CS116-Automata Theory and Formal Languages
Problem Set on Context-Free Grammars
1st semester 2025-2026

I. Give simple English language descriptions for the following grammars (In all CFGs, ***S*** is the start variable):

1. $G1 : S \rightarrow aS \mid a$

2. $G2 : S \rightarrow aSa \mid aa \mid a$

3. $G3 : S \rightarrow SaS \mid a$

4. $G4 : S \rightarrow aSa \mid aT\,b \mid bT\,a \mid bT\,b$

$T \rightarrow aT \mid bT \mid \lambda$

II. Is the following grammar G ambiguous? Justify your answer.

$G : S \rightarrow SaS \mid a \mid b$

III. The following grammar generates postfix expressions with operands ***x*** and ***y*** and binary operators **+,−,** $*$ and **/**:

$G : E \rightarrow EE + \mid EE - \mid EE * \mid EE / \mid x \mid y$

For the string ***xyxyx*** $- * + /$, give a parse tree, a leftmost derivation and a rightmost derivation.

IV. Design a CFG for each of the following languages. Make sure you specify the grammar 4-tuple description (i.e., *G=(V, T, P, S)*) in addition to providing the productions.

1. L1 = $\{a^i b^j c^k \mid (i \neq j)$, where i, j, $k \geq 0\}$

2. L2 = $\{ a^i b^j c^k \mid (i \neq k)$, where i, j, $k \geq 0\}$

3. L3 = $\{ a^i b^j c^k \mid (i \neq j$ or $i \neq k)$, where i, j, $k \geq 0\}$

4. The set of all strings over alphabet {a, b} such that the number of a's is at least as many as the number of b's.

5. The set of all strings over alphabet {a, b} that are of odd length.

V. Simplify and convert the following CFGs into Chomsky Normal Form and Greinbach Normal Form.

1. $G2 : S \rightarrow aSa \mid aa \mid a$

2. $G4 : S \rightarrow aSa \mid aT\,b \mid bT\,a \mid bT\,b$

$T \rightarrow aT \mid bT \mid \lambda$