Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(ONLINE)
SEMESTER I
SESSION 2020/2021

COURSE NAME	:	CONTROL ENGINEERING
COURSE CODE	:	BDA 30703
PROGRAMME CODE	:	BDD
EXAMINATION DATE	:	JANUARY / FEBRUARY 2021
DURATION	:	3 HOURS
INSTRUCTION	:	1) PART A (COMPULSARY) ANSWERS **ALL** QUESTIONS 2) PART B (OPTIONAL) ANSWERS **ONE (1)** QUESTION

THIS QUESTION PAPER CONSISTS OF **SIX (6)** PAGES

PART A (COMPULSARY)

Q1 The design of a water-tank temperature control system required several steps. For this system,

(a) Construct the block diagram for the closed-loop control system consisting
- (i) a heating element
- (ii) a temperature setting panel
- (iii) a temperature sensor
- (iv) a PID controller
- (v) a water tank
- (vi) a comparator

(6 marks)

(b) Indicate in the block diagram constructed in Q1 (a) the locations of the following components
- (i) measuring equipment
- (ii) controlled system
- (iii) actuator
- (iv) error signal
- (v) input reference
- (vi) output

(6 marks)

(c) If the comparator used in Q1 (a) is designed using operational amplifier,
- (i) What type of operational amplifier is suitable for the purpose?
- (ii) Construct the circuit diagram of the selected operational amplifier
- (iii) Derive the error signal for the comparator
- (iv) If the output of the comparator need to be 10 times the actual difference, what are the suitable values of all resistors and/or capacitors used in the circuit (if any)?

(8 marks)

Q2 (a) Describe the open loop and closed loop system in terms of stability.

(2 marks)

(b) A system is presented as in block diagram as shown in **Figure Q2(b)**. Use,
Set 1: By replacing a=1, b=2 and c=3, if your last matric digit is 0-5
Set 2: By replacing a=3, b=1 and c=2, if your last matric digit is 6-9

(i) Convert the block diagram into signal flow graph

(4 marks)

(ii) Evaluate the transfer function, C(s)/R(s) using method in **Q2(b)(i)**

(12 marks)

Q3 A two-dimensional pendulum is constrained to move in the vertical plane as shown in **Figure Q3** For this system, the control input is the force F that moves the cart horizontally and the outputs are the angular position of the pendulum, θ.

(a) Define the free body diagram for the pendulum systems involved.

(4 marks)

(b) Define the mathematical equations for the pendulum systems involved.

(10 marks)

(c) Obtain the transfer function $\phi(s)/U(s)$.

(6 marks)

(Hint: Since the analysis and control design techniques will be employing in this example apply only to linear systems, this set of equations needs to be linearized. Specifically, we will linearize the equations about the vertically upward equilibrium position, $\theta = \pi$, and will assume that the system stays within a small neighborhood of this equilibrium. Let ϕ represent the deviation of the pendulum's position from equilibrium, that is, $\theta = \pi + \phi$. Again presuming a small deviation (ϕ) from equilibrium, the following small angle approximations of the nonlinear functions in our system equations:

$$\cos\theta = \cos(\pi + \phi) \approx -1, \sin\theta = \sin(\pi + \phi) \approx -\phi, \dot{\theta}^2 = \dot{\phi}^2 \approx 0)$$

Q4 Given the control system shown in **Figure Q4.**

(a) Determine the type of controller in use, clearly justifying your answer What are the controller gains in terms of K?

(5 marks)

(b) Draw the location of closed-loop poles for varying K, by plotting Root Loci.

(5 marks)

(c) Determine the range of K for which the closed-loop system is stable using Routh-Hurwitz array technique.

(5 marks)

(d) Find the value of critical K, above which the system becomes unstable, using the concept of imaginary poles ($s = \pm j\omega$).

(5 marks)

PART B (OPTIONAL)

Q5 (a) Describe briefly in graphical form the relative stability in Bode diagram.

(5 marks)

(b) Sketch the open loop Bode asymptotic plot showing the magnitude in dB as a function of log frequency for the transfer function given in **Figure Q5(b)** for K = 150 From sketched Bode diagram answer the following:

(i) Determine the gain margin and the phase margin of the system.

(ii) Evaluate the stability of the system.

(15 marks)

Q6 (a) For response in **Figure Q6(a) (i),(ii) and (iii),** identify and state whether the system is stable, unstable or marginally stable. Give example of transfer function for each of the graph.

(5 marks)

(b) Consider the feedback control system in **Figure Q6(b)(i).**

(i) Determine the transfer function of the open loop plant only from **Figure Q6(b)(i).**

(2 marks)

(ii) The step response obtained from the scope is shown as in **Figure Q6(b)(ii).** Determine the PID controller parameters (K_p, T_i, T_d) using Ziegler Nichols tuning method You may use $K_p = 1.2/a$, $T_i = 2L$ and $T_d = L/2$.

(10 marks)

(iii) Determine the transfer function of the PID controller based on the parameters in part (ii).

(3 marks)

-END OF QUESTIONS-

FINAL EXAMINATION

SEMESTER / SESSION : SEM I / 2020/2021
COURSE NAME : CONTROL ENGINEERING
PROGRAMME CODE : BDD
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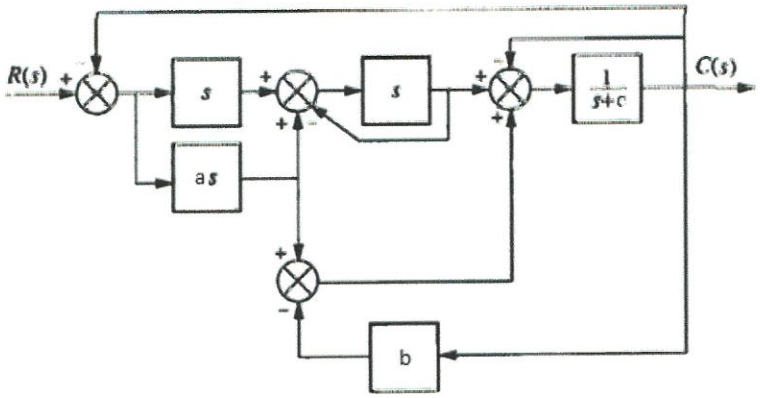

Figure Q2(b)

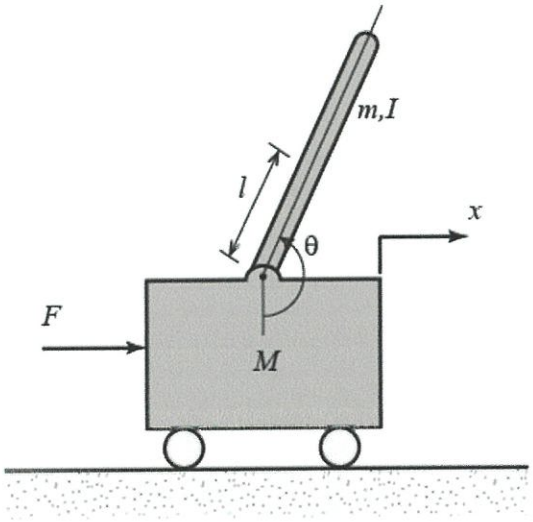

Figure Q3

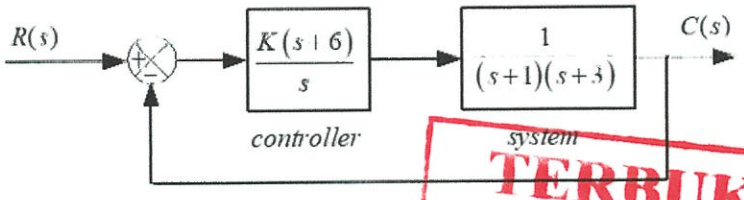

Figure Q4

FINAL EXAMINATION

SEMESTER / SESSION : SEM I / 2020/2021
COURSE NAME : CONTROL ENGINEERING
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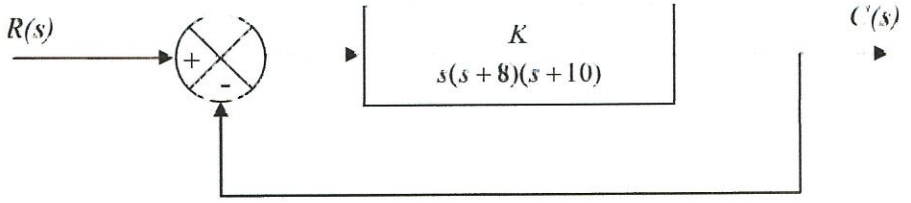
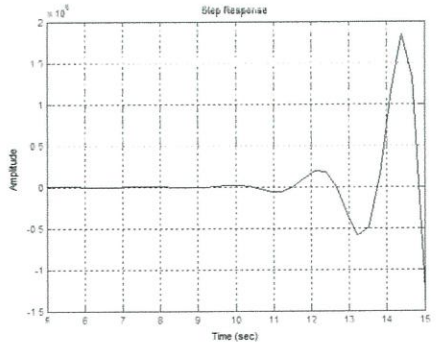
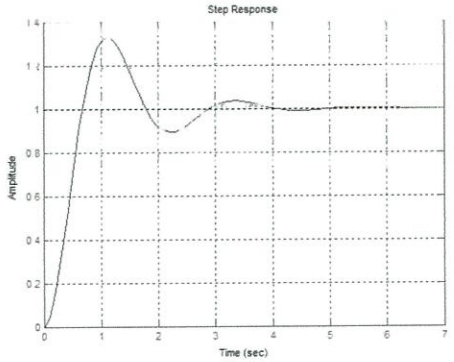


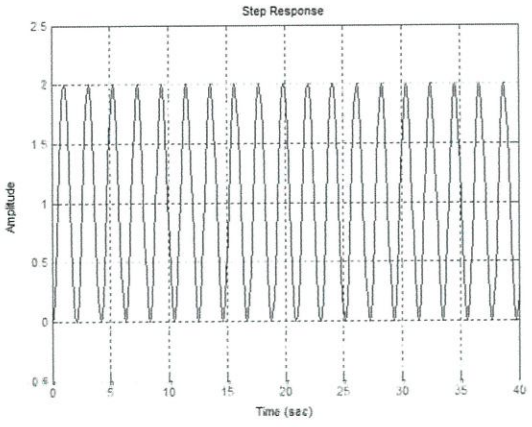
Figure Q5



(i)



(ii)



(iii)

Figure Q6 (a)

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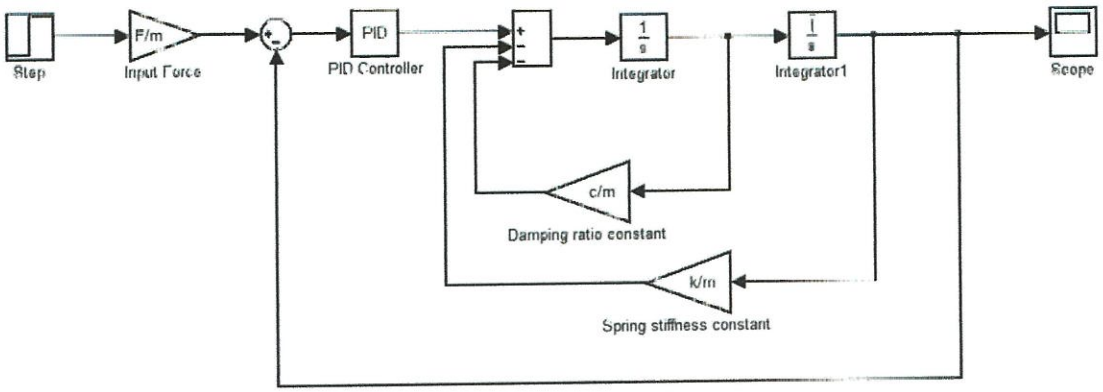

Figure Q6(b)(I)

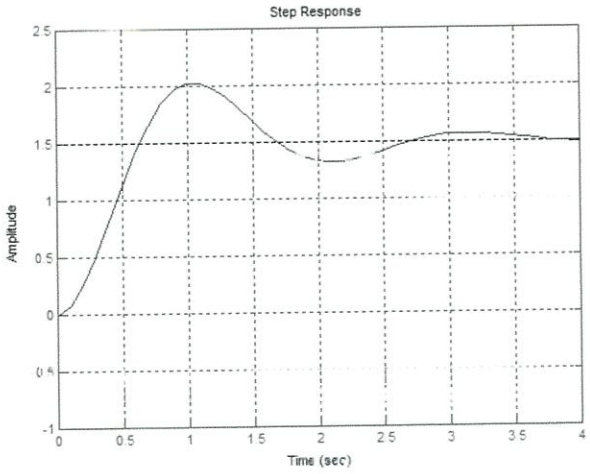

Figure Q6(b)(ii)