Write all answers in the answers book provided.
• You can keep the exam. Only return the answers book.
• You are allowed to consult one letter-size paper, handwritten on one side. Besides that, the exam is closed book, closed notes.
• There are 8 question, totaling 110 points, in this exam. You have 1 hour and 20 minutes to finish it.

(1) (20 points) What is the output of each Ruby program below? Ignore any possible warning message.
(a) puts("ab" +
    if nil
      "cd"
    else
      "ef"
    end)
(b) a = b = ["c", "a", "b"]
a = a.sort
puts b
(c) a = [1, 2, 3]
b = ["x", "y"]
c = [a, b, [a, b]]
puts c[-1][0]
(d) h = Hash.new(0)
h["a"] = h["b"]
h["b"] = 7
h["c"] += 2
puts "#{h["a"]} #{h["b"]} #{h["c"]}"

(2) (10 points) Write a Ruby program that reads several lines from the input, and prints only the lines that contain exclusively the following characters: uppercase and lowercase letters, digits, and underscore. For example, lines that contain space or punctuation should not be printed.

(3) (21 points) Write a formal regular expression for each of the languages below. The alphabet is Σ = {a, b}. The only operators allowed are concatenation, * and | (do not write a Ruby regular expression).
(a) \{w | w begins with a and ends with a \}
(b) \{w | all a’s are immediately followed by b in w \}
(c) The union of the two languages above.
(4) (8 points) Write a formal regular expression the language below. The alphabet is \( \Sigma = \{a, b, c\} \). The only operators allowed are concatenation, * and | (do not write a Ruby regular expression).

\[ \{w \mid \text{all consonants are adjacent to a consonant on at least one side in } w \} \]

Notice that \( b \) and \( c \) are the only consonants in the alphabet \( \Sigma \). For example, \( a \), \( bb \), \( bc \), and \( aabbabcba \) are in the language, but \( b \), \( ab \), and \( aba \) are not.

(5) (21 points) Write a DFA for each of the languages below. The alphabet is \( \Sigma = \{a, b\} \).

(a) \( \{w \mid w \text{ contains at most one } b \} \)

(b) \( \{w \mid \#a(w) = 0 \text{ (mod 2) and } \#b(w) \neq 0 \text{ (mod 3) } \} \)

(c) \( \{w \mid w \text{ ends with } aab \} \)

(6) (10 points) Convert the following NFA to a NFA without \( \varepsilon \) transitions.

(7) (10 points) Convert the following NFA without \( \varepsilon \) transitions to a DFA.

(8) (10 points) Convert the following formal regular expression to a NFA:

\[ (((a|b|c)^*cc(a|b))^* \]