The Theory of Computation
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Solution Manual
Chapter 4, Problem 5.17

Intuitively, the finite automaton can use ε-transitions on the input in order to work exclusively with the queue; indeed, we can think of the machine first copying the input into the queue and thereafter using only ε-transitions on the input. The queue itself is essentially like a circular tape—the finite automaton can examine any element of the queue by repeatedly removing the head and reinserting it at the tail, thereby simply rotating the queue by one position. The head of the queue is equivalent to the character under the head of the Turing machine—what the machine can check right now. Moving the head of the Turing machine in one direction is just the rotation we mentioned; to simulate a move in the other direction, we need to rotate the queue completely around, which means also identifying when the rotation is complete. To that end, we simply insert a marker (a symbol not otherwise used) into the queue and rotate until the marker appears at the head of the queue, at which time we remove it and stop the rotation. Moving past a blank at either end of the Turing machine tape corresponds simply to inserting an item in the queue. Thus our queue-based finite automaton can simulate a Turing machine and is therefore universal.