1. (3 pts) Consider the following grammar.

   \[ S \rightarrow bbCd \mid bbc \]
   \[ C \rightarrow cC \mid c \]

   The grammar is LL(k) for what value of \( k \)?

2. (18 pts) Construct the LR parsing table for the following grammar (DO NOT change the grammar.) A new start symbol \( S' \) and production have already been added to the grammar.

   1) \( S' \rightarrow S \)
   2) \( S \rightarrow Dc \)
   3) \( D \rightarrow dA \)
   4) \( D \rightarrow \lambda \)
   5) \( A \rightarrow aS \)
   6) \( A \rightarrow a \)

   (a) Calculate the FIRST and FOLLOW sets of variables.

   \[
   \begin{array}{|c|c|}
   \hline
   & \text{FIRST} & \text{FOLLOW} \\
   \hline
   S & & \\
   D & & \\
   A & & \\
   \hline
   \end{array}
   \]

   (b) Construct the transition diagram of the DFA that models the stack. Number the states, show marked productions, and identify final states by two circles.

   (c) Construct the LR parse table that corresponds to the transition diagram drawn in part b. (Note: all the rows and columns given may not be needed. If there are multiple items for an entry, put both.)
3. (3 pts) Eliminate useless productions from the following grammar. Use the algorithm from the lecture notes.

\[
\begin{align*}
S & \rightarrow \text{a} \mid \text{aA} \mid \text{B} \mid \text{C} \\
A & \rightarrow \text{aB} \mid \lambda \\
B & \rightarrow \text{Aa} \mid \text{C} \\
C & \rightarrow \text{cCD} \\
D & \rightarrow \text{ddd}
\end{align*}
\]

In particular, give the set \( V_1 \), the dependency graph and the new grammar.

4. (3 pts) Eliminate all \( \lambda \)-productions from the following grammar. Use the algorithm from the lecture notes.

\[
\begin{align*}
S & \rightarrow \text{AaB} \mid \text{aaB} \\
A & \rightarrow \lambda \\
B & \rightarrow \text{bbA} \mid \lambda
\end{align*}
\]
In particular, give the set $V_N$ and the new grammar.

5. (3 pts) Remove the unit productions from the following grammar. Use the algorithm from the lecture notes.

\[
\begin{align*}
S &\rightarrow a \mid aA \mid B \mid C \\
A &\rightarrow aB \mid \lambda \\
B &\rightarrow Aa \mid C \\
C &\rightarrow cCD \\
D &\rightarrow ddd
\end{align*}
\]

In particular, show the dependency graph, and the new grammar.

6. (3 pts) Convert the following grammar into Chomsky Normal Form.

\[
\begin{align*}
S &\rightarrow abAB \\
A &\rightarrow bAB \mid \lambda \\
B &\rightarrow BAa \mid A \mid \lambda
\end{align*}
\]