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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	**: DMX4543/MEX4243 Control Systems Engineering**
Academic Year	: 2017/18
Date	: 18th February 2019
Time	: 0930-1230hrs

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (8)** questions in **Six (06)** 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.**
5. State important, but relevant facts and information briefly and clearly. Wherever necessary, use neatly drawn sketches to explain answers.
6. Answer for each question should be commenced from a new page.
7. This is a Closed Book Test (CBT).
8. Answers should be in clear hand writing.
9. **Do not** use Red colour pen.

SECTION A

Q1.

(a) A challenging application of control system design is the use of nano-robotics in medicine. Nano-robots will require onboard computing capability, and very tiny sensors and actuators. Fortunately, advances in bio molecular computing, bio-sensors, and actuators are promising to enable medical nano-robots to emerge within the next decade. Many interesting medical applications will benefit from nano-robotics. For example use of robotic devices to precisely deliver anti-HIV drugs or to combat cancer by targeted delivering of chemotherapy.

Many concepts from underwater nano-robotics can be applied to nano-robotics within the blood stream. For example, plane surfaces and propellers can provide the required actuation with screw drives, providing the propulsion. Moreover, nano-robots can use signals from beacons, located outside the skin as sensors to determine their position. Further, nano-robots use energy from the chemical reaction of oxygen and glucose, available in the human body.

At the present time, we cannot construct practical nano-robots, but we can consider the control design process that would enable the eventual development and installation of these tiny devices in the medical field. Consider the problem of designing a nano-robot to deliver a cancer drug to a specific location within the human body as shown in figure Q1-(a). For example, target site might be the location of a tumor.

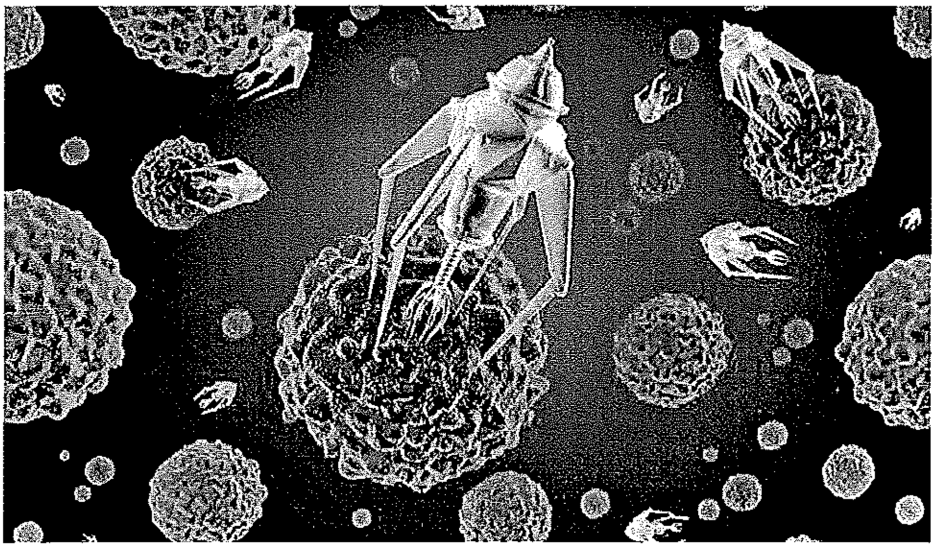

Figure Q1-(a): An illustration of a nano-robot, interacting with an infected human blood cell

Using the control design process

i. Draw the block diagram of this feedback control system by clearly showing each and every block and variables. [08 Marks]

ii. Describe how the closed loop feedback control system assists when delivering a cancer drug to a specific location inside the human body. [02 Marks]

(b) Figure Q1-(b) shows a mechanical system.

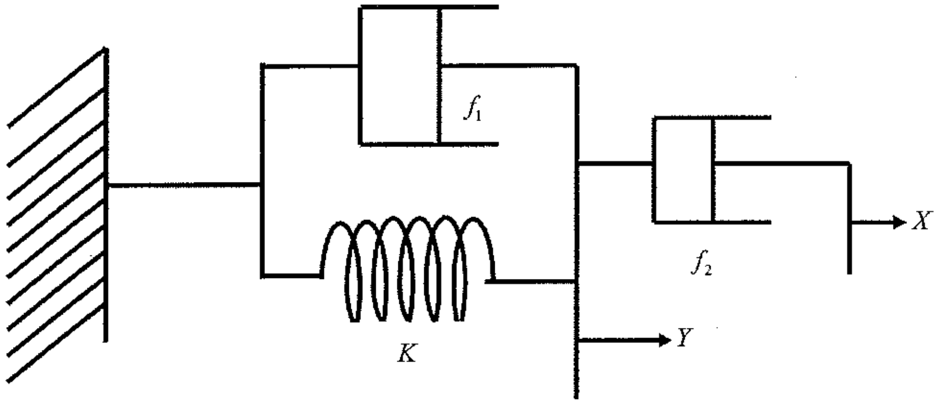

Figure Q1-(b)

i. Find the transfer function of the system, relating displacements x and y. [03 Marks]

ii. Assuming the initial conditions to be zero, obtain the Laplace transform of the system. [05 Marks]

iii. Hence find the output response of the system, $\frac{Y(s)}{X(s)}$. [02 Marks]

Q2 (a) Define the following terms related to 2[nd] order control systems.

(i) Rise Time (ii) Settling time

(iii) Peak time (iv) % Over shoot [02 Marks]

(b) The closed loop control system shown in figure Q2, employs a proportional plus error-rate control.

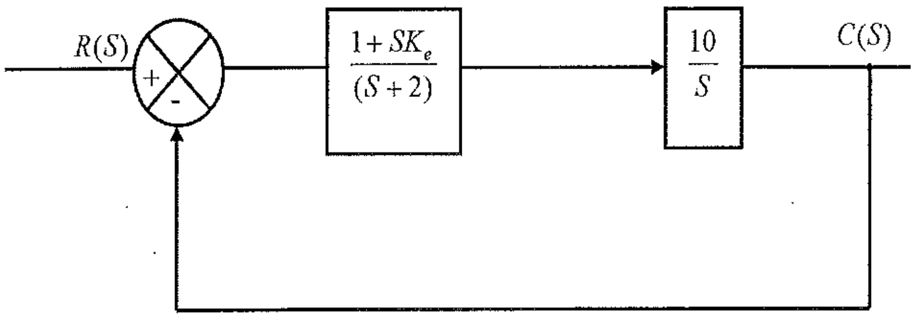

Figure Q2

(i). Determine the value of the error-rate factor K_e, assuming the damping ratio (ξ) as 0.5

[05 Marks]

(ii). For a unit ramp input, determine the values of settling time, maximum overshoot and the steady state error, with and without the error rate controller (K_e) [10 Marks]

(iii). Hence comment on the effect of error-rate control on system dynamics. [03 Marks]

Q3.

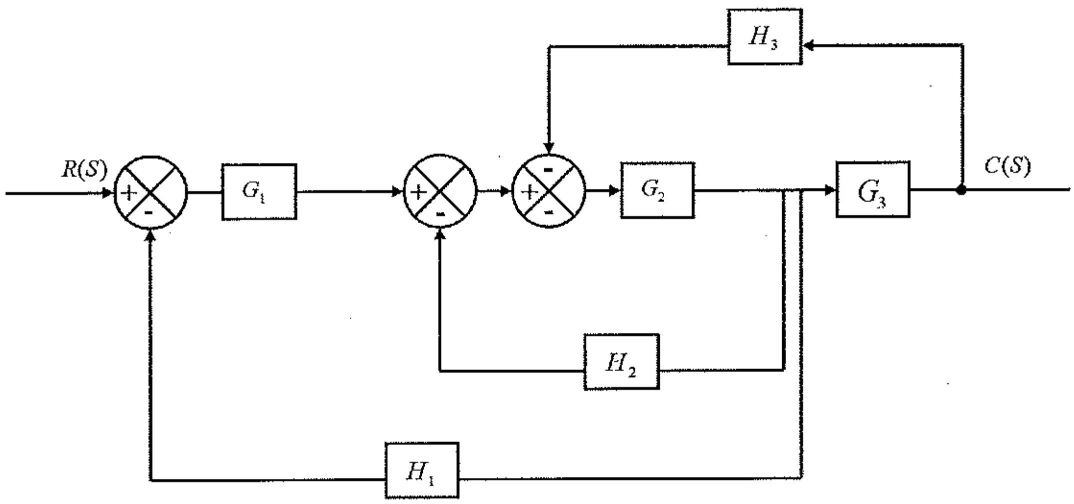

Figure Q3

(a) Reduce the block diagram shown in figure Q3 to a single transfer function.

[10 Marks]

(b) Use Mason's Gain formula to obtain the transfer function $\frac{C(s)}{R(s)}$ of the system.

(Show all the steps clearly) [10 Marks]

Q4 Consider the closed loop feedback control system shown in figure Q4.

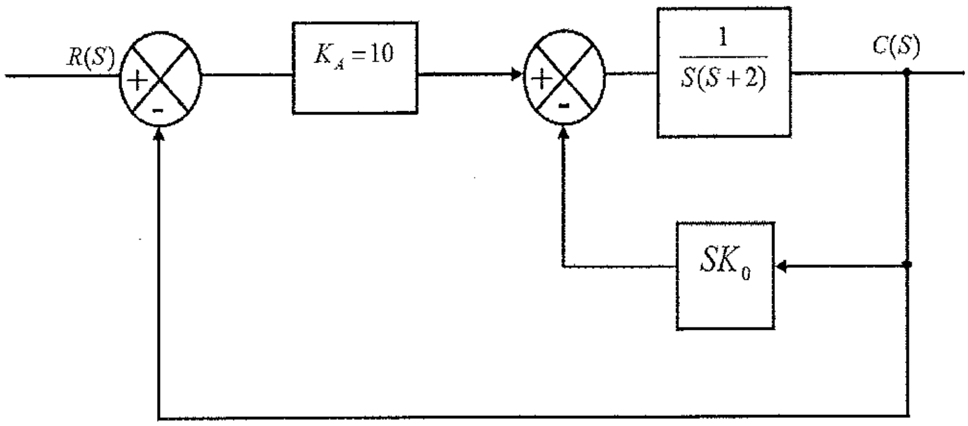

Figure Q4

(a) In the absence of derivative feedback ($K_0 = 0$), determine the damping factor and the natural frequency. [05 Marks]

(b) Determine the steady state error resulting from a unit ramp input, when $K_0 = 0$. [02 Marks]

(c) Determine the derivative feedback constant K_0, which will increase the damping factor of the system to 0.6. [05 Marks]

(d) What is the steady state error to unit ramp input with this setting of the derivative feedback constant? [04 Marks]

(e) Illustrate how the steady-state error of the system with derivative feedback to unit ramp input can be reduced to same value, obtained in part (a),while the damping factor is maintained at 0.6. [04 Marks]

(Hint: Find new K_0 and K_A values of the system, where the steady state error becomes minimum.)

SECTION B

Q5

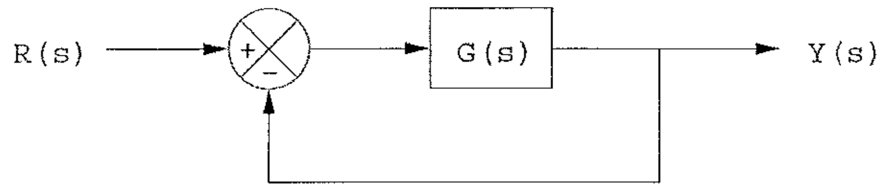

Figure Q5

The unity feedback control system shown in figure Q5, the transfer function of the open-loop control system given as $G(s)$ with damping factor ζ.

$$G(s) = \frac{100}{(s + 0.1)(s^2 + 20\zeta s + 100)}$$

(a) Draw asymptotic Bode plots (magnitude and phase) for the open-loop transfer function $G(s)$ when $\zeta = 1$. [Marks 10]

(b) Using the asymptotic Bode plots of part (a), determine the Phase margin (PM) and the Phase crossover frequency ω_c for $\zeta = 1$. [Marks 05]

(c) Explain why the closed-loop system is stable for $\zeta = 1$. [Marks 05]

Q6

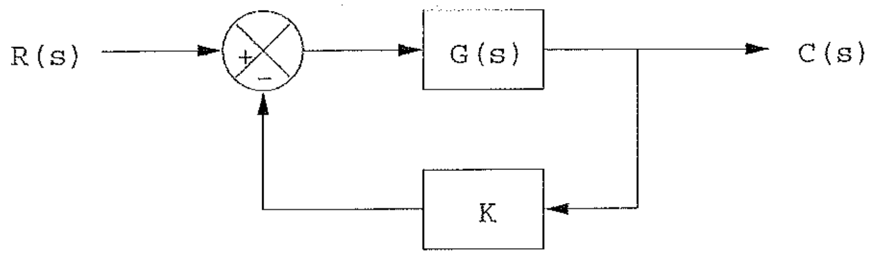

Figure Q6

The feedback control system shown in figure Q6, forward transfer $G(s)$ in the above closed-loop system is given by:

$$G(s) = \frac{1}{(s+1)(s+5)(s^2+6s+13)}$$

(a) Draw the root locus by varying $K = 0$ to $K = \infty$. [Marks 12]

(b) Identify all branches of the root locus of this particular system by specifying $K = 0$ and $K = \infty$ in the sketch. [Marks 02]

(c) Find the value of the maximum gain K_{max} for which the system is marginally stable using the Routh-Hurwitz criterion. [Marks 03]

(d) For $K = K_{max}$, solve the auxiliary equation in the Routh table and solve for the pair of purely imaginary roots on the $j\omega$-axis and their frequency of oscillation (in Hertz). [Marks 03]

Q7 The transfer function of a system $G(s)$ is:

$$G(s) = \frac{K(s+0.1)}{(s+3)(s+4)(s^2+10s+26)}$$

(a) Sketch the Nyquist plot of $G(s)$ for $K = 1$. [Marks 16]

(b) Determine the Gain margin and Phase margin of the system. [Marks 04]

Q8

(a) Describe the control actions of the following controllers.

i. Proportional controllers.

ii. Derivative controllers.

iii. Integral controllers.

(b) A PID controller is given by $u(t)_{PID} = 10e(t) + 6.5\dot{e}(t) + 1.5\int e(t)dt$. Identify controller gains, and implement the PD part of the controller using operational amplifiers.

(c) Describe an adverse effect of integral controller and how to overcome such an issue.

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