Mechano-Informatics (Subject)

Date : H25(2013), February 8th, 9:30 – 11:30

Instruction:

0) Answers should be written either in Japanese or English.
1) Do not open this problem booklet until the start of the examination is announced.
2) Three problems are provided. Solve Problem 1 (Compulsory), and solve either Problem 2A or Problem 2B (Required Elective).
3) When you have multiple interpretations of a problem statement, you may clarify your interpretation by introducing adequate definitions and/or conditions in your answer.
4) If you find missing, misplaced, and/or unclearly printed pages in the problem booklet, notify the examiner.
5) Two answer sheets are provided. Check the number of them, and if you find excess or deficiency, notify the examiner. You must use a separate sheet for each problem. When you run short of space for your answer on the front side of the answer sheet, you may use the back side by clearly stating so on the front side.
6) In the designated blanks at the top of each answer sheet, write examination name "Mechano-Informatics (Subject)", "Master" or "Doctor" , your applicant number, and the problem number. Failure to fill up these blanks may void your test score.
7) An answer sheet is regarded as invalid if you write marks and/or symbols unrelated to the answer.
8) Submit both answer sheets even if they are blank, after filling in necessary information as instructed in 6) above.
9) Use the blank pages in the problem booklet for your draft.
10) Fill in the box below with your applicant number, and submit this booklet. Also submit the Japanese booklet with your applicant number in the corresponding box.

Applicant number:

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Problem 1 (Compulsory)

P. 1. List three different types of sensors to measure a rotation angle, and explain the principle and characteristics of each.

P. 2. List three different types of actuators used in robot joints, and explain the principle and characteristics of each.

P. 3. Write a program that asks the user to type in a positive integer *n* and outputs *n*! using a recursive call in the C language.

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Problem 2A (Required Elective)

P. 1. Solve the following problems regarding an oscillation circuit.

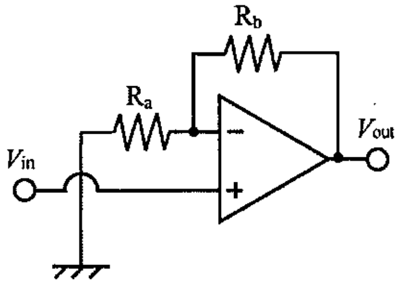

Fig. 1

(1) Obtain the transfer function $G_1(s)$ between the input V_{in} and the output V_{out} of the electric circuit in Fig. 1. Assume that the operational amplifier is ideal.

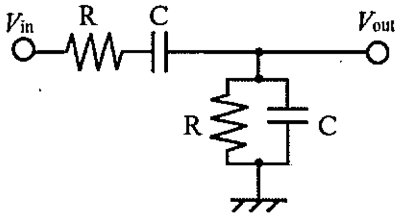

Fig. 2

(2) Obtain the transfer function $G_2(s)$ between the input V_{in} and the output V_{out} of the electric circuit in Fig. 2.

(3) The circuits of Fig. 1 and Fig. 2 are connected according to the block diagram of Fig. 3. When this system is operating at the stability limit, obtain the relationship between R_a and R_b, and obtain the oscillation frequency of the system.

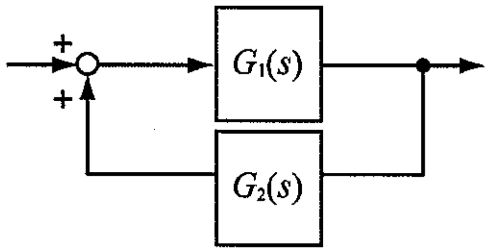

Fig. 3

P. 2. Consider a micro-scale cantilever as shown in Fig. 4. The cantilever is composed of a conductive elastic body, assuming that its weight can be ignored. A mass point P is tied to the tip of the cantilever. By turning ON the switch, AC voltage can be applied between the cantilever and the electrode placed on the ground. Consider to measure the slight change of the mass, Δm, when the mass at the mass point P changes slowly from m to $m + \Delta m$. Assume that the flexural rigidity is EI (E is Young's modulus and I is second moment of area) and length of the cantilever is ℓ.

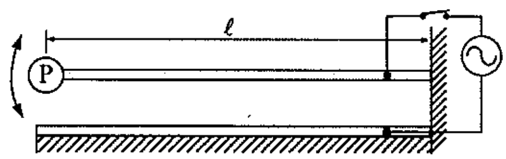

Fig. 4

(1) When the switch is OFF, obtain the maximum deflection of the cantilever caused by the change of the mass, Δm. Assume that gravity acts vertically downward and the acceleration due to gravity is g.

(2) When the switch is turned ON, the cantilever oscillates. Assuming that this oscillation can be described with a simple mass-spring system, obtain the resonant frequency. Also explain a method of detecting the change of the mass at the mass point P, Δm, using mathematical expressions. If needed, you may use an approximate expression, $1/\sqrt{1+\Delta x/x} \approx 1 - \Delta x/2x$.

(3) Explain an application where the measurement method in (2) is more appropriate than (1), and its reason(s) in 2 or 3 lines.

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Problem 2B (Required Elective)

Let $X \in \{\alpha, \beta, \gamma, \delta\}$ be a discrete random variable, whose probability distribution is defined as $P(X=\alpha)=1/2$, $P(X=\beta)=17/64$, $P(X=\gamma)=7/64$, and $P(X=\delta)=1/8$. Consider that n variables denoted by $x_1, x_2, \ldots, x_n$ are generated by this probability distribution. Consider a translation T which converts a sequence of these variables $x_1 x_2 \cdots x_n$ into a binary sequence. Assume that T converts the i-th variable x_i into 1110 when $x_i = \alpha$, 110 when $x_i = \beta$, 10 when $x_i = \gamma$, and 0 when $x_i = \delta$. Let $B_n = T(x_1 x_2 \cdots x_n) = b_1 b_2 \cdots b_{|B_n|}$ be the obtained binary variable sequence, where b_j is the j-th binary value of B_n and $|B_n|$ indicates the length of B_n. For example, $B_1 = 1110$ is obtained if $n=1$ and $x_1 = \alpha$, where $|B_1| = 4$, $b_1 = 1$, $b_2 = 1$, $b_3 = 1$, and $b_4 = 0$. Solve the following problems. Assume that $\log_2 7 = 2.81$, and $\log_2 17 = 4.09$.

P. 1. Obtain the amount of information $I(b_1 = 0)$, which is defined as

$$I(b_1 = 0) = -\log_2 P(b_1 = 0).$$

P. 2. Enumerate all the possible B_2.

P. 3. Obtain the entropy $H(b_2)$, which is defined as

$$H(b_2) = -\sum_{b_2 \in \{0,1\}} P(b_2) \log_2 P(b_2).$$

P. 4. Obtain the expected value of $|B_1|$ and $|B_2|/2$.

P. 5. Obtain the expected value of $|B_n|/n$, and explain the reason.

P. 6. Show an example of translation T' that makes the expected value of $|B_n|/n$ less than 2. Obtain the expected value of the $|B_n|/n$ in this case. Note that $x_1 x_2 \cdots x_n$ must be determined uniquely from the B_n.

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