Sample

**Mid-term Exam**
**Open book/notes**

**1. [30 points]**

The context-free grammar (Σ = {a, b, c, '+', '*', '(', ')'}), non-terminals E (start symbol) and I short for Expression and Identifier, respectively)

E → E+E | E*E | (E) | I

I → *a* | b | c

generates *all* well-formed arithmetic expressions involving the operators + and *, parentheses, and the identifiers a, b, and c. However, it is ambiguous.

(a) show why this grammar is ambiguous [15 points]

(b) construct an equivalent unambiguous grammar — include justification that your grammar is both equivalent and unambiguous [15 points].

**2. [35 points]**

For this problem you are to devise an attribute grammar whose terminal alphabet is {0,1} and having a Boolean-valued attribute called 'valid' (and other attributes if you wish) that is true for the root node of a derivation tree just in case the derived string is of the form $0^k1w$ ($k \geq 0$) for $w \in \{0,1\}^*$ where the longest substring(s) of *consecutive* '0's in w (there could be several) has length exactly k. Each such string $0^k1w$ (and no doubt others) should be derivable with your grammar. For instance, 0010100100 is valid, while 0010110 and 0010100011 are invalid. Your answer should cover the following:

(a) besides those required above, what strings are derivable with your context-free grammar component,

(b) characterize each attribute you introduce as either synthesized or inherited and state any dependencies in the order of their evaluation,

(c) explain why the 'valid' attribute evaluates to true for the proper strings, and false for all others that are derivable.

**3. [35 points]**
Modify the formal denotational definition of Wren (Figure 9.11 of our text, page 291) to add the semantics for the following command:

<command> ::= **watch** <variable> **do** <command> **end watch**

The informal description of the desired semantics is that the execution of the watch-command causes no immediate effect, but after its execution, any subsequent *change* to the <variable> will cause the immediate execution of the command following **do**, and after its completion, execution resumes normally.

This new command introduces an additional reserved word and context conditions (e.g., the watch-variable must be a declared variable), but you are not responsible for these issues in this problem. You need only make changes in the denotational semantics (i.e., domains and equations) to capture the informally stated semantics. Justify that the effect of your changes accomplishes the required behavior.