

## Homework 9

<sup>A</sup>3.10 Say that a *write-once Turing machine* is a single-tape TM that can alter each tape square at most once (including the input portion of the tape). Show that this variant Turing machine model is equivalent to the ordinary Turing machine model. (Hint: As a first step, consider the case whereby the Turing machine may alter each tape square at most twice. Use lots of tape.)

3.12 A *Turing machine with left reset* is similar to an ordinary Turing machine, but the transition function has the form

$$\delta: Q \times \Gamma \longrightarrow Q \times \Gamma \times \{R, \text{RESET}\}.$$

If  $\delta(q, a) = (r, b, \text{RESET})$ , when the machine is in state  $q$  reading an  $a$ , the machine's head jumps to the left-hand end of the tape after it writes  $b$  on the tape and enters state  $r$ . Note that these machines do not have the usual ability to move the head one symbol left. Show that Turing machines with left reset recognize the class of Turing-recognizable languages.

3.14 A *queue automaton* is like a push-down automaton except that the stack is replaced by a queue. A *queue* is a tape allowing symbols to be written only on the left-hand end and read only at the right-hand end. Each write operation (we'll call it a *push*) adds a symbol to the left-hand end of the queue and each read operation (we'll call it a *pull*) reads and removes a symbol at the right-hand end. As with a PDA, the input is placed on a separate read-only input tape, and the head on the input tape can move only from left to right. The input tape contains a cell with a blank symbol following the input, so that the end of the input can be detected. A queue automaton accepts its input by entering a special accept state at any time. Show that a language can be recognized by a deterministic queue automaton iff the language is Turing-recognizable.

3.16 Show that the collection of Turing-recognizable languages is closed under the operation of

- <sup>A</sup>a. union.
- b. concatenation.
- c. star.
- d. intersection.