CS 352 – Compilers: Principles and Practice
Mid-term Examination, 3/21/01

Instructions: Read carefully through the whole exam first and plan your time. Note the relative weight of each question and part (as a percentage of the score for the whole exam). The total points is 100 (your grade will be the percentage of your answers that are correct).

This exam is **closed book, closed notes**. You may *not* refer to any book or other materials.

You have **one hour** to complete all four (4) questions. Write your answers on this paper (use both sides if necessary).

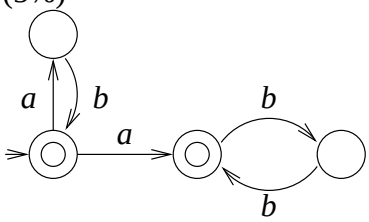
Name:

Student Number:

Signature

1. (Regular expressions; 25%) Write regular expressions that define the strings recognized by the following finite automata:

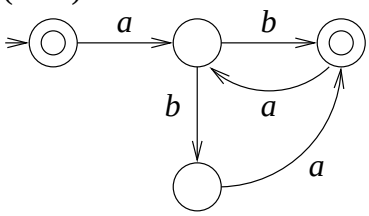
(a) (5%)



Answer:

$$(ab)^*(\varepsilon \mid a(bb)^*)$$

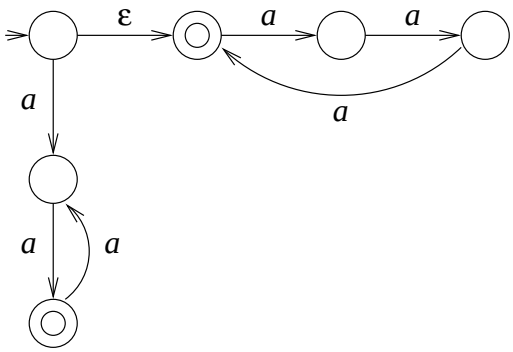
(b) (10%)



Answer:

$$(ab \mid aba)^*$$

(c) (10%)



Answer:

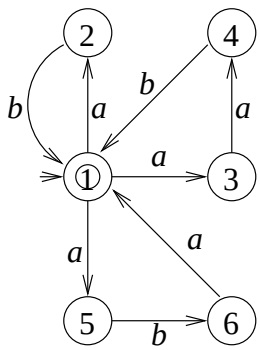
$$(aaa)^* \mid aa(aa)^*$$

2. (Finite automata; 25%) Consider the following regular expression:

$$(ab \mid aab \mid aba)^*$$

(a) (10%) Draw a *simple* NFA for this expression (i.e., *without* the extra ε-transitions that result from the more mechanical construction that was described in class).

Answer:



(b) (10%) Using the subset construction, convert the NFA into a DFA.

Answer:

$A = \{1\}$
$B = \{2,3,5\}$
$C = \{4\}$
$D = \{1,6\}$
$E = \{1,2,3,5\}$
$F = \{2,3,4,5\}$

	a	b
A	B	
B	C	D
C		A
D	E	
E	F	D
F	C	D

A is the start state.
A, D, and E are final states.

(c) (5%) Try to understand how the DFA constructed in part 2b operates. Based on your understanding, optimize the DFA as necessary to minimize states.

Answer:

States B and F are equivalent, yielding:

	a	b
A	B	
B	C	D
C		A
D	E	
E	B	D

3. (Context-free grammars; 25%) Consider the grammar

$$\begin{aligned} S &\rightarrow aSbS \\ S &\rightarrow bSaS \\ S &\rightarrow \varepsilon \end{aligned}$$

(a) (5%) Show that this grammar is ambiguous by giving two different leftmost derivations for the sentence *abab*.

Answer:

$$\begin{aligned} S &\Rightarrow_{\text{lm}} aSbS \\ &\Rightarrow_{\text{lm}} abSaSbS \\ &\Rightarrow_{\text{lm}} ab[\varepsilon]aSbS \\ &\Rightarrow_{\text{lm}} ab[\varepsilon]a[\varepsilon]bS \\ &\Rightarrow_{\text{lm}} ab[\varepsilon]a[\varepsilon]b[\varepsilon] \end{aligned} \qquad \begin{aligned} S &\Rightarrow_{\text{lm}} aSbS \\ &\Rightarrow_{\text{lm}} a[\varepsilon]bS \\ &\Rightarrow_{\text{lm}} a[\varepsilon]baSbS \\ &\Rightarrow_{\text{lm}} a[\varepsilon]ba[\varepsilon]bS \\ &\Rightarrow_{\text{lm}} a[\varepsilon]ba[\varepsilon]b[\varepsilon] \end{aligned}$$

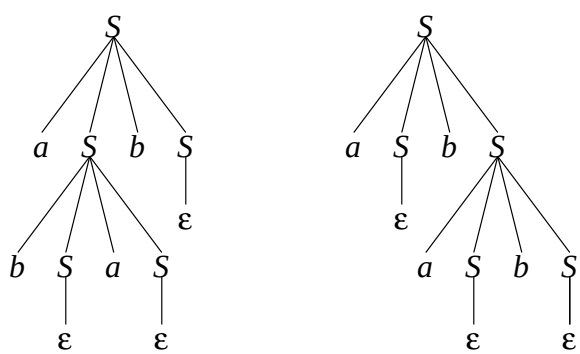
(b) (5%) Give the corresponding rightmost derivations for *abab*.

Answer:

$$\begin{aligned} S &\Rightarrow_{\text{rm}} aSbS \\ &\Rightarrow_{\text{rm}} aSb[\varepsilon] \\ &\Rightarrow_{\text{rm}} abSaSb[\varepsilon] \\ &\Rightarrow_{\text{rm}} abSa[\varepsilon]b[\varepsilon] \\ &\Rightarrow_{\text{rm}} ab[\varepsilon]a[\varepsilon]b[\varepsilon] \end{aligned} \qquad \begin{aligned} S &\Rightarrow_{\text{rm}} aSbS \\ &\Rightarrow_{\text{rm}} aSbaSbS \\ &\Rightarrow_{\text{rm}} aSbaSb[\varepsilon] \\ &\Rightarrow_{\text{rm}} aSba[\varepsilon]b[\varepsilon] \\ &\Rightarrow_{\text{rm}} a[\varepsilon]ba[\varepsilon]b[\varepsilon] \end{aligned}$$

(c) (10%) Draw the corresponding parse trees for *abab*.

Answer:



(d) (5%) What language does this grammar generate?

Answer:

Strings with an equal number of *a*s and *b*s.

4. (LL parsing; 25%) Consider the grammar

$$
\begin{array}{lcl}
S & \rightarrow & U;W \\
U & \rightarrow & Ua \\
U & \rightarrow & \varepsilon \\
W & \rightarrow & bW \\
W & \rightarrow & b
\end{array}
$$

(a) (20%) Derive the LL(1) parse table for the *language* generated by the grammar. [**Hint:** You may have to transform the grammar first in order to do so.] **Answer:**

First, left-factor and eliminate left-recursion:

$$
\begin{array}{lcl}
S & \rightarrow & U;W \\
U & \rightarrow & aU \\
U & \rightarrow & \varepsilon \\
W & \rightarrow & bW' \\
W' & \rightarrow & W \\
W' & \rightarrow & \varepsilon
\end{array}
$$

	FIRST	FOLLOW	a	b	;	\$
S	a;	\$	$S \rightarrow U;W$		$S \rightarrow U;W$	
U	$a\varepsilon$	;	$U \rightarrow aU$		$U \rightarrow \varepsilon$	
W	b	\$		$W \rightarrow bW'$		
W'	$b\varepsilon$	\$		$W' \rightarrow W$		$W' \rightarrow \varepsilon$

(b) (5%) Of the *language* classes we have discussed in this course (i.e., regular or context-free), what is the smallest category into which this language fits? Explain your answer. **Answer:**

This language is regular. It can be captured by the following regular expression: $a^*;bb^*$