

## CMPE 350 - Spring 2019

### PS 5 - 18.03.19

**2.4** Give context-free grammars that generate the following languages.

- a)  $\{w \mid w \text{ contains at least three 1's}\}$
- b)  $\{w \mid w \text{ starts and ends with the same symbol}\}$
- c)  $\{w \mid \text{the length of } w \text{ is odd}\}$
- d)  $\{w \mid \text{the length of } w \text{ is odd and its middle symbol is a 0}\}$
- e)  $\{w \mid w = w^R\}$
- f) The empty set

**2.6** Give context-free grammars that generate the following languages.

- a) The set of languages over the alphabet  $\{a, b\}$  with more  $a$ 's than  $b$ 's.
- b) The complement of the language  $\{a^n b^n \mid n \geq 0\}$
- c)  $\{w \# x \mid w^R \text{ is a substring of } x \text{ for } w, x \in \{0, 1\}^*\}$

**2.8** Show that the class of context-free languages are closed under the regular operations union, concatenation and star.

**2.26** Show that if  $G$  is a CFG in Chomsky Normal Form, then for any string  $w \in L(G)$  of length  $n \geq 1$ , exactly  $2n - 1$  steps are required for any derivation of  $w$ .

- Montext-free grammars are context-free grammars with at most one (terminal or variable) symbol at the right hand side of every rule. Do they generate any nonregular language? Do they generate all regular languages?