

NTIN071 A&G: TUTORIAL 5 – MORE ON CLOSURE PROPERTIES, REGULAR  
EXPRESSIONS

*Solve 1, 2a-f, 3abce, 4a, 5bc (the rest is for practice).*

**Problem 1** (Delete). Let  $L$  be a regular language over the alphabet  $\Sigma = a, b$ . Describe the following languages in set notation. Are these languages (necessarily) also regular? Prove or disprove.

Language consisting of all words obtained from words of the language  $L$  by...

- (a) ...deleting all occurrences of the letter  $a$ .
- (b) ...deleting the initial letter and writing this letter at the end of the word.
- (c) ...deleting the longest contiguous sequence of  $a$ 's from the beginning of the word.

**Problem 2** (Constructing regular expressions). Find regular expressions representing the following languages over  $\Sigma = \{a, b\}$  consisting of words that:

- (a) start with 'abba',
- (b) end with 'abba',
- (c) start with 'ab' and end with 'ba',
- (d) contain 'abba' or 'bab' as a subword,
- (e) do not contain 'aa' as a subword,
- (f) contain an even number of  $a$ 's,
- (g) have at least 2 letters and the first letter is the same as the last letter,
- (h) the first two letters are the same as the last two letters.

**Problem 3** (Regex to automaton). Construct finite automata accepting languages described by the following regular expressions:

- |                      |                                  |
|----------------------|----------------------------------|
| (a) $ab + ba$        | (e) $((ab + c) + a(bc)^* + b)^*$ |
| (b) $a^2 + b^2 + ab$ | (f) $((ab + c)^*a(bc)^* + b)^*$  |
| (c) $a + b^*$        | (g) $(01^* + 101)^*0^*1$         |
| (d) $(ab + c)^*$     | (h) $(01)^*11(01)^*(0 + 1)^*00$  |

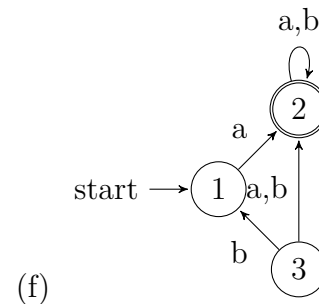
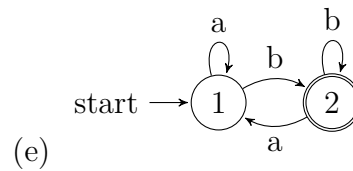
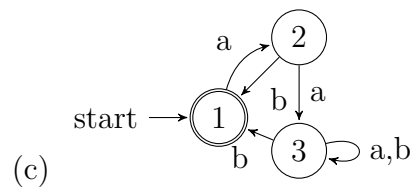
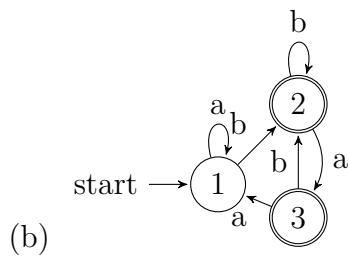
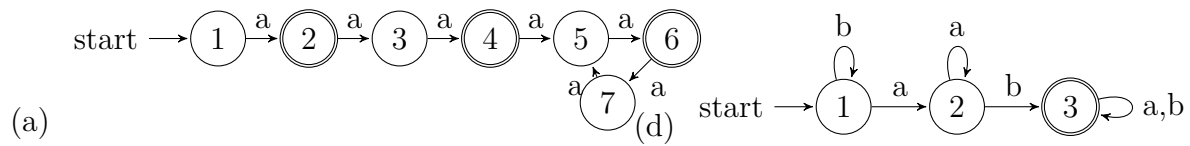
**Problem 4** (Testing equivalence of regular expressions).

(a) Describe an algorithm to test equivalence of two regular expressions.

(b) Apply it to the following pair of regular expressions:

$$(a + b)(a + b)^* \quad \text{and} \quad a(a + b)^* + b(a + b)^*$$

**Problem 5** (Automaton to regex). Construct regular expressions for languages accepted by the following automata.



**Problem 6** (Are regular expressions regular?). Fix a finite alphabet  $\Sigma$ . Is the language consisting of all regular expressions over  $\Sigma$  a regular language?