

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

## Assignment 6: Due Saturday May 2, 2026, 11:59:59 PM

Name: \_\_\_\_\_

You are permitted to work in groups, get help from others, read books, and use the internet. Turn in the assignment as instructed by the Graduate Assistant, Shubhashish Kar, [shubhashish.kar@unlv.nevada.edu](mailto:shubhashish.kar@unlv.nevada.edu)

1. True, False, or Open.
  - (i) \_\_\_\_\_ Every context-sensitive language is decidable.
  - (ii) \_\_\_\_\_ The set of unary numerals for powers of 2 is context-free.
  - (iii) \_\_\_\_\_ The Rice number of a language  $L$  is a recursive real number if and only if  $L$  is recursively enumerable.
  - (iv) \_\_\_\_\_  $L = \{a^n b^n c^n d^n : n > 0\}$  is context-sensitive.
  - (v) \_\_\_\_\_ Every context-free grammar can be parsed by some LALR parser.
  - (vi) \_\_\_\_\_ Tropical matrix multiplication, which can be used for minpath problems, is  $\mathcal{NC}$ .
2. Consider the following annotated CF grammar  $G$ , where  $E$  is the start symbol, and the action and goto tables of an LALR parser for  $G$ .

1.  $E \rightarrow E +_2 E_3$
2.  $E \rightarrow E *_4 E_5$
3.  $E \rightarrow ({}_6 E_7)_8$
4.  $E \rightarrow x_9$

	$x$	$+$	$*$	$($	$)$	$\$$	
0	$s_9$			$s_6$			1
1		$s_2$	$s_4$	$s_6$		HALT	
2	$s_9$			$s_6$			3
3		$r_1$	$s_4$		$r_1$	$r_1$	
4	$s_9$			$s_6$			5
5		$r_2$	$r_2$		$r_2$	$r_2$	
6	$s_9$			$s_6$			7
7		$s_2$	$s_4$		$s_8$		
8		$r_3$	$r_3$		$r_3$	$r_3$	
9		$r_4$	$r_4$		$r_4$	$r_4$	

- (a) There are two entries in the action table which together guarantee that multiplication has precedence over addition. There is one entry which guarantees that addition is left associative, and one which guarantees that multiplication is left associative. Identify each of those four entries, by row and column.

- (b) Walk through a computation of the parser with the input string  $x * x + x * ((x + x * x) + x)$ . I have left the next page blank for this computation.

3. Every non-empty context-free language is generated by a CNF (Chomsky normal form) grammar.

Let  $L$  be the set of all non-empty strings generated by the grammar given in Problem 2. Construct a CNF grammar for  $L$ . You will need to introduce a number of variables.

4. Prove the pumping lemma for regular languages.

5. Use the pumping lemma for context-free languages to prove that  $\{a^n b^n c^n : n \geq 0\}$  is not context-free.

6. Give a proof, by induction, that  $\sum_{i=1}^n i^3 = \frac{n^2(n+1)^2}{4}$

7. Give a context-sensitive grammar for  $\{a^n b^n c^n d^n : n > 0\}$

8. Give a proof, by contradiction, that  $\sqrt{2}$  is irrational.

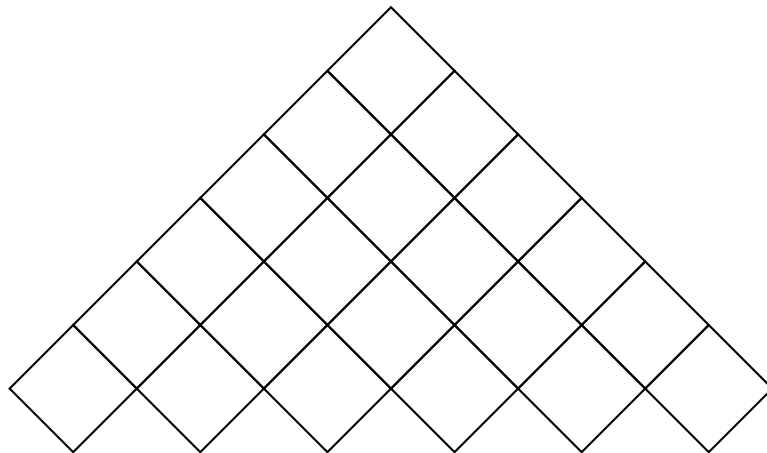
9. Which of these problems or languages are known to be  $\mathcal{NP}$ -complete? Mark each language either T if it is known to be  $\mathcal{NP}$ -complete, F otherwise.

- (i) ..... Boolean satisfiability
- (ii) ..... 3-SAT
- (iii) ..... 2-SAT
- (iv) ..... TSP

- (v) ----- DFA Equivalence
- (vi) ----- NFA Equivalence
- (vii) ----- CFG Equivalence
- (viii) ----- Regular Grammar Equivalence
- (ix) ----- Program Equivalence
- (x) ----- CVP
- (xi) ----- Knapsack problem
- (xii) ----- Regular Expression Equivalence
- (xiii) ----- Graph Coloring with 2 colors
- (xiv) ----- Graph Coloring with 3 colors
- (xv) ----- Block Sorting
- (xvi) ----- Firehouse problem
- (xvii) ----- Hamiltonian Circuit
- (xviii) ----- Graph Isomorphism
- (xix) ----- Minimum Spanning Tree
- (xx) ----- Dominating Set
- (xxi) ----- Independent Set
- (xxii) ----- Generalized Checkers (Arbitrary size board)
- (xxiii) ----- Furniture Mover's Problem
- (xxiv) ----- Jigsaw Problem
- (xxv) ----- Rush Hour, arbitrary size parking lot
- (xxvi) ----- Canadian Traveler's Problem

10. Let  $G$  be the following CNF grammar Use the CYK algorithm to decide whether  $aabbab \in L(G)$ .

- 1.  $S \rightarrow AB$
- 2.  $A \rightarrow a$
- 3.  $B \rightarrow b$
- 4.  $A \rightarrow AS$
- 5.  $B \rightarrow BS$



11. For each regular expression, draw a DFA with at most 2 states which accepts the language described by that expression.

(a)  $a$

(b)  $a^*$

(c)  $\lambda$

(d)  $\emptyset$

(e)  $a^*b^*$

(f)  $(a + b)^*$

(g)  $(ab)^*$

12. Construct a PDA which accepts the language of all palindromes over  $\{a, b\}$

13. Construct a DPDA which accepts the language generated by this grammar. The start symbol is  $E$ .

1.  $E \rightarrow a$
2.  $E \rightarrow E + E$
3.  $E \rightarrow (E)$

This problem is harder than I realized. Substitute the language generated by the grammar below. You are still welcome to work the original version.

1.  $E \rightarrow a$
2.  $E \rightarrow E + E$

14. Recall that the Rice number of a language  $L$  over an alphabet  $\Sigma$  is defined to be  $\sum_{w_i \in L} 2^{-i}$ , where  $w_1, w_2, \dots$  is the canonical enumeration of  $\Sigma^*$ . Let  $\Sigma = \{1\}$ , the *unary* alphabet. Let  $L$  be the language consisting of all strings of odd length over that alphabet. Compute the Rice number of  $L$ . (Hint: it's a simple fraction.)