# CS 352 – Compiling and Programming Systems
# Mid-term Examination, 10/23/12

**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 (*ie*, 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 **75 minutes** to complete all four (4) questions. Write your answers on this paper (use both sides if necessary).

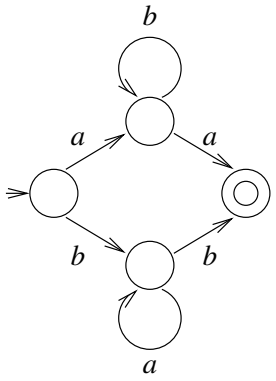
**Name:**

**Student Number:**

**Signature:**

1. (Regular expressions; 15%) Write regular expressions that define the strings recognized by the following finite automata:

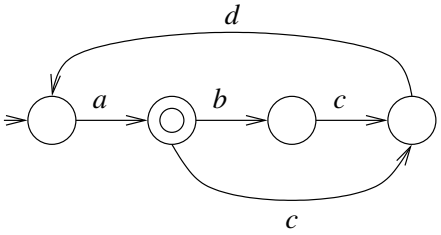
   (a) (5%)




**Answer:**

$ab^*a \mid ba^*b$

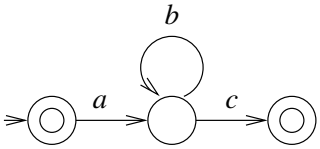
   (b) (5%)




**Answer:**

$a(bcda \mid cda)^*$

   (c) (5%)




**Answer:**

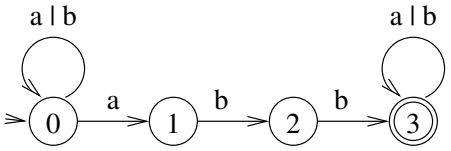
$\varepsilon \mid ab^*c$

2. (Finite automata; 35%)

(a) (10%) Draw an NFA for the following regular expression:

$$(a|b)^*abb(a|b)^*$$

**Answer:**



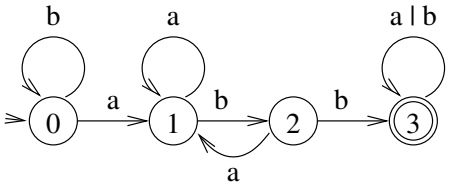

(b) (5%) Show the sequence of moves made by your NFA in processing the input string *ababbab*.

**Answer:**

$$\begin{aligned}(0, ababbab) &\vdash (0, babbab)\\ &\vdash (0, abbab)\\ &\vdash (1, bbab)\\ &\vdash (2, bab)\\ &\vdash (3, ab)\\ &\vdash (3, b)\\ &\vdash (3, \varepsilon)\end{aligned}$$

(c) (15%) Convert your NFA into a DFA.

**Answer:**




(d) (5%) Show the sequence of moves made by your DFA in processing the input string *ababbab*.

**Answer:**

$$
\begin{aligned}
(0, ababbab) &\vdash (1, babbab) \\
&\vdash (2, abbab) \\
&\vdash (1, bbab) \\
&\vdash (2, bab) \\
&\vdash (3, ab) \\
&\vdash (3, b) \\
&\vdash (3, \varepsilon)
\end{aligned}
$$

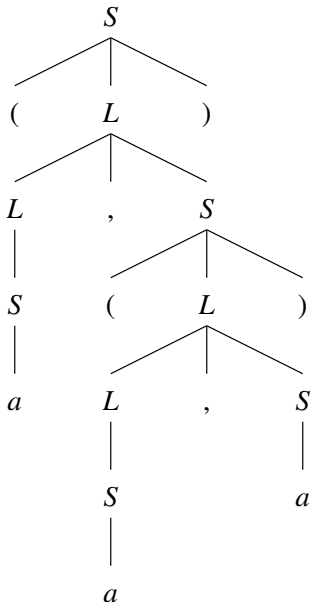
3. (Context free grammars, top-down LL parsing; 25%) Consider the following grammar:

$$\begin{aligned} S &\rightarrow (L) \\ S &\rightarrow a \\ L &\rightarrow L,S \\ L &\rightarrow S \end{aligned}$$

(a) (10%) Construct a parse tree and give both leftmost and rightmost derivations for the following sentence of the grammar:

$(a,(a,a))$

**Answer:**




$$\begin{aligned} S &\Rightarrow_{\text{lm}} (L) \\ &\Rightarrow_{\text{lm}} (L,S) \\ &\Rightarrow_{\text{lm}} (S,S) \\ &\Rightarrow_{\text{lm}} (a,S) \\ &\Rightarrow_{\text{lm}} (a,(L)) \\ &\Rightarrow_{\text{lm}} (a,(L,S)) \\ &\Rightarrow_{\text{lm}} (a,(S,S)) \\ &\Rightarrow_{\text{lm}} (a,(a,S)) \\ &\Rightarrow_{\text{lm}} (a,(a,a)) \end{aligned}$$

$$\begin{aligned} S &\Rightarrow_{\text{rm}} (L) \\ &\Rightarrow_{\text{rm}} (L,S) \\ &\Rightarrow_{\text{rm}} (L,(L)) \\ &\Rightarrow_{\text{rm}} (L,(L,S)) \\ &\Rightarrow_{\text{rm}} (L,(L,a)) \\ &\Rightarrow_{\text{rm}} (L,(S,a)) \\ &\Rightarrow_{\text{rm}} (L,(a,a)) \\ &\Rightarrow_{\text{rm}} (S,(a,a)) \\ &\Rightarrow_{\text{rm}} (a,(a,a)) \end{aligned}$$

(b) (15%) Derive an LL(1) parse table for the language generated by this grammar. [**Hint:** You may have to transform the grammar first in order to do so.]
**Answer:**

Eliminating left recursion:

$$\begin{aligned} S &\rightarrow (L) \\ S &\rightarrow a \\ L &\rightarrow SL' \\ L' &\rightarrow ,SL' \mid \varepsilon \end{aligned}$$

Here is the LL(1) parse table:

| | ( | ) | $a$ | , |
|---|---|---|---|---|
| $S$ | $S \rightarrow (L)$ | | $S \rightarrow a$ | |
| $L$ | $L \rightarrow SL'$ | | $L \rightarrow SL'$ | |
| $L'$ | | $L' \rightarrow \varepsilon$ | | $L' \rightarrow ,SL'$ |

4. (Context-free grammars, LR parsing; 25%) Consider the following grammar:

$$\begin{array}{rcl} S & \rightarrow & E\$ \\ E & \rightarrow & T \mid E;T \\ T & \rightarrow & \varepsilon \mid Ta \end{array}$$

(a) (10%) Is this grammar LR(0)? *Explain* your answer (a yes/no answer will not suffice).
**Answer:**

The LR(0) construction yields the following configuration:

$$\begin{array}{rcl} E & \rightarrow & T\bullet \\ T & \rightarrow & T\bullet a \end{array}$$

which induces an LR(0) shift-reduce conflict.

(b) (15%) Construct the SLR(1) parse table for this grammar. Is the grammar SLR(1)? Again, *explain* your answer.

**Answer:**

First, number the productions:

| | | | |
|---|---|---|---|
| 1 | $S$ | $\rightarrow$ | $E\$$ |
| 2 | $E$ | $\rightarrow$ | $T$ |
| 3 | $E$ | $\rightarrow$ | $E;T$ |
| 4 | $T$ | $\rightarrow$ | $\varepsilon$ |
| 5 | $T$ | $\rightarrow$ | $Ta$ |

Here are the LR(0) item sets:

$$\begin{array}{lrcl\quad lrcl} I_0: & S & \rightarrow & \bullet E\$ & I_3: & E & \rightarrow & E;\bullet T \\ & E & \rightarrow & \bullet T & & T & \rightarrow & \bullet \\ & E & \rightarrow & \bullet E;T & & T & \rightarrow & \bullet Ta \\ & T & \rightarrow & \bullet & I_4: & E & \rightarrow & E;T\bullet \\ & T & \rightarrow & \bullet Ta & & T & \rightarrow & T\bullet a \\ I_1: & S & \rightarrow & E\bullet\$ & I_5: & E & \rightarrow & T\bullet \\ & E & \rightarrow & E\bullet;T & & T & \rightarrow & T\bullet a \\ I_2: & S & \rightarrow & E\$\bullet & I_6: & T & \rightarrow & Ta\bullet \end{array}$$

Now, FOLLOW$(S)=\{\$\}$, FOLLOW$(E)=\{\$,;\}$ and FOLLOW$(T)=\{\$,;,a\}$.
So, the SLR(1) parse table is:

| | ACTION | | | GOTO | | |
|---|---|---|---|---|---|---|
| STATE | ; | $a$ | \$ | $S$ | $E$ | $T$ |
| 0 | r4 | r4 | r4 | – | 1 | 5 |
| 1 | s3 | – | acc | – | – | – |
| 2 | – | – | – | – | – | – |
| 3 | r4 | r4 | r4 | – | – | 4 |
| 4 | r3 | s6 | r3 | – | – | – |
| 5 | r2 | s6 | r2 | – | – | – |
| 6 | r5 | r5 | r5 | – | – | – |

which contains no conflicts; i.e., the grammar is SLR(1)