

# CS344: Programming Languages

## Homework 4

### Required Problems

1. Give context-free grammars generating the following languages:

(a)  $L_1 = \{a^n b^p \mid 0 < p < n\}$ .

(b)  $L_2 = \{a^n b^n c^m d^m \mid n, m \in \mathbb{N}\}$

2. CHOMSKY NORMAL FORM.

- (a) Remove nullable variables from the following grammar (with start symbol  $S$ ):

$$S \rightarrow aTa \mid bBb \mid BB$$

$$T \rightarrow C$$

$$B \rightarrow S \mid T$$

$$C \rightarrow S \mid \epsilon$$

- (b) This grammar (with start symbol  $S$ ) has no nullable variables. Generate its Chomsky normal form.

$$S \rightarrow TSB$$

$$T \rightarrow aTS \mid a$$

$$B \rightarrow SbS \mid T \mid b$$

3. Consider the following grammar (where lowercase letters are terminals and uppercase letters are non-terminals):

$$G \rightarrow S \$\$$$

$$S \rightarrow AM$$

$$M \rightarrow S \mid \epsilon$$

$$A \rightarrow aE \mid bAA$$

$$E \rightarrow aB \mid bA \mid \epsilon$$

$$B \rightarrow bE \mid aBB$$

- (a) Describe in English the language that this grammar generates.
- (b) Show a parse tree for the string **abab**.
- (c) Is the grammar LL(0)? Justify your answer.
- (d) Is the grammar LL(1)? If so, show a parse table (or justify your answer in a similar manner); if not, identify a prediction conflict.