This is a “closed everything” test. Answer all questions.

Keep this page up until told to start
In this test the following alphabetic sets can be used.

**Alpha** ::= a | b | c | d | e | f | g | h | i | j | k | l | m | n | o | p | q | r | s | t | u | v | w | x | y | z

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z

**Num** ::= 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9

1. [20] Specify the lexical structure of HTML. Here is an example of HTML

```html
<html><head><title>Any sequence of letters numbers </title></head>
<body>
  <p width="100">Tags are reserved words, like body, enclosed in brackets; ending tags have a slash before the reserved word. Inside of tags are attribute keywords, like width, which are followed by an equal sign delimiter and a value in quotes. Values are either all numerical, all alphabetic or a mixture of each. Tags bracket text that is a mix of numbers and letters and for paragraph (p) tagged text, bracketed text. Note overall head-body structure.
  </p>
</body>
</html>
```

Using the example as a guideline, define the LEXICAL structure of HTML by completing the following definition. (Note, the check that tags match is a syntactic part of the language.) HINT: The underlined words above refer to lexically important concepts that could correspond to a set of tokens. It is sufficient to handle the example, not all of HTML.

```plaintext
<program> ::= (<bracked_unit> | <white_space>)*
```
2. [5] Lexical analysis is the only pass that “sees” the actual text of a program, and therefore the only pass that can know which line an identifier is on. Line numbers are useful for error messages. Explain (briefly!) how a compiler can know the line number of each occurrence of an identifier in the program text. (Explaining how jflex does it would be a good answer.)

3. [15] Tables in HTML are specified with matching table tags containing a sequence of one or more rows, which are matching table-row tags, containing a sequence of one or more matching table-data tags, which can contain a mix of letters and numbers, or tables. White space is allowed. For example,

```html
<table>
  <tr><td>stuff</td><td>goes here</td></tr>
  <tr><td>good stuff usually</td></tr>
</table>
```

Give an EBNF specification for HTML tables.

4. [7] Given the following grammar, form the closure for the production $S ::= \{ .L \}$ for an LR parser.

$$S ::= \{ .L \}$$

$$S' ::= S \; \$\$$
$$S ::= \textbf{beep} \mid \{ \; L \}$$
$$L ::= S \mid L \; S$$
5. [5] The following grammar is suspected to be ambiguous. Show that it is, or argue that it can’t be.

\[
S ::= \text{beep} \mid b + B \mid B \mid \{ S \}
\]

\[
B ::= \text{bop} + B \mid \text{bop} \mid \{ \text{beep} \}
\]

6. [10] Give (a) the concrete syntax tree and (b) the abstract syntax tree for:

(a || b) && c using the grammar and MiniJava-like nodes.

\[
E ::= E \mid\mid T \mid T
\]

\[
T ::= T \&\& F \mid F
\]

\[
F ::= \text{id} \mid \text{!id} \mid ( E )
\]

<table>
<thead>
<tr>
<th>Derivation</th>
<th>AST</th>
</tr>
</thead>
</table>
7. [10] Given the following NFA, use the subset construction to find an equivalent DFA.

![NFA Diagram]

8. [8] Semantic analysis is a left-most traversal of the abstract syntax tree. Say, briefly, what the activity the semantic analysis pass performs as it moves around the tree:
   a) At internal nodes on the “down sweep”

   b) At leaf nodes

   c) At the internal nodes on the “up sweep”
9. [5] Your friend is new to programming and is having trouble understanding the EBNF for MiniJava:

\[
\text{Stmt ::= Type ID ; } \]
\[
\text{ } \}
\text{if ( Expr ) Stmt else Stmt} \]
\[
\text{while ( Expr ) Stmt} \]
\[
\text{System.out.println ( Expr ) ;} \]
\[
\text{ID = Expr ;} \]

Answer your friend’s questions about the language: “How do you know when to put in a semicolon after a statement?”

10. [20] Given the following AST, list each semantic check that would be performed during a semantic analysis pass. Suggestion: List them bottom up.

   1.
   2.