Computer Science Comprehensive Exam—Fall 1999
Compiler Construction

Instructions: Please answer all the questions directly on the exam itself. Answer **all** the questions. Explain answers as fully as possible, give examples if appropriate, define terms.

1. Name two compiler optimizations and then describe them.

   Answer:

2. Give a simple context free grammar for expressions including subtraction and multiplication. You are free to choose any typical language of expressions. Your grammar must exhibit the typical precedence of subtraction and multiplication.

   Answer:

3. Describe how a compiler translates `new`, dynamic memory allocation, with reference to the runtime organization of the program.

   Answer:

4. Describe how to implement non-local variable access in typical block-structured, statically-scoped programming languages.

   Answer:

5. Write an NFA (using Thomson's construction) and a DFA (using the subset construction) over the alphabet $\{a, b\}$ that recognizes strings defined by the regular expressions $(ab)^* \mid a$.

   (a) Use Thomson's construction to make an NFA that recognizes strings defined by the regular expressions $(ab)^* \mid a$. Be sure to label the arcs and indicate the final states.

   Answer:

   (b) Convert the NFA constructed above to a DFA using the subset construction. *Answer:*

   (c) Every state of the DFA corresponds to a set of states in the NFA. Fill in the following table to show the correspondence.

DFA	NFA
1	ϵ-closure $\{A\} = \{A, B, C, D, G, I\}$
2	ϵ-closure $\{E, H\} = \{E, H, I\}$
3	ϵ-closure $\{F\} = \{D, F, G, I\}$
4	ϵ-closure $\{E\} = \{E\}$

6. Consider the following grammar:

$$
\begin{array}{lcl}
E & \rightarrow & -\,E \\
E & \rightarrow & (\,E\,) \\
E & \rightarrow & V\,T \\
T & \rightarrow & -\,E \\
T & \rightarrow & \epsilon \\
V & \rightarrow & \mathbf{id}\,L \\
L & \rightarrow & (\,E\,) \\
L & \rightarrow & \epsilon
\end{array}
$$

(a) Compute the *FIRST* and *FOLLOW* for all nonterminals.

	FIRST	*FOLLOW*
E	**id**, (, $-$	), \$
T	ϵ, $-$	), \$
V	**id**	), $-$, \$
L	ϵ, (	), $-$, \$

(b) Compute the *FIRST* of the RHS of all productions.

			α	*FIRST*(α)
1	E	$\rightarrow$	$-\,E$	$-$
2	E	$\rightarrow$	$(\,E\,)$	(
3	E	$\rightarrow$	$V\,T$	**id**
4	T	$\rightarrow$	$-\,E$	$-$
5	T	$\rightarrow$	ϵ	), \$
6	V	$\rightarrow$	**id** L	**id**
7	L	$\rightarrow$	$(\,E\,)$	(
8	L	$\rightarrow$	ϵ	), $-$, \$

(c) Is the grammar LL(1)? Explain.
Answer: Yes, no conflicts in parsing table.

7. Consider the following grammar.

$$
\begin{aligned}
N &\rightarrow NB \\
N &\rightarrow B \\
B &\rightarrow 1 \\
B &\rightarrow 0
\end{aligned}
$$

Using the given LR parsing table, show the parsing steps of the string 110 by filling in the last 8 steps of the diagram.

Parse Table

State	1	0	$	N	B
0	s3	s4		1	2
1	s3	s4	acc		5
2	r2	r2	r2		
3	r3	r3	r3		
4	r4	r4	r4		
5	r1	r1	r1		

	stack	input	action
(1)	0	1 1 0 $	shift 3
(2)	0 1 3	1 0 $	reduce by $B \rightarrow 1$
(3)	0 B 2	1 0 $	reduce by $N \rightarrow B$
(4)	0 N 1	1 0 $	shift 3
(5)	0 N 1 1 3	0 $	reduce by $B \rightarrow 1$
(6)	0 N 1 B 5	0 $	reduce by $N \rightarrow NB$
(7)	0 N 1	0 $	shift 4
(8)	0 N 1 0 4	$	reduce by $B \rightarrow 0$
(9)	0 N 1 B 5	$	reduce by $N \rightarrow NB$
(10)	0 N 1	$	accept