UTHM
Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	CONTROL SYSTEM THEORY
COURSE CODE	:	BEJ 20503 / BEH 30603
PROGRAMME CODE	:	BEJ/BEV
EXAMINATION DATE	:	DECEMBER 2019 / JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER ALL QUESTIONS

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

Q1 (a) Describe definition of **input**, **output**, and **disturbance** in control system. Illustrates the basic relationship among these three components.

(4 marks)

(b) **Figure Q1(b)** shows the design of translational mechanical system with elements as shown below:

$f_{v1} = f_{v2} = f_{v3} = f_{v4} = 1\ N\text{-}s/m$
$K = 1\ N/m$
$M_1 = M_2 = 1\ kg$

The resulted transfer function obtained is shown below:

$$X_2(s)/F(s) = \frac{4s+1}{s(s^3+6s^2+5s+1)}$$

Investigate whether the transfer function obtained is correct or not.

(16 marks)

Q2 (a) List **TWO (2)** methods to control Direct Current (DC) motor.

(2 marks)

(b) Often (e.g., in robotic applications), the speed required by the load is too low as compared to the nominal speed of the motor. In these cases, gears are introduced between the motor and the load, thus reducing the angular velocity of the load itself. Besides the increase of damping and inertia due to the presence of the additional rotating cogwheels of the gear, the mechanical coupling between the load and the motor is altered by the gear itself. The schematic diagram of a DC motor with gear is shown in **Figure Q2(b)**. Construct the transfer function $G(s) = \frac{\theta_L(s)}{V_a(s)}$ for the DC motor.

(11 marks)

(c) Determine the transfer function, $G(s) = \frac{\theta_2(s)}{T(s)}$ for the rotational system as shown in **Figure Q2(c).**

(7 marks)

Q3 (a) Distinguish between stable systems, unstable systems, and marginally stable systems. Illustrate each condition of the poles location.

(6 marks)

(b) Razif and his team have developed a closed loop system for their line follower mobile robot as part of the preparations for competing in the next Asia-Pacific Robot Contest (ABU Robocon). The block diagram of the system is shown in **Figure Q3(b)**. By using the Routh-Hurwitz stability criterion, analyze the range of K that need to be chosen by them so that the robot provide stable performance during line tracking movement.

(14 marks)

Q4 From the experiments of "*Elementary Identification and Design*" for a close loop position control system, the data gathered by one of the group is as shown below:

$n = 30$
$K_P = 3\ v/rad$
$K_g = 0.02\ v/rads^{-1}$
$T = 100\ ms$
$K_a K_s K_g = 40$

(a) Using the above values and **Figure Q4**, determine $\dfrac{\theta_o}{\theta_i}$.

(6 marks)

(b) If K_I=0.1, by comparing the result obtain in question **Q4(a)** to a standard prototype of a second order system, calculate:

(i) Maximum overshoot (μ_s)

(3 marks)

(ii) Rise time (T_r)

(2 marks)

(iii) Peak time(T_p)

(2 marks)

(c) Analyze value of K_I that will give a 0.1353 of maximum overshoot (μ_s).

(7 marks)

Q5 The simplified block diagram for position servomechanism used in an antenna tracking system is shown in **Figure Q5**. By using root locus approach, investigate either each of these statement is correct or false to represent the root locus characteristics for the system.

(a) The break-away point of the system is at -0.835.

(12 marks)

(b) The $j\omega$-axis crossing of the system is at $\pm$ j3.67.

(8 marks)

- END OF QUESTIONS –

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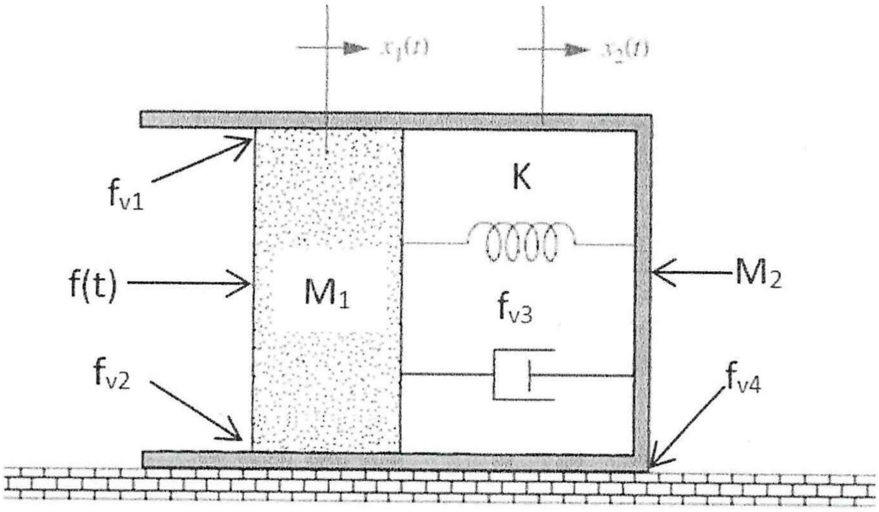

Figure Q1(b)

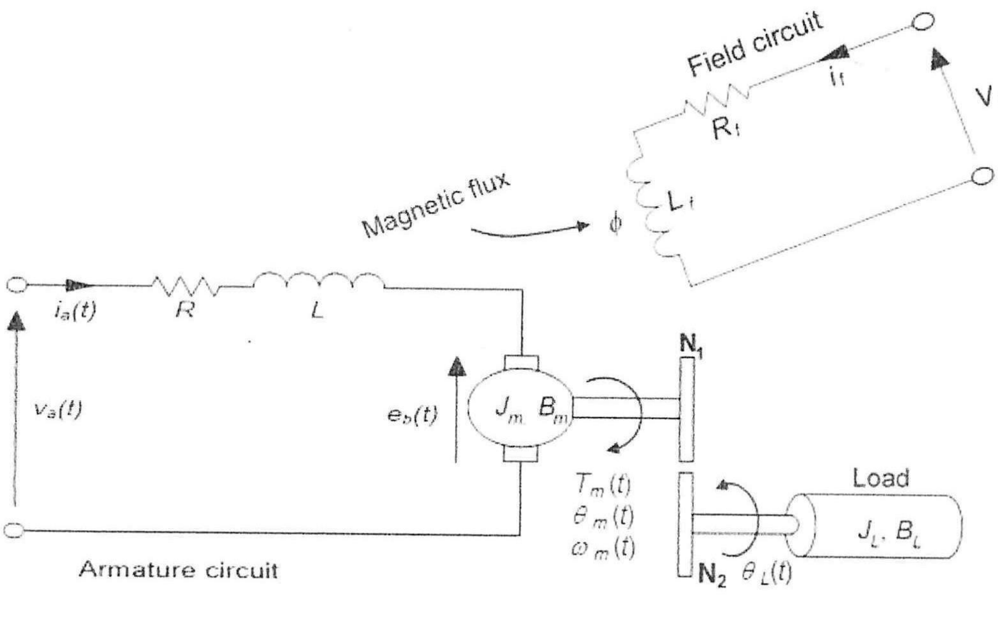

Figure Q2(b)

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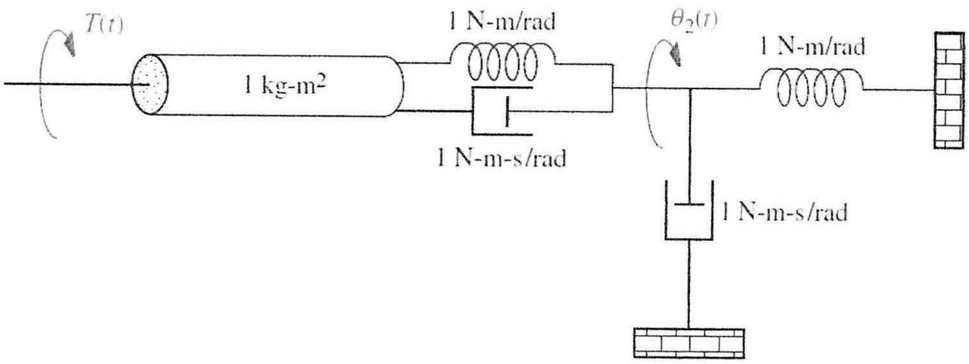

Figure Q2(c)

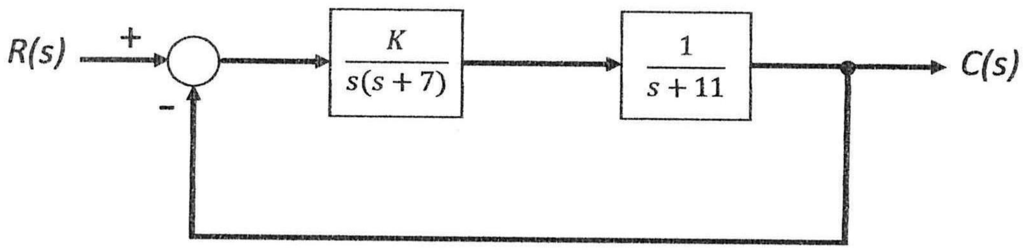

Figure Q3(b)

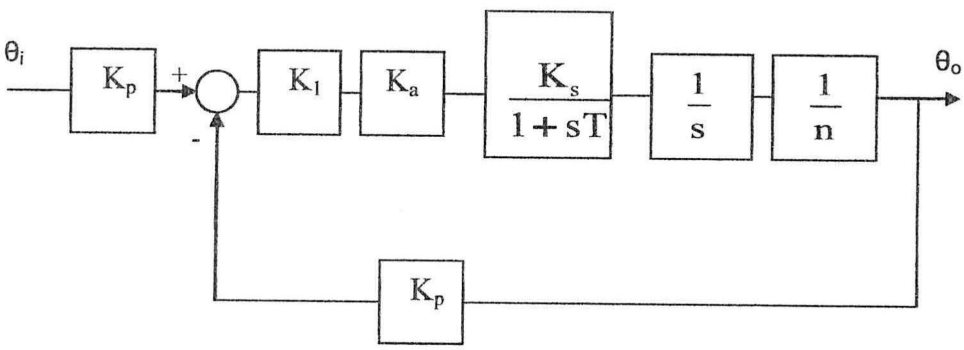

Figure Q4

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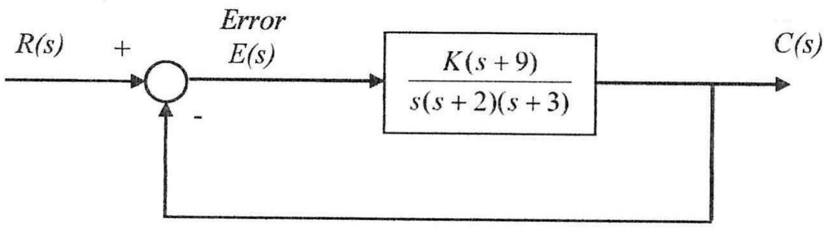

Figure Q5

FORMULAE

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