Assignment 4 **SE4I03 Fall 2002** **due on Nov. 15**

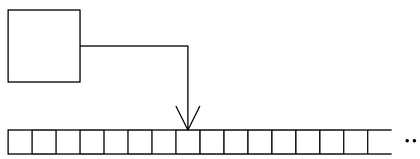
1. Suppose that we allow a second stack in push-down automata. Does the resulting model of computation capture context-free languages (just as single stack push-down automata do), or is the class of languages recognizable by this model bigger? Justify your answer.

2. Consider the following type of Turing Machines: there are two tapes, the input tape, and a work tape. The input tape is read-only, and the head on the input tape moves left to right only. The work tape is bounded by a constant c in both directions (i.e., the head of M cannot move farther than c squares to the left and right of the initial square), but the head on the work tape can move freely in both directions, read and write. What class of languages can be recognized with such Turing Machines?

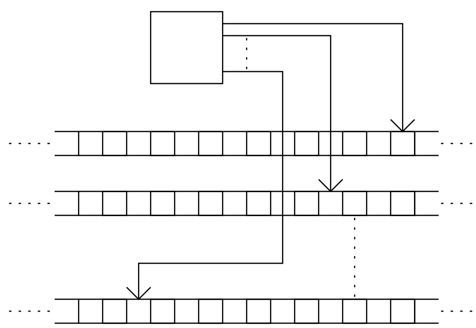
3. Show that the following types of Turing Machines are polynomially equivalent:

   (a) Turing Machines

   (b) Turing Machines, with an infinite tape in one direction only:

   (c) For any positive integer k, Turing Machines with k-many tapes:

   For example, to show that (a) and (c) are equivalent: in one direction it is trivial, as Turing Machines correspond to multi-tape Turing Machines where $k = 1$. In the other direction, show that if L is a language recognizable by a multi-tape Turing Machine, in time $f(|x|)$, then L is recognizable on a Turing Machines (with just one tape) in time $p(f(|x|))$ for some fixed polynomial p.