1. (10 points) Convert the CFG $G_4$ in Exercise 2.1 (page 119) in the textbook to an equivalent PDA using the construction in the proof of Lemma 2.13. Give the state diagram showing all the states of your PDA.

2. (10 points) Convert the PDA $M_2$ in Example 2.10 (page 105) in the textbook to an equivalent CFG $G_2$ using the construction in the proof of Lemma 2.15.

3. (15 points) What is wrong with the following proof for showing that CFLs are closed under complement? (Hint: Give a counterexample to falsify the proof).
   Theorem: CFLs are closed under complement.
   Proof: Let $L$ be any CFL and let $L = L(M)$ for a PDA $M = (Q, \Sigma, \Gamma, \delta, q_0, F)$. Then, the complement of $L$ is accepted by the PDA $M' = (Q, \Sigma, \Gamma, \delta, q_0, Q-F)$. Therefore, the complement of $L$ is also a CFL.

4. (45 points) Use the pumping lemma to show that the following languages are not context free:
   a. $\{0^n1^n0^k \mid k \leq n\}$
   b. $\{w#x \mid w, x \in \{0,1\}^* \text{ and } w \text{ is a substring of } x\}$
   c. $\{0^m \mid m \text{ is a perfect square i.e. } m = n^2 \text{ for some natural number } n \in N\}$

5. (20 points) Give the sequence of configurations that each of the following Turing machines enters when started on the indicated input strings:
   a. Turing machine $M_2$ from Example 3.4 in the textbook on: (i) input string 00 and (ii) input string 000
   b. Turing machine $M_1$ from Example 3.5 in the textbook on (i) input string 0# and (ii) input string 10#10