Computer Science Comprehensive Exam—Fall 2004
Compiler Construction

**Instructions:** Do *not* put your name on the exam, please answer all the questions directly on the exam itself. Answer **all** the questions. You have 90 minutes. Explain answers as fully as possible, give examples or define terms, if appropriate.

1. What is the relationship between the set of languages generated by ambiguous grammars and the set of languages recognized by LR(1) parsers? Circle the best response.
   (a) ambiguous grammars are a subset of LR(1)
   (b) LR(1) is a subset of ambiguous grammars
   (c) Their intersection is non-empty
   (d) Their intersection is empty
   (e) They are the same

2. 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 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

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

4. Name one specific use for dataflow analysis in a compiler.

5. Consider the following augmented grammar over the alphabet $\{\mathbf{id}, (, )\}$.

$$\begin{array}{ll} 0 & S \rightarrow E\,\$ \\ 1 & E \rightarrow T\,\$ \\ 2 & E \rightarrow E{+}T \\ 3 & T \rightarrow \mathbf{id} \\ 4 & T \rightarrow (\,E\,) \end{array}$$

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

| | *nullable* | FIRST | FOLLOW |
|---|---|---|---|
| $S$ | | | |
| $E$ | | | |
| $T$ | | | |

(b) Give the LR(0) automaton for the grammar. Give the LR(0) parse table. Is the grammar LR(0)?

6. Consider the algorithm to compute CLOSE[$I$] for the set of LR(1) items $I$ for some grammar. Suppose the grammar contains the production $X \rightarrow \gamma$ where $X$ is some non-terminal and $\gamma$ is some string of terminals and non-terminals. Answer the following questions assuming $y$ and $z$ are terminal symbols.

   (a) If $A \rightarrow \alpha \bullet X,\ z$ is in $I$, which item or items (if any) would be added to CLOSE[$I$]?

   (b) If $A \rightarrow \alpha \bullet X y,\ z$ is in $I$, which item or items (if any) would be added to CLOSE[$I$]?

   (c) If $A \rightarrow \alpha \bullet X \beta,\ z$ is in $I$, which item or items (if any) would be added to CLOSE[$I$]?

7. Using Sethi-Ullman register allocation, generate code for the following expression:

$$(a + b \times c + d) \times (e + a)$$

First, draw a tree for the given expression and label each node with the number of registers it needs during evaluation. Then give the generated code, use instructions like $r_1 \leftarrow M[a]$ (load `a` into register 1), $r_2 \leftarrow r_3 \times r_4$, $r_1 \leftarrow r_3 - r_2$, etc.