# Specialized Subjects

10:00-12:00, Monday, August 17, 2020

Instructions

1. This booklet contains five problems. The number of pages is six excluding this cover sheet.

2. Answer three problems. You can select any three out of the five. Your answer to each problem should be written on a separate sheet. Answers to a single problem may be spread over several answer sheets. However, answers to multiple problems must not be written on one answer sheet.

3. Write the problem number that you have chosen and your examinee number on top of each answer sheet.

4. Submit the answer sheets for three problems. Even if you have solved only one or two problems, you must submit answer sheets with the examinee number and the problem number.

5. Answer either in Japanese or in English.

6. This booklet cannot be downloaded nor saved to your local computers.

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

## Problem 1

Suppose a circuit, shown in Fig. 1, composed of a sine-wave AC voltage source ($E$: effective voltage value) and a load. The load is composed of a resistor ($R$: resistance) and a reactor ($X_L$: inductive reactance). Assume $E = 200\,\mathrm{V}$, $R = 3\,\Omega$ and $X_L = 4\,\Omega$. Answer the following questions regarding this circuit.

(1) Calculate the effective current value $I$ shown as an arrow in Fig. 1.

(2) Calculate the active power $P$ consumed by the load and the apparent power $S$ supplied to the load.

(3) Suppose that a capacitor ($X_C$: capacitive reactance) is connected in parallel to the load as shown in Fig. 2. Describe the synthetic impedance $\dot{Z}$ between the terminals **a** and **b** as a function of $X_C$. Use $j$ as the imaginary unit.

(4) Find the value of $X_C$ to bring the power factor of the load to 100% in the case of (3).

(5) Describe qualitatively a benefit of improving a power factor of a load by the use of a capacitor as shown in Fig. 2.

(6) Find all the values of $X_C$ to bring the power factor of the load to 90% in the case of (3). The answer must be rounded off to three significant figures. Use the following approximate values if necessary. $\sqrt{2} \simeq 1.41$, $\sqrt{3} \simeq 1.73$, $\sqrt{5} \simeq 2.24$, $\sqrt{7} \simeq 2.65$, $\sqrt{11} \simeq 3.32$, $\sqrt{13} \simeq 3.61$, $\sqrt{17} \simeq 4.12$, $\sqrt{19} \simeq 4.36$, $\sqrt{23} \simeq 4.80$ and $\sqrt{29} \simeq 5.39$.

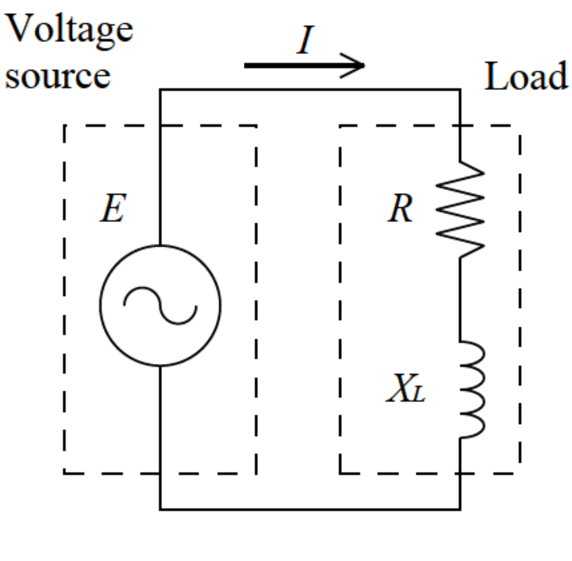



Fig. 1

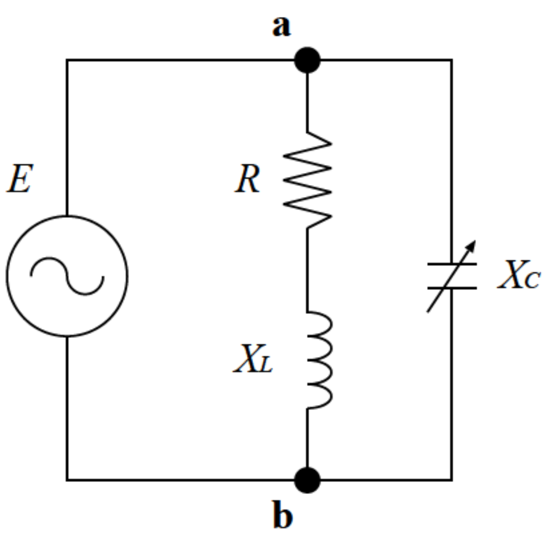



Fig. 2

## Problem 2

Suppose a data sequence $(X_0X_1X_2X_3\cdots)$ where each binary digit $X_k$ is synchronously input with a clock. Let us design a binary digital synchronous sequential circuit whose output $Z$ is 1 if and only if the number $X(i)$ defined by the following equation gets the remainder 3 when $X(i)$ is divided by 6; otherwise $Z$ is 0. Answer the following questions.

$$X(i) = \sum_{k=0}^{i}(X_k \times 2^{i-k}) \qquad (X_0X_1X_2\cdots X_i \text{ is regarded as a binary number.})$$

(1) Describe what a sequential circuit is within 25 words.

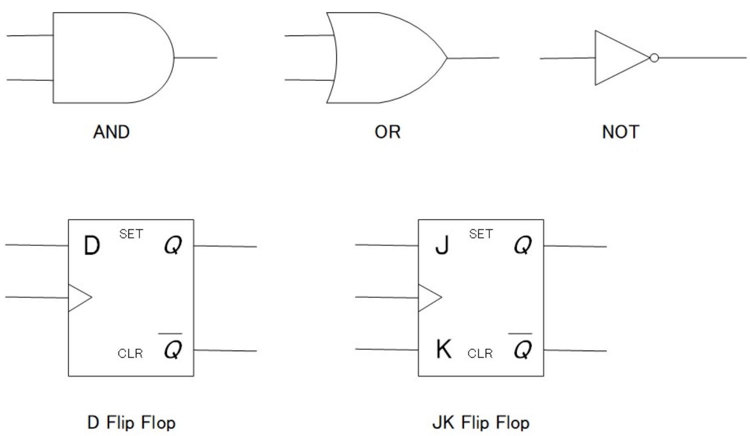
(2) Design a state transition diagram in the form of a Mealy graph.

(3) Make the state transition diagram as simple as possible. If the diagram cannot be theoretically simplified from (2), this question does not require an answer.

(4) Make the state transition table.

(5) Draw Karnaugh maps from (4).

(6) Design the sequential circuit and draw it using MIL symbols (see the Figure). Simplify the circuits as far as possible, using the Karnaugh maps in (5).



## Problem 3

There are $N$ objects moving on a field. When two objects $a$ and $b$ come into contact with each other at a time $t$, a triplet ($t$, $a$, $b$) is recorded. Once two objects have been in contact they participate in an equivalence relation and belong to the same equivalence class. At the beginning each equivalence class includes a single object. When its object is in contact with an object in another class, these classes merge into one equivalence class.

Answer the following questions.

(1) The pseudo code in the next page shows an union-find algorithm that keeps track of the equivalent class of each object. The function `init` initializes the array `parant` that records the equivalence classes (ignore the array `sizes` in this question). Every time the above mentioned triplet is recorded, the function `union` is executed and it updates the array `parent`. When $N$ equals 6, show the content of the array `parent` after the following triplets have been recorded.

$$(1, 0, 3), (2, 4, 2), (3, 1, 5), (4, 0, 1)$$

(2) Describe the order of the worst-case time complexity of the function `find` and `union` with reasons.

(3) Consider recording the number of objects in each equivalence class using the array `sizes`. Fill in (X) and (Y) in the pseudo code so that the function `size` returns the number of objects in the equivalence class including the designated object $a$. You can write multiple lines in (X) and (Y).

(4) The time complexity of the function `find` and `union` can be improved by modifying the function `union` using the array `sizes`. Modify and show the code (X) in the pseudo code. Describe the order of the worst-case time complexity of the improved `union` function with reasons.

(5) Consider finding the time when the designated objects $a$ and $b$ became equivalent. Describe how to modify the algorithm and explain the procedure of the function that finds the time. Describe the order of the worst-case time complexity of the function with reasons.

```
Union-find algorithm:
int parent[N];
int sizes[N];

void init() {
    for (int i = 0; i < N; ++i) {
        parent[i] = i;
        sizes[i] = 1;
    }
}

int find(int i) {
    while (parent[i] != i) {
        i = parent[i];
    }
    return i;
}

void union(int a, int b) {
    int i = find(a);
    int j = find(b);
    parent[i] = j;

    (X)

}

int size(int a) {

    (Y)

}
```

## Problem 4

Regarding the TCP/IP, answer the following questions.

(1) Describe an example which a bridge can do but a repeater cannot do at the data link layer.

(2) Describe the name of the protocol for retrieving the MAC address of the target host from its IP address in a network segment.

(3) Find the number of IP addresses allowed for allocation in the network segment 192.168.10.16/28.

(4) Describe three kinds of information that DHCP may distribute along with the IP address allocated for a host.

(5) Describe the role of the TTL field contained in IP packet headers.

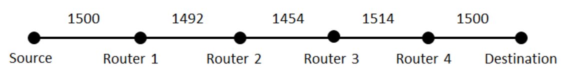
(6) Describe three typical functions that ICMP provides.

(7) Packet A (destination: 192.168.10.5) and packet B (destination: 192.168.10.12) will be transferred by a router based on the routing table shown below. Find the IP addresses respectively that packet A and packet B will be transferred to.

| Destination | Gateway |
|---|---|
| 192.168.10.8/29 | 192.168.11.249 |
| 192.168.10.0/26 | 192.168.11.246 |
| 192.168.10.0/24 | 192.168.11.244 |
| 0.0.0.0/0 | 192.168.11.1 |

(8) Describe the process when the size of a transferring IPv4 packet exceeds the maximum transmission unit (MTU) at the data link layer.

(9) In the case of TCP, find the best maximum segment size (MSS) of Source if the MTUs on Source-to-Destination path are given below. MSS is the maximum payload length of TCP segments. The IP header length is 20 octets and the TCP header length is 20 octets.




(10) Describe how the traceroute searches for a route.

(11) It is said that TCP provides reliable data delivery service. However, the use of TCP does not always enable the communication with remote hosts. The data can be tampered with during the delivery, too. Describe the reliability of TCP in this context.

(12) Describe the length of IPv6 addresses.

(13) Show an example of IPv6 addresses.

(14) Describe how the DNS resolves a name.

## Problem 5

Answer the following questions about the Fourier transform. Let

$$x(t) = \begin{cases} 1 & (-1 \le t < 0) \\ -2 & (0 \le t < 2) \\ 0 & (\text{otherwise}) \end{cases} \quad \text{and} \quad f(t) = \begin{cases} E & (|t| \le \tau/2) \\ 0 & (|t| > \tau/2) \end{cases} .$$

Here, $\tau > 0$ and $E > 0$. Note that $a(t) * b(t)$ denotes the convolution of two signals $a(t)$ and $b(t)$.

(1) Sketch the graphs of $x_o(t)$ and $x_e(t)$ that satisfy $x(t) = x_o(t) + x_e(t)$, where $x_o(-t) = -x_o(t)$ and $x_e(-t) = x_e(t)$.

(2) Let $X_o(\omega)$ be the Fourier transform of $x_o(t)$. Find $\text{Re}(X_o(\omega))$ that is the real part of $X_o(\omega)$.

(3) Derive $F(\omega)$ that is the Fourier transform of $f(t)$. And, find all $\omega$'s that satisfy $F(\omega) = 0$.

(4) Let $f_2(t) = f(t) * f(t)$. Sketch the graph of $f_2(t)$.

(5) Let $f_3(t) = f_2(t) * f(t)$. Using $F(\omega)$ of (3), find $F_2(\omega)$ and $F_3(\omega)$ that are the Fourier transforms of $f_2(t)$ and $f_3(t)$, respectively.

(6) Let $g(t) = \frac{d}{dt} f_2(t)$. Sketch the graph of $g(t)$, and express $g(t)$ as a formula using $f(t)$.

(7) Derive $G(\omega)$ that is the Fourier transform of $g(t)$.