable) if and only if it is both $\mathcal{RE}$ and co-$\mathcal{RE}$.

   (vi) _____ A language is context-free if and only if it is accepted by some PDA.

   (vii) _____ The game *Rush Hour*, where you try to move the red car out of the "parking lot," is known to be $\mathcal{P}$–SPACE complete. (Hint: look it up on the intenet.)

2. Let G_1 be the following grammar.
   1. $S \to aSb$
   2. $S \to SS$
   3. $S \to \lambda$

   (i) What language does G_1 generate? (It has a spaeific name.)

   (ii) Show that G_1 is ambiguous by writing two different leftmost derivations of some string in that language. (If you draw two different parse trees, but do not give two different leftmost derivations, you have not answered the question.)

   (iii) Give an unambiguous context-free grammar G_2 which is equivalent to G_1.

3. Let L be the language over $\{a, b\}$ consisting of all strings which have equal numbers of each symbol, that is, $L = \{w \in \{a, b\}^* : \#_a(w) = \#_b(w)\}$.

   (i) _____ (T/F/O) G is regular.

   (ii) Give a context-free grammar for L.

   (iii) Draw a DPDA which accepts L. Attach an extra sheet if necessary.

4. State the pumping lemma for regular languages. Write it carefully. The statement contains both implications and nested quantifiers, which must be in the correct order.

5. Here is another context-free grammar G_3 which gnerates L.. The start symbol of G_3 is E.
   1. $E -> E + E$
   2. $E -> E * E$
   3. $E -> (E)$
   4. $E -> x$

   (i) G_3 is ambiguous.
   Draw two different parse trees
   for some $w \in L(G_3)$.

   (ii) Both parse trees are valid as far as the grammar is concerned, but only one of them would be considered "correct" by your high school algebra teacher. Which one?

   (iii) _____ (T/F/O) There exists an unambiguous context-free grammar which generates the same language as G_3 but resolves the ambiguity.

6. Give the certificate/verifier definition of the class $\mathcal{NC}$.

7. List the Chomsky grammar classes, giving their standard type numbers.