

Design *nondeterministic* finite-state automata that accept the following languages over the binary alphabet $\{0, 1\}$. Briefly describe how your NFA works.

Your NFAs can have multiple start states and/or ε -transitions, but remember to write that down as part of your description. Either drawings or formal descriptions are acceptable, as long as the states Q , the start state s (or start states S), the accepting states A , and the transition function δ are all clear.

- o. $\emptyset$
 1. Binary strings that end with the suffix 001 .
 2. Binary strings that contain at least one of the substrings 11 , 101 , and 1001 .
 3. $(01)^*(010)^*(10)^*$
 4. $\{w \in \{0, 1\}^* \mid \min\{\#(0, w), \#(1, w)\} \leq 3\}$
 5. Binary strings that contain a substring of the form $1x1$, where $|x|$ is odd.
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Problems to think about later:

6. Binary strings with length at least 7 whose 7th symbol from the end is 1 .
7. Binary strings that contain at least one palindrome¹ substring of length 4. [*Hint: What are the palindromes of length 4?*]
8. Binary strings that contain both 01010 and 1001001 as substrings.
9. Binary strings that contain *at least two* of the substrings 11 , 101 , and 1001 .
10. Binary strings of length at least 547 such that the 173d symbol from the beginning is equal to the 374th symbol from the end.
[*Hint: Use mathematical notation.*]

¹A *palindrome* is a string that is equal to its reversal, like A or $POOP$ or $STRESSED \diamond DESSERTS$ or the empty string.