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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2021/2022

COURSE NAME	:	CONTROL SYSTEMS
COURSE CODE	:	BEJ 20503
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	JULY 2022
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWERS **ALL** QUESTIONS **OPEN BOOK EXAMINATION** 2. THIS FINAL EXAMINATION IS **AN ONLINE ASSESSMENT AND** CONDUCTED VIA OPEN BOOK

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

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Q1 (a) **Figure Q1(a)** shows a gear system.

(i) Find the relationship between the number of the gear teeth N1 & N2 and the radius r1 & r2

(1 mark)

(ii) Identify the distance travelled along the surface of each gear

(1 mark)

(iii) Show the work done by each gear

(1 mark)

(b) Construct the transfer function $G(s) = \frac{\theta_2(s)}{T(s)}$ for the gearing system as shown in **Figure Q1(b)**.

(22 marks)

Q2 (a) Zainal is an engineer at MEGAHU Holding. He has developed a new positioning system for the robotic arm and closed loop transfer function of the system is as shown below:

$$G(s) = \frac{s(s+4)}{(s+5)(s^2+2s+1)}$$

(i) Illustrate the zeros and poles of the system on s-plane

(5.5 marks)

(ii) Based on **Q2(a)(i),** show whether the system developed by Zainal is stable or unstable.

(1 mark)

(b) The characteristics equation for a system is as illustrated below:

$$1 + G(s)H(s) = 3s^6 + 6s^5 + 2s^4 + 2s^3 + 3s + 6$$

By using the Routh-Hurwitz stability approach, identify whether the system is stable or unstable

(6.5 marks)

(c) Abu has develop closed-loop line follower robot system and the block diagram of the system is as shown in **Figure Q2(c).** Using Routh Hurwitz stability Criterion, estimate the range of K that need to be chosen by Abu so that the robot provides stable performance during tracking the line.

(12 marks)

Q3 (a) Describes the characteristics of the critically damped and under damped response.

(4 marks)

(b) A simplified block diagram for a space telescope is shown in **Figure Q3(b)**.

(i) Find the closed-loop transfer function for the system.

(2 marks)

(ii) Calculate the damping ratio, ζ and the natural frequency, ω_n associated with the closed-loop transfer function. Give your answer in terms of K_1 and K_2.

(3 marks)

(iii) If the value of K_1 =32 and K_2= 7 calculate the damping ratio, ζ , peak time T_p, rise time T_r , settling time, T_s with *2% band* and percentage of overshoot, $\%\mu_s$ of the system.

(7 marks)

(c) A block diagram for the antenna positioning system is shown in **Figure Q3(c)**. Based on steady-state error analysis;

(i) Identify the type of the system.

(2 marks)

(ii) If the system has been tested with three different reference inputs, which are 5 u(t), 5t u(t), and 5t2 u(t), Examine which could give infinite (∞) steady-state error

(7 marks)

Q4 (a) A simplified block diagram of a pressure vessel for hydrogen is shown in **Figure Q4**. By using the root locus approach, investigate whether each of these statements is correct or incorrect to represent the root locus characteristics for the system.

(i) The number of locus that ends at infinity is 2.

(4 marks)

(ii) The asymptote of the infinite zeros is at 1.5.

(1.5 marks)

(iii) The angles of the lines that intersect at 1.5 are 90° and 270°

(2.5 marks)

(iv) The jω-axis crossing is at j±1.82

(7 marks)

(v) The angle of departure is at -31°.

(3 marks)

(b) Illustrate the root locus of the system.

(7 marks)

-END OF QUESTIONS –

FINAL EXAMINATION

SEMESTER / SESSION	: SEM II / 2021/2022	PROGRAMME CODE	: BEJ
COURSE NAME	: CONTROL SYSTEMS	COURSE CODE	: BEJ 20503

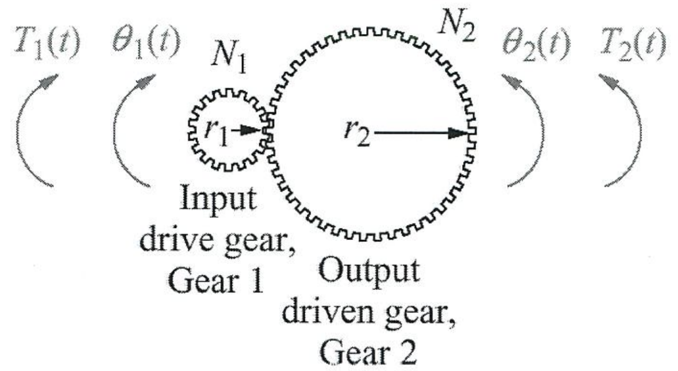

Figure Q1 (a)

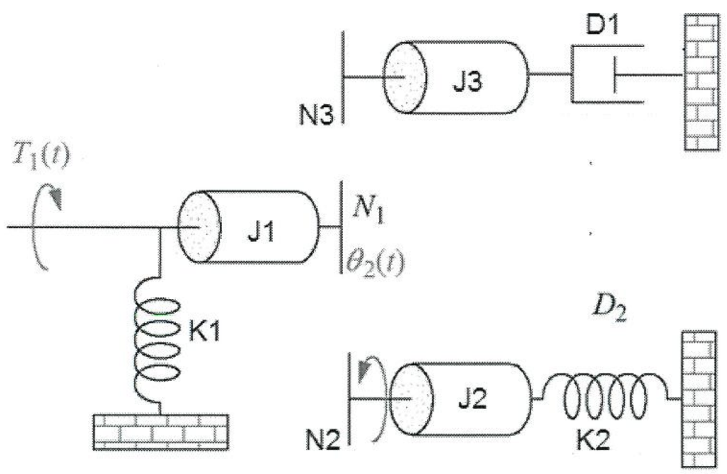

Figure Q1 (b)

FINAL EXAMINATION

SEMESTER / SESSION	: SEM II / 2021/2022	PROGRAMME CODE	: BEJ
COURSE NAME	: CONTROL SYSTEMS	COURSE CODE	: BEJ 20503

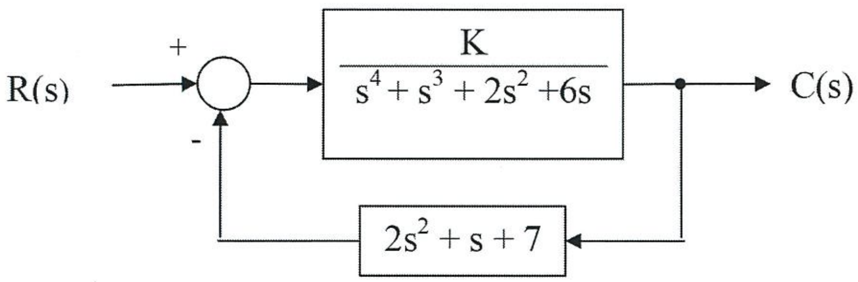

Figure Q2 (c)

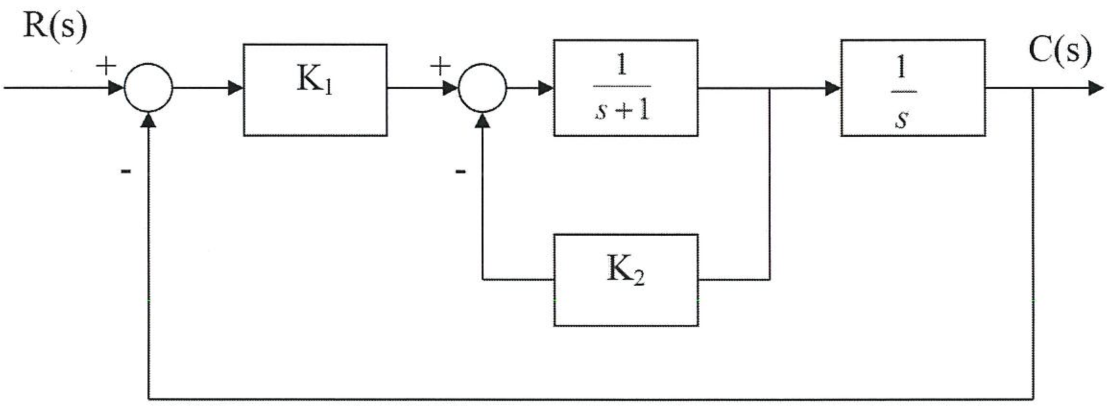

Figure Q3 (b)

FINAL EXAMINATION

SEMESTER / SESSION	: SEM II / 2021/2022	PROGRAMME CODE	: BEJ
COURSE NAME	: CONTROL SYSTEMS	COURSE CODE	: BEJ 20503

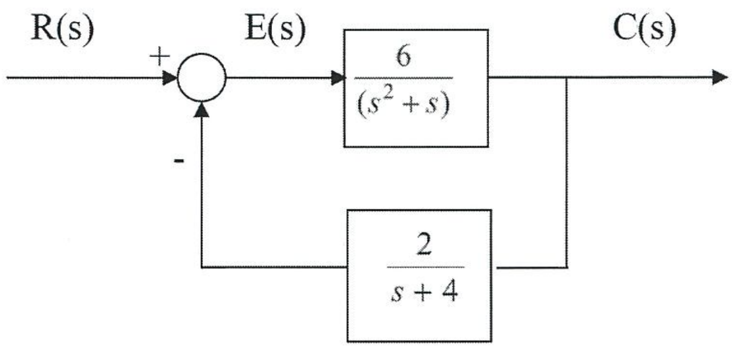

Figure Q3(c)

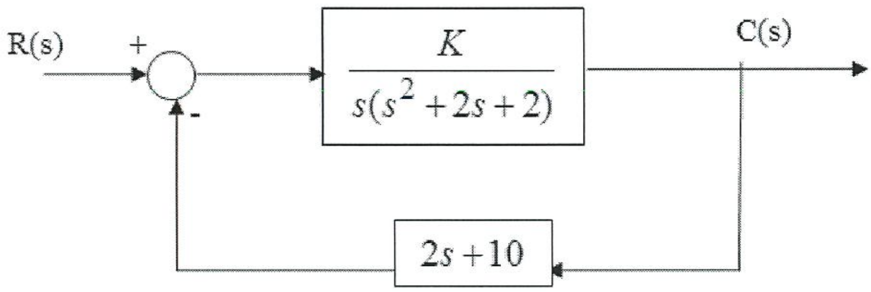

Figure Q4

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2021/2022 PROGRAMME CODE : BEJ
COURSE NAME : CONTROL SYSTEMS COURSE CODE : BEJ 20503

FORMULAS

Table A
Laplace transform table

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

FINAL EXAMINATION

SEMESTER / SESSION	: SEM II / 2021/2022	PROGRAMME CODE	: BEJ
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Table B
Laplace transform theorems

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

Table C
2^{nd} 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)