# COMP 335: Introduction to Theoretical Computer Science

## Assignment 4

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1. [20 Points] For each of the following languages, give a context-free grammar (CFG).

   (a) (5 Points) $L_a = \{a^n b^m : m, n \geq 0 \text{ and } 2n \leq m \leq 3n\}$

   (b) (5 Points) $L_b = \{a^n b^m c^k : k = 2m + n\}$

   (c) (5 Points) $L_c = \{a^n b^m c^k : n = m \text{ or } m \leq k\}$

   (d) (5 Points) $L_d = \{w \in \{a, b\}^* : w \neq xx, \text{ for any } x \in \{a, b\}^*\}$

2. [10 Points] Consider the language $L = \{a^{n+1}b^n : n \geq 0\}$

   (a) (5 Points) Describe in English the complement $\overline{L}$ of $L$. Your description should specify the types of strings that are in $\overline{L}$. That is, it is not acceptable to say $\overline{L}$ includes every string over $\{a, b\}$ that is not in $L$, which is obviously true.

   (b) (5 Points) Give a CFG for $\overline{L}$.

3. [15 Points]

(a) (5 Points) Using the procedure discussed in the class, convert $G$ into an equivalent grammar in Chomsky Normal Form (CNF).

(b) (5 Points) Find an equivalent grammar to $G$ in Greibach Normal Form (GNF).

(c) (5 Points) Suppose we modify the original grammar $G$ as follows: remove the $\lambda$-production $A \to \lambda$ and instead add the unit production $A \to A$. Let us call the resulting grammar $G'$. Convert $G'$ into CNF, and simplify, if possible. Also describe in English language $L(G')$.