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Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(TAKE HOME)
SEMESTER II
SESSION 2019/2020

COURSE NAME	:	CONTROL SYSTEM/ CONTROL SYSTEM THEORY/ ELECTRICAL CONTROL SYSTEM
COURSE CODE	:	BEJ 20503/ BEH 30603/ BEF33003
PROGRAMME CODE	:	BEJ/BEV
EXAMINATION DATE	:	JULY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWERS **ALL** QUESTIONS **OPEN BOOK EXAMINATION**

THIS QUESTION PAPER CONSISTS OF **SEVEN** (7) PAGES

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Q1 (a) Determine the transfer function $\emptyset_2(s)/T(s)$ for the rotational mechanical system with gears shown in **Figure Q1(a).**

(10 marks)

(b) Establish the equation of each motions for mechanical network shown in **Figure Q1(b).**

(15 marks)

Q2 (a) List down **THREE (3)** important requirements to design a control system.

(3 marks)

(b) State the possible consequence when a physical system becomes unstable.

(2 marks)

(c) Consider the following characteristic Equation shown below:

$$P(s) = s^5 + 6s^3 + 5s^2 + 8s + 20$$

(i) Construct Routh table for the characteristic Equation.

(6 marks)

(ii) Using the Routh – Hurwitz criterion, determine the stability of the system.

(2 marks)

(iii) Determine the numbers of roots on the right half-plane, left half-plane, and jω –axis.

(4 marks)

(d) A control system is given by the block diagram shown in **Figure Q2 (d).** Find the range of gain K to obtain a stable system.

(8 marks)

Q3 (a) A feedback control system is given in **Figure Q3 (a)**. If the control input of the system, R(s) has been tested with two different inputs, which are step input $(u(t))$ and ramp input $(tu(t))$. Differentiate the steady state error for each kind of input.

(5 marks)

(b) The unity feedback system is given as in **Figure Q3 (b)**.

(i) Determine the closed loop transfer function of the system.

(2 marks)

(ii) Calculate the damping ratio ξ, peak time T_p, rise time T_r, percentage of overshoot $\%\mu_s$ and settling time T_s (5% criterion) of the system.

(11 marks)

(iii) Investigate the characteristic of the system response.

(1 marks)

(c) With appropriate sketching and with your own words, explain the relationship between damping ratio and system response.

(6 marks)

Q4 A unity negative feedback system with the forward transfer function $G(s)$ is as below;

$$G(s) = \frac{K}{(s+3)(s+2)(s+1)}$$

where K is the feedback gain.

(a) Sketch the root locus of the feedback system.

(10 marks)

(b) Your supervisor states that the system in **Q4 (a)** will always be stable for any values of K. Based on the sketch plotted in **Q4 (a)**, explain why your supervisor's statement is wrong.

(5 marks)

(c) Without any adjustments to the original location of poles and zero of the system in **Q4 (a)**,

(i) Select an improvement to the feedback system in **Q4 (a)** so that the system is always stable for any values of K.

(3 marks)

(ii) Analyze the effectiveness of your improvement **in Q4 (c) (i)** with the root locus of the modified system.

(7 marks)

-END OF QUESTIONS -

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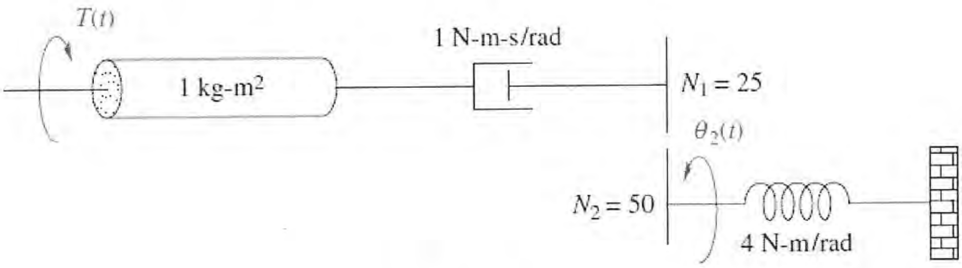

Figure Q1 (a)

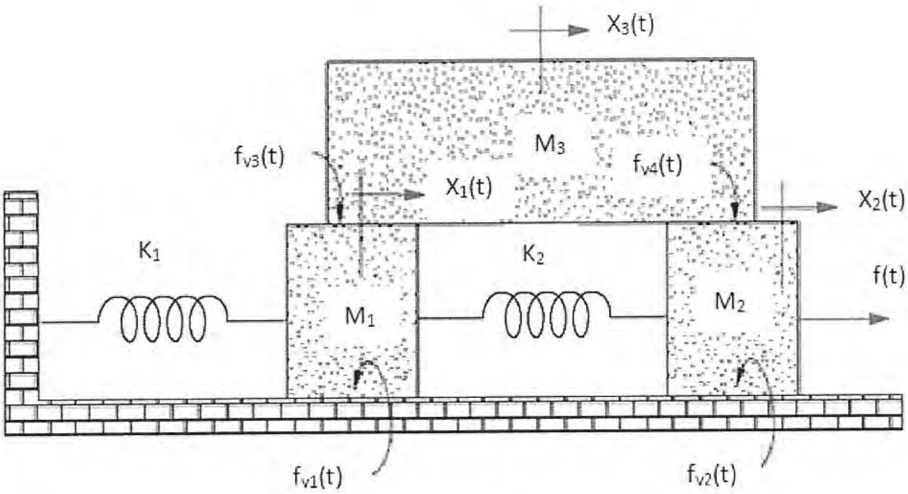

Figure Q1 (b)

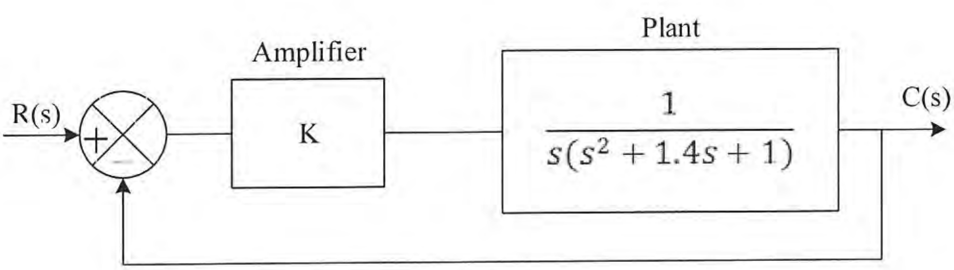

Figure Q2 (d)

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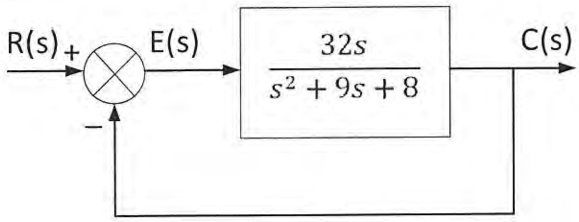

Figure Q3(a)

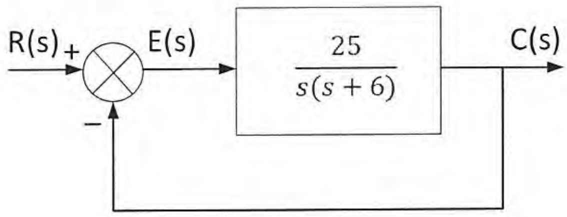

Figure Q3(b)

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FORMULAS

Table A
Laplace transform table

$f(t)$	$F(s)$
$\delta(t)$	1
$u(t)$	$\frac{1}{s}$
$tu(t)$	$\frac{1}{s^2}$
$t^n u(t)$	$\frac{n!}{s^{n+1}}$
$e^{-at}u(t)$	$\frac{1}{s+a}$
$\sin \omega t u(t)$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t u(t)$	$\frac{s}{s^2+\omega^2}$
$e^{-at}\sin \omega t u(t)$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos \omega t u(t)$	$\frac{(s+a)}{(s+a)^2+\omega^2}$

Table B
Laplace transform theorems

Name	Theorem
Frequency shift	$\mathcal{L}\left[e^{-at}f(t)\right]=F(s+a)$
Time shift	$\mathcal{L}\left[f(t-T)\right]=e^{-sT}F(s)$
Differentiation	$\mathcal{L}\left[\frac{d^n f}{dt^n}\right]=s^n F(s) \quad \sum_{k=1}^{n} s^{n-k} f^{k-1}(0^-)$
Integration	$\mathcal{L}\left[\int_{0^-}^{t} f(\tau)d\tau\right]=\frac{F(s)}{s}$
Initial value	$\lim_{t\to 0} f(t)=\lim_{s\to\infty} sF(s)$
Final value	$\lim_{t\to\infty} f(t)=\lim_{s\to 0} sF(s)$

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Table C

2nd Order prototype system equations

$\frac{C(s)}{R(s)} = \frac{\omega_n^{\,2}}{s^2 + 2\zeta\omega_n s + \omega_n^{\,2}}$	$T_r = \frac{\pi - \cos^{-1}\zeta}{\omega_n\sqrt{1-\zeta^2}}$
$\mu_p = e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}$	$T_p = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$
$T_s = \frac{4}{\zeta\omega_n}$ (2% criterion)	$T_s = \frac{3}{\zeta\omega_n}$ (5% criterion)