UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2012/2013

COURSE NAME	:	CONTROL SYSTEM/ ELECTRICAL CONTROL SYSTEM
COURSE CODE	:	BEE 3143 / BEX 31603 / BEF 33003
PROGRAMME	:	3 BEE / 3 BEF
EXAMINATION DATE	:	JUNE 2013
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FOUR (4)** QUESTIONS ONLY

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

Q1 (a) A ship steering control system is represented by the block diagram in Figure Q1(a). In the diagram, $C(s)$ is the ship's heading, $R(s)$ is the desired heading and $A(s)$ is the rudder angle. Find the transfer function, $\dfrac{C(s)}{R(s)}$.

(12 marks)

(b) Let the block diagram of ship steering control system to be simplified by the block diagram in Figure Q1(b) with controller gain, $K = 10$.

(i) Obtain the transfer function relating the sea wave and wind disturbance to the ship's heading, $\dfrac{C(s)}{U(s)}$. Assume the desired heading, $R(s) = 0$.

(3 marks)

(ii) Find the steady state value of the ship's heading due to a constant sea wave and wind disturbance which can be approximated as the Laplace transform of the unit step, $U(s) = \dfrac{1}{s}$.

(10 marks)

Q2 The block diagram of the welding robot arm control system in the automotive industry is given in Figure Q2.

(a) Obtain the transfer function, $\dfrac{C(s)}{R(s)}$.

(7 marks)

(b) Determine the values of K and b when the damping ratio of the system is 0.5 and the settling time (2% criterion) of the unit-step response is 0.2s.

(8 marks)

(c) Calculate

(i) Rise time

(2 marks)

(ii) Peak time

(2 marks)

(iii) Maximum overshoot

(2 marks)

(d) Draw the unit step response on the graph paper. Show precisely the rise time, peak time, maximum overshoot and settling time in the drawing.

(4 marks)

Q3 (a) A self-parking system is an autopilot technology for an automobile that allows it to park by itself. The basic components of such a system are a camera, servo-motors for turning the steering column and activating brakes, and a micro-computer based control system to perform the parking manoeuvres. Draw the block diagram of the self-parking system; identify the components, input and output of the system.

(5 marks)

(b) Figure Q3(b) shows a block diagram of an armature controlled dc motor. The parameters of the motor are:

- Armature coil inductance, L: 0.4 H
- Armature coil resistance, R: 5 Ω
- Torque constant, K_t: 0.5 N-m/A
- Rotor inertia, J_m: 0.1 N-m-s^2/rad
- Viscous friction constant, B_m: 0.2 N-m-s/rad
- Back e.m.f. constant, K_b: 0.3 V-s/rad

Obtain the transfer function of the motor $\dfrac{\Omega_m(s)}{V_a(s)}$ in the simplest numerical form.

Consider the load torque equals to zero.

(10 marks)

(c) A simplified representation of a vehicle's front wheel system consisting of a tire of mass M and a shock absorber of damping coefficient B is shown in Figure Q3(c). K_2 represents the elasticity of the tire, while K_1 represents the spring of the shock absorber. It is assumed that the moment of inertia of the car body is so large that the body can be considered as a fixed support.

(i) Draw the free body diagram of the system.

(3 marks)

(ii) Derive the differential equation governing the behaviour of the system.

(3 marks)

(iii) Obtain the transfer function, $\dfrac{Y_1(s)}{Y_2(s)}$.

(4 marks)

Q4 (a) Describe the three conditions of stability and explain on how the system will fall into that condition using a pole placement example.

(6 marks)

(b) The simplified form of a block diagram for a position servomechanism is shown in Figure Q4(b).

(i) Find the characteristic equation of the system.

(2 marks)

(ii) Develop the Routh-Hurwitz table.

(14 marks)

(iii) Determine the range of K that results in stable system.

(3 marks)

Q5 Consider the simplified form of the transfer function for a position servomechanism used in an antenna tracking system as shown in Figure Q5. By using root locus technique:

(a) Sketch its root locus.

(20 marks)

(b) Find the value of K so that the damping ratio, $\zeta = 0.342$.

(5 marks)

Q6 Figure Q6 shows a position control system with a lead compensator attached to it.

(a) Without the compensator, the system settling time for ±2% band is 0.5s and the percentage of overshoot is 1.516%.

(i) Obtain the closed loop poles of the original system and calculate the angles that this poles contribute to the system.

(6 marks)

(ii) Calculate K.

(1 marks)

(b) With compensator, parameters of P_c, Z_c, and K_c need to be tuning in order to improve the settling time to 50ms while maintaining its previous overshoot. By using the value of K obtained from Q6(a)(ii):

(i) Obtain the desired poles and calculate the angle of the compensator in the desired poles.

(4 marks)

(ii) Calculate P_c, Z_c and K_c by using bisect angle method.

(11 marks)

(iii) Determine the values of resistors R_1 and R_2 of the compensator if the compensator capacitor has a value of 1μF and then sketch the full circuit of the compensator.

(3 marks)

- END OF QUESTION -

FINAL EXAMINATION

SEMESTER/SESSION : SEM II / 20122013
COURSE : CONTROL SYSTEM / ELECTRICAL CONTROL SYSTEM

PROGRAMME : 3 BEE / 3BEF
COURSE CODE : BEE 3143 / BEX 31603 / BEF 33003

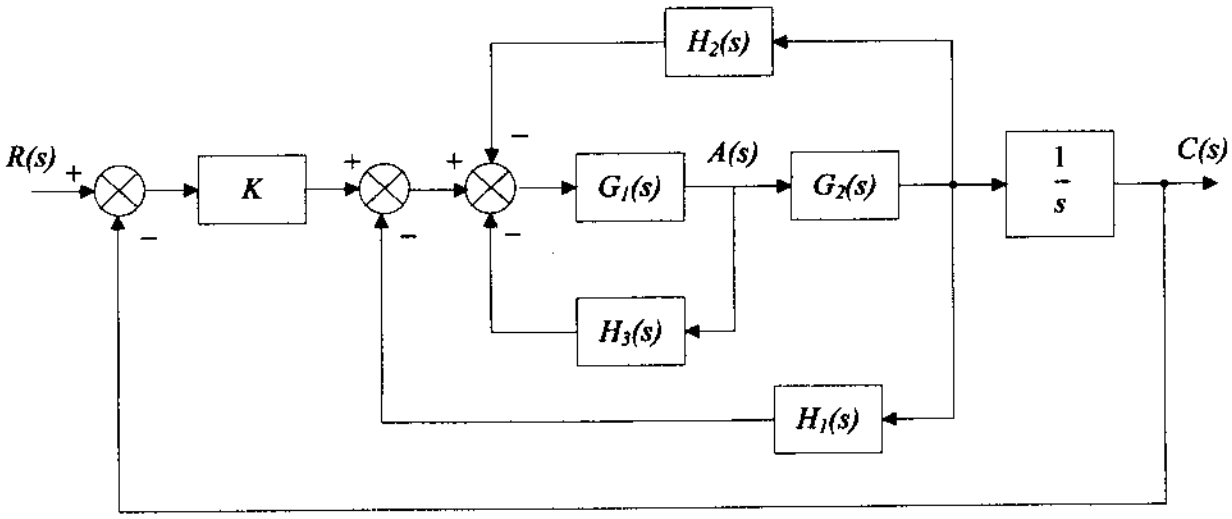

FIGURE Q1(a)

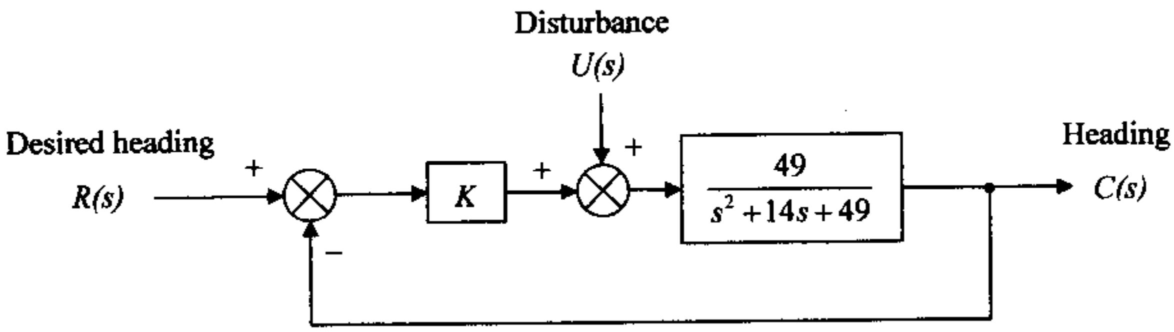

FIGURE Q1(b)

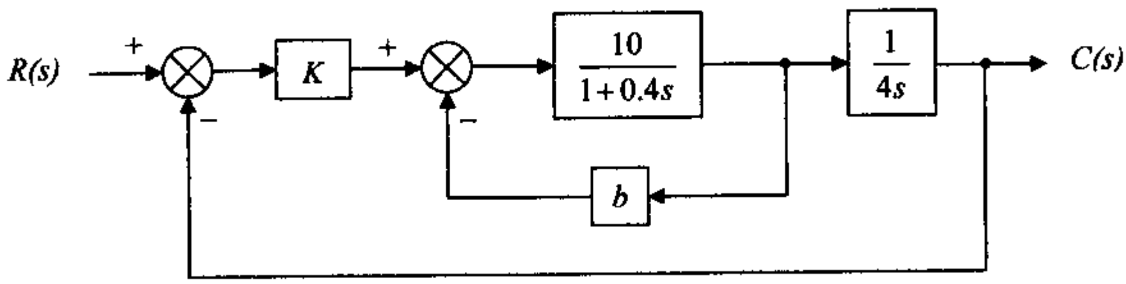

FIGURE Q2

FINAL EXAMINATION

SEMESTER/SESSION	: SEM II / 20122013	PROGRAMME	: 3 BEE / 3BEF
COURSE	: CONTROL SYSTEM / ELECTRICAL CONTROL SYSTEM	COURSE CODE	: BEE 3143 / BEX 31603 / BEF 33003

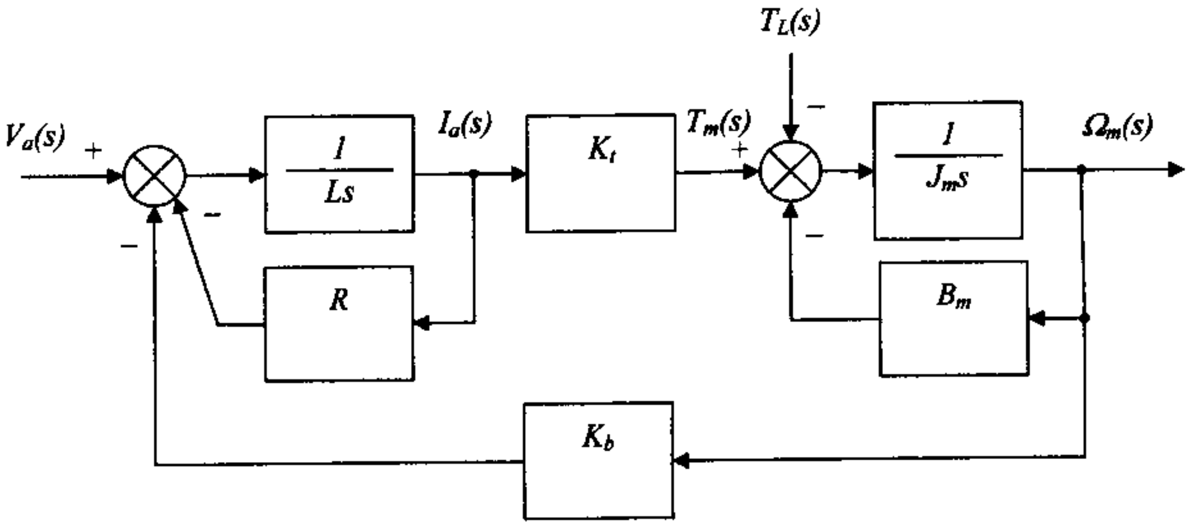

FIGURE Q3(b)

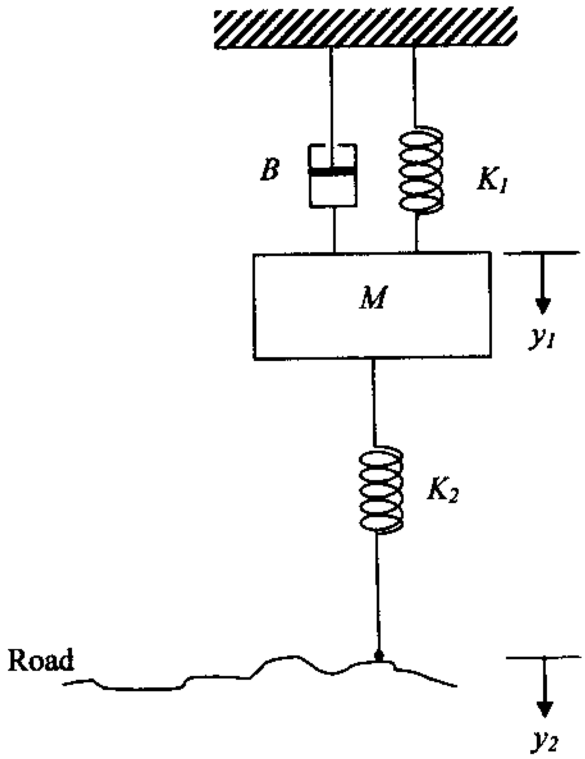

FIGURE Q3(c)

FINAL EXAMINATION

SEMESTER/SESSION : SEM II / 20122013
COURSE : CONTROL SYSTEM / ELECTRICAL CONTROL SYSTEM

PROGRAMME : 3 BEE / 3BEF
COURSE CODE : BEE 3143 / BEX 31603 / BEF 33003

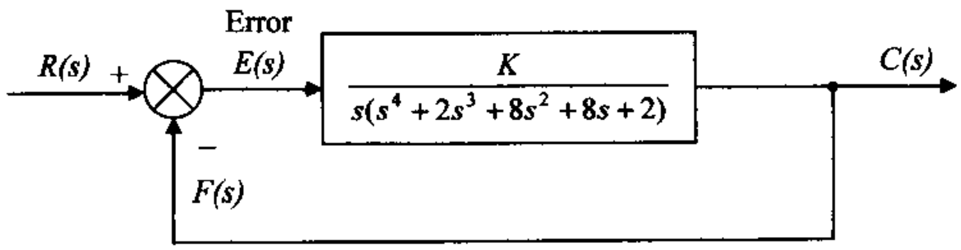

FIGURE Q4(b)

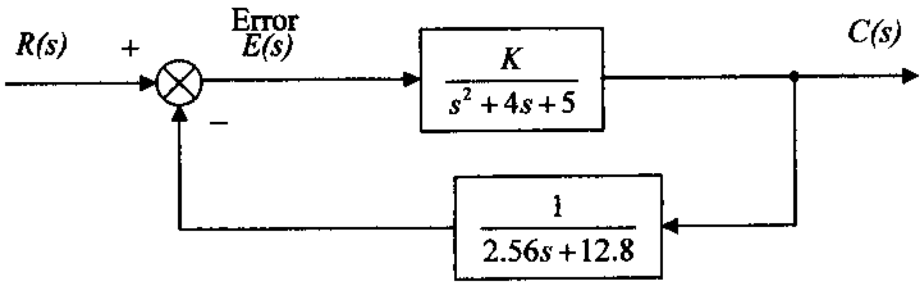

FIGURE Q5

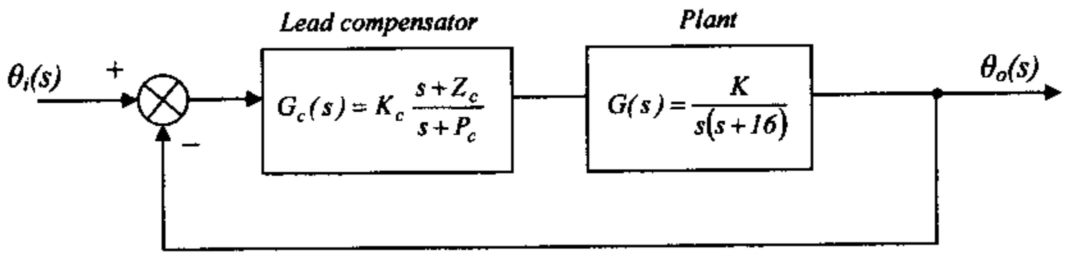

FIGURE Q6

FINAL EXAMINATION

SEMESTER/SESSION : SEM II / 20122013
COURSE : CONTROL SYSTEM / ELECTRICAL CONTROL SYSTEM

PROGRAMME : 3 BEE / 3BEF
COURSE CODE : BEE 3143 / BEX 31603 / BEF 33003

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

FINAL EXAMINATION

SEMESTER/SESSION	: SEM II / 20122013	PROGRAMME	: 3 BEE / 3BEF
COURSE	: CONTROL SYSTEM / ELECTRICAL CONTROL SYSTEM	COURSE CODE	: BEE 3143 / BEX 31603 / BEF 33003

TABLE 3

2^{nd} 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)