Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2018/2019

COURSE NAME	:	CONTROL SYSTEM THEORY / ELECTRICAL CONTROL SYSTEM
COURSE CODE	:	BEH 30603 / BEF 33003
PROGRAMME CODE	:	BEJ/BEV
EXAMINATION DATE	:	JUNE / JULY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWERS FOUR (4) QUESTIONS FROM FIVE (5) QUESTIONS

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

Q1 (a) The schematic diagram of a train carriage is as shown in **Figure Q1(a)** and the resulted transfer function $\frac{X(s)}{F(s)}$ obtained for the system is as given below:

$$\frac{X(s)}{F(s)} = \frac{1}{s^8+4s^6+8s^4+9s^3+5s^2+2s}$$

Investigate either the transfer function, $\frac{X(s)}{F(s)}$ obtained for the system is correct or not.

(17 marks)

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

(8 marks)

Q2 (a) HelpMate is an autonomous robot that uses vision, ultrasonic proximity and infrared proximity to sense its environment for navigation along hallways and for obstacle avoidance. HelpMate can navigate throughout a hospital, following a map stored in its memory, carrying medical supplies, late meal trays, records and lab samples for delivery to nursing units or hospital departments. Given the simplified the transfer function of the system is as shown below:

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

By using s-plane plot, analyze either the HelpMate developed by Evens is stable, marginally stable or unstable.

(11 marks)

(b) A closed loop transfer function of feedback controller for line follower robot system was derived as

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

Using Routh Hurwitz stability Criterion, investigate the range of *K* for the system that will cause the system to be stable.

(14 marks)

Q3 (a) With your own words and sketching, describe the relationship between damping ratio and system response.

(7 marks)

(b) The differential equation for closed loop transfer function of unity feedback system is given as below, where $y(t)$ and $x(t)$ are output and input of the system, respectively.

$$\frac{dy^2(t)}{dt^2} + 2\frac{1}{4}\frac{dy(t)}{dt} + 6\frac{1}{4}y(t) = 6\frac{1}{4}x(t)$$

(i) Determine the transfer function of the system. (2 marks)

(ii) Calculate the damping ratio ζ, peak time T_p, rise time T_r, and percentage of overshoot, $\%\mu_s$ of the system. (10 marks)

(iii) Investigate the characteristic of the system response. (1 mark)

(c) A feedback control system is given in **Figure Q3(c).** 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 $(tu(t))$. Calculate steady state error for each kind of input. (5 marks)

Q4 (a) Describe the five rules to sketch the root locus using minimal calculation. (7 marks)

(b) Based on root locus sketch in **Figure Q4(b),**

(i) Derived the open loop transfer function of the system. (5 marks)

(ii) Ensure breakaway and break-in point are -1.45 and 3.82. (13 marks)

Q5 **Figure Q5** shows a feedback control system. Based on the figure:

(a) Determine the system open-loop transfer function. (5 marks)

(b) Sketch the Bode plot of the system described in **Figure Q5.** (14 marks)

(c) Calculate the gain and phase margins. (3 marks)

(d) Identify whether the system is stable or unstable. (3 marks)

-END OF QUESTIONS -

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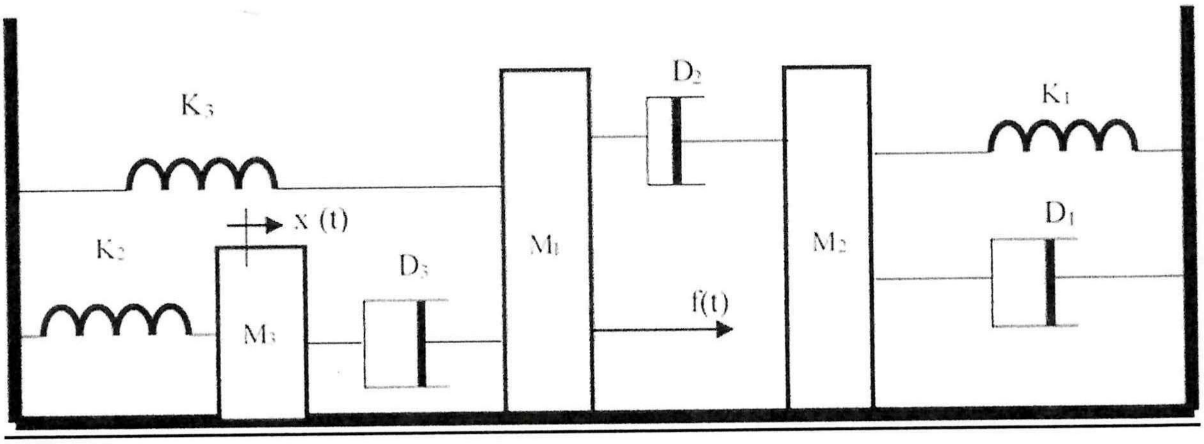

Figure Q1(a)

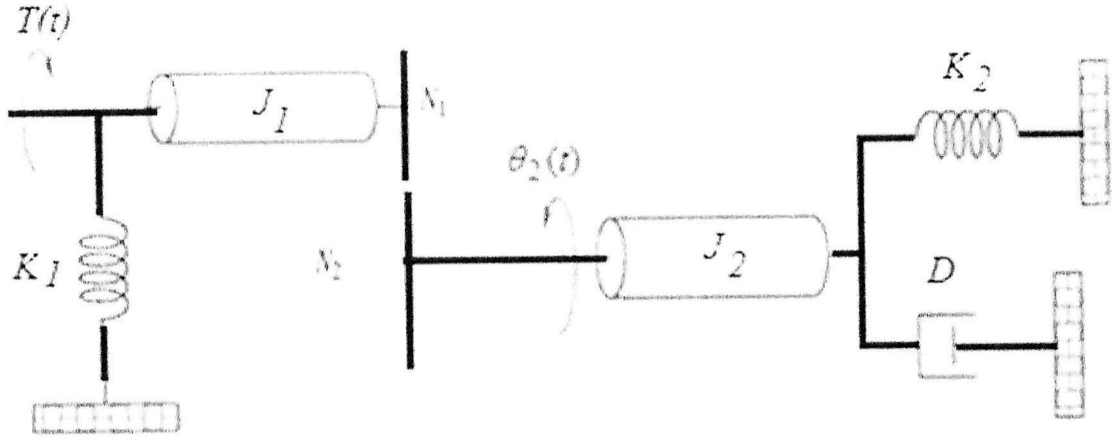

Figure Q1(b)

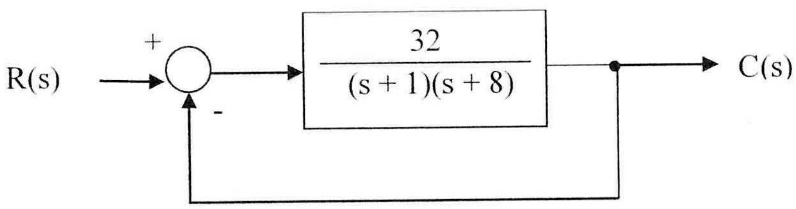

Figure Q3(c)

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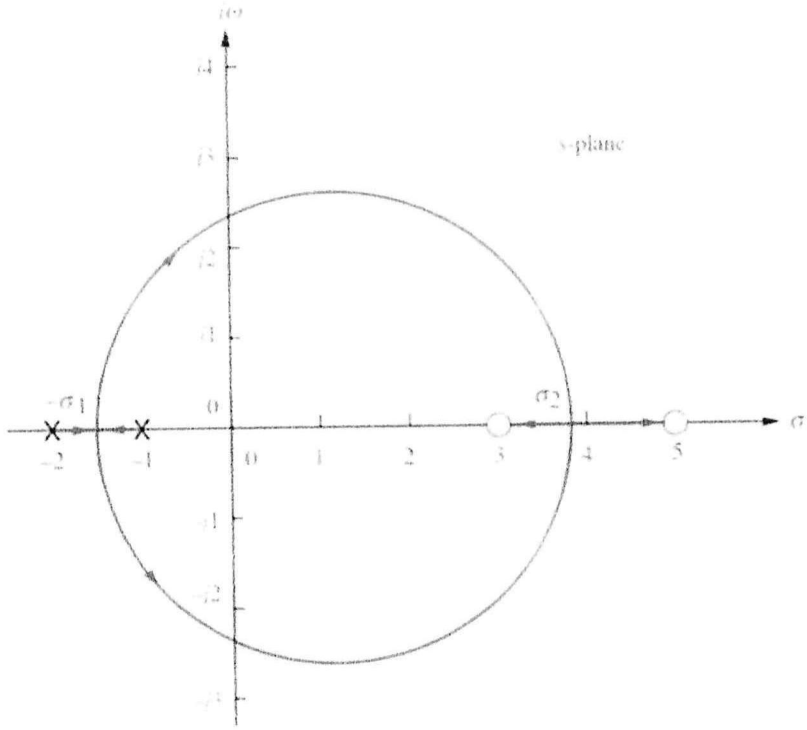

Figure Q4(b)

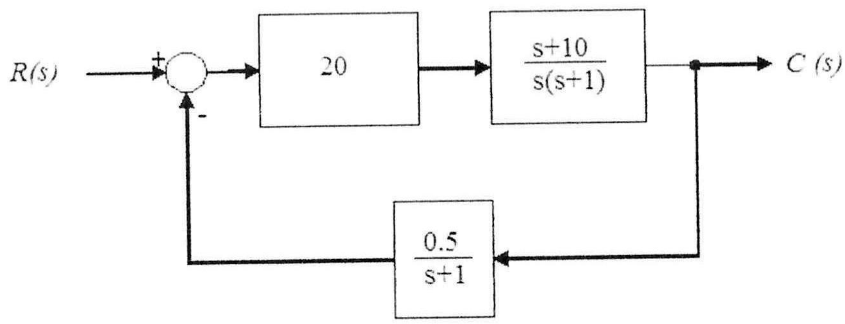

Figure Q5

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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	$\mathscr{L}\left[\dfrac{d^n f}{dt^n}\right]=s^nF(s)-\sum_{k=1}^{n}s^{n-k}f^{k-1}(0^-)$
Integration	$\mathscr{L}\left[\int_{0^-}^{t}f(\tau)d\tau\right]=\dfrac{F(s)}{s}$
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

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