University of Nevada, Las Vegas Computer Science 456/656 Spring 2023

Assignment 4: Due Saturday February 25, 2023, 11:59 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, Sandeep Maharjan, telling you how to turn in the assignment.

1. (i) **T** The complement of every undecidable language is undecidable.

   (ii) **F** Every context-free language can be parsed with an LALR parser.

   (iii) **F** LALR parsers require that the grammar be unambiguous.

   (iv) **F** Every context-sensitive language is decidable.

   (v) **T** If a language L is both RE and co-RE, L is decidable.

   (vi) **T** The set of undecidable binary languages is uncountable.

   (vii) **T** Every language has a canonical order enumeration.

   (viii) **T** A language L is accepted by some non-deterministic machine, if and only if L is recursively enumerable.

   (ix) **F** Since many programming languages are not context-free, LALR parsing is useless for those languages.

   (x) **T** If A and B are countable infinite sets, there must be a 1-1 correspondence between A and B.

   (xi) **F** The set of all real numbers is countable.

   (xii) **T** The set of all recursive real numbers is countable. (A real number x is called *recursive* if there is a machine M which runs forever, printing the decimal expansion of x. For example, π is recursive.)

   (xiii) **T** The context-free grammar equivalence problem is co-RE.

2. Consider the annotated CF grammar given below, with start symbol E. and the corresponding LALR parser given by the ACTION and GOTO tables. Write the computation of the parser with input string $x * (y - x)$, in the style used in the lalr handouts. There should be room on the right side of the page.

   1. $E \to E -_2 E_3$
   2. $E \to E *_4 E_5$
   3. $E \to (_6 E_7)_8$
   4. $E \to x_9$
   5. $E \to y_{10}$

ACTION / GOTO

	x	y	-	*	(	)	$	E
0	s9	s10			s6			1
1			s2	s4			HALT	
2	s9	s10			s6			3
3			r1	s4		r1	r1	
4	s9	s10			s6			5
5			r2	r2		r2	r2	
6	s9	s10			s6			7
7			s2	s4		s8		
8			r3	r3		r3	r3	
9			r4	r4		r4	r4	
10			r5	r5		r5	r5	

$\$_0$	$x * (y - x)\$$		
$\$_0 x_9$	$*(y - x)\$$		$s9$
$\$_0 E_1$	$*(y - x)\$$	4	$r4$
$\$_0 E_1 *_4$	$(y - x)\$$	4	$s4$
$\$_0 E_1 *_4 (_6$	$y - x)\$$	4	$s6$
$\$_0 E_1 *_4 (_6 y_{10}$	$-x)\$$	4	$s10$
$\$_0 E_1 *_4 (_6 E_7$	$-x)\$$	45	$r5$
$\$_0 E_1 *_4 (_6 E_7 -_2$	$x)\$$	45	$s2$
$\$_0 E_1 *_4 (_6 E_7 -_2 x_9$	$)\$$	45	$s9$
$\$_0 E_1 *_4 (_6 E_7 -_2 E_3$	$)\$$	454	$r4$
$\$_0 E_1 *_4 (_6 E_7$	$)\$$	4541	$r1$
$\$_0 E_1 *_4 (_6 E_7)_8$	$\$$	4541	$s8$
$\$_0 E_1 *_4 E_5$	$\$$	45413	$r3$
$\$_0 E_1$	$\$$	454132	$r2$
		454132	HALT

3. The CF grammar given in Problem 2 is ambiguous: a string can have more than one correct parse tree. The parser resolves the ambiguity. If the entry in row 3 column "$*$" were changed from s4 to r1, the parser would still compute a parse tree for every string in the language. So, why is it s4 instead of r1?

   Because multiplication has precedence over subtraction.

4. Similarly, If the entry in row 3 column "$-$" were changed from r1 to s2, the parser would still compute a parse tree for every string in the language. So, why is it r1 instead of s2?

   Because subtraction is left-associative.

5. Prove that the halting problem is undecidable.

   See the handout `halt.pdf` on my website.

6. Prove that every decidable language can be enumerated in canonical order by some machine.

   Let L be a decidable language over an alphabet Σ.

   Let $w_1, w_2, \ldots$ be a canonical order enumeration of Σ^*, which is easily generated by a simple program.

   The following (pseudo-code) program enumerates L in canonical order.

   For all $i = 1, 2, \ldots$
     If($w_i \in L$) (L is decidable, so this condition can be checked.)
       Write w_i.