University of Nevada, Las Vegas Computer Science 456/656 Spring 2026

Assignment 1: Due Saturday August 29, 2026, midnight

Name:_____

You are permitted to work in groups, get help from others, read books, and use the internet. Turn in the assignment as instruced by the Graduate Assistant, Sabrina Wellace, `wallace4@unlv.nevada.edu`

1. Work Exercises 1-6 on page 2 of the handout introduction.pdf.

   (1) $A + A = A$

   (2) $\{\lambda\}A = A$

   $\{a, ab\}a, ba = \{aa, aba, abba\}$. The string aba is obtained in two different ways.

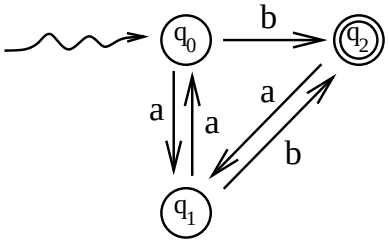
   (3) $\emptyset A = \emptyset$

   (4) $\emptyset^*$, the Kleene closure of the empty language is $\{\lambda\}$, not the empty language, but the language which contains only the empty string.

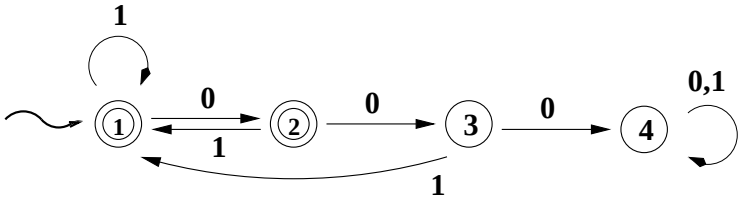
   (5) Is it true that $\{\lambda\} + A = A$?

   It's true if $\lambda \in A$, false otherwise.

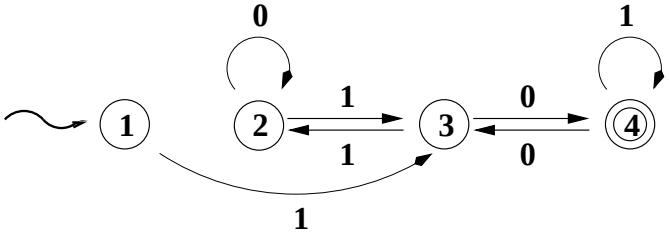
2. Let M_1 be the DFA shown below.



Let M_2 be the DFA shown below.



Let M_3 be the DFA shown below.



Which of the following languages is accepted by M_1? By M_2? By M_3?

(a) The language of all binary strings in which every substring 00 is followed by 1.

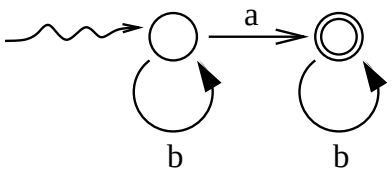
(b) All strings over $\{a, b\}$ which end in b and which do not contain the substring bb.

(c) The language of all binary numerals for positive integers equivalent to 2 modulo 3.

(d) The language of all strings over $\{a, b\}$ in which every a is followed by b.

M_1 accepts language (b). M_2 accepts language (a). M_3 accepts language (c). Language (d) is not accepted by any of the machines.

3. Construct a DFA which accepts the language $\{b^i a b^j : i, j \geq 0\}$, the language of all strings over $\{a, b\}$ which contain exactly one a. Your figure need not show the dead state.



4. Recall that $\emptyset$ is the empty language. If L is some language, what is the concatenation $\emptyset L$?

   $\emptyset$

5. Let $L_1 = \{\lambda\}$. the language consisting of only the empty string. If L_2 is some other language, what is the concatenation $L_1 L_2$?

   L_2

6. Is concatenation of languages commutative? That is, is the equation $L_1 L_2 = L_2 L_1$ always true?

   No.

7. Which of the following is true:

   (a) If L is any language, $L^0 = L$.

   (b) If L is any language, $L^0 = \emptyset$.

   (c) If L is any language, $L^0 = \{\lambda\}$.

   (c) is true.

8. What is $\emptyset^*$, the Kleene closure of the empty language?

   $\{\lambda\}$.

9. True(T) or False(F).

   i **F** Every subset of a regular language is a regular languge.

   ii **F** Every language is generated by a grammar.

   iii **F** Every language is finite.

iv **F** 'Every language is infinite.

v **F** Concatenation is commutative. That is, $L_1L_2 = L_2L_1$ for any languages L_1 and L_2.

vi **T** Concatenation is associative. That is, $(L_1L_2)L_3 = L_1(L_2L_3)$ for any languages L_1, L_2, and L_3.

vii **T** The intersection of any two regular languages is regular.

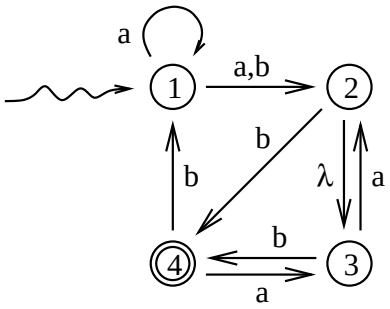
viii **T** The complement of any regular language is regular.

ix **T** The Kleene closure of any regular language is regular.

x **F** $\{\lambda\} + A = A$

xi **T** Concatenation of languages distributes over union. That is, $L_1(L_2 + L_3) = L_1L_2 + L_1L_3$ for any languages L_1, L_2, L_3.

10. Construct a DFA equivalent to the following NFA.



We call the NFA $M_1 = (Q, \delta)$, where $Q = \{1, 2, 3, 4\}$ and its transitions are as shown in the figure. The only final state4 of M_1 is 4. Let M_2 be the DFA $(2^Q, \Delta)$) We first construct a transition table of M_2, There is a row for each reachable subset of 2^Q. I write sets with simplified notation, *e.g.* 123 instead of $\{1, 2, 3\}$. The non-final states are 1, 123, 23, 3, and the final states are 4, 14, 234.

Δ	a	b
1	123	23
23	23	4
123	123	234
3	23	4
4	3	1
234	23	14
14	123	123

We now determine which of those states are equivalent. Let E be the 7×7 matrix where the rows and columns are labeled with the reachable states of M_2. We will write a 0 for each equivalent pair, and X for each pair proved to be non-equivalent. The construction is by dynamic programming. We define two states A and B to be non-equivlent if either one is final and the other non-final, or if there is a symbol s such that $\Delta(A, s)$ nad $\Delta(B, s)$ are already known to be not equivalent. We proceed until no new non-equivalences can be found. Initially, there are many empty cells.

	1	23	123	3	4	234	14
1	O				X	X	X
23		O			X	X	X
123			O		X	X	X
3				O	X	X	X
4	X	X	X	X	O		
234	X	X	X	X		O	
14	X	X	X	X			O

Because of symmetry, there are 9 cells to fill in. Since the transition table rows for 3 and 23 are identical, we can write 0 in the two cells corresponding to that pair, and since $\Delta(1, b) = 23$ is not equivalent to $\Delta(23, b) = 4$, we can write X in the two cells corresponding to that pair, updating E and also in the two cells corresponding to the pair 1 and 3.

	1	23	123	3	4	234	14
1	O	X		X	X	X	X
23	X	O		O	X	X	X
123			O		X	X	X
3	X	O		O	X	X	X
4	X	X	X	X	O		
234	X	X	X	X		O	
14	X	X	X	X			O

$4 \in \Delta(234, b)$, while neither $\Delta(4, b)$ nor $\Delta(14, b)$ contains 4. Thus 234 is not equivalent to either 4 or 14. Also, $4 \in \Delta(3, b)$, $4 \in \Delta(23, b)$ and $4 \in (123, b)$, but $4 \notin \Delta(1, b)$, and thus 1 is not equivalent to either 3, 23, or 123. Since $4 \in \Delta(234, b)$ but not in $\Delta(14, b)$, 14 and 234 are not equivalent. We update E.

	1	23	123	3	4	234	14
1	O	X	X	X	X	X	X
23	X	O		O	X	X	X
123	X		O		X	X	X
3	X	O		O	X	X	X
4	X	X	X	X	O	X	
234	X	X	X	X	X	O	X
14	X	X	X	X		X	O

$\Delta(3, b) = 4$, which is known to not be equivalent to $\Delta(123, b) = 234$. Thus 3 and 123 are not equivalent. Since 3 and 23 are equivalent, 23 and 123 are not equivalent. $\Delta(4, b) = 1$, which is not equivalent to $\Delta(14, b) = 123$. Thus, 4 and 14 are not equivalent.

	1	23	123	3	4	234	14
1	O	X	X	X	X	X	X
23	X	O	X	O	X	X	X
123	X	X	O	X	X	X	X
3	X	O	X	O	X	X	X
4	X	X	X	X	O	X	X
234	X	X	X	X	X	O	X
14	X	X	X	X	X	X	O

Since E is completely filled in, we know that there is only one equivalence of different reachable members of 2^Q, namely the equivalence of 3 and 23. The minimal DFA equivalent to M_1 thus has 6 states.

