# Computer Science Comprehensive Exam—Spring 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. In general terms, what are the major steps of the typical compiler for an imperative language?

2. What is the difference between an abstract syntax tree and a concrete parse tree?

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

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

5. 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

6. 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

7. 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

8. 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

9. 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

10. 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*$(N)$? | FIRST$(\alpha)$ | 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** | { | } |
|---|---|---|---|---|---|---|
| $S$ | | | | | | |
| $E$ | | | | | | |
| $B$ | | | | | | |
| $L$ | | | | | | |

11. Give the definition of an LR(1) item for an arbitrary grammar.

12. Sketch the algorithm for computing the closure of a set of LR(1) items for an arbitrary grammar.

13. For the following 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 the LR(1) states.

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