Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER 1
SESSION 2019/2020

COURSE NAME	:	CONTROL ENGINEERING
COURSE CODE	:	BDA 30703
PROGRAMME	:	BDD
EXAMINATION DATE	:	DECEMBER 2019 / JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	1) PART A (COMPULSORY): ANSWER **ALL** QUESTIONS 2) PART B (OPTIONAL): ANSWER **ONE (1)** QUESTION

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

PART A (COMPULSORY):
ANSWER **ALL** FOUR QUESTIONS

Q1 (a) **Figure Q1(a)** shows the heat flow measurement systems and illustrates the operation of the system. The heat flow sensor is used to detect the temperature from source side of the system. Explain **FOUR (4)** static characteristics for sensor to get quality output reading.

(8 marks)

(b) If heat flow totalizer in **Figure Q1(a)** use summing amplifier as shown in **Figure Q1 (b)**, design a summing amplifier to produce a specific output signal, such that $\mathbf{v_o = 1.25 - 2.5 \cos \omega t}$ volt. Let the input signals are $\mathbf{v_{I1} = -1.0\ V}$, $\mathbf{v_{I2} = 0.5 \cos \omega t}$ volt. Assume the feedback resistance $R_F = 10\ k\Omega$. Neglect $\mathbf{v_{I3}}$.

(8 marks)

(c) Explain the function of display devices such as:

(i) Strip Chart Recorder. (2 marks)

(ii) Printer. (2 marks)

Q2 (a) Explain briefly the comparison between open loop and closed loop system.

(6 marks)

(b) Solve and simplify the block diagram shown in **Figure Q2(b)**. Then, obtain the closed-loop transfer function C(s)/R(s).

(6 marks)

(c) Apply Mason's Rule to obtain the transfer function of the system represented by signal flow graph in **Figure Q2(c)**. Given:

$$\frac{Y(s)}{R(s)} = \frac{\sum P_k \Delta_k}{\Delta}$$

(8 marks)

Q3 **Figure Q3** shows a liquid-level system that is commonly used in industry for process control. The system consists of two liquid storage tanks and three short pipes that regulate flow of liquid. The associated parameters can be defined as follows:

q_i = liquid inflow rate to tank 1, m^3/sec
$q_{j=1,2}$ = liquid outflow rate from tanks 1 and 2, m^3/sec
$A_{j=1,2}$ = cross-sectional area of tanks 1 and 2, m^2
$h_{j=1,2}$ = height of liquid level in tanks 1 and 2, m
$R_{j=1,2}$ = resistance for liquid flow in pipe, $m/(m^3/sec)$

(a) Derive the differential equations describing the entire system in time domain. (4 marks)

(b) Transfer the equation derived in Q3(a) in Laplace domain. (4 marks)

(c) Draw the block diagram of the entire system using the equations in Q3(b). Note that h_2 is the output, and q_i is the input. In your block diagram you must show variables $H_1(s)$, $H_2(s)$, $Q_i(s)$, $Q_1(s)$ and $Q_2(s)$. (4 marks)

(d) Using block diagram reduction method, find the transfer function of the entire system that is $G(s) = H_2(s)/Q_i(s)$ (8 marks)

Q4 (a) Consider the model of a position servo system with velocity feedback shown in **Figure Q4.** Velocity feedback is attached to the system to reduce 80% overshoot. Given that $K_1 = 0.173$

(i) Find the transfer function of the system (3 marks)

(ii) Examine the values of K_2 and the settling time, T_S (8 marks)

(b) Characteristic equation for a solar tracker control system is given by $F(s)$. In order to set the correct setting of azimuth angle of the solar tracker, it is required to design a proper values of constant K

$$F(s) = s^4 + 25s^3 + 15s^2 + 20s + K = 0$$

(i) Analyze the range of values of K so that the system is marginally stable. (5 marks)

(ii) Find the frequency of sustained oscillations. (4 marks)

PART B (OPTIONAL):
ANSWER **ONE(1)** OUT OF TWO QUESTIONS

Q5 **Figure Q5(a)** shows a PID-controlled system block diagram. **Figure Q5(b)** is another variations of control system named I-PD controller that makes use of feedforward control to increase the effectiveness of the output response.

(a) Find the closed loop transfer function of the system shown in **Figure Q5(a)**
(10 marks)

(b) Find the closed loop transfer function of the system shown in **Figure Q5(b)**
(10 marks)

(c) Compare and show that the PID-controlled system in **Figure Q5(a)** is equivalent to the I-PD-controlled system as shown in **Figure Q5(b)**
(5 marks)

Q6 (a) Describe briefly in graphical form the relative stability in Bode Diagram
(5 marks)

(b) **Figure Q6** shows the block diagram control system of an automatic colour sorter machine.

(i) 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 Q6**. Let $K=150$.
(10 marks)

(ii) What is the gain margin and phase margin of the system
(3 marks)

(iii) Discuss the stability of the system
(2 marks)

-END OF QUESTIONS-

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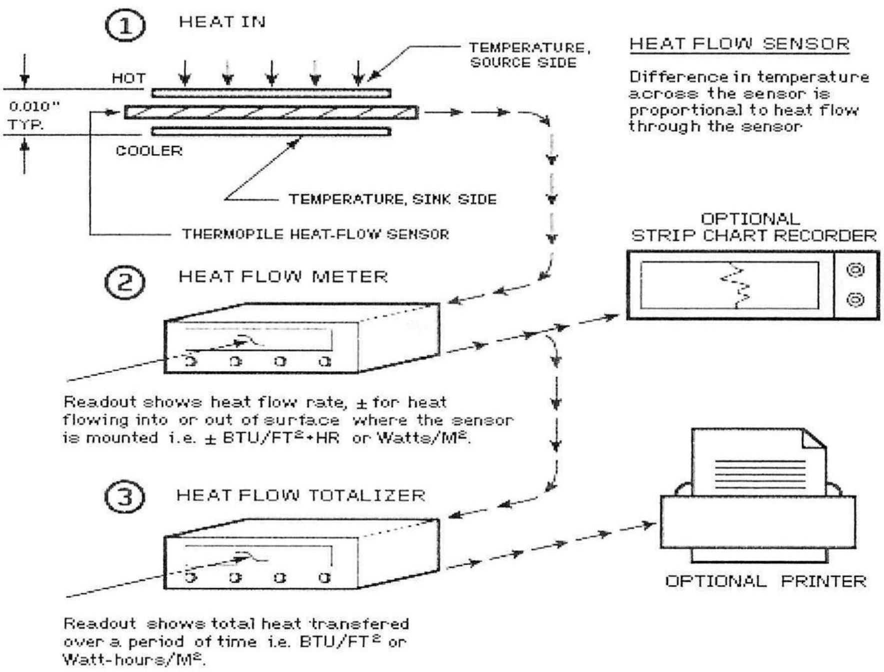

Figure Q1(a)

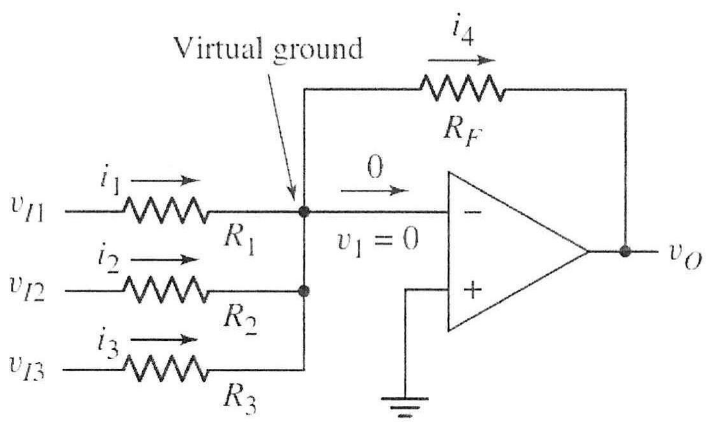

Figure Q1(b)

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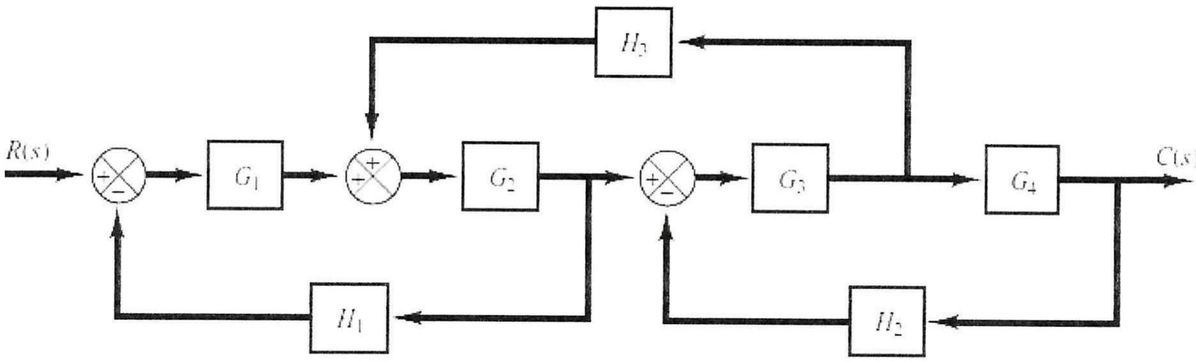

Figure Q2(b)

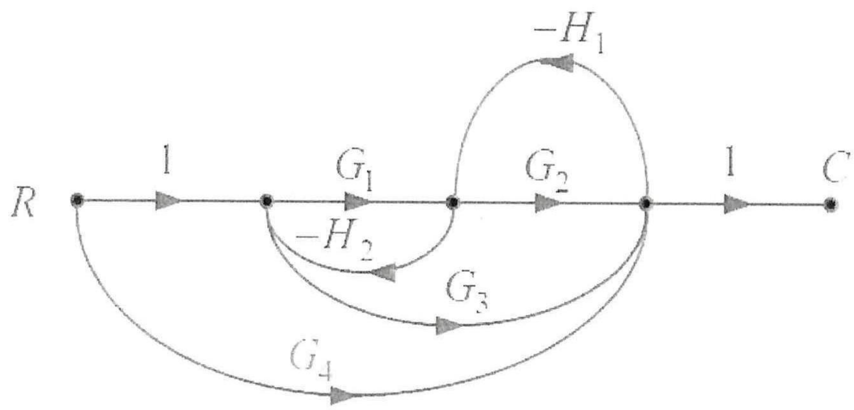

Figure Q2(c)

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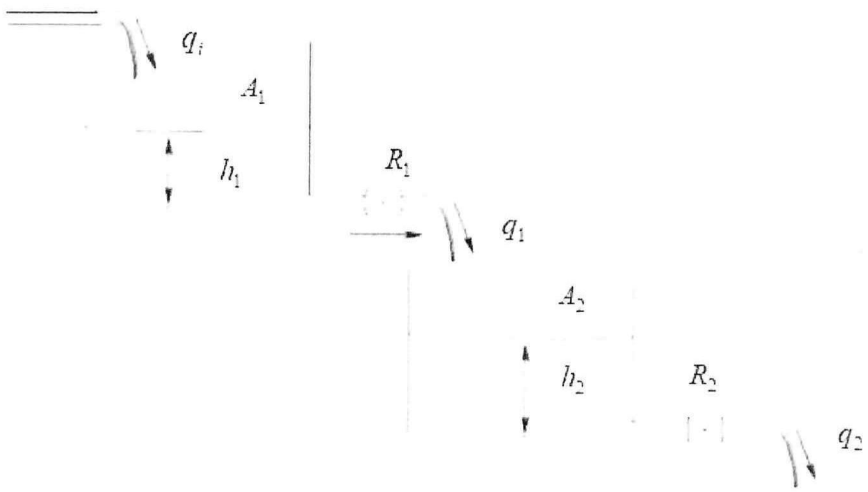

Figure Q3

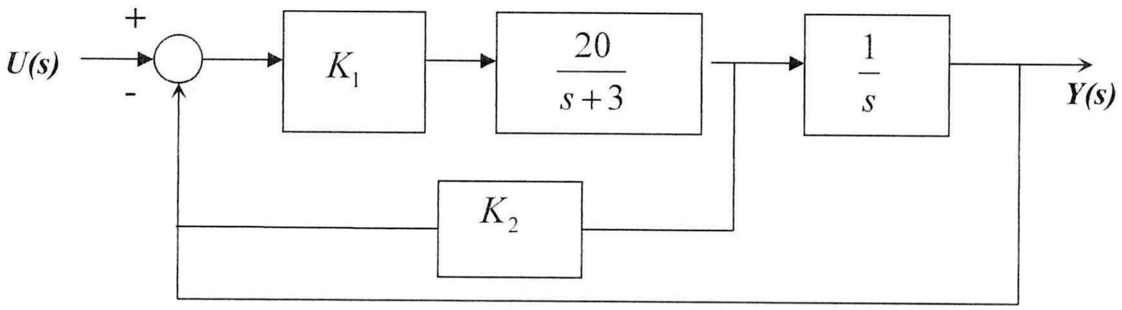

Figure Q4

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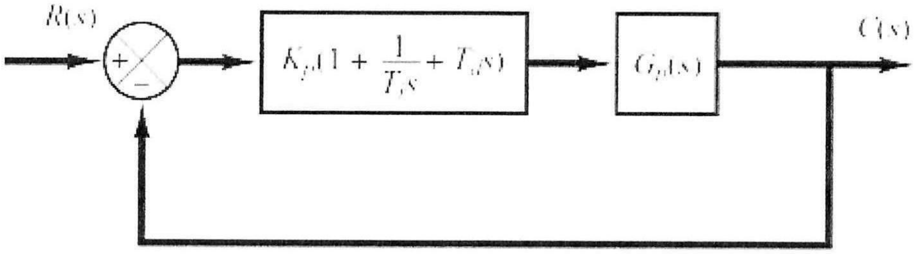

Figure Q5(a)

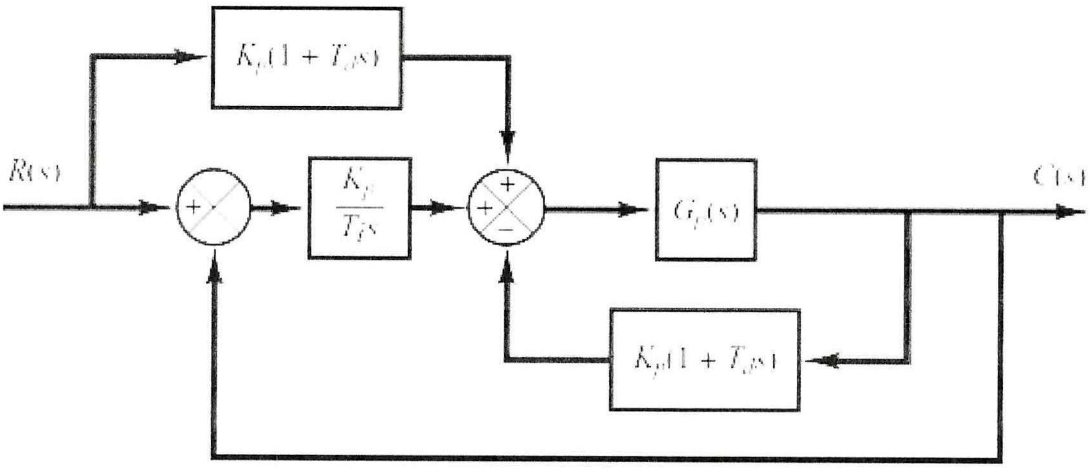

Figure Q5(b)

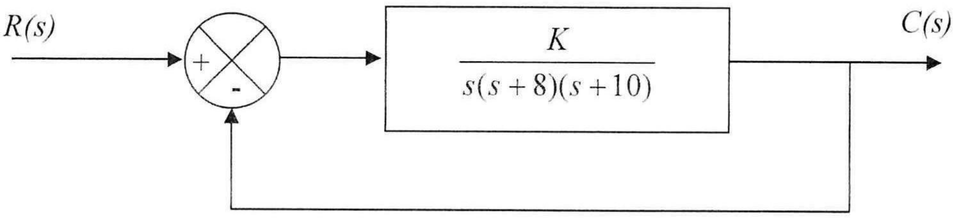

Figure Q6

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REFERENCES:

Laplace Transform

Original	Image
a	$\frac{a}{s}$
t	$\frac{1}{s^2}$
t^2	$\frac{2}{s^3}$
$t^n, n \in N$	$\frac{n!}{s^{n+1}}$
e^{at}	$\frac{1}{s-a}$
te^{at}	$\frac{1}{(s-a)^2}$
t^2e^{at}	$\frac{2}{(s-a)^3}$
$t^ne^{at}, n \in N$	$\frac{n!}{(s-a)^{n+1}}$

Original	Image
$\sin(\omega t)$	$\frac{\omega}{s^2+\omega^2}$
$\cos(\omega t)$	$\frac{s}{s^2+\omega^2}$
$\sinh(\omega t)$	$\frac{\omega}{s^2-\omega^2}$
$\cosh(\omega t)$	$\frac{s}{s^2-\omega^2}$
$t\sin(\omega t)$	$\frac{2s\omega}{(s^2+\omega^2)^2}$
$t\cos(\omega t)$	$\frac{s^2-\omega}{(s^2+\omega^2)^2}$
$e^{at}\sin(\omega t)$	$\frac{\omega}{(s-a)^2+\omega^2}$
$e^{at}\cos(\omega t)$	$\frac{s-a}{(s-a)^2+\omega^2}$

Time Response

$$C(s)=\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2} \qquad \zeta=\frac{-\ln(\%OS/100)}{\sqrt{\pi^2+\ln^2(\%OS/100)}} \qquad \%OS=100e^{-\left(\frac{\zeta\pi}{\sqrt{1-\xi^2}}\right)}$$

$$T_p=\frac{\pi}{\omega_n\sqrt{1-\zeta^2}}=\frac{\pi}{\omega_d} \qquad T_s=\frac{4}{\zeta\omega_n}=\frac{4}{\sigma_d} \qquad T_f=\frac{1.321}{\omega_k}$$