

Name: _____

Solutions

1. (1 pt.)
 - **Read all material carefully.**
 - *If in doubt whether something is allowed, ask, don't assume.*
 - You may refer to your books, papers, and notes during this test.
 - E-books may be used.
 - Computers are permitted but discouraged.
 - **Electronic and network resources must only be used as a passive library.**
 - Write, and draw, carefully. Ambiguous or cryptic answers receive zero credit.
 - Use class and textbook conventions for notation, algorithmic options, etc.

Write your name in the space provided above.

2. (3 pts.) Write down the names of the three kinds of stacks used by the *JCoCo virtual machine*.
(A) *Run-time stack (or call stack); operand stack; block stack.*
3. (3 pts.)
 - (a) What is the primary programming language **in which** the JCoCo virtual machine is implemented? (A) *Java.*
 - (b) What is the primary programming language **for which** (to implement which) the JCoCo virtual machine is designed? (A) *Python. [Assembler/Assembly is also acceptable but Python is the better answer.]*
 - (c) From where do JCoCo instructions typically get their operands? (Name the specific part of the virtual machine where the operands reside.) (A) *The operand stack.*
4. (3 pts.) Consider the following context-free grammar from the textbook page 40 except that, for clarity in printing, it uses the symbol \odot instead of $.$ (period):

$$\begin{aligned} E &\rightarrow E+T \mid T \\ T &\rightarrow T \odot K \mid K \\ K &\rightarrow F* \mid F \\ F &\rightarrow \text{character} \mid (E) \end{aligned}$$

For each symbol used above ($E, T, K, F, \rightarrow, \mid, +, \odot, *, \text{character}, (, \text{and })$), indicate whether it belongs to the *language* (defined by the grammar) or the *metalanguage* or

the *meta-metalanguage*. Provide *brief* explanations **iff** (if and only if) you wish to qualify for any partial credit.

Ⓐ Language symbols: +, \odot , *, (,). Metalanguage (CFG) symbols: E, T, K, F, \rightarrow . Meta-metalanguage symbols: | (shorthand for multiple rules), **character** (shorthand for a rule for each character). [There is some permissible variation in answers.]

5. (2 pts.) Provide a sentence (input string) that belongs to (is accepted by) the language defined by the grammar of Question 4. (If the grammar does not accept any strings then briefly explain why that is so. Otherwise, no explanation is needed here.)

Ⓐ c (the single character c). [There are very many correct answers, and likewise for incorrect ones.]

6. (3 pts.) Provide a leftmost derivation of the sentence of Question 5. For each step of the derivation, indicate which rule is used (by numbering rules starting at 1) as well as which nonterminal is replaced (by underlining it).

Ⓐ [As in Q 5, there are many correct answers here, but only one correct answer corresponding to each correct answer to the earlier question.] $\underline{E} \xrightarrow{2} \underline{T} \xrightarrow{4} \underline{K} \xrightarrow{6} \underline{F} \xrightarrow{7} c$

7. (5 pts.) State clearly whether the *sentence* below is *valid* (belongs to the language of) the grammar of Question 4.

$h \odot i \odot i *$

If it is valid then provide a leftmost derivation for it; else explain (as precisely as possible) why it is not.

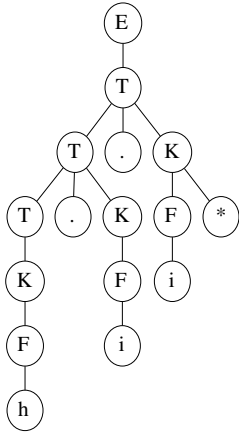
Ignore all whitespace and assume that **character** in the grammar refers to a lowercase letter in the range **a** through **z**.

Ⓐ The sentence is valid. Leftmost derivation, with each number above an arrow denoting the rule used in that step: $\underline{E} \xrightarrow{2} \underline{T} \xrightarrow{3} \underline{T} \odot K \xrightarrow{3} \underline{T} \odot T \odot K \xrightarrow{4} \underline{K} \odot T \odot K \xrightarrow{6} \underline{F} \odot T \odot K \xrightarrow{7} h \odot \underline{T} \odot K \xrightarrow{4} h \odot \underline{K} \odot K \xrightarrow{6} h \odot \underline{F} \odot K \xrightarrow{7} h \odot i \odot \underline{K} \xrightarrow{5} h \odot i \odot \underline{F} \xrightarrow{7} h \odot i \odot i *$

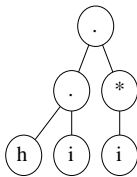
8. (5 pts.) Provide a parse tree for the sentence of Question 7.

If (and only if) that sentence is not valid then make as small a change as possible to yield a valid sentence and then provide a parse tree for that changed sentence.

Ⓐ [There is only one correct parse tree.]



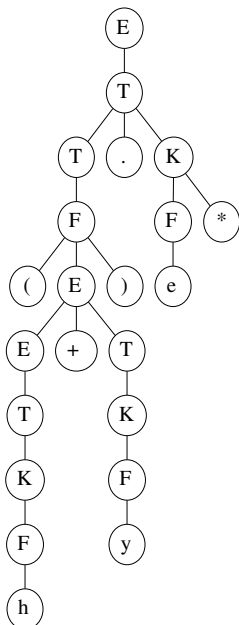
9. (5 pts.) Repeat Question 8 using an *abstract syntax tree* instead of a parse tree.
 (A) [It is important to recognize that the * is a unary operator.]



10. (10 pts.) For the language defined by the grammar of Question 4, is following sentence valid (accepted by the grammar)?
 (h + y) ⊙ e *

If it is not valid, then make as small a change as possible to result in a valid sentence. Further, using either the original or modified sentence as appropriate, provide either a parse tree or a leftmost derivation (your choice).

- (A) [There is only one correct parse tree.]



11. (5 pts.) Repeat Question 10 using a *abstract syntax tree* instead of a parse tree.

Ⓐ [The abstract syntax tree depicted here is preferred, but there are some acceptable variants. For example, the parentheses (together) may be considered an operator and mapped to a node in the AST.]

