CMPT 379: Principles of Compiler Design

Syntax Analysis Worksheet (Answers)

1. Given language $\left\{wcw^R | w \in (a|b)*\right\}$ (w^R is w in reverse), write a CFG which produces this language.
   Answer: $S \rightarrow aSa|bSb|c$
2. Given language $\left\{a^n b^m c^m d^n | n \geq 1, m \geq 1\right\}$, write a CFG which produces this language.
   Answer: $S \rightarrow aSd|aAd; A \rightarrow bAc|bc$
3. Does bottom-up parsing create a rightmost or leftmost derivation?
   Answer: Rightmost derivation (reversed).
4. Where is a handle located?
   Answer: At the top of the stack (as a sequence of symbols).

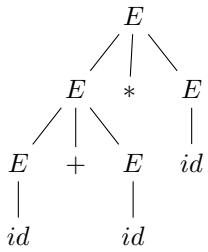
5. Given the production rules in table 1, write out the parse tree for the string $id + id * id$.

Figure 1: Question 5: Production Rules

$$E \to E + E$$
$$E \to E * E$$
$$E \to id$$

Answer: See figure 2.

Figure 2: Question 5: Parse Tree



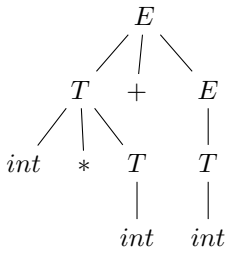
6. Given the production rules in table 3, write out the parse tree for the string $int * int + int$.

Figure 3: Question 6: Production Rules

$$E \to T + E$$
$$E \to T$$
$$T \to int$$
$$T \to int * T$$
$$T \to (E)$$

Answer: See figure 4.

Figure 4: Question 6: Parse Tree



7. Given the production rules and action/goto table in figure 5, write the trace of the LR(0) parse. Answer: See figure 6.

Figure 5: Question 7: Production Rules and Action/Goto Table

	Production Rules
1	$T \rightarrow F$
2	$T \rightarrow T * F$
3	$F \rightarrow id$
4	$F \rightarrow (T)$

States	**Actions**					**Gotos**	
	*	(	)	id	$	T	F
0		S5		S8	2	1	
1	R1	R1	R1	R1	R1		
2	S3				ACC		
3		S5		S8		4	
4	R2	R2	R2	R2	R2		
5		S5		S8		6	1
6	S3		S7				
7	R4	R4	R4	R4	R4		
8	R3	R3	R3	R3	R3		

Figure 6: Question 7: Answer

Stack	Input	Action
0	(id)*id	Shift 5
0, 5	id)*id	Shift 8
0, 5, 8	)*id	Reduce using production rule 3: $F \rightarrow id$
		Pop 1 symbol from the stack (8)
		Push $goto[5, F] = 1$ onto the stack
0, 5, 1	)*id	R1: $T \rightarrow F$
		Pop 1
		$goto[5, T] = 6$
0, 5, 6	)*id	S7
0, 5, 6, 7	*id	R4, $F \rightarrow (T)$
		Pop 6, 7, 5
		$goto[0, T] = 1$
0, 1	*id	R1: $T \rightarrow F$
		Pop 1
		$goto[0, T] = 2$
0, 2	*id	S3
0, 2, 3	id	S8
0, 2, 3, 8	$	R3: $F \rightarrow id$
		Pop 8
		$goto]3, F] = 4$
0, 2, 3, 4	$	R2: $T \rightarrow T * F$
		Pop 4, 3, 2
		$goto[0, T] = 2$
0, 2	$	ACCEPT

8. Given the set of production rules and dotted rule in figure 7, find the configuration set resulting from the closure of the dotted rule.

Figure 7: Question 8: Closure

Production Rules	$T \to F$
	$T \to T * F$
	$F \to id$
	$F \to (T)$
Dotted Rule	$T \to T * \bullet F$
$closure(T \to T * \bullet F)$	$T \to T * \bullet F$
	$F \to \bullet(T)$
	$F \to \bullet id$

9. Given a set of production rules, a configuration set, and a successive character in figure 8, apply the successor function to create a new configuration set.

Figure 8: Question 9: Successor

Production Rules	$S' \to T$
	$T \to F$
	$T \to T * F$
	$F \to id$
	$F \to (T)$
Configuration set I	$S' \to \bullet T$
	$T \to \bullet F$
	$T \to \bullet T * F$
	$F \to \bullet id$
	$F \to \bullet (T)$
$successor(I, \text{“(”})$	$F \to (\bullet T)$
	$T \to \bullet F$
	$T \to \bullet T * F$
	$F \to \bullet id$
	$F \to \bullet (T)$

10. Given a set of production rules in figure 9, find the First and Follow sets of the non-terminal symbols.

Figure 9: Question 10: First/Follow

Production Rules:	$A \rightarrow Bc \vert d$
	$B \rightarrow e$
First sets	$FIRST(A) = \{d, e\}$
	$FIRST(B) = \{e\}$
Follow sets	$FOLLOW(A) = \{\$\}$
	$FOLLOW(B) = \{c\}$

11. Given the set of production rules in figure 10, find the First and Follow sets of the non-terminal symbols.

Figure 10: Question 11: First/Follow

Production Rules:	$A \rightarrow Bc$
	$B \rightarrow d \vert BC \vert Be$
	$C \rightarrow f$
First sets	$FIRST(A) = \{d\}$
	$FIRST(B) = \{d\}$
	$FIRST(C) = \{f\}$
Follow sets	$FOLLOW(A) = \{\$\}$
	$FOLLOW(B) = \{c, e, f\}$
	$FOLLOW(C) = \{c\}$

12. Given a set of production rules in figure 11, find the First and Follow sets of the non-terminal symbols.

Figure 11: Question 12: First/Follow

Production Rules	$S \rightarrow AB$
	$A \rightarrow c \vert \epsilon$
	$B \rightarrow cbB \vert a$
First sets	$FIRST(A) = \{c, \epsilon\}$
	$FIRST(B) = \{c, a\}$
	$FIRST(S) = FIRST(A) = \{c, \epsilon\}$
Follow sets	$FOLLOW(A) = FIRST(B) = \{c, a\}$
	$FOLLOW(B) = \{\$\}$
	$FOLLOW(S) = \{\$\}$

13. Given a set of production rules in figure 12, find the First and Follow sets of the non-terminal symbols.

Figure 12: Question 13: First/Follow

Production Rules	$S \rightarrow cAa$
	$A \rightarrow cB \vert B$
	$B \rightarrow bcB \vert \epsilon$
First sets	$FIRST(A) = \{c, b, \epsilon\}$
	$FIRST(B) = \{b, \epsilon\}$
	$FIRST(S) = \{c\}$
Follow sets	$FOLLOW(A) = \{a\}$
	$FOLLOW(B) = FOLLOW(A) = \{a\}$
	$FOLLOW(S) = \{\$\}$

14. Given left-recursive grammar $A \rightarrow A*B|B; B \rightarrow a$, create an equivalent grammar which is no longer left-recursive.

Figure 13: Question 14: Answer

Production Rules	$X \rightarrow BA$
	$A \rightarrow *BA\|\epsilon$
	$B \rightarrow a$

15. Given grammar $A \rightarrow Bc|D; B \rightarrow ef; D \rightarrow e$, left-factor this grammar.

Figure 14: Question 15: Answer

Production Rules	$A \rightarrow eB$
	$B \rightarrow fc\|\epsilon$

16. Given the set of production rules in figure 15, remove left-recursion from the grammar.

Figure 15: Question 16: Production Rules

Production Rules	$S \rightarrow Aa \vert b$
	$A \rightarrow Ac \vert Sd \vert \epsilon$

Figure 16: Question 16: Answer

Remove $A \rightarrow S$ recursion	$S \rightarrow Aa \vert b$
	$A \rightarrow bdA' \vert A'$
	$A' \rightarrow A'c \vert A'ad$
Remove A' left-recursion	$S \rightarrow Aa \vert b$
	$A \rightarrow bdA' \vert A'$
	$A' \rightarrow cA' \vert adA'$

17. Given the set of production rules in table 17) which form an $LL(1)$ grammar, find the following symbols upon which the production rule $Y \rightarrow \epsilon$ is the valid option.

Figure 17: Question 17: LL(1) Conflict Resolution

Production Rules	$E \rightarrow TX$
	$X \rightarrow \epsilon$
	$X \rightarrow +E$
	$T \rightarrow (E)$
	$T \rightarrow idY$
	$Y \rightarrow *T$
	$Y \rightarrow \epsilon$
$FOLLOW(Y)$	$= FOLLOW(T)$
	$= (FIRST(X) - \{\epsilon\}) + FOLLOW(E)$
	$= \{+,), \$\}$