CS46 Lab 7

In typical labs this semester, you’ll be working on a number of problems in groups of 3-4 students each. Lab problems are an opportunity for discussion and trying many different solutions. They are **not counted towards your grade**, and **you do not have to submit your solutions**.

The purpose of these problems is to get more comfortable with reasoning and writing about Turing machines. You should be practicing writing out descriptions and proofs for your solutions to these problems.

1. Give an implementation-level description of a Turing machine that, when given an input $w \in \{a, b\}^*$, shifts $w$ one square to the right, resulting in $\sqcup w$ on the input tape.

2. **Closure properties for decidable languages.** (Sipser 3.15)
   Show that the collection of decidable languages is closed under the operations:
   
   (a) union
   (b) concatenation
   (c) Kleene star
   (d) complement
   (e) intersection

3. **The power of two stacks.** We know that PDAs with zero stacks are just NFAs. We also know that PDAs with 1 stack are more powerful than NFAs, because they can recognize $\{a^n b^n\}$ which is not a regular language. We also know that PDAs with 2 stacks are more powerful than 1-stack PDAs, because they can recognize $\{a^n b^n c^n\}$ which is not context-free.
   How do 2-stack PDAs compare with Turing machines?

   (a) Show that every Turing machine has an equivalent 2-stack PDA. (Every standard Turing machine: one tape, one read/write head. Don’t make this more complicated than it needs to be.)

   (b) Show that every 2-stack PDA has an equivalent Turing machine.

   (c) What about a 3-stack PDA? Will it be more powerful, less powerful, or equivalent to a Turing machine? Support your answer with a proof.

   (d) What about a 4-stack PDA? What about 5 stacks? 6 stacks? $n$ stacks?