Homework 3
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Please think carefully about how you are going to organise your answers *before* you begin writing. Make sure your answers are complete, clean, concise and rigorous.

1. Do both parts of Exercise 1.21 from the textbook. Use the R_{ij}^k method as described in the lecture notes for the Oct 12 lecture; do not use the textbook's "GNFA method." Try to simplify the intermediate regular expressions, so as to make your own life simple! [6+7 points]

2. Are the following statements *always* true? If true, give a brief justification and if false, give a concrete counterexample. Below, A and B denote languages over some alphabet Σ.

   2.1. If $A \cup B$ is regular, then at least one of A and B is regular. [5 points]

   2.2. If $A \cap B$ is regular, then at least one of A and B is regular. [5 points]

   2.3. If $\overline{A}$ (defined as $\Sigma^* - A$) is regular, then A is regular. [5 points]

   2.4. A union of arbitrarily many regular languages is regular, even if it is an infinite union. [5 points]

   2.5. An intersection of arbitrarily many regular languages is regular, even if it is an infinite intersection. [5 points]

3. For a language L over alphabet Σ, define $\textsc{Max}(L) = \{x \in \Sigma^* : x \in L$ and x is not a proper prefix of any string in $L\}$. Prove that if L is regular, then so is $\textsc{Max}(L)$. [8 points]

4. For a language L over alphabet Σ, define $\textsc{Cycle}(L) = \{x_1 x_2 : \exists\, x_1, x_2 \in \Sigma^*$ such that $x_2 x_1 \in L\}$. Prove that if L is regular, then so is $\textsc{Cycle}(L)$. [12 points]

Continued overleaf...

5. For each of the following languages, say whether or not the language is regular and prove your answer. To prove that a language is regular, specify a finite automaton or a regular expression for that language. To prove that a language is not regular, use the pumping lemma or closure properties of regular languages.

   Proofs *must* be precisely written. *Make sure you fully understand the definitions of the sets before answering.*

   5.1. $\{0^m 1^n 0^{m+n} : m, n \geq 0\}$. [7 points]

   5.2. $\{0^m 1^n : m \text{ divides } n\}$. [7 points]

   5.3. $\{xwx^R : x, w \in \{0,1\}^*, |x| > 0 \text{ and } |w| > 0\}$. [7 points]

   5.4. $\{0^{2^n} : n \geq 0\}$. [7 points]

   5.5. Problem 1.35 from the textbook. [7 points]

   5.6. $\{0^m 1^n : m, n \geq 0 \text{ and } m \neq n\}$. [7 points]

Challenge Problems

CP3: Let L be any subset of 0^*. Prove that L^* is regular.

This is a delightful problem and will teach you something nice about regular languages if you solve it.