1. Determine if each of the following claims is true (T) or false (F).

_____ A language consists of a set of strings, its grammar structure, and a set of operations.

_____ Tokens can be described using regular grammars (RGs) but not context free grammars (CFGs).

_____ NFA is more powerful than DFA since it allows epsilon and nondeterministic moves.

_____ L1=\{[i^+]|i>=1\} CANNOT be described using a regular expression (RE).

_____ Since C language is a context free language, we use CFG to parse C programs.

_____ A grammar is considered ambiguous if, for a sentence in the language generated by the grammar, we can find two or more parse trees.

_____ Given a sentence to parse, top-down parsing strategies such as LL(k) find its left-most derivation starting from the start symbol.

_____ LR(k) can process both left-recursive and right-recursive grammars.

_____ LL(2) parse table is bigger than LL(1) parse table.

_____ For LR-parsing, a handle always appears on the top of the syntax stack.

_____ SLR(1) parsing is less powerful than LR(1).

_____ The parse scheme used in YACC tool is LALR parsing.

_____ For LALR parsing, when an error is detected, the content stored in the syntax stack may become non-viable.

_____ Type checking removes all type errors in the program.

\[
\begin{align*}
O \vdash e_0 : T \\
T \leq T_0 \\
O[T_0/x] \vdash e_1 : T_1 \\
O \vdash \text{let } x : T_0 \leftarrow e_0 \text{ in } e_1 : T_1
\end{align*}
\]

_____ is a correct let-rule for declaration with initialization.
2. Give **brief** answers to the following questions.

   a. What is left factoring? Why is it necessary in a predictive parser but not a recursive descent parser?

   b. Describe two ways that you could extend the power of an SLR(1) parser so that it can parse more grammars.

   c. Write a grammar for the pattern $a^i b^j c^i (i,j \geq 1)$.

   d. In an LR(1) state graph, for the following conflicting states:

      $\text{S1} = \{ \ldots [A \rightarrow \cdot \ a \ B , \ c/d], \ [ \ C \rightarrow \ e \ \cdot , \ c/d ], \ [ \ E \rightarrow \ e \ \cdot , \ a ] \ \} $

      The items that conflict are ____________________

      Type of conflict is ____________________

      $\text{S2} = \{ \ldots [A \rightarrow \cdot \ a \ B , \ c/d], \ [ \ C \rightarrow \ e \ \cdot , \ c/d ], \ [ \ F \rightarrow \ e \ \cdot , \ c/d ] \ \} $

      The items that conflict are ____________________

      Type of conflict is ____________________

   e. Briefly describe LL(0) and LR(0) grammars. That is what does lookahead 0 mean for each of these grammars?
3. Construct a DFA for the following NFA:

![DFA Diagram]

4. Give the First and Follow sets of the following grammar and then explain why or why not the grammar is LL(1). Explain in words without building the parse table. All capital letters are non-terminals and small letters are terminals.

\[
\begin{align*}
S & \rightarrow \text{A B C} \\
A & \rightarrow \text{a | B B} \\
B & \rightarrow \text{b | C} \\
C & \rightarrow \text{c | } \epsilon
\end{align*}
\]

Fill in the first and follow set table for non-terminal symbols.

<table>
<thead>
<tr>
<th>First Set</th>
<th>Follow Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>N/A</td>
</tr>
<tr>
<td>b</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

Is the grammar LL(1)?
5. Considering the following augmented grammar,

\[
\begin{align*}
0: & \quad S' \rightarrow S \\
1: & \quad S \rightarrow S \ A \\
2: & \quad S \rightarrow A \\
3: & \quad A \rightarrow a \\
4: & \quad A \rightarrow ( S )
\end{align*}
\]

(1) Complete the construction of LR(0) set of items and the state graph.
(2) Build the parse table; and
(3) Decide if the grammar is SLR(1) or not.
6. Given the following inference rules:

\[
\frac{i \text{ is an integer}}{i \ : \ int} \quad \text{and} \quad \frac{e_0 \ : \ int}{e_1 \ : \ int} \quad \frac{e_0 + e_1 \ : \ int}{
\]

Prove the following:

\[
\frac{3 \text{ is an integer}}{4 \text{ is an integer}} \quad \frac{5 \text{ is an integer}}{3 + 4 + 5 \ : \ int}
\]