1. Give pushdown automata that recognize the following languages. Give both a drawing and 6-tuple specification for each PDA.

A = { w ∈ {0, 1} ∗ | w contains at least three 1s }

**B = { w ∈ {0, 1} ∗ | w = wR and the length of w is odd }**

**C = { w ∈ {0, 1} ∗ | w = wR }**

**D = { a i b j c k | i, j, k ≥ 0, and i = j or j = k }**

**E = { a i b j c k | i, j, k ≥ 0 and i + j = k }**

**F = { a 2n b 3n | n ≥ 0 }**

**L = { a i b j c k | i, j, k ≥ 0 and i + k = j }**

**h=∅, with Σ = {0, 1}**

(i) The language H of strings of properly balanced left and right brackets: every left bracket can be paired with a unique subsequent right bracket, and every right bracket can be paired with a unique preceding left bracket. Moreover, the string between any such pair has the same property. For example, [ ] [ [ [ ] [ ] ] [ ] ] ∈ A.

1. (a) Use the languages A = { a mb n c n | m, n ≥ 0 } and B = { a n b n c m | m, n ≥ 0 } together with Example 2.36 of the textbook to show that the class of context-free languages is not closed under intersection.

(b) Use part (a) and DeMorgan’s law (Theorem 0.20 of the textbook) to show that the class of context-free languages is not closed under complementation.

1. Consider the following CFG G = (V, Σ, R, S), where V = {S, T, X}, Σ = {a, b}, the start variable is S, and the rules R are S → aT Xb T → XT S | ε X → a | b Convert G to an equivalent PDA using the procedure given in Lemma 2.21.