University of Nevada, Las Vegas Computer Science 456/656 Fall 2025

Assignment 6: Due November 8, 2025, 11:59:59 PM

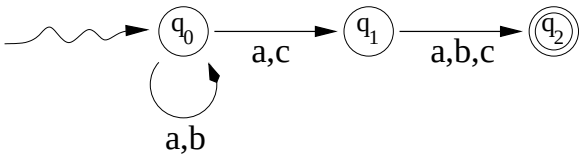
Name:_____

You are permitted to work in groups, get help from others, read books, and use the internet. You will receive a message from the graduate assistant, Sabrina Wallace, telling you how to turn in the assignment.

There are problems in this homework that were on the second examination. I have concentrated on problems which many students did badly. They will likely be repeated in the next examination or the final examination.

$\mathcal{P}$ means $\mathcal{P}$–TIME.

1. True/False. If the answer is not known to science at this time, enter "O" for Open.
   (a) _____ $\mathcal{P} = \mathcal{NC}$
   (b) _____ Given any $\mathcal{P}$–TIME problem P, there is a $\mathcal{NC}$ reduction of P to the circuit value problem.
   (c) _____ Every context-free languags is $\mathcal{NC}$.
   (d) _____ If a language L is generated by a general grammar, L must be decidable.
   (e) _____ Every undecidable language is $\mathcal{NP}$-hard.
2. Draw a DFA equivalent to the following NFA.



3. Give a definition of the class $\mathcal{P}$-complete, and name a language in that class.

4. Every language, or problem, falls into exactly one of these categories. For each of these languages or problems, write a letter indicating the correct category. You will need to search the internet for some of these.

A Known to be $\mathcal{NC}$.
B Known to be $\mathcal{P}$–TIME, but not known to be $\mathcal{NC}$.
C Known to be $\mathcal{NP}$, but not known to be $\mathcal{P}$–TIME and not known to be $\mathcal{NP}$–complete.
D Known to be $\mathcal{NP}$–complete.
E Known to be $\mathcal{P}$–SPACE but not known to be $\mathcal{NP}$
F Known to be EXP–TIME but not known to be $\mathcal{P}$–SPACE.
G Known to be EXP–SPACE but not known to be EXP–TIME.
H Known to be decidable, but not known to be EXP–SPACE.
I $\mathcal{RE}$ but not decidable.
K co-$\mathcal{RE}$ but not decidable.
L Neither $\mathcal{RE}$ nor co-$\mathcal{RE}$.

(i) _____ The circuit value problem (CVP).

(ii) _____ All C++ programs which halt with no input.

(iii) _____ All base 10 numerals for perfect squares.

(iv) _____ All configurations of RUSH HOUR from which it's possible to win.

(v) _____ All satisfiable Boolean expressions.

(vi) _____ Binary numerals for composite integers. (Composite means not prime.)

(vii) _____ Decimal numerals for positive multiples of seven, such as 7, 14, 21, 28, ...

(viii) _____ The furniture mover's problem. Given a room with a door and a set of furniture, is it possible to move all the furniture into the room through that door?

(ix) _____ The set of all positions of Chinese GO, on a board of any size, from which white can win. (You will need to look this up.)

(x) _____ The Dyck language.

(xi) The Jigsaw problem. (That is, given a finite set of two-dimensional pieces, can they be assembled into a rectangle, with no overlap and no spaces.)

(xii) _____ Factorization of binary numerals.

(xiii) _____ Boolean matrix multiplication.

(xiv) _____ All C++ programs which do not halt if given themselves as input.

(xv) _____ SAT.

(xvi) _____ 3-SAT.

(xvii) _____ 2-SAT.

(xviii) _____ The Independent Set problem.

(xix) _____ The Subset Sum Problem.

(xx) _____ The Block sorting problem.

(xxi) _____ The Sliding block problem.

(xxii) _____ The Hamiltonian cyle problem.

(xxiii) _____ The Traveling salesman problem.

(xxiv) _____ The Graph isomorphism problem.

(xxv) _____ The 3-coloring problem.

(xxvi) _____ The 2-coloring problem.

(xxvii) _____ TOT, the set of all machine descriptions $\langle M \rangle$ such that M halts on all possible inputs.

5. Fill in the ACTION table and GOTO table of an LALR parser or the following annotated context-free grammar. Your table should enforce the convention that both operations are left-associative, and that multiplication has higher precedence than subtraction, where x represents any identifier.
   1. $E \to E -_2 E_3$
   2. $E \to E *_4 E_5$
   3. $E \to x_6$

	x	$-$	$*$	\$	E
0					
1					
2					
3					
4					
5					
6					

6. Consider the following annotated CF grammar G.
   1. $E \to E -_2 E_3$
   2. $E \to -_4 E_5$
   3. $E \to E \wedge_6 E_7$
   4. $E \to ({}_8 E_9)_{10}$
   5. $E \to x_{11}$

   Here is an LALR parser for G. Walk through the computation of the parser for the input string $x - -(-x \wedge x \wedge -x)$

	x	$-$	$\wedge$	(	)	\$	
0	$s11$	$s4$		$s8$			1
1		$s2$	$s6$				
2	$s11$	$s4$		$s8$			3
3		$r1$	$s6$		$r1$	$r1$	
4	$s11$	$s4$		$s8$			5
5		$r2$	$r2$		$r2$	$r2$	
6	$s11$	$s4$		$s8$			7
7		$r3$	$s6$		$r3$	$r3$	
8	$s11$	$s4$		$s8$			9
9		$s2$	$s6$		$s10$		
10		$r4$	$r4$		$r4$	$r4$	
11		$r5$	$r5$		$r5$	$r5$	

7. Let N be a large integer, and $w = \langle N \rangle$ its binary numeral. Let $n = |w|$. Explain how $O(n)$ parallel processors can decide, in $O(\log n)$ time, whether N is divisible by 3.

   Example: in this case, N is a divisible by 3.
   1011111111000011101010111100110011010100010011011111100010001011110000001011110001111110010111000010

   I will give a hint for this problem in class on Thursday. Be there!

8. State the pumping lemma for regular languages. Do not get confused this time!

9. Prove that $L = \{a^n b^n : n \geq 0\}$ is not regular. Hint: By contradiction, using the pumping lemma.

10. Give a polynomial time reduction of 3-SAT to the independent set problem.

11. Prove that the halting problem is undecidable.