

## COMS 461 - Midterm 2 Review

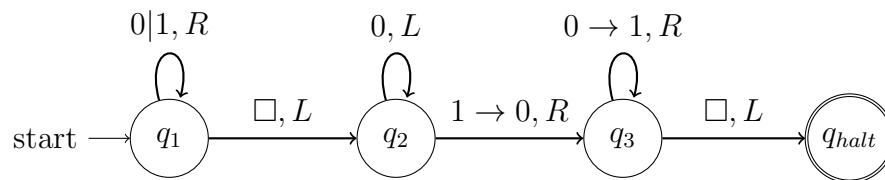
1. (12 points) Create a context free grammar that generates the following language.

$$L = \{w \in \{a, b\}^* : w \text{ starts and ends with different symbols}\}.$$

2. (12 points) Draw a state diagram for a nondeterministic pushdown automata (NPDA) that recognizes

$$L = \{w \in \{a, b\}^* : w \text{ starts and ends with different symbols}\}.$$

3. (12 points) Consider the Turing machine with state diagram shown below.



- (a) What will this TM output if the input tape initially contains the string 101000 and the head is initially pointing at the left-most digit? For your answer, write down the final tape contents and indicate the position of the head when the TM halts.
- (b) This TM corresponds to a simple function on binary numbers. What is that function?

4. (12 points) Consider the context free grammar below.

$$\begin{aligned}S &\rightarrow aB|bA \\A &\rightarrow a|aS|AAB \\B &\rightarrow b|bS|BBA\end{aligned}$$

This grammar generates the language of all strings in  $\{a, b\}^*$  with an equal number of  $a$ 's and  $b$ 's. Prove that this grammar is ambiguous by finding two different left derivations of the string  $abba$ . Draw parse trees for the two different derivations that makes it clear that they are different.

5. (20 points) The following statements are all false. For each one, explain why it is false.

- (a) For any function  $f : \{0, 1\}^* \rightarrow \{0, 1\}$ , you can always find a Turing machine that accepts a string  $w \in \{0, 1\}^*$  if and only if  $f(w) = 1$ , but the Turing machine might loop forever on  $w$  if  $f(w) = 0$ .

- (b) All decidable languages are regular.

- (c) Let  $P = \{\langle M \rangle : M \text{ is a Turing machine with only one state}\}$ . Then Rice's theorem implies that  $P$  is an undecidable language because both  $P$  and its complement  $\overline{P}$  (in the language of all TM encodings) are nonempty sets.

- (d) No Turing machine  $M$  can ever accept its own encoding  $\langle M \rangle$ .

6. (12 points) Let

$$\text{FINITE} = \{\langle M \rangle : M \text{ is a TM and the set of strings accepted by } M \text{ is finite}\}.$$

Explain clearly why FINITE is an undecidable language.

7. (20 points) Let

$$L_1 = \{a^n b a^m b a^n : m, n \in \mathbb{N}\}$$

and let

$$L_2 = \{a^n b a^n b a^n : n \in \mathbb{N}\}.$$

(a) Prove that  $L_1$  is context free.

(b) Use the pumping lemma to show that  $L_2$  is not context free.