Specialized Subjects

10:00-12:30, Monday, August 21, 2023

Instructions

1. Do not open this booklet before the examination begins.

2. This booklet contains five problems. The number of pages is seven excluding this cover sheet and blank pages. If you find missing or badly printed pages, ask the proctor for exchange.

3. Answer three problems. You can select any three out of the five. Your answer to each problem should be written on a separate sheet. You may use the reverse side of the sheet if necessary.

4. Fill the top parts of your three answer sheets as instructed below. Before submitting your answer sheets, make sure that the top parts are correctly filled.

専　門　科　目

第　　問

↑ Write the problem No.

受験番号				

↑ Write the examinee No.

5. Submit all the three answer sheets with the examinee number and the problem number, even if your answer is blank.

6. Answer either in Japanese or in English.

7. This booklet and the scratch paper must be returned at the end of the examination.

8. This English translation is supplemental and provided for the convenience of applicants. The Japanese version is the formal one.

Problem 1

Consider the circuit consisting of a power supply E, a resistor (resistance R), a capacitor (capacitance C), and an inductor (inductance L), as shown in Fig. Let i be the current in the circuit. Answer the following questions. If necessary, you may use the Laplace transform table shown in Table.

(1) Suppose that the power supply E is a sine-wave AC voltage source with amplitude V_0 and angular frequency ω, and its voltage at time t is $v(t) = V_0 \sin(\omega t)$. Calculate the effective value of the AC current i.

(2) In the case of (1), suppose that C varies, while V_0, ω, R, and L are fixed. Find the value of C that maximizes the effective value of the AC current i. Answer the name of the phenomenon of this circuit at this situation.

(3) Next, we consider the case that the voltage of the power source E varies according to time t as follows.

$$v(t) = \begin{cases} 0 & (\text{if } t < 0) \\ V_1 & (\text{if } 0 \le t) \end{cases}$$

Here, $V_1 > 0$. We would like to analyze the behavior of the circuit by using the Laplace transform. Let $i(t)$ be the current i at time t, and $I(s)$ be its Laplace transform. Calculate $I(s)$. Assume that the energy is not stored either in the inductor or the capacitor at time $t = 0$.

(4) In the case of (3), calculate the current $i(t)$.

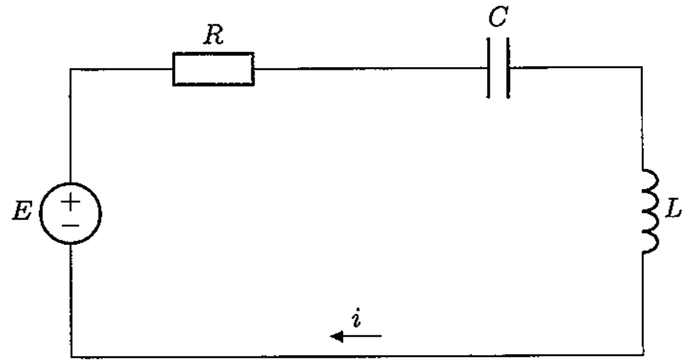

Fig.

Table

$f(t)$ $(0 \le t)$	$F(s)$
1	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$e^{at} f(t)$	$F(s-a)$
$\sin at$	$\frac{a}{s^2+a^2}$
$\sinh at$	$\frac{a}{s^2-a^2}$

Note that $a \in \mathbb{R}$.

Problem 2

Consider designing a binary digital synchronous sequential circuit as follows.

- The circuit has 2 inputs (X_1, X_0) and 1 output (Z).
- The inputs (X_1, X_0) represent a character from A to D encoded as $A = (0, 0)$, $B = (0, 1)$, $C = (1, 0)$, and $D = (1, 1)$.
- The output Z is 1 when the last two consecutive inputs are AA, AC, CB, CD, DA, or DC; otherwise Z is 0.

Answer the following questions.

(1) Explain in 50 words or less what a synchronous sequential circuit is.

(2) Draw a state transition diagram of the circuit in the form of a Mealy graph. Use 4 states corresponding to each character. Each state represents that the corresponding character is the last input.

(3) The output Z must be 0 until the first two characters are given as inputs to the circuit. Answer which state in the state transition diagram in (2) should be the initial state to achieve this.

(4) Simplify the state transition diagram in (2) so that it has 3 states.

(5) Create a state transition table from the state transition diagram in (4).

(6) Draw Karnaugh maps from the state transition table in (5).

(7) Simplify the logic as much as possible using the Karnaugh maps in (6), and draw the circuit using MIL simbols shown in the Fig.

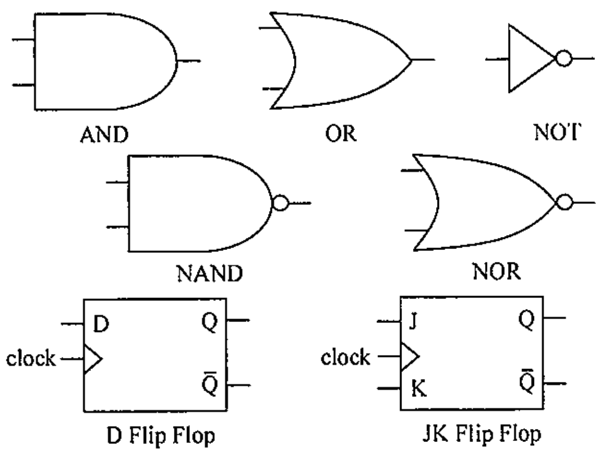

Fig.

Problem 3

Let A be an array of length n ($n \geq 1$) and the elements of this array be integers. The maximum element sum of possible continuous subarrays in a given array is called the maximum subsequence sum. Consider the algorithm MSS1 that finds the maximum subsequence sum of possible subarrays with length k ($1 \leq k \leq n$) in the array A. The array indices are assumed to start from 0.

```
MSS1(A, n, k):
  sumV = 0
  for j = 0 to k-1 do
     sumV = sumV + A[j]
  maxV = sumV
  for i = 1 to n-k do
     ┌─────────────────────┐
     │sumV = 0             │
     │for j = i to i+k-1 do│ (P)
     │  sumV = sumV + A[j] │
     └─────────────────────┘
     maxV = max(sumV, maxV)
  return maxV
```

Assume $A = \langle -1, 2, -3, 3, -2, 5, 3, -3, -2, 3 \rangle$.
Answer the following questions.

(1) Apply MSS1 with $n = 10$ and $k = 3$. During the execution of this algorithm, show the transition of the values of `i`, `sumV`, and `maxV` just before evaluating `max(sumV, maxV)`. Also, describe the time complexity of this algorithm in the Big O notation.

(2) Modify the pseudo code in the box shown by `(P)` so that time complexity of MSS1 is $O(n)$.

(3) MSS2 is an an algorithm that takes A and n and returns the maximum subsequence sum of possible subarrays <u>with length 1 or more</u> in the time complexity of $O(n)$. Design MSS2 based on MSS1 and write its pseudo code. You must not define any new arrays. Also, write down the subarray corresponding to the maximum subsequence sum.

(4) Write a pseudo code for MSS3 that takes A, n, and k and returns the maximum subsequence sum of possible subarrays <u>with length k or more</u> in the time complexity of $O(n)$. You may use newly defined two arrays B and C by the following code. Also, write down the subarray corresponding to the maximum subsequence sum when $k = 5$.

```
B[0] = A[0]
C[0] = min(B[0], 0)
for i = 1 to n-1 do
   B[i] = B[i-1] + A[i]
   C[i] = min(B[i], C[i-1])
```

(5) Explain how to realize an algorithm to determine in the time complexity of $O(n)$ whether there exists a subsequence of length k or more whose elements have mean value L or more.

Problem 4

Consider the convolutional encoder shown in Fig. Here, the convolutional encoder consists of 1-bit shift registers S_1 and S_2, as well as exclusive-OR operations. Also, a denotes an input bit and (b_1, b_2) denote encoded bits. Assume that each initial state (at the time index $t = 0$) of S_1 and S_2 is 0. Answer the following questions.

(1) Give the convolutional encoder's coding rate and constraint length. Also, show the generating polynomials for b_1 and b_2, respectively.

(2) Answer the encoded bit sequence when the input bit sequence of the convolutional encoder is 0100.

(3) Draw the Trellis diagram showing the state transitions of S_1 and S_2 from $t = 0$ to $t = 4$.

(4) When the encoded bits at $t = 2$ are $(b_1, b_2) = (0, 1)$, and the encoded bits at $t = 3$ are $(b_1, b_2) = (1, 1)$, show all the possible encoded bits (b_1, b_2) at $t = 4$.

(5) Suppose an encoded bit sequence is transmitted, and a bit sequence 10101011 is received over a noisy communication channel. Obtain the decoding result (the input bit sequence) with error correction. Also, show the reason for the result.

(6) a) State an advantage and a disadvantage of increasing the coding rate.
b) State an advantage and a disadvantage of increasing the constraint length.

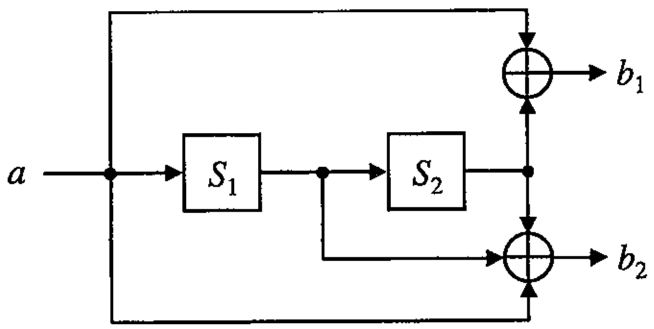

Fig.

Problem 5

The source S is a first-order Markov information source outputting 0 and 1. 0 is followed by 0 with a probability of 0.9 and 1 is followed by 1 with a probability of 0.6. The following may be used. $\log_2 3 = 1.58$, $\log_2 5 = 2.32$. For the calculations, two significant digits are sufficient.

(1) Show a state transition diagram of the source S.

(2) Obtain the probability of each 0 and 1 output from the source S.

(3) Obtain the entropy of the source S.

Assume the following four methods of coding to compress the output symbols of the source S.

a. fixed-length coding of fixed-length symbol sequences

b. variable-length coding of fixed-length symbol sequences

c. fixed-length coding of variable-length symbol sequences

d. variable-length coding of variable-length symbol sequences

Consider the fixed-length symbol sequences as 00, 01, 10, and 11, and the variable-length symbol sequences as 000, 001, 01, and 1 that are 0's run lengths up to length 3. The variable-length coding is Huffman coding consisting of 0 and 1.

(4) Obtain the probability of each of the fixed-length symbol sequences of 00, 01, 10, and 11.

(5) In the case b, show the Huffman code and obtain the average code length per symbol of the source S.

(6) Obtain the probability of each of the variable-length symbol sequences of 000, 001, 01, and 1.

(7) In the case c, obtain the average code length per symbol of the source S.

(8) Show the Huffman code for the case d and obtain the average code length per symbol of the source S.

(9) Arrange the methods of a, b, c, and d from the shortest to the longest in terms of the average code length.