

[5] 1. Give a grammar equivalent to $G = (\{S\}, \{a, b\}, P, S)$ where $P = \{S \rightarrow SS \mid SSa \mid bS \mid ab\}$, but with no immediate left-recursion.

[10] 2. Prove that $L = \{w \in \{a, b, c\}^+ \mid \#_a(w) = \#_b(w) = \#_c(w)\}$ is not a context-free language.

[25] 3. Let $L = \{a^n b^m \mid 1 \leq n \leq m \leq 2n\}$

[5] (a) Find a cfg for L

[5] (b) Give a CNF grammar for L .

[5] (c) Give a GNF grammar for L .

[5] (d) Give a one-state pda accepting L .

[5] (e) Give a pda accepting L by final state.

[10] 4. Let M be a pda for which there exists a constant k s.t. ~~at most~~ at most k symbols can be on the stack at one time. Show that $L_f(M)$ is a regular language. [Hint: find a fsa accepting $L_f(M)$].