Problem 1: Key terms. Regular expression, generalized NFA, pigeon-hole principle, pumping lemma, pumping length, pumping up, pumping down.

Problem 2: True or False?
1. If \( L_1 \) and \( L_2 \) are regular, then \( L_1 \cup L_2 \) is regular.
2. If \( L_1 \) and \( L_2 \) are non-regular, then \( L_1 \cap L_2 \) is non-regular.
3. If \( L_1 \) is regular and \( L_2 \) is non-regular, then \( L_1 \cup L_2 \) is non-regular.
4. If \( L_1 \) is regular, \( L_2 \) is non-regular, and \( L_1 \cap L_2 \) is regular, then \( L_1 \cup L_2 \) is non-regular.

Problem 3: Regular Expressions. Write regular expressions for the following languages. The alphabet is \( \{0,1\}^* \).
1. \( A_1 = \{w|w \text{ contains at least two 0's}\} \).
2. \( A_2 = \{w|w \text{ contains an even number of 0's}\} \).
3. \( A_3 = \{w|w \text{ does not contain 100 as a substring}\} \).

Problem 4: Proving non-regularity: the Pumping Lemma. Prove that the following languages are not regular.
1. \( L_1 = \{0^i1^j0^k| k > i + j\} \).
2. \( L_2 = \{0^i1^j| j \text{ is a multiple of } i}\) .
3. \( L_3 = \{0^i1^j| i > j\} \).

Problem 5: Proving non-regularity using closure properties
1. \( L_5 = \{\text{0}^i\text{1}^j, i \neq j\} \)