CONFIDENTIAL

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION

SEMESTER I

SESSION 2013/2014

COURSE NAME	:	CONTROL SYSTEMS THEORY/CONTROL SYSTEMS
COURSE CODE	:	BEH 30603/BEE 3143
PROGRAMME	:	BEJ/BEE
EXAMINATION DATE	:	JANUARY 2014
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

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

Q1 (a) By using a suitable block diagram, differentiate clearly the function of the components in the general block diagram of a closed loop control system.

(8 marks)

(b) It is known that an open loop control system has many advantages. Illustrate the most important advantage that must be considered in order to implement a particular practical open loop control system by providing a practical control system example.

(6 marks)

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(6 marks)

Q2 Figure **Q2** shows a schematic diagram of an armature-controlled direct current motor. This motor is assumed to have a constant magnetic field. Assume the following numerical values for system constants:

R = armature resistance = 0.2 ohm.

L = armature inductance = negligible

J_m = the moment of inertia of the motor and load = 5.4 x 10^{-5} kg-m^2

B_m = the viscous friction constant of the motor and the load = 4 x 10^{-4} N-m/rad/sec

k_t = the motor torque constant = 6 x 10^{-5} N-m/A

k_b = the back emf constant = 5.5 x 10^{-2} V-sec/rad

(a) Derive the transfer function $\theta(s)/V(s)$ where $\theta(s)$ and $V(s)$ are the transformations of the angular displacement $\theta(t)$ and the input voltage $v(t)$ respectively.

(12 marks)

(b) Construct a control system where the angular displacement $\theta(t)$, can be controlled in a closed-loop manner and explain its operation.

(8 marks)

Q3 (a) Consider a position closed loop control system as shown in Figure **Q3(a)**. Categorize the output of this system for a unit step input signal when the amplifier gain is set at the following values:

(i) $K_s = 0$
(ii) $K_s = 0.01$
(iii) $K_s = 0.25$
(iv) $K_s = 4$

(8 marks)

(b) A tacho-generator with a sensitivity K_g was inserted into the system in Figure **Q3(a)** so that a velocity feedback is being employed. The overall system diagram is shown in Figure **Q3(b)**.

(i) Design this control system such that the output response for a unit step input will have a maximum value 1.2 at time t = 1.0 s.

(5 marks)

(ii) Derive an expression for the output c(t) for a unit step input.

(5 marks)

(iii) Evaluate whether your design requirement has been met.

(2 marks)

Q4 (a) Explain the significance of root locus technique in control system design.

(4 marks)

(b) Consider a control system with unit feedback which has the open-loop transfer function:

$$G(s) = \frac{K}{(s^2 + 8s + 16)^2}$$

(i) Design this control system by using root locus technique such that the dominant closed loop poles will have a damping ratio $\zeta = 0.707$.

(14 marks)

(ii) Obtain all the closed-loop poles for the damping ratio $\zeta = 0.707$

(2 marks)

Q5 (a) Derive the state equation for the single input single output (SISO) plant as shown in Figure **Q5(a)**.

(5 marks)

(b) The plant illustrated in Figure **5(a)** is to be compensated by state variable feedback using states $x_1(t)$, $x_2(t)$, and $x_3(t)$ as illustrated. The specified eigenvalues are $s = -1$, $s = -3$, and $s = -5$. Design and draw the compensated system stating the gains in the feedback paths.

(15 marks)

– END OF QUESTION –

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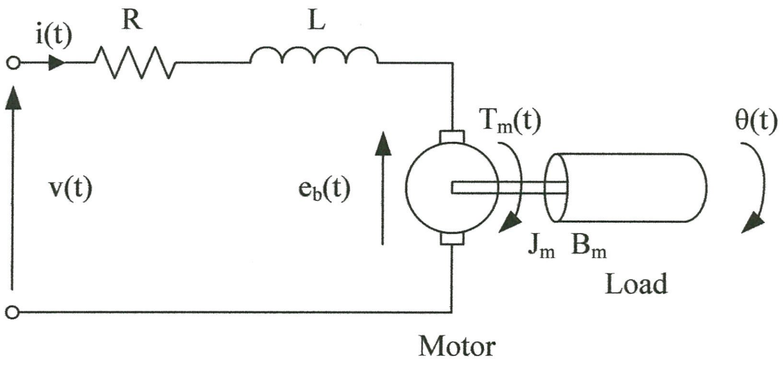

FIGURE Q2

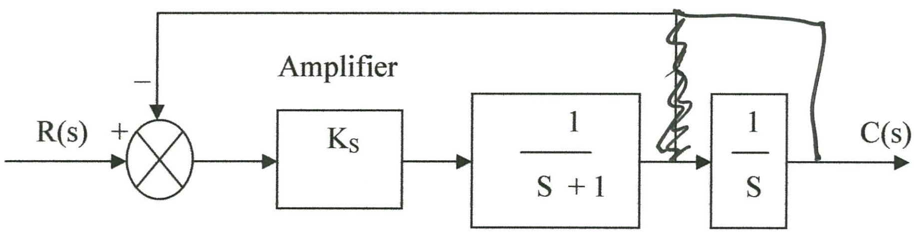

FIGURE Q3(a)

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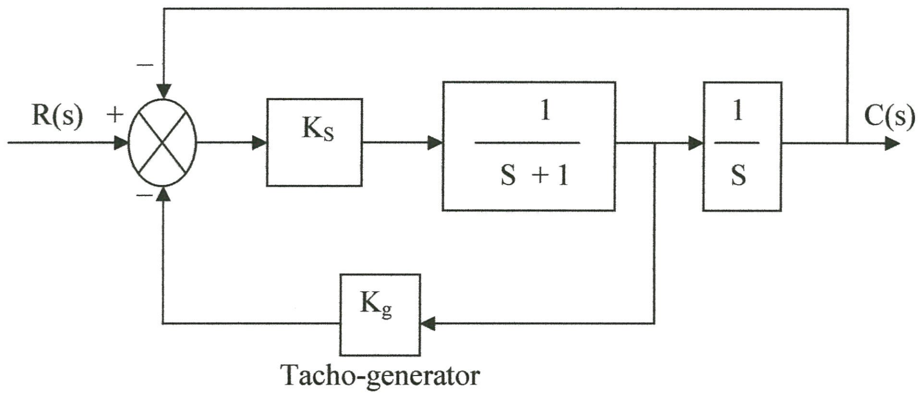

FIGURE Q3(b)

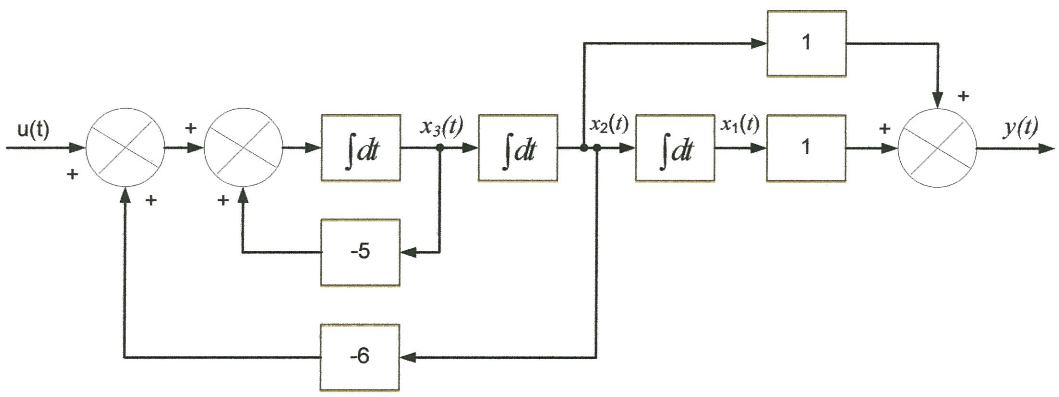

FIGURE Q5(a)

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Table 1 : Laplace Transform Table

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

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Table 2 : Second order prototype 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)