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Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2022/2023

COURSE NAME	:	CONTROL SYSTEMS
COURSE CODE	:	BEJ 20503
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	FEBRUARY 2023
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWERS ALL QUESTIONS

2. THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSE BOOK**

3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

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

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Q1 (a) List **two (2)** conditions of armature control for a Direct Current (DC) motor.

(2 marks)

(b) The schematic diagram for a speed boat gearing system is given in **Figure Q1(b)**. Develop the transfer function, $\frac{\theta_2}{T(s)}$ of the system.

(10 marks)

(c) Determine the transfer function of the following for the gearing system as shown in **Figure Q1(c)** is correct or false:

$$\frac{\theta_2}{T(s)} = \frac{0.1}{200.03s^2 + 4000s + 250}$$

(13 marks)

Q2 (a) Differentiate between stable systems, unstable systems, and marginally stable systems. Provide your explanations with appropriate diagrams.

(3 marks)

(b) LinaBot is an autonomous robot that uses vision, ultrasonic proximity and infrared proximity to sense its environment for navigation along hallways and for obstacle avoidance. LinaBot can navigate throughout a hospital, following a map stored in its memory, carrying medical supplies, late meal trays, and lab samples for delivery to nursing units or hospital departments. The simplified transfer function of the system is shown below:

$$G(s) = \frac{s(s+3)}{s^3 + 5s^2 + 4s + 20}$$

By using s-plane plot, analyze whether the LinaBot is stable, marginally stable, or unstable.

(11 marks)

(c) A closed loop transfer function of the feedback controller for the line follower robot system was derived as the following:

$$T(s) = \frac{1}{s^4 + 7s^3 + 14s^2 + (8+K)s + 3K}$$

By using the Routh-Hurwitz stability criterion, investigate the range of K for the system that will cause the system to be stable.

(11 marks)

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

(i) Determine the peak time Tp , rise time Tr , and percentage of overshoot, %μs of the system.

(13 marks)

(ii) The percentage maximum overshoot obtained in **Q3 a(i)** is reduced by 60%. Calculate the new value of the damping ratio, ζ for the system.

(4 marks)

(b) The system shown in **Figure Q3(a)** is modified and the new block diagram of the system is as shown in **Figure Q3(b)**. Given that the value of K = 100 and the system has been tested with three different reference inputs, $r(t)$ which are 5 $u(t)$, $5t\ u(t)$ and $5t^2\ u(t)$. Based on **Figure Q3(b)** and by using steady state-error analysis, calculate which $r(t)$ could give infinite (∞) steady state error.

(8 marks)

Q4 (a) A simplified block diagram of an antenna tracking system is shown in **Figure Q4**. Illustrate the root locus for this system.

(25 marks)

-END OF QUESTIONS –

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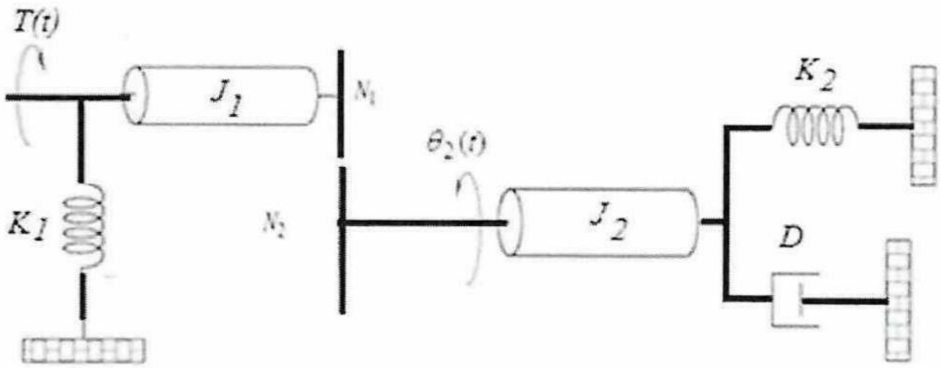

Figure Q1 (b)

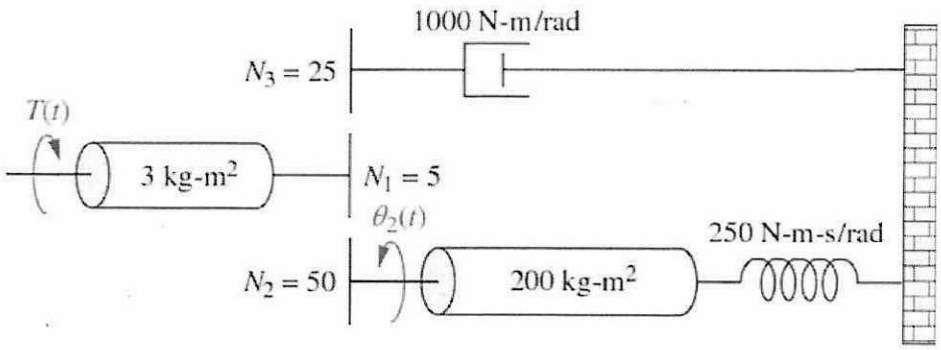

Figure Q1 (c)

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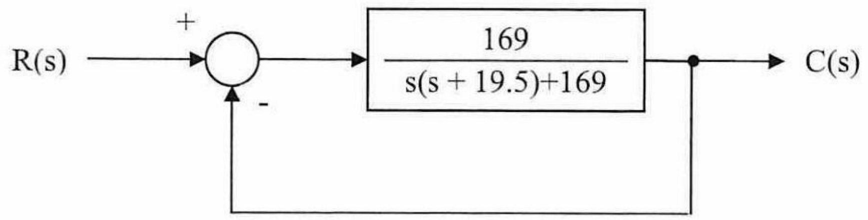

Figure Q3 (a)

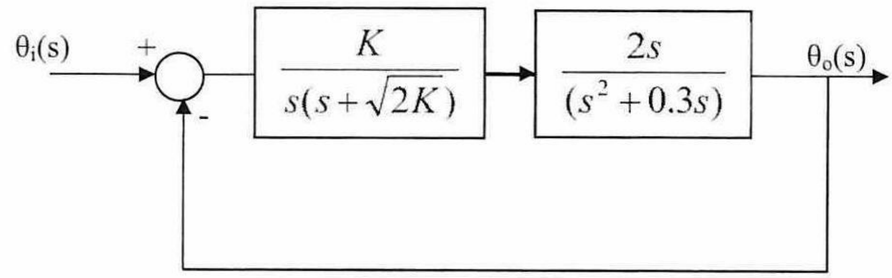

Figure Q3 (b)

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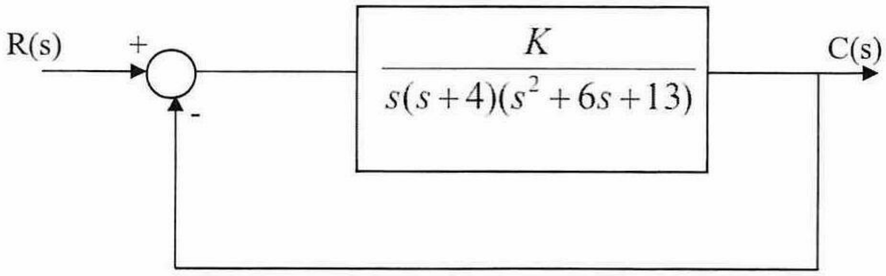

Figure Q4

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FORMULAS

Table A
Laplace transform table

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

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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	$\mathscr{L}\left[\frac{d^n f}{dt^n}\right]=s^n F(s)-\sum_{k=1}^{n} s^{n-k} f^{k-1}(0^-)$
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)