CS 154
Formal Languages and Computability

Department of Computer Science
San José State University
Spring 2016
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MIDTERM EXAMINATION #2

100 points total

This examination is open book, open notes, open laptop, and open Internet.
You have **1 hour and 15 minutes** to complete it.

Put all your written answers into a Word or text document. Keep your drawings in separate files, and name the files to clearly indicate which questions they answer. Photograph drawings made by pencil and paper to create image files.

Submit all your files into Canvas: **Assignments/Exams/Midterm Exam #2**.

Academic Integrity Notice

It is explicitly forbidden to use e-mail, instant messaging, tweeting, or any other means to communicate or share answers with another person during the examination.
No form of cheating will be tolerated.
Severe consequences for cheating include immediately failing the class.

1. [20 points] You are given the following excerpt from English grammar:

Grammar	Key

`<s>` → `<np><vp>` | `<vp><pp>`
 `<np>` → `<adj><n>` | `<art><n>` | `<n>`
 `<vp>` → `<v><np>`
 `<pp>` → `<p><np>`
 `<adj>` → time
 `<art>` → an
 `<n>` → arrow | flies | time
 `<p>` → like
 `<v>` → like | time
	Key
	 s = sentence
	 np = noun phrase
	 vp = verb phrase
	 pp = prepositional phrase
	 n = noun
	 v = verb
	 adj = adjective
	 art = article
	 p = preposition

Use the sentence

time flies like an arrow

to show that the English language is ambiguous.

2. [10 points] We demonstrated that language $L_1 = \{ww^R : w \in \{a, b\}^+\}$ is context-free by building an NPDA for it. On the other hand, we proved by using the pumping lemma that the language $L_2 = \{ww : w \in \{a, b\}^*\}$ is not context-free. Without resorting to the simple argument "because it's not context-free" explain why it isn't possible to build a PDA for language L_2.

3. Now consider the context-free language $L_3 = \{w@w^R : w \in \{a, b\}^+\}$ and @ is also a character in the language's alphabet.

   a. [10 points] Explain why L_3 is deterministic whereas L_1 is nondeterministic.

   b. [20 points] Use a flowchart to design a DPDA that accepts L_3. Specify your stack alphabet Γ and the stack start symbol.

4. [10 points] Consider the context-free grammar $G = \{V, T, S, P\}$ used by the "Super Calculator" of Assignment #4. List the components of the elements of G.

5. [10 points] Let L be any language. Define the language L^T to be the transpose of L such that it consists of all the words in L spelled backwards. For example, if L contains the words *table*, *chair*, and *kitten*, then L^T contains the words *elbat*, *riahc*, and *nettik*. Show that if L is context-free, then so is L^T.

6. [20 points] Use the pumping lemma to prove that the language $L = \{a^n b a^{2n} b a^{3n} : n \geq 0\}$ is not context-free.