00135

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	: **DMX5403 Control Systems Engineering**
Academic Year	: 2020/21
Date	: 10th February 2022
Time	: 09:30 – 12:30 hrs.
Duration	: **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **eight (8)** questions in **Five (5)** pages.
3. Write the answers for the **Section A** and **Section B** in separate answer books.
4. Answer **Q1**, which is **compulsory** and **FOUR** other questions, selecting at least **ONE** from **SECTION A** and **TWO (2)** from **SECTION B**. Answer for each question should commence from a new page.
5. Relevant charts/codes are provided.
6. This is a **Closed Book Test** (CBT).
7. Answers should be in clear handwriting and do not use Red colour pen.
8. Clearly state your assumptions, if any.

SECTION A

Q1 An automatic depth control of a Submarine in the deep sea is shown in Figure Q1. Suppose the submarine's Captain needs to hover (float) at a desired depth and sets the desired depth as a voltage from a calibrated potentiometer;

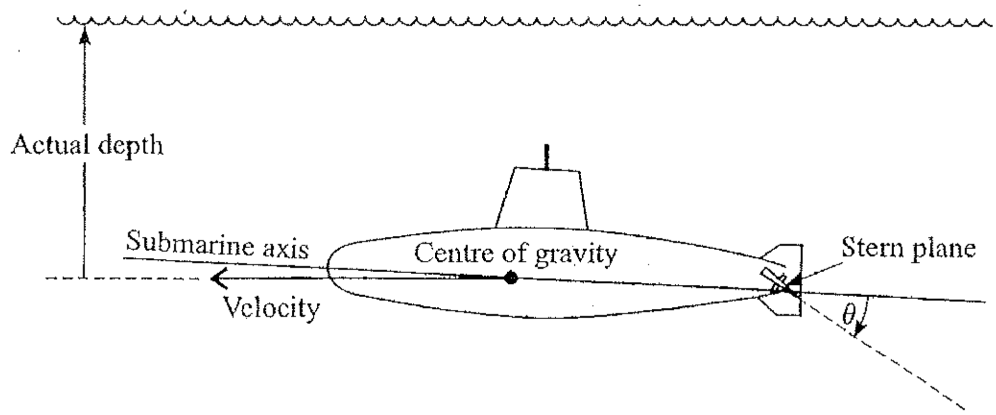

Figure Q1

(a) Explain briefly, how the system output can be measured and the type of transducer to be used. [03]

(b) What is the Actuator of the system? [02]

(c) Propose and explain the operation of this control system. [06]

(d) Draw a complete block diagram, identifying each block with its function. [04]

(e) Let $G_i(s)$'s and $H_i(s)$'s are the transfer functions (where i = 1, 2, 3, . . .) for the *forward* and *feedback* path blocks in (d), respectively. Find the closed loop transfer function of the system.

[05]

Q2 A feed forward transfer function of a unity feedback system is given by

$$\frac{5000}{s(s+75)}$$

(a) For a unit step input, find the [10]

i) Expected percent overshoot ii) Settling time of the system

(b) If $u(t)$ is a unit step function, find the steady state error for an input of [06]

i) $5u(t)$ ii) $5t \times u(t)$

(c) Explain briefly, how the overshoot and settling time are influenced on the stability of a control system. [04]

Q3 Figure Q3 shows the block diagram of a feedback control system.

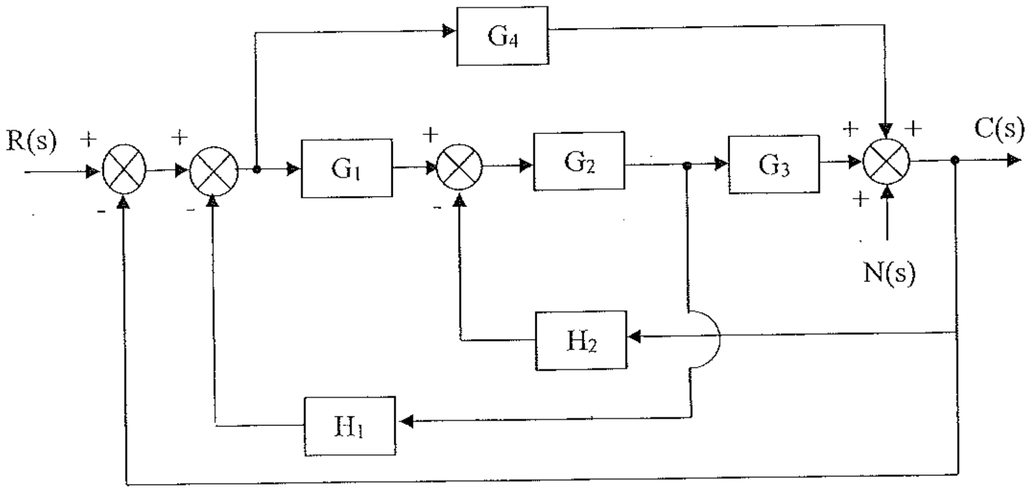

Figure Q3

(a) Draw the signal flow graph (SFG) for the given system. [12]

(b) Apply the SFG gain formula to find the transfer functions. [04]

i) $\left.\frac{C(s)}{R(s)}\right|_{N=0}$ ii) $\left.\frac{C(s)}{N(s)}\right|_{R=0}$

(c) Express the output C(s) in terms of R(s) and N(s) when both inputs are applied simultaneously. [04]

Q4

(a) A feedback control system is shown in Figure Q4.

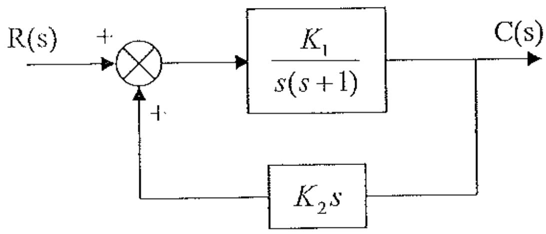

Figure Q4

i) Explain briefly, what is meant by *sensitivity* of a system. [02]

ii) Determine the sensitivity of the system to variations in each of the parameters K_1 and K_2 separately. [04]

(b) An open loop transfer function of a unity feedback system is given by

$$G(s) = \frac{(s+2)}{0.25s(s+1)(s+4)}$$

i) What is the *Type* of this system? [02]

ii) For the system, find the following error constants: [06]

I Acceleration II Velocity III Position

iii) For the system, find the steady state errors for the following unit inputs: [06]

I Parabolic II Ramp III Step

SECTION B

Q5

(a) Determine the Z transformation of "Zero- order Hold".

$$G_h(s) = \frac{1 - e^{-Ts}}{s}$$

[06]

(b) Consider the sampled data system shown in figure Q5. If sampling time "T" **is 0.5 sec.**

i. Find the Z domain transfer function of the system.

[08]

ii. Hence find the stability of the system.

[06]

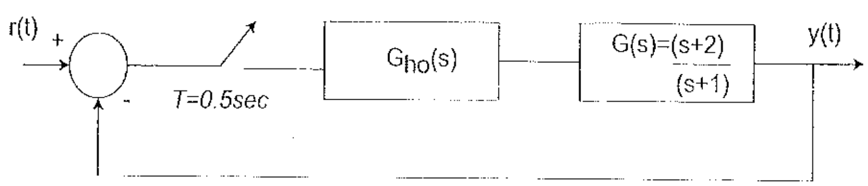

Figure Q5

Q6.

(a) A feedback system has an open loop transfer function of

$$G(s)H(s) = \frac{Ke^{-s}}{s(s^2 + 5s + 9)}$$

Determine, by using the Routh criterion, the maximum value of K for the closed loop system to be stable.

[06]

(b) A feedback control system has a open-loop transfer function

$$G(s)H(s) = \frac{K}{(s+2)(s^2 + 4s)}$$

Find the root locus as K is varied from 0 to ∞.

[12]

(c) Hence find the range of K to keep the system stable.

[02]

Q7.

(a) Define following terms.

i. Phase margin
ii. Gain margin
iii. Phase crossover point
iv. Gain crossover point

[08]

(b) Sketch the asymptotic bode plot for a unity feedback system characterized by loop transfer function

$$G(s) = \frac{K(1 + 0.1s)}{s^2(1 + 0.001s)}$$

Show that the system is continuously stable. Find the range of values for which the system is stable.

[12]

Q8.

(a) State three compensators used in control system engineering. Write the transfer functions each compensator and label the parameters.

[08]

(b) Briefly explain the how PID controller parameters effect to the rise time, overshoot, settling time and steady state error.

[12]

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