UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2015/2016

COURSE NAME	:	ELECTRICAL CONTROL SYSTEM
COURSE CODE	:	BEF 33003
PROGRAMME	:	BACHELOR OF ELECTRICAL ENGINEERING WITH HONOURS
EXAMINATION DATE	:	DECEMBER 2015/JANUARY 2016
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **TEN (10)** PAGES

Q1 (a) Give **three (3)** examples of open loop system.

(3 marks)

(b) A high-speed proportional solenoid valve is shown in **Figure Q1(b)**. A voltage proportional to the desired position of the spool is applied to the coil.The resulting magnetic field produced by the current in the coil causes the armature to move the spool. A linear voltage differential transformer (LVDT) that outputs a voltage propotional to displacement senses the spool's position. This voltage can be used in a feedback path to implement closed loop operation. Draw a functional block diagram of the valve, showing input and output positions, coil voltage, coil current and spool force.

(7 marks)

(c) For the rotational system shown in **Figure Q1(c)**, find the transfer function, $G(s) = \theta_2(s) / T(s)$.

(10 marks)

Q2 (a) The pole plot is shown in **Figure Q2(a)**. Find the

(i) damping ratio, ζ

(1 mark)

(ii) natural frequency

(1 mark)

(iii) peak time

(1 mark)

(iv) percent overshoot

(1 mark)

(v) settling time.

(1 mark)

(b) Consider a closed-loop system with the following transfer function

$$T(s) = \frac{s-2}{s(s^2+6s+25)}$$

(i) Determine the poles and zeros of $T(s)$

(2 marks)

(ii) Plot the pole-zero map in the s-plane

(2 marks)

(iii) Is this system stable? Justify the answer

(1 mark)

(c) For a system with the following closed-loop transfer function $T(s)$, determine the number of poles that lie:

(i) in the left half-plane,

(2.5 marks)

(ii) in the right half-plane,

(2.5 marks)

(iii) on the $j\omega$-axis.

(2.5 marks)

$$T(s) = \frac{50s - 100}{s^3 + s^2 + 150s - 100}$$

(d) Determine whether the system in Q2(b) is stable or not?

(2.5 marks)

Q3 (a) State the **five (5)** rules to sketch a root locus.

(5marks)

(b) Consider the system shown in **Figure Q3(b)**.

(i) Sketch the root locus of the system

(6 marks)

(ii) Find the departure angle

(3 marks)

(iii) Find the range of K for the system to be stable

(3 marks)

(iv) Choose the value of K when the system is critically stable
(1 mark)

(v) Find the closed-loop poles for the value of K in Q3(iv).
(2 marks)

Q4 (a) The simplified and linearized model for the transfer function of a certain bicycle from steer angle (θ) to roll angle (φ) is given by

$$P(s) = \frac{\theta(s)}{\varphi(s)} = \frac{10(s+25)}{s^2-25}$$

Assume the rider can be represented by a gain K, and that the closed-loop system is shown in **Figure Q4(a)** with $G(s) = KP(s)$ and $H(s) = 1$. Use the Nyquist stability criterion to find the range of K for closed-loop stability.

(10 marks)

(b) The Bode diagram for a plant used in a unity-feedback system is shown in **Figure Q4(b)**. Find the:

(i) gain margin
(2.5 marks)

(ii) phase margin
(2.5 marks)

(iii) zero dB frequency
(2.5 marks)

(iv) 180° frequency.
(2.5 marks)

Q5 (a) Explain the purpose of

(i) phase-lag compensator
(1.5 marks)

(ii) phase-lead compensator
(1.5 marks)

(b) A unity feedback open-loop transfer function of a control system is given by

$$G(s) = \frac{8}{s(s+5)}$$

Design a phase-lead compensator that gives $\omega_n = 7$ rad/sec and ζ=0.4.

(17 marks)

-END OF QUESTIONS –

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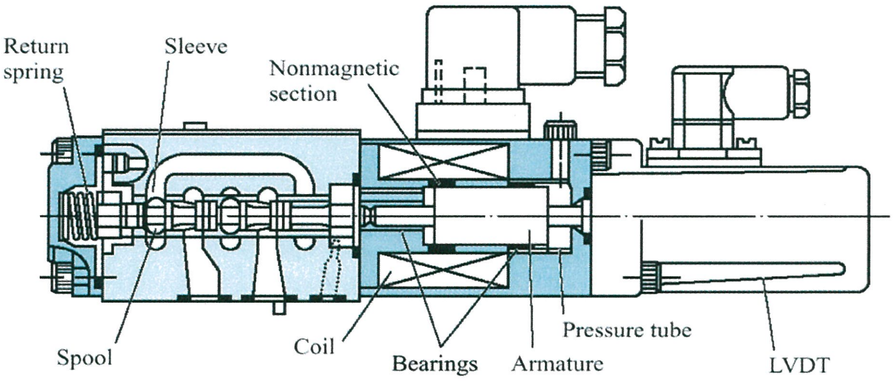

FIGURE Q1(b)

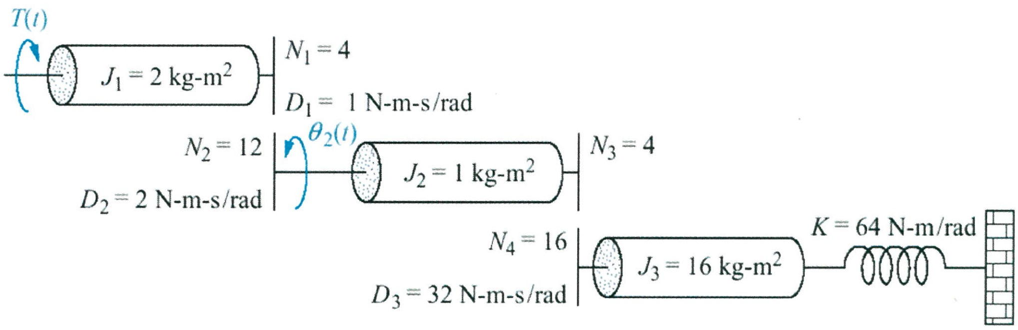

FIGURE Q1(c)

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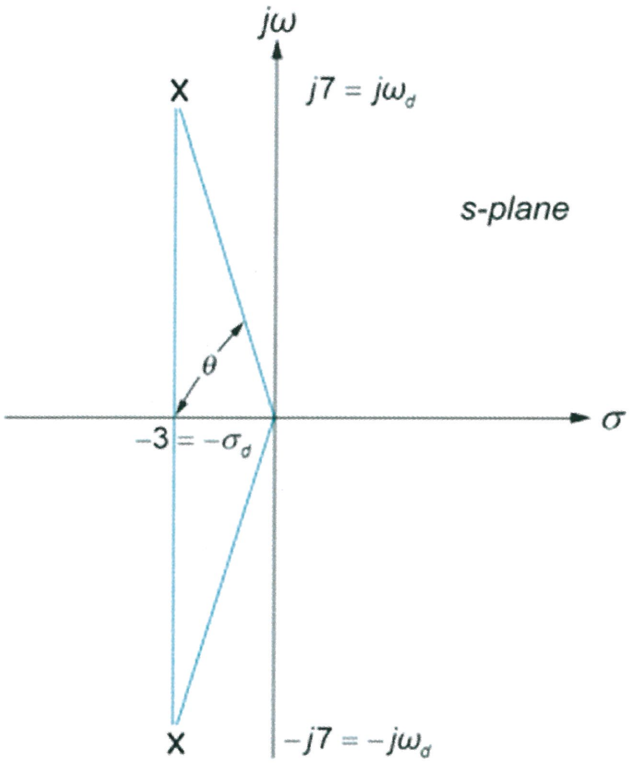

FIGURE Q2(a)

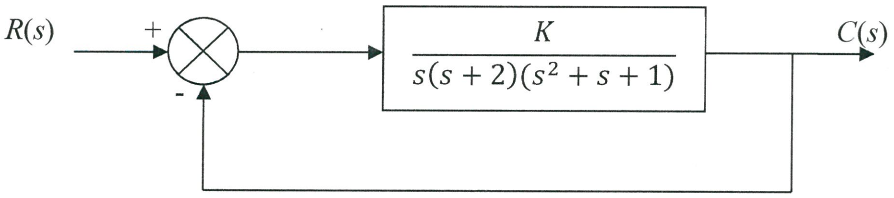

FIGURE Q3(b)

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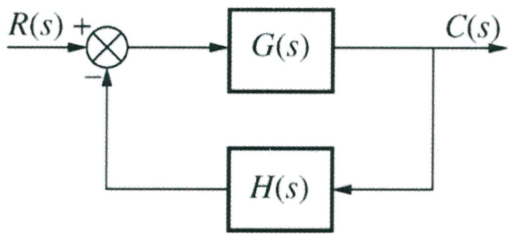

FIGURE Q4(a)

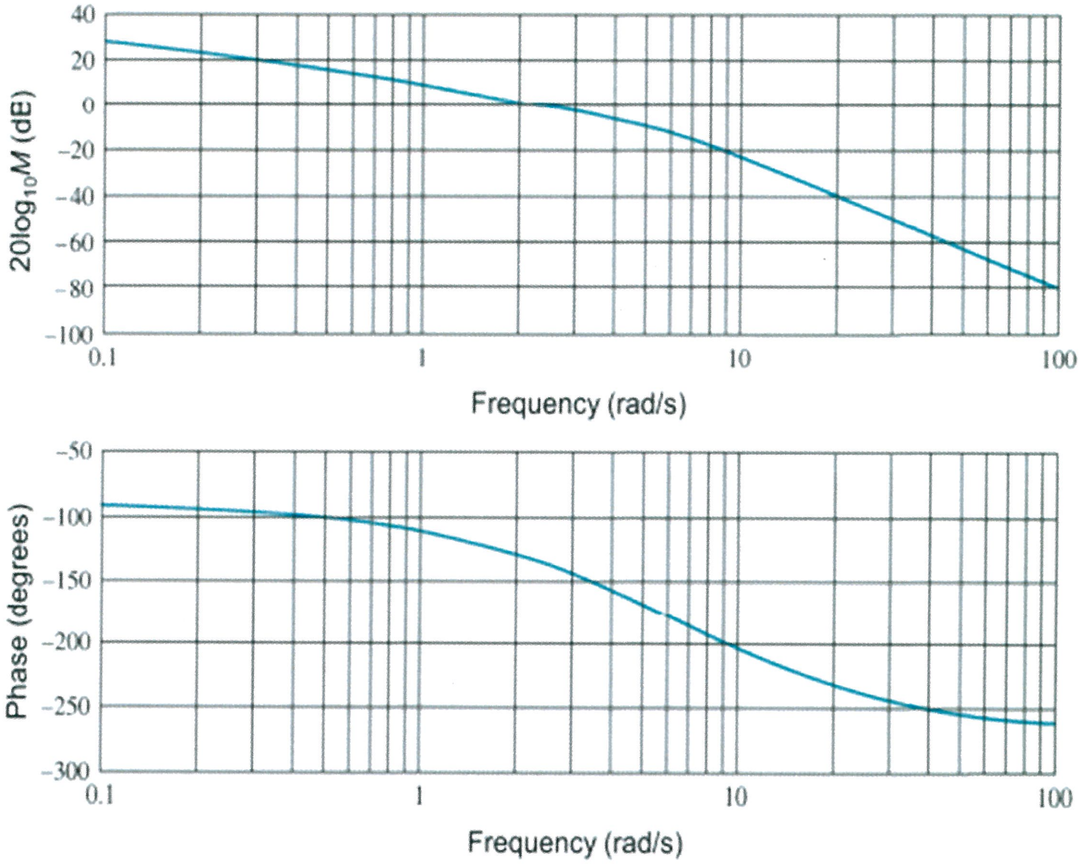

FIGURE Q4(b)

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TABLE 1

Laplace transform table.

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

TABLE 2

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	$\lim_{t\to\infty} f(t)=\lim_{s\to 0} sF(s)$

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TABLE 3

2^{nd} order prototype system equation.

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