Computer Science Comprehensive Exam—Fall 2008
Compiler Construction

Instructions: Do *not* put your name on the exam, please answer all the questions directly on the exam itself. You may need scratch paper. Answer **all** the questions. Explain answers as fully as possible, give examples or define terms, if appropriate.

1. Suppose you are writing a compiler for a language like Modula-3 which has procedure variables. In the program `Main`, `x` is a procedure variable.

```
MODULE Main;
    TYPE f = PROCEDURE (z: INTEGER); (* procedure type *)
    VAR x: f;
    PROCEDURE P (z: INTEGER) = BEGIN (* ... *) END P;
BEGIN
    x := P;    (*  assignment  *)
    x(2);      (*  call        *)
END Main.
```

   Explain exactly how the assignment gets implemented and how the call gets implemented so that non-local variable access works correctly.

2. Give a regular expressions for comments in Ada. Comments in Ada begin with two dashes `--` and continue until the end of the line.

3. What is the definition of the FIRST(N) for some nonterminal N of a grammar?

4. What is the relationship between the set of languages recognized by LR(1) parsers and the set of languages recognized by SLR parsers? Circle the best response.

   (a) LR(1) is a proper subset of SLR
   (b) SLR is a subset of LR(1)
   (c) Their intersection is non-empty
   (d) Their intersection is empty
   (e) They are the same set

5. What is the relationship between the set, S, of ambiguous grammars and the set of LL(1) grammars? Circle the best response.

   (a) S is a proper subset of LL(1)
   (b) LL(1) is a proper subset of S
   (c) Their intersection is non-empty
   (d) Their intersection is empty
   (e) They are the same set

6. What is the relationship between the set of languages recognized by LR(1) parsers and the set of languages recognized by LL(1) parsers? Circle the best response.

   (a) LR(1) is a proper subset of LL(1)
   (b) LL(1) is a subset of LR(1)
   (c) Their intersection is non-empty
   (d) Their intersection is empty
   (e) They are the same set

7. What is the relationship between the set of languages recognized by LR(1) parsers and the set of languages recognized by LALR(1) parsers? Circle the best response.

   (a) LR(1) is a proper subset of LALR(1)
   (b) LALR(1) is a proper subset of LR(1)
   (c) Their intersection is non-empty
   (d) Their intersection is empty
   (e) They are the same set

8. What is the relationship between the set, S, of ambiguous grammars and the set, T, of unambiguous grammar? Circle the best response.

   (a) S is a proper subset of T
   (b) T is a proper subset of S
   (c) Their intersection is non-empty
   (d) Their intersection is empty
   (e) They are the same

9. Consider the following grammar with non-terminals $\{S, E, B, L\}$.

1 $S \rightarrow \textbf{print}\,(\,E\,)\,;$
2 $S \rightarrow \textbf{while}\,(\,B\,)\,S$
3 $S \rightarrow \{\,L\,\}$
4 $E \rightarrow \textbf{id}$
5 $E \rightarrow \textbf{num}$
6 $B \rightarrow E > E$
7 $L \rightarrow S\,L$
8 $L \rightarrow \epsilon$

(a) Compute nullable, FIRST, and FOLLOW for all nonterminals of the grammar.

	nullable	FIRST	FOLLOW
S			
E			
B			
L			

(b) Fill-in the table below. Fill-in the FIRST of the right-hand side, or the FOLLOW of the left-hand side, as appropriate for computing the LL(1) parsing table.

$N \rightarrow \alpha$	*null*(α)?	FIRST(α)	FOLLOW(N)
1 $S \rightarrow \textbf{print}\,(\,E\,)\,;$			
2 $S \rightarrow \textbf{while}\,(\,B\,)\,S$			
3 $S \rightarrow \{\,L\,\}$			
4 $E \rightarrow \textbf{id}$			
5 $E \rightarrow \textbf{num}$			
6 $B \rightarrow E > E$			
7 $L \rightarrow S\,L$			
8 $L \rightarrow \epsilon$			

(c) Fill-in the partial LL(1) parse table below for the indicated terminals.

	id	**num**	**while**	**print**	{	}
S						
E						
B						
L						

10. For an arbitrary grammar, give the definition of an LR(1) item.

11. For an arbitrary grammar, sketch the algorithm for computing the *closure* of a set of LR(1) items

12. For the following augmented grammar:

$$
\begin{array}{llll}
0 & S' & \rightarrow & S\,\$ \\
1 & S & \rightarrow & V = E \\
2 & S & \rightarrow & E \\
3 & E & \rightarrow & V \\
4 & V & \rightarrow & \textbf{id} \\
5 & V & \rightarrow & \textbf{*}\,E
\end{array}
$$

(a) Give a diagram of the LR(1) states and transitions

(b) Give the LR(1) parsing tables.