1. The two Turing machines for this problem are given on the next page. Although it is not important for solving the problem, you may wish to know that both the Turing machines recognize the language \( \{ w w \mid w \in \{0, 1\}^* \} \).

(a) Show the computation (that is, the sequence of configurations) for the deterministic Turing machine given on next page on input 001001.

(b) Show one accepting and one rejecting computation for the nondeterministic Turing machine given on next page on input 001001.

2. Give a state diagram for a Turing machine that recognizes the language \( \{ a^i b^j c^i d^j \mid i, j \in \mathbb{N} \} \).

3. (a) Give a state diagram for a two-tape Turing machine that recognizes the language \( \{ a^n b^n c^n \mid n \in \mathbb{N} \} \). One suitable way of representing the transition \( \delta(r, a_1, a_2) = (s, b_1, b_2, D_1, D_2) \) is

(b) Give a state diagram for a nondeterministic Turing machine that recognizes the language

\( \{ \# w_1 \# w_2 \# \ldots \# w_n \# \mid w_i \in \{0, 1\}^* \text{ for all } i \text{ and } w_i = w_j \text{ for some } i \neq j \} \)

over the alphabet \( \{0, 1, \#\} \).

4. [Sipser Problem 3.9] Let a \( k \)-PDA be a pushdown automaton that has \( k \) stacks. Thus a 0-PDA is an NFA, and a 1-PDA is a conventional PDA.

(a) Show that 2-PDAs are more powerful than 1-PDAs.

(b) Show that 3-PDAs are not more powerful than 2-PDAs.

Hint: Simulate the tape of a Turing machine using two stacks. Give the basic idea of the simulation using high-level pseudocode without getting too deep into details.

(Turing machines for Problem 1 on the next page.)
Deterministic Turing machine for Problem 1(a).

Nondeterministic Turing machine for Problem 1(b).