$L_1 = \{\varepsilon, 0, 1, 00, 01, 10, 11\}$

$L_2 = \{0\}$

$L_3 = \{\ \} = \Phi$

$L_4 = \{\ \varepsilon\ \}$

The alphabet is $\Sigma = \{0, 1\}$.

What are the languages:

1. $\overline{L_1}$
2. $\overline{L_3}$
3. $\overline{L_4}$
4. $L_1 \cdot L_1$
5. $L_3 \cdot L_2$
6. $L_4 \cdot L_2$
7. $L_2 \cup L_3$
8. $L_2 \cup L_4$
9. $L_1 \cap L_3$
10. $L_1 \cap L_4$

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Operations on Languages:

1. Complement of L defined over Σ = $\overline{L}$

   = { $w \in \Sigma^*$: w is not in L }

2. Concatenation of Languages $L_1 \cdot L_2 = L_1 L_2 =$

   $\{w = x \cdot y$ for some $x \in L_1$ and $y \in L_2\}$

3. Kleene star of L, L^* = { $w = w_1 w_2 w_3 \ldots w_k$ for some $k \geq 0$ and $w_1, w_2, w_3, \ldots, w_k$ are all in L}

4. $L^+ = L \cdot L^*$

(Concatenate together one or more strings from L.)

Matrix multiplication:

$$\begin{bmatrix} 1 & 2 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} = \begin{bmatrix} 3 & 3 \\ 1 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} 1 & 2 \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 3 \\ 1 & 3 \end{bmatrix}$$

Concatenation:

ab · bb = abbb

bb · ab = bbab

$L_1 = \{\varepsilon, 0, 1, 00, 01, 10, 11\}$

$L_2 = \{0\}$

$L_3 = \{\ \} = \Phi$

$L_4 = \{\ \varepsilon\ \}$

What are the languages:

1. $L_1{}^*$
2. $L_2{}^*$
3. $L_3{}^*$
4. $L_4{}^*$
5. $L_2 \cdot (\ L_1{}^*)$
6. $(L_2 \cdot L_1)^*$
7. $L_2 \cdot (\ L_1{}^*\ ) \cdot L_2$

What does $L_2 \cdot L_1{}^*$ mean?

Precedence of Operators

Exponents	highest	Kleene star
Multiplication	⇩	Concatenation
Addition	lowest	Union

$L_1 = \{\varepsilon, 0, 1, 00, 01, 10, 11\}$

$L_2 = \{0\}$

$L_3 = \{\ \} = \Phi$

$L_4 = \{\ \varepsilon\ \}$

What are the languages:

1. $L_4 \cup (L_3 \cdot L_2)$

2. $(L_4 \cup L_3) \cdot L_2$

What does $L_4 \cup L_3 \cdot L_2$ mean?

How is this interpreted (add parentheses)?

$\{a\} \cdot \{b\} \cup \{a\} \cdot \{b\}^* \cdot \{a\}$

$L_2 = \{w \in \{0,1\}^* : w$ is the binary representation of a prime with no leading zeroes$\}$

The complement is:

$\{w \in \{0,1\}^* : w$ is the binary representation of a number which is not prime which has no leading 0's or w starts with $0\}$

Note: 1 is not prime or composite. The string 1 is in the complement since it is not in L.

Regular Languages over Alphabet Σ:

[Basis] 1. Φ and $\{\sigma\}$ for each $\sigma \in \Sigma$ are regular languages.

[Inductive step] If L_1 and L_2 are regular languages, then so are:

2. $L_1 \cdot L_2$,

3. $L_1 \cup L_2$, and

4. $L_1{}^*$.

Regular Languages over Alphabet Σ:

[Basis] 1. Φ and $\{\sigma\}$ for each $\sigma \in \Sigma$ are regular languages.

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2. $L_1 \cdot L_2$,
3. $L_1 \cup L_2$, and
4. $L_1{}^*$.

Example:
$\{w \in \{a, b\}^* : w$ contains aab as a substring$\}$

Regular expressions over Σ:

[Basis] 1. Φ and σ for each $\sigma \in \Sigma$ are regular expressions.

[Inductive step] If α and β are regular expressions, then so are:

2. $(\alpha\beta)$

3. $(\alpha \cup \beta)$ and

4. α^*

Note: Regular expressions are strings over

$\Sigma \cup \{ \, (\, , \,) \, , \, \Phi \, , \cup \, , \, * \, \}$

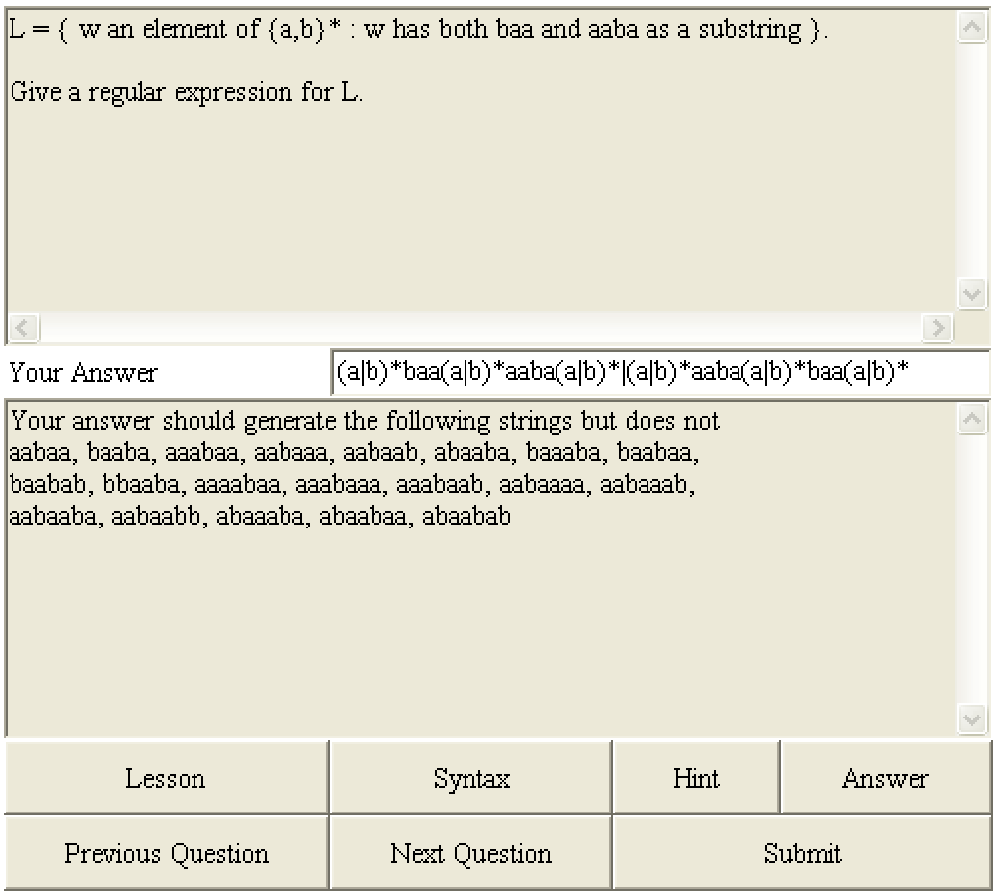
for some alphabet Σ.

Prove the following languages over $\Sigma=\{0,1\}$ are regular by giving regular expressions for them:

1. $\{w$: w has odd length$\}$
2. $\{w$: w contains 0011$\}$
3. $\{w$: w does not contain 01$\}$
4. $\{w$: w starts and ends with the same symbol ($|w| \geq 1$)$\}$

TUTORIAL: L = { w an element of {a,b}* : w has both baa and aaba as a substring }.

(a|b)*baa(a|b)*aaba(a|b)*|(a|b)*aaba(a|b)*baa(a|b)*



MISSING:
aabaa,
baaba,
...

See home page for link to regular expression tutorial