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

Assignment 5: Due October 23, 2025, 08:00:00 AM

Name:____

You are permitted to work in groups, get help from others, read books, and use the internet. This homework will not count toward your grade, so do not turn it in.

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

1. True/False. If the answer is not known to science at this time, enter "O" for Open.
   (a) ________ There are only countably many decidable binary languages.
   (b) ________ If a number x can be approximated to any desired accuracy by a computer, then x is a recursive real number.
   (c) ________ If L_1 is an $\mathcal{NP}$ language and L_2 is an $\mathcal{NP}$-complete language, there must be a polynomial time reduction of L_1 to L_2.
   (d) ________ If some machine can compute an increasing sequence of fractions which converges to x, then x must be a recursive real number.
   (e) ________ The Busy Beaver function is recursive.
   (f) The programming language Pascal is decidable.
   (g) Every context-sensitive language is decidable.
   (h) Every recursively enumerable language is decidable.
   (i) An LALR parser is basically a DPDA with output.

2. State the pumping lemma for regular languages. If your answer contains all the right words, but not in the right order, you might get no credit.

3. Use the pumping lemma for regular languages to prove that $\{a^n b^n : n \geq 0\}$ is not regular. Given languages L_1 and L_2, exactly one of the following statements is correct. Which one? ________

(i) If there is an easy reduction from L_1 to L_2 and L_1 is hard, then L_2 must be hard.

(ii) If there is an easy reduction from L_1 to L_2 and L_2 is hard, then L_1 must be hard.

(iii) If there is an easy reduction from L_1 to L_2 and L_1 is easy, then L_2 must be easy.

(iv) If there is a hard reduction from L_1 to L_2 and L_2 is easy, then L_1 must be hard.

4. Give a polynomial time reduction of subset sum to the partition problem.

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

6. Prove that the halting problem is undecidable.

7. The following annotated CF grammar generates the Dyck language, using the alphabet $\{a, b\}$.

   1. $S \Rightarrow a_2 S_3 b_4 S_5$
   2. $S \Rightarrow \lambda$

   Here is an LALR parser for that language. Sketch a computation of this parser, with input $aababb$.

	a	b	$\$$	S
0	$s2$		$r2$	1
1			HALT	
2	$s2$	$r2$		3
3		$s4$		
4	$a2$	$r2$	$r2$	5
5		$r1$	$r1$	

STACK	INPUT	OUTPUT	ACTION
$\$_0$	$aababb\$$		
$\$_0 a_2$	$ababb\$$		$s2$
$\$_0 a_2 a_2$	$babb\$$		$s2$
$\$_0 a_2 a_2 S_3$	$babb\$$	2	$r2$
$\$_0 a_2 a_2 S_3 b_4$	$abb\$$	2	$s4$
$\$_0 a_2 a_2 S_3 b_4 a_2$	$bb\$$	2	$s2$
$\$_0 a_2 a_2 S_3 b_4 a_2 S_3$	$bb\$$	22	$r2$
$\$_0 a_2 a_2 S_3 b_4 a_2 S_3 b_4$	$b\$$	22	$s4$
$\$_0 a_2 a_2 S_3 b_4 a_2 S_3 b_4 S_5$	$b\$$	222	$r2$
$\$_0 a_2 a_2 S_3 b_4 S_5$	$b\$$	2221	$r1$
$\$_0 a_2 S_3$	$b\$$	22211	$r1$
$\$_0 a_2 S_3 b_4$	$\$$	22211	$s4$
$\$_0 a_2 S_3 b_4 S_5$	$\$$	222112	$r2$
$\$_0 S_1$	$\$$	2221121	$r1$
$\$_0 S_1$	$\$$	2221121	HALT

8. Here is an annotated algebraic CF grammar, where **id** is any variable.

   1. $E \to E +_2 E_3$
   2. $E \to E *_4 E_5$
   3. $E \to (_6 E_7)_8$
   4. $E \to \mathbf{id}_9$

   Here are the ACTION and GOTO tables for an LALR parser for this grammar.

	id	$+$	$*$	(	)	$\$$	E
0	$s9$						1
1		$s2$	$s4$	$s6$		HALT	
2	$s9$			$s6$			3
3		$r1$			$r1$		
4	$s9$			$s6$			5
5		$r2$	$r2$		$r2$		
6	$s9$			$s6$			7
7		$s2$	$s4$		$s8$		
8		$r3$	$r3$		$r3$	$r3$	
9		$r4$	$r4$		$r4$	$r4$	

Identify:

(a) The entry that guarantees that addition is left-associative.

(b) The entry that guarantees that multiplication is left-associative.

(c) The two entries that guarantee that multiplication has precedence over addition.

9. Work the problems in lalrhandout1.pdf, lalrhandout2.pdf, lalrhandout3.pdf, and lalrhandout4.pdf on the Handouts page. There is overlap among those files. lalrhandout4 is where I go through the steps of building the Action and Goto tables from the grammar. I will post answers later.