Total marks 65 - Total time is 50 minutes. Answer all 4 questions.

Instructions: This midterm is open book, open notes. Non-programmable calculators allowed. No electronic communication devices allowed.

The line numbers in grammars are for reference only and are not part of the grammars. Ellipses ... indicate omitted, correct text. $\epsilon$ indicates an empty string.

If you need to make any assumptions in order to answer a question, state the assumptions clearly in your answer book.

I. [7 marks] Type declarations.

Let the following type declaration in a fictional (but inspired by Pascal) language be given:

```plaintext
typedef B = *A;  /* create a type of pointers to type A */
typedef A =
    X : integer;
    Y : B;
end;

var Z : A;
```

1. [5 marks] Without defining new types, can you create an expression that is structure equivalent to $Z$ (other than $Z$ itself)? If so, do it. If not - explain why not.

2. [2 marks] What about name equivalent to $Z$?

II. [20 marks] Parsing and Lexical Analysis.

Suppose we are interested in defining $\textit{const}$, and are doing so with the following set of expressions:

1. $\textit{const} ::= \textit{id} \mid \textit{number} \mid \textit{intconst} \mid \epsilon$
2. $\textit{number} ::= \textit{bin} \mid \textit{oct} \mid \textit{hex}$
3. $\textit{le} ::= \textit{a}-\textit{z}$
4. $\textit{di} ::= 0-9$
5. $\textit{bin} ::= b (0 1)^+$
6. $\textit{oct} ::= o (0|1|2|3|4|5|6|7)^+$
7. $\textit{hex} ::= h (\textit{di}|\textit{A}|\textit{B}|\textit{C}|\textit{D}|\textit{E}|\textit{F})^+$
8. $\textit{intconst} ::= \textit{di}^+$
9. $\textit{id} ::= \textit{le}(\textit{le}|\textit{di})^+$

1. [8 marks] Create the NFA for recognizing $\textit{const}$.

2. [8 marks] Make this automaton deterministic.

3. [4 marks] Is the resulting grammar LL(1)?
III. [18 marks] LL parsing.
Let the following grammar be given:

\[
\begin{align*}
1: & \quad S ::= E \\
2: & \quad E ::= \neg E \\
3: & \quad \mid (E) \\
4: & \quad \mid E - V \\
5: & \quad \mid V \\
6: & \quad V ::= \text{id} \\
7: & \quad \mid \text{id} (E) \\
\end{align*}
\]

1. [4 marks] Is this grammar LL(1)? If not, convert it into an LL(1) grammar.

2. [10 marks] Create the LL(1) parse table for the (potentially modified) grammar.

3. [4 marks] Is this grammar LR(1)? Explain why or why not.

IV. [20 marks] LR parsing.
Show that the following grammar is LALR(1) but not SLR(1):

\[
\begin{align*}
1: & \quad S ::= A a \\
2: & \quad \mid b A c \\
3: & \quad \mid d c \\
4: & \quad \mid b d a \\
5: & \quad A ::= d \\
\end{align*}
\]